# PORT INNOVATION

## METHODOLOGY APPROACH

*Authors:*

*Vanelslander, T., Sys, C., Acciaro, M., Giuliano, G., and Roumboutsos, A.*

# A holistic approach to research

Vanelslander et al. (2013) provide a synopsis of the recent port-related academic literature covering the 2011-2013 period. This set of papers contains also an overview of the used methodologies (see table 1). Some papers apply two methodologies, all other papers were assigned to one methodology. The used methodologies span from literature review to modeling.

Table 1: Overview methodology

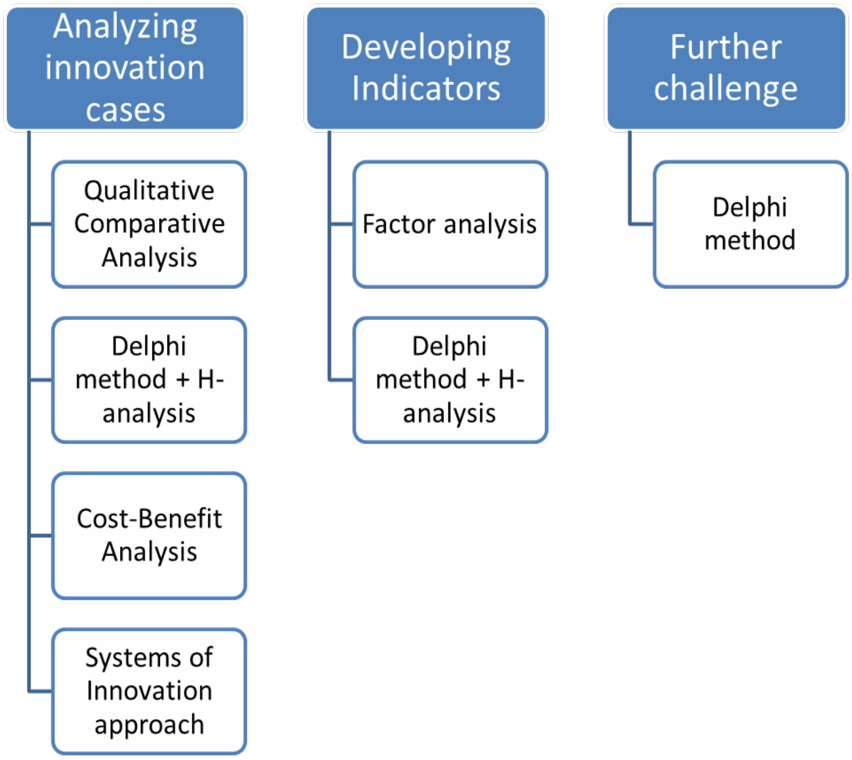
| Methodology | Published Research |
| --- | --- |
| Comparative study | Sharif, O. and Huynh, N. (2013) |
| Cost functions | Defilippi (2012); Van der Horst and Van der Lugt (2011) |
| Cross-disciplinary approach | Monios and Wilmsmeier (2013) |
| Descriptive case study | Klopott (2013); Do, N.-H., Nam, K.-C. and Ngoc Le, Q.-L. (2013); De Langen et al., 2013; Defilippi, 2012; Veenstra et al. (2012) |
| Fuzzy quality function deployment | Yang (2013) |
| Heuristic, mathematical programming | Chao and Yu (2012); Monaco and Sammarra (2011); Golias, M. (2011) |
| Literature review | Nam and Song, 2011; Lam, J. and Gu, Y. (2012) |
| Literature review, in-depth interviews and a survey | Thai, V. (2012) |
| Mixed-integer programming | Klerides and Hadjiconstantinou (2012) |
| (time-extended) Optimisation modelling | Olivo et al. (2013); Ambrosino et al. (2013); Vojdani et al. (2013); Iannone, F. (2012) |
| Qualitative analysis -  SWOT analysis & benchmarking | Keceli (2011); Marianos et al. (2011) |
| Simulation; genetic algorithm; stochastic | Zhao and Goodchild (2013); Dang et al. 2013; Golias and Haralambides (2011); Fancello et al. (2011) |

The challenge of the present research is to combine in a new context the application of quantitative instruments with international insights regarding port innovations.

Four methodologies (see figure 1) will be applied to analyze past innovations. The application of these methdologies, by their joint application, aims to understand the main patterns and characteristics, success factors and failure factors of port innovations, taking into account the context of the respective challenges which prevailed when they emerged, and the goals they were planned to serve (economic, social and environmental). In addition, actor analysis and related costs and benefits seem to be a crucial element in the analysis. Moreover, actor co-operation also seems an important trend. As some elements are more of a descriptive rather than a numeric nature, qualitative and quantitative approaches are combined.

The use of multiple methods and sources of data collection (indepth and focus (group) interview) will allow to check for trends in port-related innovation.

**Figure 1: Flow chart**




Next, indicators of how well the port industry behaves in terms of innovation level, both in time and in comparison to other economic sectors will be developed. To do this, two methodologies are applied, viz. the Factor Analysis and the Delphi Method.

Ultimately, the Delphi analysis is applied to check for future challenges, and the way current innovations and innovation trends will be able to cope with those challenges, or new types of innovation will be needed.

In this publication, subsequently, a description of the methodologies is given, followed by a literature review. Furthermore, the number of innovation cases necessary for applying the methodologies and the type of variables needed for each of the cases is described.

A template in Excel is used for data collection (see Annex). The first tab sheet contains information about how to collect the data per innovation case; while the second tab sheets lists the characteristics of the innovation cases. The subsequent four tab sheets are linked with the methodology and should be completed per innovation case.

# 1 Qualitative Comparative Analysis

## *1.1 Description of the methodology*

Till present, not so many studies make use of a relatively restrained number of cases where only a limited amount of information is available per case. This is true in science in general, an certainly also in transport and more in particular for ports. A lot of studies do exist in the port scene that deal with information taken from many cases, often compiled through publicly available databases, where statistical analysis is being performed. At the same time, lots of studies deal with single cases, making in-depth analyses.

A good method to deal with situations where only a limited number of cases with each time limited information are available, is the Qualitative Comparative Analysis (hereafter QCA). This method keeps the middle between a qualitative and a quantitative approach. The latter two extremes are shown in table 2.

**Table 2: Case analyses extremes**

| Single case study | QN study of case variation |
|---|---|
| Case-oriënted | Variable-oriented |
| Small N | Large N |
| Qualitative | Quantitative |
| Intensive | Extensive |
| Within-case analysis | Cross-case analysis |
| Problem of representation | Problem of inference |

Source: Fiss (2008)

The method was till now mainly used in social sciences. The difference with classical social science analysis is shown in table 3.

**Table 3: Classical social science vs. comparative analyses**

| Characteristic | Textbook social science | Comparative analysis |
|---|---|---|
| Main goal | To document general patterns characterizing a large population of observations | Making sense of a relatively small number of cases, selected on purpose |
| Case nature | Cases and populations are typically seen as given, and a representative sample of given observations | Cases change as the researcher learns more about the phenomenon |
| Number of cases | The more, the better | Rareness is important. Cases are large-scale, historically determined and culturally significant. |
| Relation to theory | Well-defined theories are available | Theories are not well enough developed. Prime objective is concept formation and theory development |
| Causation | Assess variable importance to understand causation and test theory | Causation is looked at in terms of combinations: it is researched what combinations typically lead to what outcomes. |
| Variable analysis | Relationships between variables, and other variables controlled | Focus is on configurations of characteristics |
| Case relationships | Cross-case analysis is at the core | Within-case analysis is prime, using cross-case analysis to deepen out the within-case analysis |
| Logic | Correlational | Boolean; half-verbal-conceptual, half-mathematical-logical |

Source: Fiss (2008)

Previous research has indicated qualitative methods, surveys and factor analysis for assessing equifinality (Gresov and Drazin, 1997). Set-theoretic methods such as QCA offer a systematic approach that at the same time can examine extensive numbers of different combinations but does not disaggregate the case as a variable-based approach would (Fiss, 2008)

Cases are considered combinations of attributes. They are coded for having membership in a set of causal conditions. The information is formalized in a truth table, and Boolean logic is used to reduce the table to a number of sufficient and necessary conditions. Set-theoretic methods allow us to strip away elements that are not causally involved with the outcome. Furthermore, these methods allow to measure “coverage,” i.e. the relative importance of different paths to an outcome, and “consistency,” i.e. what proportion of observed cases are consistent with the pattern. (Fiss, 2008)

Set membership need not be restricted to binary values but can be defined using fuzzy sets. More than merely rescaling variables: fuzzy sets tie variables to theoretical concepts and substantive thresholds. (Fiss, 2008)

QCA involves the imposition of theoretical and substantive knowledge in examining imperfect evidence. In this regard, set-theoretic methods are faced with the same issues of causal inference as all other methods that use non-experimental data. QCA is not useful in very small-N situations (e.g. less than 12 cases). Effective use of QCA depends on the ratio of cases to causal conditions. QCA is currently also not designed to do truly dynamic longitudinal analyses. (Fiss, 2008)

All variables are transformed into fuzzy sets using the “direct” method of calibration (Ragin, 2008). The variables are assigned thresholds for full membership, full non-membership, and the crossover point. Variables scores are translated into the metric of log odds. Membership scores are calculated using the formula below:

$$\text{Degree of Membership} = \exp(\text{log odds})/(1 + \exp(\text{log odds}))$$

where “ exp” stands for the exponentiation of log odds to simple odds.

The rescaled measures range from 0 to 1 and are tied to their respective membership thresholds and crossover points.

The Inclusion algorithm described in Ragin (2000) is the one used in most previous analyses using fuzzy sets. However, this algorithm circumvents the creation of a truth table and thus forfeits some analytical advantages when e.g. analyzing limited diversity. To overcome this limitation, Ragin (2005) introduced a Truth Table algorithm that is now implemented in the fs/QCA software package (Ragin, Drass, & Davies 2006). This algorithm additionally allows the calculation of consistency and coverage scores. (Fiss, 2008)

In fuzzy set analysis, an important aspect relates to modeling the absence of the outcome. In this case that means modeling the absence of high performance; note that this is different from modeling causes leading to low performance. Using the negation of the outcome here leads to consistency scores considerably below the acceptable level of 0.75, indicating the absence of a clear set-theoretic relationship. Put differently: there are few configurations that consistently lead to high performance, but many configurations that lead to no high performance. Note that QCA thus allows for Causal Asymmetry, a concept foreign to correlational methods that always conceive of causal relations in symmetric terms. (Fiss, 2008)

## 1.2 A literature review of past application, in ports, but also wider

Some promising applications of STMs to management and strategy research are those below.

- Complementarities at the firm level (e.g. Milgrom & Roberts 1990, 1995; Porter 1996; Siggelkow 2002)
- Complementary HR practices (e.g. Huselid 1995; Ichniowski, Shaw, & Prennushi, 1997; MacDuffie, 1995)
- The resource-based view (e.g. Barney, 1991; Wernerfelt, 1984; Black & Boal 1994)
- Research on organizational configurations (Meyer, Tsui & Hinings 1993; Ketchen et al., 1997; Miller, 1986)
- The literature on institutional complementarities (Hall & Gingerich 2004; Hall & Soskice, 2001; Kogut and Ragin 2006)

## 1.3 The number of innovation cases necessary for applying your methodology

The number of cases needed to do a good QCA amounts to about 12. Depending on the cases submitted by companies, it can be decided to start from the broad types of innovation initiatives resulting from the InnoSuTra analysis (see deliverable 6), or staying within one or more of them. The broad InnoSuTra typology looks as in table 4. It was indicated in deliverable6 that category VI will not be analysed in this research.

**Table 4: InnoSuTra case typology**

| | |
|---|---|
| I: Technology-Unit Change | II. Technology – Market Change |
| III. Technological, Managerial, Organisational, Cultural – Business Change | IV. Technological, Managerial, Organisational, Cultural - Market Change |
| V. Managerial, Organisation, Cultural - Market Change | VI. Policy Initiatives (Managerial, Organisation, Cultural – Market Change) |

## 1.4 The type of variables needed for each of the cases

Variables will be a combination of success / failure factors and actors, both as identified in the InnoSuTra project (Aronietis et al., 2012). The type of concrete variables to be collected depends on the choice made as to case types. In general, from the InnoSuTra research (Aronietis et al., 2012), following key variables can be indicated (table 7).

**Table 5: InnoSuTra key variables**

| All Innovations | Actors | Institutional Environment (SI) |
|---|---|---|
| Initiation | **All Relevant Actors** | ***Soft Rules*** (Economic Demand) |
| Development | **All Relevant Actors** | ***Soft Rules*** (Economic Demand) |
| Implementation | **All Relevant Actors** | ***Soft Rules*** (Economic Demand) |
| **Technology Innovations** | | |
| *Initiation Phase* | Initiator and Manufacturer | ***Soft Rules*** (Internal Investment; Joint Industry Funding; Bank Funding) |
| | **Knowledge Institutes** | ***Soft Rules*** (Public Innovation Funding, Grants and Loans) |
| | | ***Hard Rules*** (Regulations: Stimulus) |
| *Development Phase* | Pilot Customer | ***Hard Rules*** (Standards) |
| | | Public or Private Funding |
| *Implementation Phase* | Sector Customers | ***Hard Rules*** (Standards) |
| | | ***Infrastructure*** Investment |
| | | ***Capabilities*** (ensure all actors can implement the innovation) |
| | | ***Soft Rules*** (Marketing by initiator/promoter) |
| **Organisational Innovations** | | |
| *Initiation Phase* | Initiator/promoter to ensure that all network actors to be involved | ***Strong Networks*** Avoid capture by strong networks |
| | **Knowledge Institutes** | ***Infrastructure*** provision |
| *Development Phase* | Involve weak actors, e.g. SMEs | ***Weak Networks*** |
| | | Strengthen complete network involving all actors |
| | | ***Soft Rules*** (Public or Private Funding required) |
| | | ***Soft Rules*** (net benefits for transport chains/networks |
| | | |
| *Implementation Phase* | All actors | ***Infrastructure*** provision |
| | | ***Soft Rules*** (Marketing by initiator/promoter) |
| **Cultural/Marketing Innovations** | | |
| *Initiation Phase* | | |
| *Development Phase* | All key actors, including lobbying groups | ***Infrastructure*** provision |
| | | ***Soft Rules*** (Economic demand) |
| | | ***Soft Rules*** (Marketing by initiator/promoter) |
| *Implementation Phase* | All key actors, including lobbying groups | ***Infrastructure*** provision |
| | | ***Soft Rules*** (Economic demand) |
| | | ***Soft Rules*** (Marketing by initiator/promoter) |
| **Public Policy Initiatives/Innovations** | | |
| *Initiation Phase* | **All key actors**, including lobbying groups and national (and regional/local) governments **Knowledge Institutes** | ***Soft Rules*** (sufficient net socio-economic benefit) |
| *Development Phase* | **All key actors**, including lobbying groups and national (and regional/local) governments, to remain supportive | ***Capabilities*** (ensure that all key actors have the necessary capabilities) |
| *Implementation Phase* | **All key actors**, including lobbying groups and national (and regional/local) governments, to remain supportive | ***Capabilities*** (ensure that all key actors have the necessary capabilities) |
| | | ***Hard Rules*** including, as appropriate, taxes, subsidies, and regulations |
| | | ***Infrastructure*** provision |

# 2 Applying the Delphi Method and the Heterogeneity Index Method to Innovation

## 2.1 Description of the methodology

The methodology, developed in Acciaro et al. (2013), consists of the assessment of success of an innovation on the basis of the degree such innovation has contributed to the achievement of a certain set of objectives. The method originates from the observation that every innovation appears generally with a specific purpose or set of purposes, i.e. improve efficiency, increase market power, or respond to a new regulation.

As such its success can be defined only as a measure relative to the objectives the innovation aimed at achieving. Those objectives may differ substantially from industry to industry and from firm to firm, as they are embedded within the characteristics of the industry and each firm strategy.

A first step in the definition of a methodology to assess the success of innovation is therefore the development of a comprehensive list of objectives that are relevant for the firm or for the industry under analysis. Naturally this list may be rather comprehensive, but should be general enough so that similar objectives can be grouped under the same heading. Researchers should verify such list, that can be originally drafted on the basis of academic literature with industry experts. A possible way to conduct such verification process is through the Delphi method.

The Delphi method is a technique developed in the 60s and popularized by Linstone and Turoff (1979). It consists in circulating a document or research idea anonymously among experts in a certain field. The researchers collect the reviews and comments from the experts, amend the document and circulate further. Experts can be contacted sequentially or all at the same time. Through the iterations, the document or research idea is amended and converges towards a shared and commonly agreed concept.

The Delphi method can be used to shape and refine certain abstract concept definitions, such as firm or industry objectives, so that to reach a commonly accepted and exhaustive formulation. In the case in point, such process would allow to have a general definition of the objectives that a single firm or various firms in the industry aim at achieving against which to benchmark a certain innovation.

Once the researcher is satisfied with the formulation of the objectives, it proceeds to survey experts involved in the development and implementation of various types of innovation. Each expert is asked to indicate the relevance of each objective for the specific innovation, in other words what the innovation was aiming at achieving, and how successful the innovation has been in achieving each objective.

After completion of the survey for a sufficiently large number of innovations, the researcher has two rankings. A ranking that summarizes the importance of each objective for the firm or the group of firms under analysis and the success ranking of the innovations surveyed with respect to each objective.

Ideally we would assume that highly relevant objectives are more often targeted by innovations, therefore indicating that the importance ranking indicates on average what the priorities are for the firm or the industry. If an innovation process is will conducted we would expect that important objectives are priorities, so that innovations aiming at targeting such objectives are more successful in delivering the expected results. Therefore we would assume there are some similarities among the two rankings.

The similarity between the rankings can be statistically tested for example using the Wilcoxon test or the paired Student's t-test. So that significant differences can be interpreted as an indication that success is not aligned with firm priorities, highlighting some common anomalies in the innovation process. Furthermore the rankings can be analysed using an homogeneity index that allows to asses whether there is accordance among respondents on the importance of each objective and on the success of each innovation. High heterogeneity is indicative of a sample that is not aligned in terms of strategy, i.e. the firms pursue different objectives, and an innovation sample that shows a lot of diversity in innovation processes. In these cases, valuable insights can be obtained from firm specific case studies.

## 2.2 A literature review of past applications

The Delphi method has been applied in a variety of settings and also in the port literature, although not in conjunction with the heterogeneity analysis presented above. Examples of the application in the port management research areas include in supporting the definition of constructs, in exploratory analyses and in indicators validation. Brett and Roe review the use of Delphi methods in general and highlight that it has been successfully employed when there is lack of reliable or accurate information sources, for preliminary data analysis and when there is the need to better understand complex social constructs or there is need to achieve consensus on previously identified issues (Brett and Roe, 2010). The case of innovation in ports appears a particularly suitable ground for such applications.

Lirn et al. (2003; 2004) for example use Delphi method to determine the criteria that are used by shipping lines in transshipment port selection in conjunction with Analytical Hierarchical Processes Analysis (AHP). Several scholars have employed Dephi analysis in conjunction with AHP. Peris-Mora (2005) apply the method to support the development of a set of indicators for sustainable port management. In this case the Delphi method is used to validate a system of indicators. Bichou (2004) makes use of a Delphi analysis to validate a framework for port security management. Brett and Roe (2010) use the method to determine the extent and potential of the maritime cluster in the greater Dublin region. Other application examples include the validation of a framework for organisational effectiveness (Cetin and Gerrit, 2010), risk management (Trucco et al. 2008), or the analysis of container terminal performance in conjunction with fuzzy set methods (Cho et al. 2007).

The homogeneity index is one of the traditional statistical measures of heterogeneity, such as distribution variance or entropy. This indicator works well for the analysis of rankings, as it is simple and intuitive and provides an indication of how much agreement is there on the results obtained from the data collection. In Acciaro et al. (2013) the analysis is built using the heterogeneity index and is expanded including hypothesis testing (Wald sign test), although this are not requirements for the use of the methodology.

## 2.3 The number of innovation cases necessary for applying your methodology

The methodology is still new and requires further testing. It would be therefore valuable to have as many innovation cases as possible. In the previous application in Acciaro et al. (2013), 11 environmental innovations where analysed in six ports. On the basis of the experience form the previous application, 20 comparable innovation would probably be enough to obtain results with a good degree of significance. The methodology, however, can also be applied to a smaller number of innovations.

## 2.4 The type of variables needed for each of the cases

The type of variables needed for the application of the methodology are a table of the specific objectives and the rankings (on a Likert scale) to be obtained though survey. Given the potential complexity and possible respondents' fatigue in answering the survey, especially in case of a large set of objectives, it would be recommended to limit the focus of the analysis to specific sub-sets of objectives.

# 3 Applying Actor Cost-Benefit approach

## *3.1 Description*

Cost benefit analysis (CBA) is a decision procedure that allows decision makers to understand the trade off between costs and benefits of public actions.

The cost benefit approach has its roots in the need to anchor the decision making process to economic efficiency principles. It is based on the proposition that decision makers should maximize collective good and that monetary values represent collective welfare. Its goal is to provide a neutral and comprehensive method of evaluating policy proposals, a way of aligning the diverse consequences and values implied by collective choices along a single quantitative metric (Sinden et al., 2009).

In practice, a CBA entails (a) the identification of a number of alternatives to address a social issue; (b) the quantification and monetization of costs and benefits of the alternatives throughout their life; (c) the actualization of future costs and benefits of each alternative using a rate of discount and (d) the determination of the Net Present Value (NPV) of each alternative[1]. At this point, the decision maker has the instruments to choose the solution that maximizes public welfare, or, at least, an alternative whose benefits outweight the costs (Zerbe & Dively, 1994).

CBA differs from a traditional commercial project evaluation for two reasons. It considers costs and benefits to all members of society and not only the monetary expenditures and revenues of the agent responsible for the action. It adopts a social discount rate that could be different from the private discount rate, because it takes into account the social opportunity cost of resources rather than the strictly financial opportunity cost.

The US Corp of Engineers has been using CBA to evaluate public projects since the 1930s, but CBA did not become mandatory for Federal agencies until the 1980s. In 1981, president Reagan made the balance between costs and benefits the guiding principle to assess the effects of major regulations and welfare maximization the criterion of choice among alternatives (EO, 1981). Since 1981, president Clinton (EO, 1993) and president Obama have restated the relevance of CBA, and extended the scope of the evaluation to include distributive effects and equity concerns (EO, 2011)[2].

Critics point out process and fundamental flaws of CBA (Kelman, 1981). Some claim that it is easy to manipulate its results. Since there is great scientific uncertainty and little scientific agreement in predicting future effects of projects and regulations, it is easy to overstate benefits or minimize future costs and to bend results according to political wills and opportunities (Sinden et al., 2009). Others argue that the fundamental tenets of CBA are flawed and that market prices used to monetize benefits and costs do not reflect the social value of goods and services (Kelman, 1981). They claim that many benefits of public actions are not often quantifiable and cannot be reduced to monetary values (Harrington et al., 2010). In addition, they are concerned that current CBA practices do not take into account that benefits and costs have different marginal values for the wealthy and for the poor and,

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[1] $\text{NPV} = \sum_{t=1}^{T} \frac{(Benefit_t - Cost_t)}{(1+r)^t}$

[2] Projects financed from EU funds need to be supported with a cost-benefit analysis method.

as a consequence, the results of CBA do not effectively represent the real effects of regulatory actions on collective welfare (Sinden et al. 2009).

Its supporters, on the other hand, contend that as a decision procedure, CBA forces agencies to think about the outcomes of the proposed projects and regulations over the public realm, over health, the economy and the environment (Zerbe, 1998). It pushes agencies to realistically consider relevance and magnitude of these outcomes. The process, they maintain, al least guarantees a degree of transparency, provides a consistent framework for data collection and a tool to identify gaps in scientific knowledge. Monetization, although imperfect, makes possible the aggregation of dissimilar effects and allows for comparison among different alternatives (Sunstein, 2001; Adler & Posner, 2006).

## *3.2 Major issues in applying CBA*

The practice of CBA encounters numerous obstacles and indeterminacies. Discounting future costs and benefits is one of the most controversial. Discounting takes into account the different value that society attributes to future gains and losses as compared to the value of present gains and losses. It is based on the principle that individuals and society value present consumption more than future consumption. The discount rate determines the NPV of each alternative and is therefore a central element for assessing the social value of the action and for orienting the choice of the alternative that maximizes societal welfare. The choice of a discount rate can favour some projects over others. Low discount rates value long term benefits and costs, while high discount rates underplay long term effects and favours projects and regulations that have larger effects in the short term.

A fundamental critique to using a discount rate is based on the notion of intergenerational justice (Rose-Ackerman, 2011). Analysts are concerned that by discounting the future CBA attributes little value to the effects of a project on future generations, especially for projects that accrue benefits way into the future. Also they are concerned with the ethical stance of discounting the value of future human lives, if the project will reduce mortality in the future, and this poses ethical questions that undermine CBA's credibility.

Economists debate about the proper discount rate and explain that in a perfect market the CBA discount rate should be equal to the market price of capital, but taking into account the fact that perfect market conditions do not apply in reality, a social discount rate should be used. The designation of the social discount rate, however, is controversial. A group of experts contend that most public investments displace private investments and that public projects and regulations should be considered viable if the balance of their future costs and benefits were discounted at the average pre-tax return to private capital investment (Burgess & Zest, 2013). Another group claims that public investments largely displace private consumption and that future costs and benefits should be discounted at the average price of government funds (the pre-tax return to long term government bonds) (Moore et al., 2004; Moore et al., 2013).

In practice, in the absence of consensus, the White House Office of Management Budget requires US agencies to use two different rates (3 percent and 7 percent) and to apply the same rates to both benefits and costs. In other countries, analysts test the sensitivity of the results to changes in the interest rate.

Other major concerns for the credibility of CBA are the uncertainty inherent in the estimates of future events and the complexity integral to attributing monetary values to many consequences of projects and regulations.

Many pressing regulatory issues are motivated by the precautionary principle and concerned with the effects of emissions whose future consequences are not well understood. Greenhouse gas emissions, whose effects are not yet quantifiable at regional scale and could trigger feed- back loops with irreversible consequences, are, perhaps, the most recent example (Harrington et al. 2010; Masur & Posner, 2011; Sinden et al. 2009). Even supporters of CBA recognize that in these cases CBA might not be the best decision making support instrument (Masur & Posner, 2011).

When possible consequences of projects and regulations can be predicted and quantified with a sufficient degree of certainty, in some cases they affect non market goods like human life, health and the environment. They might entail the reduction of the number of illnesses, the protection of endangered species or the conservation of unique ecosystems. Economists have gone a long way to find ways to quantify how to translate the value of these goods to society in monetary terms. With ad hoc surveys, they have elicited information about the public's willingness to pay for protecting endangered species or unique ecosystems. They have revealed the monetary values of emissions or noise by observing how environmental nuisances influence home market prices. They have inferred the value of non-market goods by comparing human behaviours in market situations. These methods are expensive and time consuming (Harrington et al., 2010) and often require very specialized inputs. Additionally, they have been criticized for making implicit value judgements and biased assumptions (Ackerman & Heinzerling, 2002; Alred, 2006) that are easy targets for political attacks.

As an alternative, to avoid the issues with quantifying social benefits, US agencies often estimate the cost effectiveness of their regulatory decisions. They estimate the costs of the project and don't evaluate monetary benefits. They rather measure quantities of emissions reductions and chose the alternative that minimizes the costs of one unit of pollution reduction. Of course this approach works well for projects that affect one individual element, while it does not work well for regulations and projects that affect different elements with diverging cost effectiveness ratio.

## *3.3 A literature review of applications of CBA to maritime transportation*

The cost-benefit approach has been used to assess the feasibility of many transportation projects, but it has been used sparsely to evaluate emission reduction strategies of port operations.

There is general consensus that externalities of maritime transport include accidents, water and sediments contamination, coastal erosion, loss of biodiversity, habitat degradation and ship emissions in the atmosphere (ozone and aerosol precursors such as NOx, CO, Volatile Organic Compounds; $SO_2$; Particulate Matter and the emissions of greenhouse gases) (Miola et al., 2009). The studies that quantify maritime transport environmental effects are numerous (McArthur & Osland, 2013; Miola et al., 2009; Sieber & Kummer, 2013; Song, 2014; van Essen et al. 2011; Tzannatos 2010) and considerable efforts have been made in estimating the external marginal costs of maritime transportation in Europe (Bickel et al.

2006; Holland et al., 2005). However, their application to evaluate emission reductions strategies is sparse.

One of the few examples of an extensive cost benefit analysis of emissions mitigation strategies of maritime transport is the EPA's regulatory impact assessment (RIA) of its 2009 strategy to reduce airborne emissions of large ocean going vessels (with category 3 diesel engines)(EPA, 2009).

The strategy includes three major actions: 1) emission standards for large marine motors for US flagged ocean going vessels; 2) the institution of an Emission Control Area within 200 miles from the US coastline where all vessels would be required to meet the most stringent engine and marine fuel requirements to reduce NOx and SOx emissions, and 3) new engine emission and fuel sulfur limits.

The analysis assumes that all the private costs borne by the private sector to comply with the new regulations will be passed on to the consumers and treats them as social costs. The assessment quantifies both investment and maintenance costs. Investment costs are estimated only for upgrading the US flagged vessels. Operational costs to maintain the equipment to reduce NOx emissions are estimated for both domestic and international vessels. The differential price of lower sulfur fuel compared to the price of high sulfur fuel is also included for both domestic and international vessels. Future high and low sulfur prices were projected with World Oil Refining Logistics and Demand (WORLD) model.

To quantify and monetize the benefits of the strategy, the assessment focuses on its effects on human health and specifically on the health effects of improved air quality and reduced concentrations of $PM_{2.5}$ and Ozone. The study explicitly excludes other smaller benefits, like the reduction of sulfur and nitrogen depositions and improved visibility, and claims that since the health benefits are much larger than the costs there is no need to quantify other benefits.

Quantifying and attributing a monetary value to the health effects of the strategy is a complex process that relies heavily on existing modeling tools and on specialized knowledge of the marine transportation industry and of the health effects of criteria pollutants[3]. The study first estimates a baseline scenario of maritime transportation emissions in the US coastal waters by merging an existing geographically based inventory with "bottom up" studies on 9 different ports. Then it projects fuel consumption and emission in a business as usual (BAU) scenario in 2020 and 2030, using regional growth factors that have been estimated by a consultant specifically for the RIA. Subsequently, it extrapolates the contribution of large ocean going vessels to the overall emissions and it estimates the emission reductions attainable with the proposed strategy. The results of these projections are then fed to CMAQ, an open source modeling tool that combines current knowledge in atmospheric science and air quality modeling. CMAQ models the effect of criteria pollutant on ambient air quality, specifically on the concentrations of ambient $PM_{2.5}$ and Ozone. The results of CMAQs are then sent to BenMAP, an EPA proprietary program that includes health impact functions, demographic data, values to monetize health impacts and interpolation factors. Health impact functions are based on a literature review that includes the most recent longitudinal research on the health effects of air pollution. Monetization factors, on the other hand, are drawn from older studies, mainly done in the late 1990s.

[3] EPA has set National Ambient Air Quality Standards for six primary air pollutants called "crieteria pollutants": $NO_2$, Pb, $SO_2$, CO, $PM_{10}$ and $PM_{2.5}$

BenMAP analyzes the pollutants' concentration without and with the strategy, quantifies the effects of the proposed policies in terms of avoided premature deaths and other health effects, and gives them a monetary value. The analysts discount the benefits of reduced premature mortality and the costs of non-fatal myocardial infractions, but not the other health costs.

The study concludes with a comparison of costs and benefits and claims that: "the annual benefits of the total program will range between $47 to $110 billion annually in 2020 using a three percent discount rate, or between $42 to $100 billion assuming a 7 percent discount rate, compared to estimated social costs of approximately $1.9 billion in that same year." (EPA, 2009; p. 6-32).

Other studies published in peer reviewed journals have a much smaller scope than EPA's RIA: they are limited to cost benefit ratio estimates and to cost effectiveness assessments.

A group of studies has analyzed the cost benefit ratio of strategies to reduce $SO_2$ emissions.

In order to compare different $SO_2$ mitigation strategies, Wang and Corbett (2009) evaluate costs and benefits of reducing $SO_2$ emissions from ships in the US West Coastal waters. The authors hypothesize two different sulfur control strategies: a large and a small emissions control area along the Northwestern Coast of the US. They study the costs and and benefits of adopting two different types of low sulfur fuels (1.5% and 0.5% sulfur content). They estimate the quantity of fuel used in each area and the amount of $SO_2$ emissions reaching land from each control area in the baseline conditions. They define the costs of their strategies as the differential between more costly low sulfur fuels and a cheaper high sulfur fuel. They calculate the benefits as a function of the savings in $SO_2$ emissions and of the avoided health and environmental damages of $SO_2$. Based on previous studies that estimate the monetary value of avoided $SO_2$ emissions, they calculate the benefit/cost ratio of the four alternatives and conclude that all the alternatives have a ratio larger than 1.

Tzannatos (2010) estimates the cost/benefits ratio of reducing $SO_2$ emissions from marine shipping in Greece. The study estimated $SO_2$ yearly emissions in the Greek seas for domestic passenger, for domestic freight shipping and for international shipping. His study estimates the amount of $SO_2$ reductions that could be attained by substituting ordinary maritime fuel with fuels that have respectively 1.5%, 0.5% and 0.1% of sulphur content and determines the differential cost of low and high sulfur fuels. It estimates the reduction of social costs using previous research on the quantification of sulfur effects on mortality and morbidiy and on building materials. The analysis finds that the external benefits of the application of 1.5 % and 1.0 % sulfur limit to marine fuels will outweigh the increase in fuel costs. It also finds that the benefits associated with very low sulfur fuels (0.1%) do not outweight their costs, but that $SO_2$ scrubbers on domestic shipping vessels provide emission reductions similar to those attained with 0.1% sulfur fuels and their benefits outweight the yearly cost of installation and maintenance.

Only a couple of studies have branched to include the evaluation of the cost/benefit ratio of emission reduction devices taking into account larger range of air emissions. Jiang and al. (2012) estimate the costs and benefits of Sea Water Scrubbers (SWS). The authors first estimate a "baseline" cost of emissions for a typical return trip of a 5,000 Twenty Foot Equivalent Units (TEU) container ship between Gothenburg and Rotterdam. They use marginal external costs for emissions of $SO_x$, $NO_x$, $PM_{2.5}$ and $CO_2$ estimated by an EU wide study and apply emission factors derived by previous studies for three different ship conditions: free sailing, manoeuvering and berth time. They estimate the yearly costs of installing and maintaining SWS. Although they do not explain how they derive the amount of emissions reductions obtained by the scrubbers, they provide an estimate of their monetary benefits and claim that the additional cost of installing SWS on new ships can be offset by one round trip per year, and the additional costs of retrofitting existing vessels can be offset by two round trips per year.

More recently, Jiang et al. (2014) compared the benefit/cost ratio of scrubbers and low sulfur fuels based on the typical return trip of a typical medium size container ship between Gothenburg and Rotterdam and conclude that low sulfur fuels benefit/cost ratio is far more favorable that the benefit/cost ratio of installing scrubbers. However, should prices of low sulfur fuel increase dramatically, scrubbers would be the most cost-effective option.

Another group of studies is concentrated on the cost effectiveness of measures aimed at reducing air emissions of port operations and includes analysis done locally and analysis of national relevance.

Using similar procedures, the Port of Long Beach (Environ, 2004) and the Port of San Diego (Yorke Engineering, 2007), estimated the cost effectivenss of cold ironing. The Port of Long Beach selected 12 vessels and their berths to represent the fleet that uses its infrastructure and studied the cost effectiveness of providing cold ironing facilities to each type of vessel, taking into account the effective number of yearly port calls and the actual docking behavior of each vessel. The study estimates the capital and maintenance costs of improving the electricity infrastructure of each berth and of retrofitting the vessels to receive the shore side power. It also determines the amount of criteria pollutants that will be reduced by connecting the ships to the electrical grid rather than using their auxiliary motors to produce electricity while docking. It finds that cold ironing is cost effective for those vessels that have longer berth time and relatively frequent port calls. In addition, the study estimates costs and reductions of other emission reductions strategies such as combustion management, engine replacement, fuel replacement and exhaust treatment and concludes that fuel replacement would be more cost effective than any other emission reduction technique.

The EPA’s Office of Transportation and Air Quality (OTAQ) evaluated the costs effectiveness of retrofitting nonroad equipment such as cranes and other heavy equipment with four different devices to reduce $NO_x$ and Particulate Matter (PM) emissions. Using NONROAD, a proprietary model that EPA has devised to estimate non road mobile equipment and information on operation times, the study estimated baseline emissions of $NO_x$ and PM for each non road diesel equipment. It assesses the abatment potential of the four different strategies using data from a Retrofit Technology Verification Program run by the agency. Subsequently, it estimates capital costs of the different solutions. At this point the analysts quantify the present lifetime emission reductions of the four solutions and extimate the cost effectiveness of each device. They find that upgrade kits for $NO_x$ reductions and selective catalytic reduction (SCR) systems are more cost effective than diesel oxidation catalysts (DOCs) and catalyzed diesel particulate filters (CDPFs) for every nonroad diesel equipment category (EPA 2007).

## *3.4 CBA fit into a study of port innovation*

CBA is a powerful decision tool that allows the analysis of the effects of regulations and projects on public welfare by reducing benefits and costs under a common denominator:

their monetary value. As illustrated in the literature review, it is applied to individual policies or strategies, but can be successfully used to compare different programs aimed at addressing a specific issue.

It is a data intensive process, that requires time and considerable resources that only large organizations have. Every CBA requires a well defined project, whose effects are well known and well predictable. It involves in depth analysis of investment and operative costs and sophisticated research to define, quantify and monetize benefits, especially when externalities are involved. As seen in the RIA of EPA's 2009 strategy to reduce airborne emissions of large ocean going vessels, it requires researchers able to make choices on whether to focus on a small number of impacts or be more comprehensive. In many cases it involves proprietary models to establish a base line and to project future emissions and their effects. It entails in depth analysis of existing literature to find indicators and factors to be used in the estimates and, when current data is not available, relies on previous studies. When all these tools are not at hand, analysts need input from research institutions, as seen in Jiang et al. 2012 and 2014 and in Tzannatos 2010. They used research done by the European Commission to quantify the amount of benefits of switching to less sulfur intensive fuels.

CBA could be used fruitfully to compare types of innovations and to understand the relevance and magnitude of their effects. When data needed for monetization of benefits is not available, it could be replaced by a cost effectiveness assessment. It is important, however, that analysts are clear about what they include and what they exclude from the investigation, and about the limits of their assessment. It is also important that decision makers understand these limits.

# 4 Applying Systems of Innovation approach

## 4.1 Introduction

As put by Lundvall (1992/2010, 8): *"In modern capitalism, innovation is a fundamental and inherent phenomenon; the long-term competitiveness of firms, and of national economies, reflect their innovative capability and, moreover, firms must engage in activities, which aim at innovation just in order to hold their ground."*

In mainstream or neo- classical economics innovation is centered on the idea of "sunk" costs (irrecoverable commitments) for improved efficiency (Sutton, 1992, 1998) and supports a linear model of innovation connected to two principal "market failures": (i) innovation can be imitated once successful so innovators cannot appropriate the full benefits of their investment and social returns of innovation exceed private returns: this means that private firms do not have sufficient incentives to undertake innovation to socially efficient levels (Arrow, 1962); (ii) negative externalities provide the rationale for economic and other instruments to "internalize" these externalities. This approach, also, provides the theoretical basis for public support to innovation directly (through subsidies) or indirectly (through funding of linear components of innovation).

An alternative approach to the linear development of innovation is the *system-oriented* approach. In recent innovation research, the systemic nature of the innovation process has gained much attention. The focus here is both on the actors in the innovation process (which had been the focus of the traditional "linear model" of innovation) but also on the linkages and feedback loops between the actors. More specifically, the Systems' Innovation (SI) approach views innovation as an interactive, non-linear process, in which actors interact with other organizations and institutions (laws, regulations, values etc.). This complex process, characterized by reciprocity and feedback mechanisms, determines the success of innovation (cf. Lundvall, 1992/2010; Nelson, 1993 and Edquist, 1997).

Relations between innovation actors are characterized both by elements of competition and cooperation, by interactive learning, and by complementarities. A systemic view of the innovation process does not only study the individual actor in the innovation process, but the linkages between (potential) actors and the supply of relevant complementary actors also. Systems of innovation approaches most distinctly embody the systemic view of the innovation process and have been developed based on (1) technological, industrial or sectorial characteristics of innovation actors, or on (2) spatial characteristics (national systems of innovation and regional systems of innovation).

The systems of innovation approach takes as a given that a particular application has the potential for efficiency in terms of reducing costs or providing added value. That is it considers that its starting point is that the "new" application has a potential to be accepted in the market and withstand market competition. It primarily studies interactions between actors so as to provide answers to *"who"* should act, *"how to act"*, *"what to act upon"* and "*when*" to intervene in order to lead to the successful uptake of innovation.

## 4.2 Literature review

The Systems of Innovation (SI) approach has its roots in the evolutionary theory (Nelson and Winter, 1982). Ever since its emergence in the early 1990's, SI has attracted the interest of international policy think-tanks such as the OECD (Mytelka and Smith, 2002). In the SI approach, innovation does not take place in isolation. Actors, within the system, interact, cooperate and learn (Lundvall, 1992). Institutions, hard (regulations, laws etc.) and soft (cultural norms, values, codes etc.), are crucial to economic behavior and performance. Institutions formulate the "rules of the game" or "code of conduct" (Smith, 1997). The system evolves, generates variety, selects across that variety and produces feedback (Norgren and Hauknes, 1999). This process of novelty and variety creation is the result of constant interaction among heterogeneous actors in a population (Smith, 1999). It is necessary to maintain the diversity that makes selection possible (McKelvey, 1997). Hence, under the SI approach asymmetries are essential in providing novelty and variety. Different actors and/or different institutions form different Systems of Innovation.

A particular example are Technology Innovation Systems (TIS). TIS are defined as socio-technical systems, which aim to enhance the development, diffusion and use of a particular technology (Bergek et al., 2008). The technology definition is used as a differentiation, as technology innovations will most probably trigger or require innovation in processes (management, operational, cultural etc.). "Technology" may refer to a knowledge field or a product (Carlsson et al., 2002). Typically, a TIS may cut across national, regional and sectoral boundaries (Hekkert et al., 2007; Markard and Truffer, 2008) and this characteristic reflects on both the deployment of the technology and the interdependency of actors and their interrelations. However, their analysis on a specific level, application or "node" is important in understanding key mechanisms. This is the case of studying technology innovations in ports.

In a systemic setting including numerous actors and their socio-economic environment, systemic imperfections (or systemic problems) can occur, if the combination of mechanisms is not functioning efficiently. If so, innovation by actors may be blocked. These systemic problems as summarized by Norgren & Haucknes (1999), Smith (2000), Woolthuis *et al.* (2005) and Edquist & Chaminade (2006) include failures in following domains.

- *Infrastructure*: The physical infrastructure that actors need for functioning (such as IT, telecom, and roads) and the science and technology infrastructure may not be available hindering further development.
- *Transition:* The inability of firms to adapt to new technological developments.
- *Lock-in/path dependency failures*: The inability of complete (social) systems to adapt to new technological paradigms.
- *Hard institutions:* The failures in the framework of regulation and the general legal system to support the development of a new application.
- *Soft institutions:* The failures in the social institutions such as political culture and social values that hinder the uptake of the innovation.
- *Strong networks:* The 'blindness' that evolves if actors have close links and as a result miss out on new outside developments.
- *Weak networks:* The lack of linkages between actors as a result of which insufficient use is made of complementarities, interactive learning, and creating new ideas. The same phenomenon is referred to as dynamic complementarities' failure.
- *Capabilities:* Firms, especially small firms, may lack the capabilities to learn rapidly and effectively and hence may be locked into existing technologies/patterns, thus being unable to jump to new technologies/business patterns. In an extension, it can also include *financial* capability.

Within the SI approach, (policy) interventions (Edquist & Chaminade, 2006) are needed either because: (i) there is no market mechanism operating at all and the activities are fulfilled through other mechanisms, e.g., regulation or (ii) the market mechanism does not lead to the fulfillment of the objectives established.

Woolthuis *et al.* (2005), in order to identify "system failures" and estimate the expected impact of innovation policy interventions, proposed a "Systems' Failure Framework". This concerned a matrix including all relevant market actors and the systemic problems, as identified previously. As such, the "Systems' Failure Framework" was proposed as a diagnostic tool, with respect to innovation failure.

The key characteristic of evolution is "time". Roumboutsos *et al.* (2011) introduced this temporal aspect by proposing the introduction of temporal frameworks representing stages in the process of innovation uptake. This allows for the study of the evolution of the innovation adoption process as the innovation matures. Evidently, these stages are not discrete as organisational changes evolve over time (Perez 1983; Fagerberg 2005). This evolution may be directly affected by "market demand" and competitors to the market mechanisms. This element was also added by Roumboutsos *et al.* (2011).

A further improvement to the "Systems' Failure Framework" was proposed by Aronietis *et al.* (2012). It concerned the registration of both positive and negative correlations between actors and institutions as opposed to only the negative correlations of the Systems' Failure Framework. This allowed for the mapping of the positive system forces and their respective study through case studies. In this context, the Systems' Failure Framework is transformed to the Systems' of Innovation Framework. Their proposed methodology was applied in the study of innovations in ports.

Vanelslander *et al.* (2012), reporting on the analysis of case studies following this approach, introduced "layers" in the analysis in order to guide the focus of the analysis. The first "layer" concerned the characterisation of the innovation as commercial or within the context of public policy depending on whether the primary aim was to produce profit or social welfare. This was important in order to focus on the potential innovation Champion. The second "layer" concerned the type of innovation: technological, managerial and/or cultural. The third "layer" was, finally, the Systems' Innovation Framework. This framework did not include *Transition* and *Lock-in/path dependency failures.*

In addition to the above developments and in order to capture the impact of the global environment and respective competition, Roumboutsos et al (2013) proposed that the methodological framework foresees both the expected influence of these factors and the expected competitive advantage of competing innovations by introducing a *qualitative scale of assessment* in the framework. This is an important contribution as it allows the estimation of intensity of the interactions and may be combined with indicators of the TIS. Examples of such indicators may be found in Hillman *et al* (2011).

## 4.3 Description of the methodology

With this latter addition to the Systems' Innovation Framework (SIF), the innovation methodology is structured improving on the multi-layer approach presented by Vanelslander *et al.* (2012). A final addition to the proposed methodology is to include in the framework "dependency vectors" to illustrate the linkages between actors. The impact of these linkages are to be qualitatively assess within a range of [-3,3]. Hence, setting the grounds for the introduction of a systems dynamic study of innovation within the System of Innovation.

More specifically, the proposed SIF methodology foresees three layers of analysis. The first layer concerns the distinction between commercial innovations and those seeking to increase welfare. This layer may be related to and receive input from other methodologies used in this study such as the Cost-Benefit Approach (see below).

The second layer of the methodology involves the identification of innovation predominant component/aspect, i.e. technological, organizational, managerial, cultural or policy. For example, an innovation may be characterized as predominantly "technological" and also include organizational change. In this layer, other typical characteristics are also identified. These include determining the timeline of development of the innovation process as presented in the scientific literature: initiation, development, and implementation. In reality, the innovation process is actually a continuous process (ibid.). This layer also concerns the assessment of whether the application of the specific innovation requires trans-sectoral collaboration and/or forms of cooperation in the transport chain (example e-freight applications) or whether the adoption of the specific innovation influences only local stakeholders and, hence, the innovation is confined to a specific location (such cold ironing). That is, the impact of the innovation is characterized as specific to the business unit (the specific port) involved or as having a wider market dependency.

The third layer of the methodology involves the use of the SIF. This framework provides a means to identify the set of external factors (the so-called 'institutional environment' and 'rules') and the 'sets of actors' involved in the innovation being analyzed. Defining all of the components of the innovation is important as the focus of attention and intervention may alter as the innovation moves through the process from initiation to implementation. Finally, the role and importance of the initiator (Champion) of the innovation is explored.

## *4.4 Systematic Application of methodology*

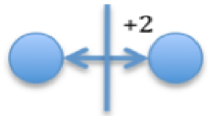
In this section, the system of innovation framework and the number of cases is described.

### 4.4.1 System of Innovation Framework description

Layers one and two of the methodology are activities undertaken in support of producing the Systems of Innovation Framework (SIF).

Table 3 provides an example layout of a typical SIF as described in the present methodology. The typical actors described in the innovation process are depicted in the horizontal axis. These actors may not apply to all cases or there may be other influential actors, who are not foreseen. These actors are identified in layer one (as key promoters) and in layer two (as actors influencing the uptake of innovation).

**Table 6: Systems of Innovation Framework**

| Actors / Institutions | Innovation Champion | Port Actors | | | | | Immediate External Stakeholders | | | | Capacity Building Stakeholders | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Port Authority | Terminal Operators | Shipping Lines | Freight Forwarders/ Shippers etc. | Unions | Municipal Authorities & Society | Innovation Sponsors (e.g. Manu-facturers) | Regulators & Regulations | Standardi-sation Bodies | Research Institutes | Financing Institutions | Institutions with vested interests (e.g. EC) |
| Infra/cture | | | | | | | | | | | | | |
| Hard Inst/ions | | |   | | | | | | | | | | |
| Soft Inst/ions | | | | | | | | | | | | | |
| Weak Networks | | | | | | | | | | | | | |
| Strong Networks | | | | | | | | | | | | | |
| Capacities | | | | | | | | | | | | | |
| Lock-in effects | | | | | | | | | | | | | |
| Market Demand | | | | | | | | | | | | | |
| Competition (innovation) | | | | | | | | | | | | | |
| Competition (Port) | | | | | | | | | | | | | |

In the vertical axis, the relationships developed between actors that influence the innovation process are depicted. Not all relationships may be present and not all will have a positive impact on the innovation process. These linkages are depicted by dependency vectors qualified qualitatively in the range [-3,+3]. For example in table 1, a positive impact is expected (+2) due to the hard institutions between terminal operator and shipping line.

Notably, input from other methodologies proposed in this study may support this qualitative assessment such as input from the Qualitative Comparative Analysis (see below) or the Delphi method (see also below).

In order to facilitate Actor identification, actors are grouped:

- Port Actors are all actors identified in the port who may be influenced by or influence the innovation process
- Immediate external stakeholders are all those who may impact or be impacted (and therefore re-act) to the uptake of a specific innovation.
- The final group of stakeholders may include capacity builders or impedents.

The vertical axis includes all forms of relations which may influence the process as described above. It also includes three parameters / factors describing the external environment: Market demand; Innovation Competition (i.e. the level that another "application" may provide the expected efficiency); Port competition (i.e. the level of need for market advancement).

The above describe the innovation process are particular moments in time.

### 4.4.2 Number of cases

Each analysis describes a specific case. Conclusions may be drawn to respond to specific innovation processes. Achieving a larger number of cases analysed based on this framework may allow to address hypothesis formulated in this respect.

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# Annex

University of Antwerp

University of the Aegean

University of Genova

Kühne Logistics University

Technical University of Lisbon

Nanyang University of Technology

University of South-California