SEIZING OPPORTUNITIES FROM PANAMA CANAL EXPANSION THROUGH ADAPTIVE PORT PLANNING

O. Soto Reyes[1], P. Taneja[2], B.A Pielage[3], M. van Schuylenburg[4]

ABSTRACT

The third set of locks of the Panama Canal opened to traffic on June 26th, 2016 enabling the transit of Neo-Panamax[5] (NPX) vessels through the 100-year old maritime route. This historic milestone will impact the business cases of port- and transport infrastructure within its region of influence which includes Caribbean countries such as Bahamas, Trinidad and Tobago, Venezuela, Colombia, Jamaica, Panamá, Puerto Rico and Dominican Republic. This paper presents a study carried out to first assess the impact of the Panama Canal Expansion (PCE) on selected Caribbean ports, and thereafter, to examine how the ports can adapt in order to seize new opportunities created by the expansion. An applied case of long-term planning and flexibility in engineering design under uncertainty by using Adaptive Port Planning (APP) framework is presented for a new port terminal in Barranquilla, Colombia. Further, a method for quantifying opportunities from containerized traffic using dynamic forecasting, Real Options Analysis and Monte Carlo Simulation is presented.

Keywords: Port planning, adaptive, uncertainty, opportunities, flexibility, Panama Canal expansion, Caribbean, dynamic forecasting, Real Options.

1. INTRODUCTION

1.1. Background

The third set of locks of the Panama Canal opened to traffic on June 26th, 2016 enabling the transit of Neo-Panamax (NPX) vessels through the 100-year old maritime route. This historic milestone will impact the business cases of port- and transport infrastructure within its region of influence which includes Caribbean countries such as Bahamas, Trinidad and Tobago, Venezuela, Colombia, Jamaica, Panamá, Puerto Rico and Dominican Republic.

1.2. Objective

This paper presents the results of a study related to the impact of the Panama Canal Expansion (PCE) on selected Caribbean ports. Having examined the vulnerabilities and opportunities created by the PCE for Caribbean ports in general, it focusses on a case study, i.e. a port in Barranquilla, Colombia. It further proposes an approach for adaptive planning of a port whereby ports can deal with the vulnerabilities and seize new opportunities. This approach is applied for the case study and the results are presented in the paper. Further, a method for quantifying opportunities from containerized traffic using dynamic forecasting, Real Options Analysis and Monte Carlo Simulation is presented.

2. IMPACTS OF PANAMA CANAL EXPANSION

2.1. Major impacts

A detailed study of Panama Canal Expansion (PCE) on Caribbean ports (Soto Reyes, 2017) was carried out. The study concluded that the major short-term impact for Caribbean ports would be a decrease in transhipment container volumes, lost to new direct services deploying NPX vessels calling to the newly adapted ports of the United States (US) East Coast and the Gulf of Mexico. However, due to their

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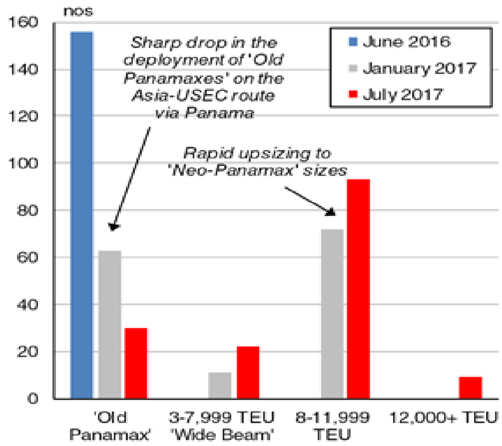
[5] Neo-Panamax (NPX) vessels: Vessels with the following maximum dimensions 366 meters Length over All (LOA), 49 meters beam, and 15.2 meters draught in Tropical Fresh Water (TFW).

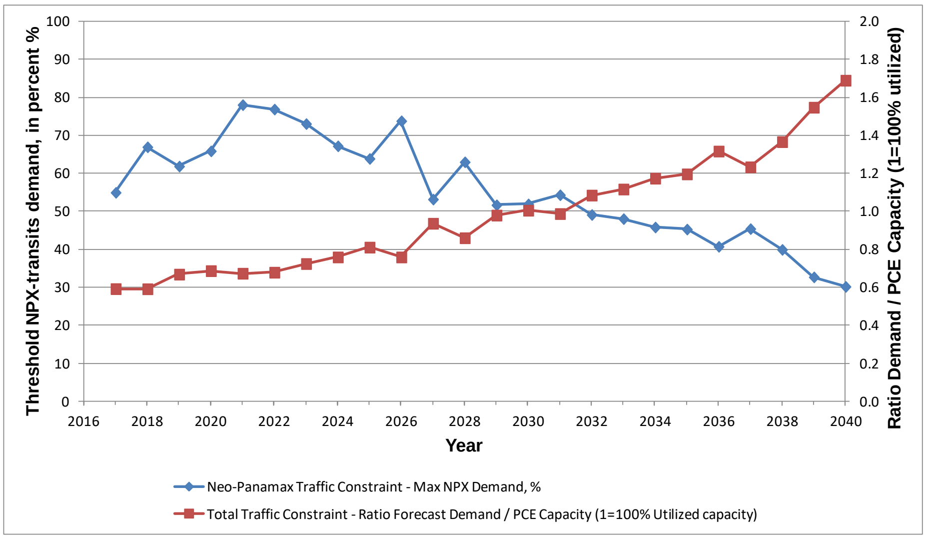
privileged geographical location in the crossroad of important maritime routes their development will continue to be intrinsically linked to the Panama Canal beat.



Source: Excerpted from (Clarksons Research, 2017)

Figure 1. Deployment shift of Panamax (PX) vessel in Trans-Pacific Panama Canal services, after PCE

Contemporaneously, a sharp drop in deployment of Panamax (PX) vessels in Panama Canal services, and a surge in the scrapping of such "old" Panamax take place; thus the substitute fleet of NPX vessels being deployed in services via Panama Canal is expected to continue growing steadily, as shown in Figure 1. Accordingly, it has been also estimated in this research that expanded Panama Canal, may reach its full capacity around year 2030 (Soto Reyes, 2017), as shown in Figure 2.



Source: Excerpted from (Soto Reyes, 2017)

Figure 2. Expanded Panama Canal capacity, 1-run dynamic forecasting

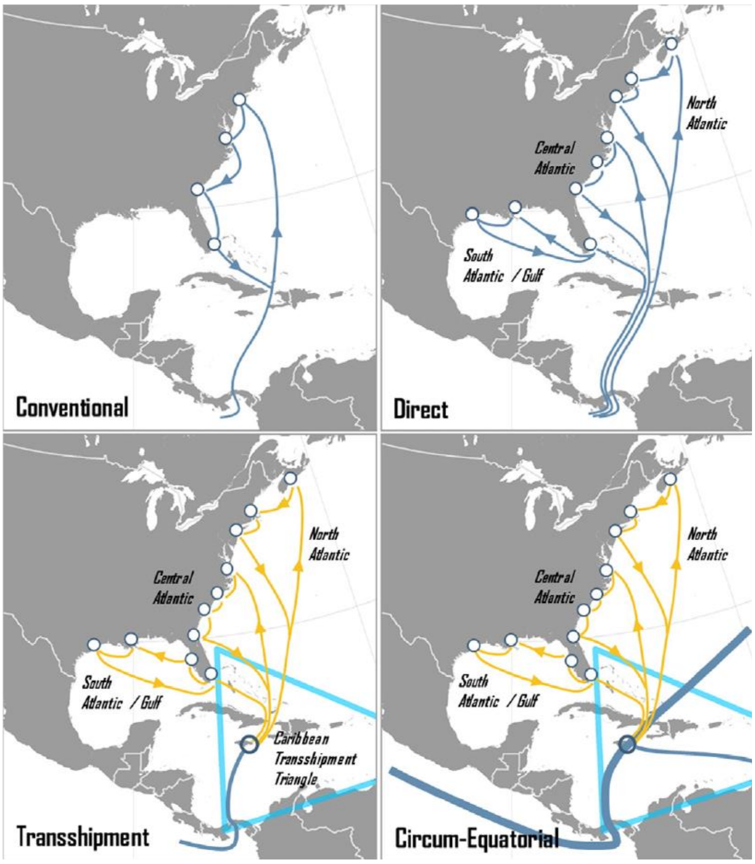
Since the construction of a fourth set of locks remains uncertain, such future bottlenecks in the expanded Panama Canal, in its current configuration, may result in new opportunities for the Caribbean ports. Hence, the study concludes that the expanded Panama Canal may eventually attract more Caribbean port traffic and thus container transhipment may regain business, in the mid- and long term.

In addition to the intrinsic uncertain developments discussed above, the Caribbean Ports are beset with other future uncertainties related to technology, market and economy, politics and legislation as well as society and environment and yet must ensure functionality, capacity and service quality during their design life time in a sustainable manner (PIANC, 2014a, 2014b; Taneja, 2013). We advocate an adaptive planning approach in the next sections.

2.2. Uncertainties in the aftermath

As previously noted, it may be expected a certain extent of decreased container transhipment traffic in the Caribbean region just after the completion of PCE, mostly due to the migration towards direct calls to the ports in the US East Coast and the Gulf of Mexico (Rodrigue & Ashar, 2016). However, such new sailing patterns, as the shown in Figure 3, may evolve themselves into diverse configurations –e.g., "conventional or traditional single rotation", "direct regional specialized service", "transhipment hub-and-spoke", "equatorial round-the-world", "fourth-revolution global grid" (Knight, 2008; Rodrigue & Ashar, 2016) – depending on a variety of uncertain developments, including but not limited to such related to:

- Development options of individual Caribbean port terminals (Notteboom, Ducruet, & Langen, 2010), and with regard to their respective level of transhipment incidence, namely gateway/feeder ports, regional gateway ports, hub ports, pure transhipment ports (Rodrigue & Ashar, 2016).
- Trans-Pacific trade development, congestion issues at US West Coast and Land Bridge, the emergence of new US East Coast gateways (Notteboom et al., 2010)
- Inter-range evolution of different transhipment patterns involving the Caribbean port system namely, direct services, "by-passing" services, "tail-cutting" services, "hub-and-spoke" services, "intersection" services, "relay" services (Rodrigue & Ashar, 2016).
- Competition and collaboration schemes amongst Caribbean ports (Notteboom et al., 2010)
- Intra-range transhipment structures of Caribbean ports, e.g., the development and evolution of a "transhipment funnel", "transhipment triangle", "transhipment corridors" or individual "transhipment clusters" (Rodrigue & Ashar, 2016).
- Dynamics of LNG[6] trade patterns or game-changers such a Valemax-class very large ore carriers.
- Global impacts of One Belt One Road long-term project (China Britain Business Council, 2017).
- Increased navigability of seasonal Arctic routes (Snyder, Doyle, & Toor, 2013).
- The construction of a new Interoceanic Canal in Nicaragua (HKND Group, 2018).
- Global maritime industry trends, e.g., mergers, acquisitions, and bankruptcy of shipping lines.



Source: Excerpted from (Notteboom et al., 2010)

Figure 3. Potential sailing patterns in Caribbean basin, after PCE

[6] Liquefied Natural Gas (LNG)

In Section 5, a method for quantifying opportunities from containerized traffic using dynamic forecasting, Real Options Analysis and Monte Carlo Simulation is presented.

3. ADAPTIVE PORT PLANNING: THEORETICAL FRAMEWORK

APP aims at developing plans that take uncertainties explicitly into account, allowing for change, learning, and adaptation over time based on new knowledge and changing circumstances. Such flexible or adaptable plans will allow the port to be functional under new, different, or changing requirements in a cost-effective manner, and seize opportunities.

Figure 4 portrays the basic steps of the Adaptive Port Planning methodology that were followed during the development of the real case study in Barranquilla, Colombia, as defined and thoroughly depicted by (Taneja, 2013)**.**

3.1. Step 1: Definition of the project objectives and success criteria

This stage includes the definition of both success and, consequently the objectives of the project. With such input, preliminary forecasting and planning are performed as well as the initial set of alternatives and/or strategies, for the expected useful time horizon of the project.

Definition of Success: Compiled specification or desired project outcomes *vis-à-vis* the previously stated mission, vision, objectives and constraints which the stakeholders would find as of an acceptable satisfaction level (Taneja, 2013; Walker, Rahman, & Cave, 2001). Consequently, failure may be defined as any set of possible project results which would be deemed as unacceptable by the stakeholders (Walker et al., 2001).

3.2. Step 2: Definition of the basic plan and assumptions

For the initial set of alternatives/strategies, a SWOT[7] analysis should be performed for each alternative or strategy, in order to rank the most prominent opportunities and vulnerabilities for the project.

Assumption: Is an assertive statement about relevant and specific features of the future that underlies the existing operations or plans of an enterprise. Vulnerable assumptions are those which, if impacted by vulnerabilities within the planning time horizon, will certainly fail (Dewar, Builder, Hix, & Levin, 1993; Taneja, Walker, Ligteringen, Schuylenburg, & Plas, 2008).

Critical assumption: Assumption whose failure would mean the failure of the plan (Taneja et al., 2008). Not all the vulnerable assumptions are critical, but all the critical assumptions are vulnerable.

Development or element of change: Is a future world event or condition that means a change to status quo, it is credible within the planning time horizon and is relevant to the existing operations or plans of an organization (Dewar et al., 1993; Taneja, 2013).

3.3. Step 3: Proactive incorporation of flexibility and robustness

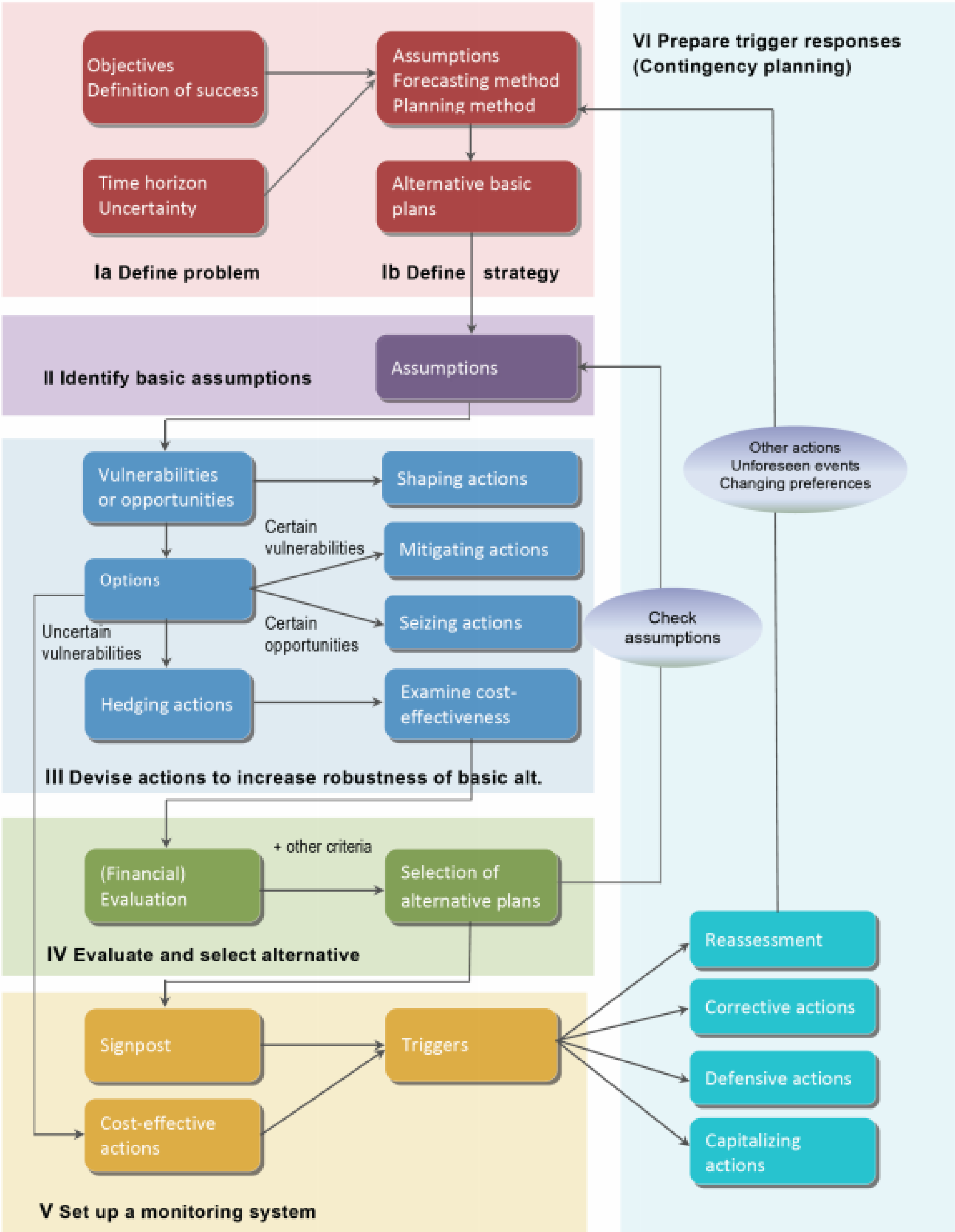
This stage, along with Step 4 may be deemed as the core stages in APP methodology. At this point, efforts should be focused on enhancing “certain and uncertain” opportunities and, more importantly on, planning actions to be taken for the mitigation of “certain” threats and to turn “uncertain” vulnerabilities into new opportunities in the future.

Vulnerabilities: Any possible development or element of change that may be a hindrance to the success of the plan (Taneja et al., 2008).

Opportunities: Any possible development of element of change that may enhance the success of the plan (Taneja et al., 2008).

Mitigating actions: Organizational actions to be taken *in advance* to reduce the negative effects of reasonably *certain* vulnerabilities of the plan, i.e., seeking the *robustness* of the plan (Kwakkel, Walker, & Marchau, 2010; Walker et al., 2001).

[7] SWOT: Strengths, Weaknesses, Opportunities and Threats



Source: Excerpted from (Taneja, 2013)

Figure 4. Adaptive Port Planning (APP) methodology

Hedging actions: Organizational actions to be taken *in advance* to reduce the potential negative effects of *uncertain* vulnerabilities of the plan, i.e., seeking the *robustness* of the plan (Kwakkel et al., 2010; Walker et al., 2001).

Shaping actions: Organizational *pro-active* actions precisely intended 'to shape' future *certain and uncertain* externalities to either weaken vulnerabilities or enhance opportunities (Dewar et al., 1993; Kwakkel et al., 2010), or turning vulnerabilities into opportunities or a combination thereof.

Seizing actions: Organizational actions planned *in advance* to be executed in the future to grab at reasonably *certain* available opportunities (Kwakkel et al., 2010).

3.4. Step 4: Evaluation and selection of alternatives (strategies)

At this stage the most challenging tasks are expected to be the valuation, or quantitative assessment, of the "flexibilities" incorporated in the previous stage, and the internalization of the associated additional costs into the final project appraisal.

3.5. Step 5: Contingency planning (incorporation of adaptive elements)

Since the proposed APP methodology should be proactive and dynamic, then monitoring the specific external factors affecting the maritime industry in the studied region becomes of a paramount importance. Accordingly, to close the loop on the adaptive and flexible nature of the planning, it is necessary also to draft the lines of action for the cases when residual vulnerabilities become reasonably evident to occur, or to seize any new opportunities as they may appear on the lifetime horizon of the project.

<u>Signposts</u>: Originally defined as an event or threshold indicative of the future development of any given uncertainty, signposts may be also depicted as mechanisms implemented for specifying, collecting, and monitoring information deemed as an indicators of whether the plan is on track for success, or not. Such indicators should be *unambiguous* and, should be duly paired with their respective vulnerabilities or opportunities (Dewar et al., 1993; Kwakkel et al., 2010).

<u>Triggers</u>: Threshold values of signpost indicators which, when surpassed, should spark the implementation of either defensive, corrective or capitalizing mechanisms, as established in the contingency plan (Taneja et al., 2008; Walker et al., 2001).

<u>Defensive actions</u>: Organizational *after-the-fact* actions to either clarify the plan, respond to external challenges or to preserve its benefits; while the basic plan remains substantially unchanged (Kwakkel et al., 2010; Taneja et al., 2008).

<u>Corrective actions</u>: Signpost-triggered organizational adjustments leading to a better enforcement of the plan in response to dynamic external conditions (Kwakkel et al., 2010; Taneja et al., 2008).

<u>Capitalizing actions</u>: Organizational *after-the-fact* actions to leverage future opportunities and thus enhancing plan's performance (Kwakkel et al., 2010; Taneja et al., 2008).

<u>Reassessment</u>: It is the *re-examination and revision* of the plan to be triggered whenever neither defensive, nor corrective actions would suffice to reroute the plan towards success or whenever the plan's critical assumptions have, undoubtedly and irreversibly, lost their validity (Dewar et al., 1993; Kwakkel et al., 2010; Walker et al., 2001).

3.6. Step 6: Implementation and monitoring

Finally, after duly setting up the signposts, triggers and contingency responses, the adaptive port planning process should then transition to the implementation phase, e.g. design, construction, operations and maintenance, while the managerial team should continue proactively monitoring the signposts-and-trigger indicators (Taneja et al., 2008). Hence, an adaptive planning approach enables policy-makers and decision-takers to take advantage of the benefits from both a proactive present-to-future outlook and, future-to-present retrospective analysis (Walker et al., 2001).

4. CASE STUDY: BARRANQUILLA NEW PORT TERMINAL

4.1. Project description and objectives

The new port terminal is projected to be constructed on the East bank of Magdalena River, two (2) kilometres upstream from the mouth of the river at Bocas de Ceniza, as shown in Figure 5, and would become part of the port complex of Barranquilla, Colombia.

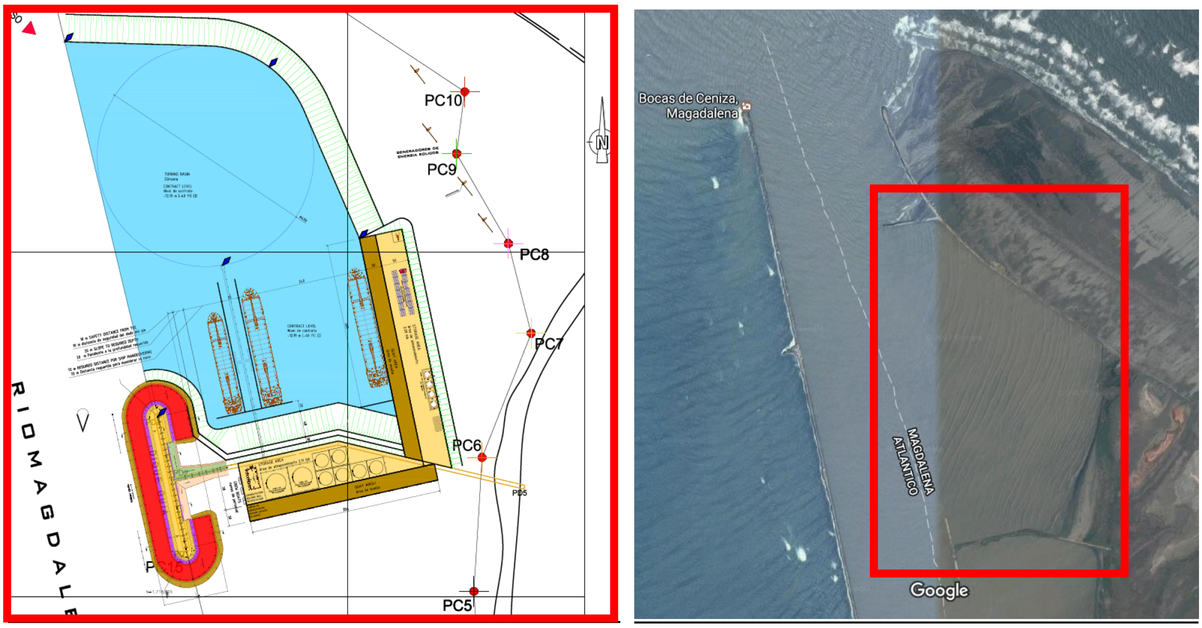
The core business of the new port terminal will be the imports of liquid bulk, e.g., diesel and other oil and petroleum derivatives. A single-buoy mooring system for super-tankers is also projected to be installed as part of the project. Nevertheless, the three main cargoes to be handled will be liquid bulk, grain dry bulk and containers. Aboveground storage tank farms will be built for the liquid bulk whereas the grain dry bulk will be shifted by conveyor belt to storage silos. The container stacking yard has been originally conceived for a declared capacity of 6,000 TEU/year.[8]

The initial project will consist of 4.2-Hectare land reclamation, with two (2) berths, loading/unloading platform and trestle for the liquid bulk terminal, and one (1) multi-purpose 300-meter berth for the dry bulk and container terminal, as shown in Figure 5.

The design vessel dimensions are 200 meters Length Over-All, beam of 32.2 meters and, a draught of 10.0 meters, i.e., slightly smaller than Panamax dimensions. The terminal only hinterland connection should be via river barges sailing the Magdalena River, in diverse push boat-barge convoy configurations.

The conceptual design provides for a 300-meter length multi-purpose quay wall. The quay area devoted for ship-to-shore operations is 30-meter width, but such an area is not taken into account for container handling capacity calculations. The container handling yard, as conceptually designed, is 1.5 hectares, i.e., a rectangular-shaped yard with dimensions 300x50m. The throughput capacity for the fixed base case has been estimated to be 30,000 TEUs/year.[9]

The contractual dredging design level for the base case has been set to elevation -12,20m CD, hence, allowing only for a maximum draught of 10m. Such restriction will make this terminal unable to handle the Neo-Panamax (NPX) vessels, with a 15.2m draught, now transiting the Panama Canal Expansion (PCE), and hence will render the terminal unable to profit from the PCE-generated traffic.



Source: Adapted from (Soto Reyes, 2017)

Figure 5. General layout and regional location of the case study port terminal

4.2. Identification of project uncertainties

Adaptive Port Planning (APP) methodology makes use of the multi-stakeholder brainstorming as an out-of-the-box process to identify and categorize project uncertainties, as well as to perform a qualitative assessment of their drivers and impacts on the development of the project. Moreover, the so called “wildcards” or “black-swans” developments are also brought into consideration (Taneja, 2013).

[8] The reader may find a difference between the declared capacity of 6,000 TEU/year as indicated in the conceptual design (confidential) documentation and, the estimated handling capacity of 30,000 TEU/year used in this paper as the fixed base case design. Nevertheless, it is necessary to explain that, for the purpose of this paper and real case study, the latter capacity has been calculated following the best practice and benchmarking on terminal capacity calculations and, under the paramount assumption of installing one (1) Ship-To-Shore (STS) crane per each 100-meter length of quay wall, with a capacity of 100,000 TEU/year/STS crane and, a standard 500-meter wide container handling yard all along the quay wall length.

[9] Ibid.

Table 1 presents the different sources of intrinsic uncertainties identified for the case study project, grouped under four (4) major categories, namely Technology, Market and Economy, Politics and Legislation and, Society and Environment.

Table 1. Categorized credible developments and their impacts

Category	Credible development	Impact
Technology	Development of new and more environmentally-friendly technologies.	Environmental dredging may facilitate the permits for deeper capital and maintenance dredging of ports along Magdalena river, especially nearby protected areas.
	Supply of utilities across Magdalena river.	Since the project will be basically an island in the middle of an environmentally protected area, logistics for utilities supply from the West bank to the terminal would represent a logistics issue for the construction of the terminal.
Market & Economy	Construction of offshore Single Buoy Mooring (SBM) for bigger LNG vessels.	The project may raise opposition from the public and stakeholders on grounds of the environmental issues of laying a pipeline across a protected area.
	Development of inland waterway terminals (infrastructure and operators).	The case study terminal is being projected to serve the hinterland by means of river barge convoys; hence, for the business case to remain valid, a proper network of inland intermodal terminals should be developed and maintained by externals.
	Less Panamax ships deployed on Panama Canal routes.	Since both the case study terminal and Magdalena river navigability plan only provide for 10-meter draught Panamax vessels, the fact that such vessels may incrementally be scrapped would severely impact the business plan of the port terminal.
Politics & Legislation	Peace process implementation.	Should the peace process be implemented, opportunities for a bigger economic growth of the country could also foster new port developments, e.g., greenfield port of Antioquia-Urabá (Puerto Antioquia Website, 2017), that would be competitors to the case study terminal.
	Trade with Venezuela.	A large share of Colombian trade is conducted with Venezuela. A highly unstable political turmoil in the neighboring country may have repercussions on maritime trade.
	Granting of concession by CORMAGDALENA.[10]	The whole project execution is subject to the approval of the full package of studies required by CORGMAGDALENA.
Society & Environment	Upstream river basin development plans by regulatory entity CORMAGDALENA.	The planning and design process for future port terminals.
	Climate change / Sea Level Rise (SLR).	Port infrastructures should duly take into account climate change and sea level rise issues; otherwise, such costly projects may become vulnerable to such impacts.
	Society's opposition (wetlands, erosion).	Should the project promoters fail to effectively engage stakeholders of the overall benefits of the new port, societal and environmental opposition may be able to put the project on hold for an uncertain period of time.

Source: Excerpted from (Soto Reyes, 2017)

[10] Corporación Autónoma Regional del Río Grande de la Magdalena (CORMAGDALENA)

Table 2 concisely shows some sources of uncertainty, either vulnerabilities or opportunities, which may be deemed as external to the case study project.

Table 2. External sources of uncertainties for the project

Vulnerability / Opportunity	Specific drivers
Vulnerability: Scrapping of Panamax vessels.	The opening of the expanded Panama Canal. Economies of scale from Neo-Panamax and other Post-Panamax categories of vessels.
Vulnerability: Decay of transhipment on Caribbean ports.	Deepening of US East Coast and Gulf ports and improvement of their hinterland connections.
Vulnerability: Global economics.	Slowdown of China's economy.
Opportunity: LNG import / storage / bunkering business.	LNG becomes the generalized "cleaner" fuel of the future.

Source: Excerpted from (Soto Reyes, 2017)

Table 3 summarizes some of the so called "wildcards" or "Black Swans" (Taneja, 2013) identified for the specific case study project.

Table 3. Major external wildcards and their impacts

Wildcards (or "Black Swans")	Impacts
One Belt One Road (OBOR).	It may be deemed as the Chinese response strategy to USA protectionism. Europe and Asia linked by land and maritime bridges with six (6) economic corridors over 60 countries may negatively impact Asia-US East Coast/Gulf trade, from which both the Panama Canal and Caribbean ports benefit.
USA Protectionism policies.	Colombian and other Latin American exports to the United States of America may decrease substantially. Consequently, port activity may be affected negatively.
EU (partial) disintegration.	Trade agreements would have to be negotiated separately with different European countries and most likely under diverse conditions, which may render trade more difficult.
China's decline and India's surge.	The two competitive advantages of Colombian port system are: Shorelines in both the Pacific and Atlantic/Caribbean basin and its proximity to the Panama Canal. The latter one would be negatively impacted if the manufacturing pole shifts from Northeast/Southeast Asia to Western India, because the Suez canal route would gain market from the Panama Canal route.
Global economic collapse (and reset).	All business cases for port terminals would have to be extensively revised. Only the adaptable or resilient ones may prevail and become stronger after the reset.
Latin American integration and upsurge, e.g. "Chile-con Valley" (The Economist, 2012).	Colombia and other Latin American countries unite to conform a strong economic conglomerate, exporting value-added products and services, thus fostering port activity.

Source: Adapted from (Soto Reyes, 2017)

4.3. Action plan

After the preliminary scanning of the project's uncertainties, a flexible action plan is drafted, from which the planners will pick their specific flexibilities and formulate the diverse strategies to be further quantified (Taneja, 2013), as it will be performed in the following sections.

Table 4 summarizes the "known" uncertainties for the project and the conceptual responsive actions to either mitigate vulnerabilities, shape the future or seize opportunities in the future, respectively.

Table 4. Certain developments and responsive actions

Vulnerabilities/Opportunities	**Actions: Mitigation (MI): reduce negative effects; Shaping (SH) the future: proactive; Seizing (SZ): grab opportunities**
Opportunity: Panama Canal Expansion and traffic enhanced by Neo-Panamax container vessels.	Seizing: Design and build port infrastructures enabled to handle Neo-Panamax container ships to attract a share of the new demand.
Opportunity: Panama Canal Expansion and new transits of (Neo-Panamax) LNG/LPG vessels.	Seizing: To design and build LNG/LPG importing/storage/bunkering terminals, also enabled for Neo-Panamax carriers.
Opportunity/Vulnerability: Panama Canal Expansion and change in sailing patterns by shipping lines.	Shaping: Foster and establish cooperation agreements with Panama Canal and/or with Caribbean transhipment hub ports to manage their overflow in the long-term. Shaping: To broker agreements with shipping lines wanting to offer “greener” hinterland transport by means of inland waterways system of Magdalena river.
Vulnerability: Expansion of existing (and competitor) dedicated container terminal in Barranquilla.	Mitigation: Design and built multi-purpose terminals. To sign cooperation agreements with other terminal operators within Barranquilla port complex, perhaps focusing more on the hinterland import/export niche market rather than transhipment. Shaping: Investing in inland waterway terminals and/or “dry port” (Woxenius, Roso, & Lumsden, 2004) facilities.

Source: Adapted from (Soto Reyes, 2017)

Table 5 summarizes the “unknown” uncertainties for the project and the conceptual responsive actions to either hedge vulnerabilities or shape the future, accordingly.

Table 5. Uncertain developments and responsive actions

Vulnerabilities/Opportunities	**Actions: Hedging (HE): reduce negative effects of vulnerabilities; Shaping (SH): proactive, shape future**
Vulnerability: Drastic scrapping and eventual disappearing of Panamax vessels from the fleet.	Hedging: Design and build port infrastructures enabled to handle Neo-Panamax vessels. Shaping: Negotiate with minor shipping lines to continue deploying Panamax vessels in their feeder services.
Vulnerability: Development of new container terminal at Urabá-Antioquia, Colombia.	Shaping: Join efforts with other Barranquilla port complex terminals to establish cooperation agreements with other Colombian Caribbean ports, to focus in different but complementary niche markets.
Vulnerability: Construction of super- deep water port at Bocas de Ceniza, Barranquilla.	Shaping: Establish cooperation agreements with other terminal operators within Barranquilla port complex, to focus in different but complementary niche markets.
Opportunity: Regulation enforcing LNG/LPG-powered river vessels.	Shaping: To design and build LNG/LPG importing/storage/bunkering terminals, which are also enabled for Neo-Panamax carriers.

Source: Adapted from (Soto Reyes, 2017)

4.4. Monitoring, contingency and implementation plans

Table 6 concisely summarizes the opportunities and vulnerabilities to be monitored, as well as their respective threshold values and timing to trigger the implementation of contingency actions, as per APP approach.

Table 6. Monitoring thresholds and triggers

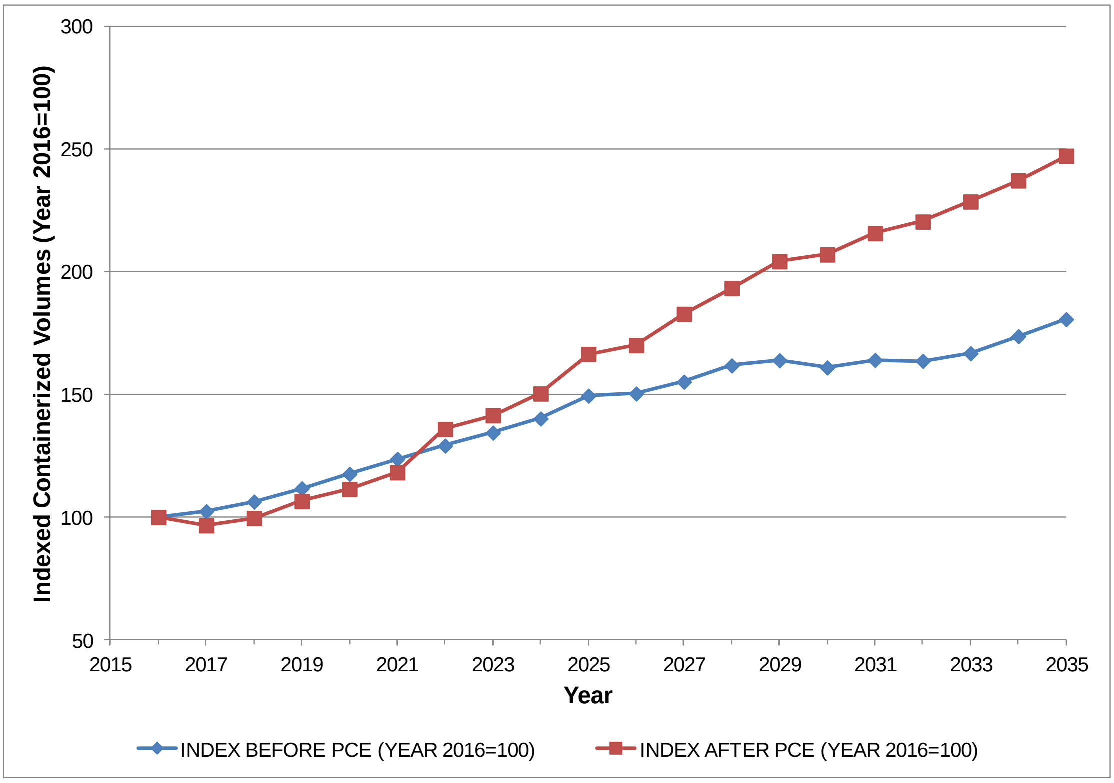
Vulnerabilities / Opportunities	Monitoring & Thresholds	Actions: Reassessment (RE) or Corrective (CR) or Defensive (DE) or Capitalizing (CP)
Opportunity: To gain share in existing demand that would otherwise go to another port.	Demand / Capacity ratio equal or greater than 0.95 for two (2) consecutive years.	Capitalizing: Triggers the addition of (modular) handling capacity, i.e., sequential incorporation of flexibilities 1, 2 and 3, as applicable [See Section 5].
Opportunity: To gain share in existing demand that would otherwise go to another port.	NPX-traffic / Capacity ratio greater o equal to 1.00 for two (2) consecutive years.	Capitalizing: Triggers the execution of additional dredging works, i.e., incorporation of flexibility 5, as applicable [See Section 5].
Vulnerability: Total replacement of Panamax vessels.	Yearly scrapping and new orders reports.	Re-Assessment: Enable the port terminal to handle Neo-Panamax vessels, even if traffic volumes are low (better than none).

Source: Adapted from (Soto Reyes, 2017)

5. CASE STUDY: QUANTIFYING OPPORTUNITIES FROM PANAMA CANAL EXPANSION

5.1. Dynamic forecasting of containerized traffic

Based on calculated container-traffic indexes after the Panama Canal Expansion, as shown in Figure 6, the new demand was calculated by means of dynamic forecasting, which offers the advantage of taking into account the stochastic nature of uncertainties when estimating future demand of variables which may either go up or go down the next year, without any function attached (De Neufville & Scholtes, 2011).



Source: Excerpted from (Soto Reyes, 2017)

Figure 6. Indexed Caribbean containerized port traffic, before and after PCE (1-run estimation)

Available historic traffic data from years 2008-2016 jointly with World Economic Outlook for years 2017-2021 by the International Monetary Fund (IMF, 2016) were used as starting point for the dynamic forecasting process.

For the sake of consistency with flexibility concepts, it was necessary to generate at least 1,000 “possible futures” by means of spreadsheet-based Monte Carlo Simulation. Such simulated future demands thereafter became the input for the screening models performance calculations.

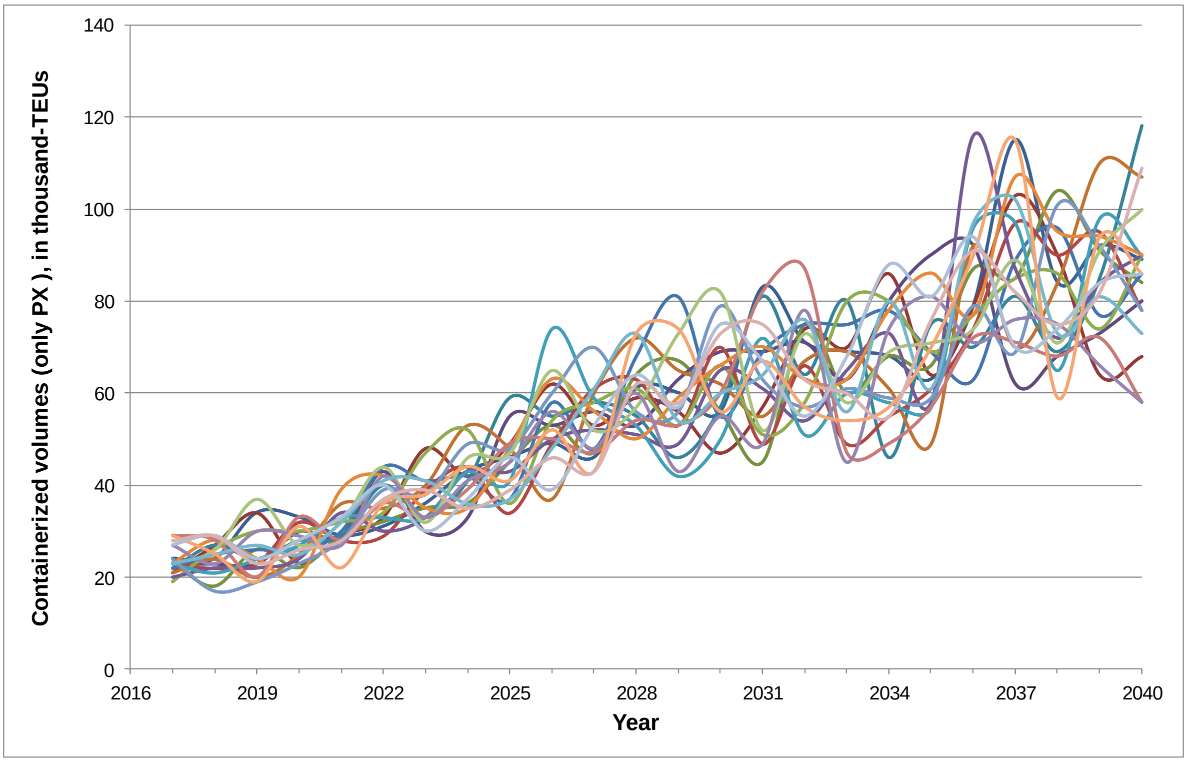
Further assumptions were superimposed on the dynamically forecast Caribbean port traffic to convert it to the demand for the case study port. Accordingly, randomly and gradually-varied market shares were assumed, as shown in Table 7.

After having incorporated such assumptions into the extended dynamic forecasting model, it was possible to obtain both, the dynamic forecasting for only Panamax-borne container traffic, as shown in Figure 7; as well as the dynamic forecast for the total container traffic, i.e. carried in both Panamax and Neo-Panamax vessels, as presented in Figure 8.

Table 7. Market share assumptions for screening models

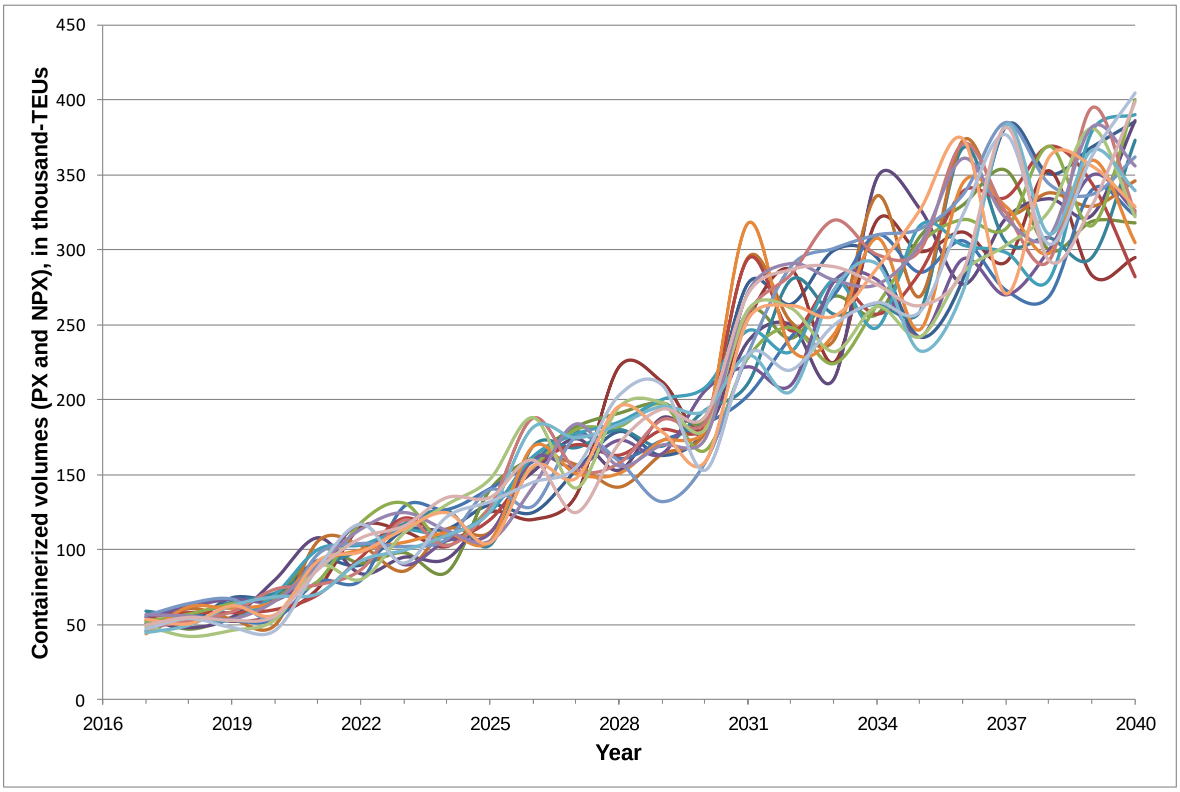
Year	2017		2040	
Range	Min	Max	Min	Max
PX-borne traffic share, PX	40.0%	50.0%	20.0%	30.0%
NPX-borne traffic share, NPX	50.0%	60.0%	70.0%	80.0%
Colombian Caribbean share (of Caribbean Port System)	18.0%		22.0%	25.0%
Rest of Caribbean System ports	82.0%		75.0%	78.0%
Barranquilla share (of Colombian Caribbean)	5.0%		9.0%	10.0%
Santa Marta/Cartagena/Antioquia-Urabá (future)	95.0%		90.0%	91.0%
Potential Case Study Port share (of Barranquilla)	30.0%	40.0%	30.0%	40.0%
Calls to other terminals within Barranquilla complex	60.0%	70.0%	60.0%	70.0%

Source: Excerpted from (Soto Reyes, 2017)



Source: Excerpted from (Soto Reyes, 2017)

Figure 7. Dynamic forecasting for case study port: PX-borne only (20-future sample)



Source: Excerpted from (Soto Reyes, 2017)

Figure 8. Dynamic forecasting for case study port: PX- and NPX-borne (20-future sample)

5.2. Evaluation of flexibility by Real Options Analysis

For the sake of conciseness and the purpose of this paper, in the proposed methodology to evaluate flexibilities by means of Real Options Analysis and Monte Carlo Simulation, only uncertainty-flexibility pairs related to containerized market segment will be further assessed throughout the following sections.

5.2.1. Identification and description of specific flexibilities

Base Case (Flexibility 0): It consists of a 300-meter length multi-purpose quay wall. The Ship-to-Shore (STS) operations area is a 30-meter wide strip all. The container handling yard has been originally conceived as a 300-meter length and 50-meter wide, for a total of 1.5 Hectares. This conceptual design, as of today, may be deemed as a fixed (non-flexible) design since, with regard to the container niche market, since it does not provide for either a future quay wall extension nor for additional container handling yards. Assuming the installation of three (3) STS container cranes, the yearly container throughput for this configuration has been estimated in 30,000 TEUs per year, as per standard practice.

Flexibility 1: It consists of an additional container handling area just adjacent to the original yard. Accordingly, additional reclamation works should be performed to allow for such future expansion eastward the original yard. Such expansion may be performed in three phases, by habilitating 1.5Ha in each instance, up to a total of three-fold modular expansion of 4.5Ha, upon market demand. The physical restraint for the implementation of this flexibility will then be the boundaries of the concession polygon. Hence, flexibility in this option stems from its expandable and modular attributes. Flexibility 1 may add a capacity of 90,000 TEUs per year to the system.

Flexibility 2: It consists of the addition of 300-meter of quay wall to the North of the original one. Such quay wall extension may allow for the berthing of more and different combinations of simultaneous vessel calls (e.g., two Panamax ships) in response to potential increase traffic calling to Barranquilla port. The 300-meter quay wall extension should be complemented with the construction of another modular 3x1.5Ha extension of the container handling area, upon market demand. As in Flexibility 1, flexibility in this option stems from its expandable and modular attributes. Flexibility 2 may add a capacity of 90,000 TEUs per year to the system.

<u>Flexibility 3</u>: It consists of the extension of the quay wall 100-meters northward plus a subsequent 3x1.5Ha modular extension of the container handling area, upon market demand. Such additional quay wall length may enable the port to handle two (2) feeder-type vessels simultaneously; however, the handling of two Panamax ships will not be feasible with this layout. As in Flexibilities 1 and 2, flexibility in this option stems from its expandable and modular attributes. Flexibility 3 may add a capacity of 90,000 TEUs per year to the system.

<u>Flexibility 4</u>: Flexibility 4 does not directly add physical capacity but, conversely enables future management to seize new business opportunities, upon market demand. It is a built-in flexibility, consisting of quay wall structures being designed for a dredging design elevation of -16.70m CD, instead of the base case dredging elevation of -12.20m CD. By means of such "over-design" of the quay wall structures, the terminal will be provided with a "dormant capacity" to be enabled in the future to handle Neo-Panamax vessels provided *sine qua non* that:

- Additional dredging works are performed (see Flexibility 5) and,
- Quay wall length is also extended either to a total of 600-meters (Flexibility 2) or 400-meters (Flexibility 3).

<u>Flexibility 5</u>: Flexibility 5 does not directly add physical capacity but, conversely enables future management to activate "dormant built-in" Flexibility 4 and, seize new business opportunities, upon market demand. It consists of additional dredging works down to design level of -16.70m CD, at a later phase, in order to enable the terminal to handle Neo-Panamax vessels provided *sine qua non* that:

- Quay wall structures have been designed and built for a final dredging elevation of -16.70m CD (see Flexibility 4) and,
- Quay wall length is also extended either to a total of 600-meters (Flexibility 2) or 400-meters (Flexibility 3).

Table 8 summarizes the different flexible real options in terms of quay wall infrastructure, container handling yards and, dredging works, as well as the corresponding (non-) capability of the terminal to handle Neo-Panamax vessels.

Table 8. Summary of flexibility real-option structural features

Flexibility	**0**	**1**	**2**	**3**	**4**	**5**
Quay wall length, meters						
300.00	✓	✗	✗	✗	✗	✗
100.00	✗	✗	✗	✓	✗	✗
300.00	✗	✗	✓	✗	✗	✗
Total (flexible) expansion, m	***300.0***	***0.0***	***300.0***	***100.0***	***0.0***	***0.0***
Container handling yard, Ha						
1.50	✓	✗	✗	✗	✗	✗
4.50	✗	✓	✗	✗	✗	✗
4.50	✗	✗	✓	✓	✗	✗
Total (flexible) expansion, Ha	***1.5***	***4.5***	***4.5***	***4.5***	***0.0***	***0.0***
Extra-depth at quay wall design	✗	✗	✗	✗	✓	✓
Extra-dredging to -16.70m CD	✗	✗	✗	✗	✗	✓
Non NPX-capable	✓	✓	✓	✓	✗	✗
Dormant NPX-capable	✗	✗	✗	✗	✓	✗
NPX-capable	✗	✗	✗	✗	✗	✓
ADDED throughput capacity, TEUs/year	***30,000***	***90,000***	***90,000***	***90,000***	***0***	***0***

Source: Excerpted from (Soto Reyes, 2017)

<u>*5.2.2. Definition of real option strategies and screening models*</u>

After short-listing the real options for incorporating flexibility, it becomes necessary to define the different strategies for the implementation of such selected flexibilities either as stand-alone or as combined alternative responses to the plausible future developments of global and regional developments in containerized trade. Table 9 summarizes the basic descriptions of strategies in terms of the flexibilities incorporated in each instance.

Table 9. Basic matrix of strategies and flexibilities

Scenarios	Strategy ID	Base Case	Flexi 1	Flexi 2	Flexi 3	Flexi 4	Flexi 5
Non NPX-capable	1	✓	✗	✗	✗	✗	✗
	2	✓	✓	✗	✗	✗	✗
	3	✓	✓	✓	✗	✗	✗
	4	✓	✓	✗	✓	✗	✗
Dormant NPX-capable	5	✓	✗	✗	✗	✓	✗
	6	✓	✓	✗	✗	✓	✗
	7	✓	✓	✓	✗	✓	✗
	8	✓	✓	✗	✓	✓	✗
NPX-capable	9	✓	✓	✓	✗	✓	✓
	10	✓	✓	✗	✓	✓	✓

Source: Excerpted from (Soto Reyes, 2017)

Once the strategies have been defined, simple “screening models” (De Neufville & Scholtes, 2011) are required to initiate the process of quantifying the value of the preliminarily proposed flexibilities.

Following recommended practice from (De Neufville & Scholtes, 2011; De Neufville, Scholtes, & Wang, 2006), a particular spreadsheet-based and “adaptive” Discounted Cash Flow (DCF) methodology is then implemented as the backbone of the calculations featuring case-specific threshold-and-trigger mechanisms for the “automated” rules for incorporation of flexibilities (De Neufville & Scholtes, 2011), upon monitoring of external environment and drivers, i.e., relevant expected containerized trade, previously calculated by means of dynamic forecasting (De Neufville & Scholtes, 2011).

For each and every strategy, the following key system parameters were assumed:

<u>Demand</u>: Main input is the expected increased containerized trade derived from the Panama Canal Expansion (PCE).

<u>Thresholds-and-triggers:</u>

- Threshold Demand / Capacity ratio equal or greater than 0.95 for two (2) consecutive years, triggers the addition of (modular) handling capacity, i.e., sequential incorporation of flexibilities 1, 2 and 3, as applicable.
- Threshold NPX-traffic / Capacity ratio greater o equal to 1.00 for two (2) consecutive years, triggers the execution of additional dredging works, i.e., incorporation of flexibility 5, as applicable.

<u>Capacity</u>: Initial and sequentially added flexibility-related capacities are summed up to update a yearly total capacity.

<u>Revenues</u>: Calculated upon a composite average handling tariff estimated as USD 156.0 per TEU.

For the purpose of this paper, it is assumed that the revenues of the system are exclusively originated from the tariffs for handling containerized cargo, either for hinterland or for transhipment markets.[11]

TEU-factor was assumed as to be 1.50, i.e., 50% of the containers are 20-foot equivalent units (TEUs) and 50% of the containers are 40-foot equivalent units (FEUs)

<u>Analysis period</u>: 23-year horizon, from year 2017 until year 2040, inclusive. Fixed interest rate of eight percent (8.00%). Lead time between trigger and physical implementation was set to one (1) year.

The fixed concession lease and fixed costs have been assumed to be USD 250,000.00 and, the operational expenditures (OPEX) have been estimated to be USD 65.00 per TEU.

Finally, Table 10 summarizes infrastructural features and capabilities for the different analyzed strategies.

[11] The case study port may also get revenues from providing a diversity of ancillary services, including but not limited to: Concessions to terminal operators, storing of containers, terminal use fees to river barges operators, value-adding services, among others. Nevertheless, estimation of these additional revenues falls beyond the scope of this paper.

Table 10. Infrastructures and capabilities of strategies

Strategy	1	2	3	4	5	6	7	8	9	10
Quay wall length, meters										
300.00	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
100.00	✗	✗	✗	✓	✗	✗	✗	✓	✗	✓
300.00	✗	✗	✓	✗	✗	✗	✓	✗	✓	✗
Total (flexible) expansion, m	***300.0***	***300.0***	***600.0***	***400.0***	***300.0***	***300.0***	***600.0***	***400.0***	***600.0***	***400.0***
Container handling yard, Ha										
1.50	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4.50	✗	✓	✓	✓	✗	✓	✓	✓	✓	✓
4.50	✗	✗	✓	✓	✗	✗	✓	✓	✓	✓
Total (flexible) expansion, Ha	***1.5***	***6.0***	***10.5***	***10.5***	***1.5***	***6.0***	***10.5***	***10.5***	***10.5***	***10.5***
Extra-depth at quay wall design	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓
Extra-dredging to -16.70m CD	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓
Non NPX-capable	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗
Dormant NPX-capable	✗	✗	✗	✗	✓	✓	✓	✓	✗	✗
NPX-capable	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓
Max. TOTAL throughput capacity, TEUs/year	***30,000***	***120,000***	***210,000***	***210,000***	***30,000***	***120,000***	***210,000***	***210,000***	***210,000***	***210,000***

Source: Excerpted from (Soto Reyes, 2017)

5.2.3. Quantifying flexibilities by Monte Carlo Simulation (MCS)

We have identified the sources of uncertainty and their corresponding flexibilities. Later on, we have put together a set of flexible strategies and their corresponding screening models. Such screening models have been set up as having the expected built-in rules for exercising flexibilities as recommended by (De Neufville & Scholtes, 2011).

The main uncertain variable input for the above depicted screening models is the expected volumes of containerized cargo, previously calculated taking into account uncertainties by means of dynamic forecasting (De Neufville & Scholtes, 2011).

Flexible design and adaptive port planning strive to achieve port infrastructures that are enabled to perform successfully in a wide range of plausible futures. Therefore, in order to quantify the value of flexibility within this framework, it becomes necessary to somehow simulate such wide range of plausible futures. For the purpose of this research, this task was performed by means of a spreadsheet-based Monte Carlo Simulation (De Neufville & Scholtes, 2011; De Neufville et al., 2006).

Accordingly, runs of one thousand futures were generated for each of the ten (10) strategies, calculating their performances in terms of Expected Net Present Values (ENPV). Such ENPV array values were processed by standard statistics methods to generate target curves, i.e. the cumulative distribution function versus the “target” or Expected Net Present Value, for every and each of the analyzed strategies.

(De Neufville & Scholtes, 2011) propose that, given a non-flexible case target curve, the implementation of a flexible design should increase the upsides and reduce the downsides of a project by “pushing” the upper curve to the right positive side and “pushing” the lower curve down, respectively.

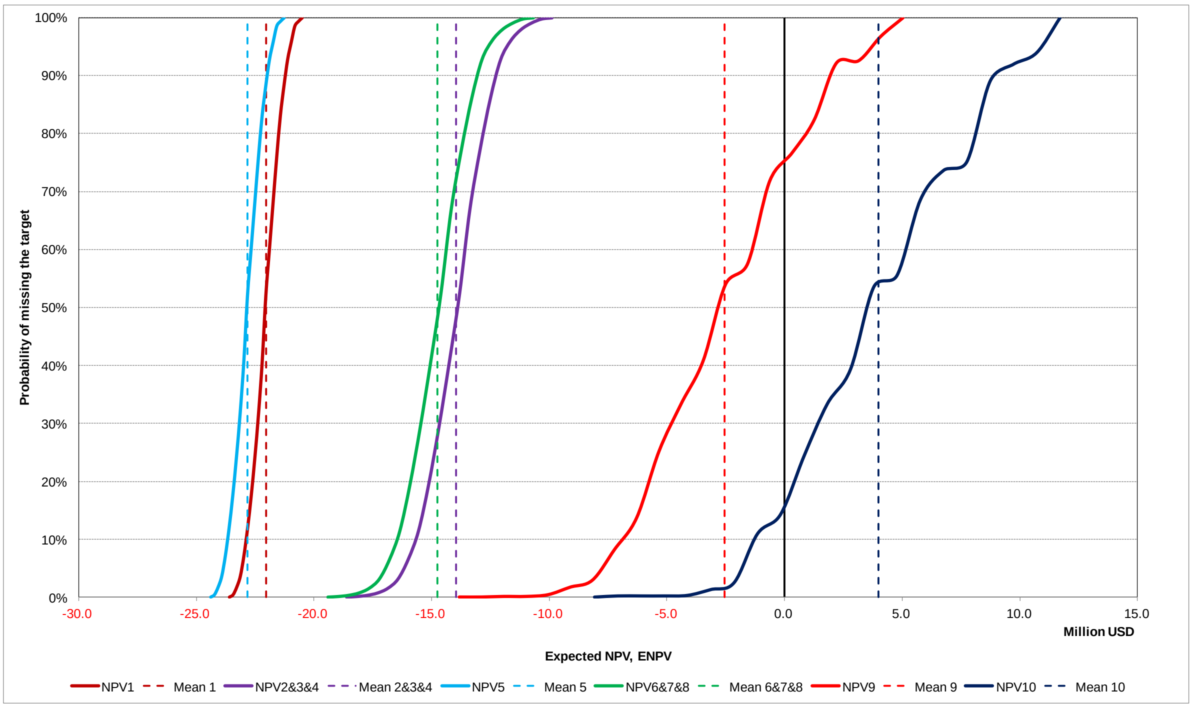
The following sections seek to briefly and concisely explain the processed outputs from Monte Carlo Simulations, to interpret such results and findings in terms of the flexible design theory and, shortlist the most promising alternatives for the case study port in Barranquilla.

Figure 9 showcases simulated target curves for fixed design and flexible strategies, as generated by 1,000-future Monte Carlo Simulation.

5.2.4. Ranking and selection of promising alternatives

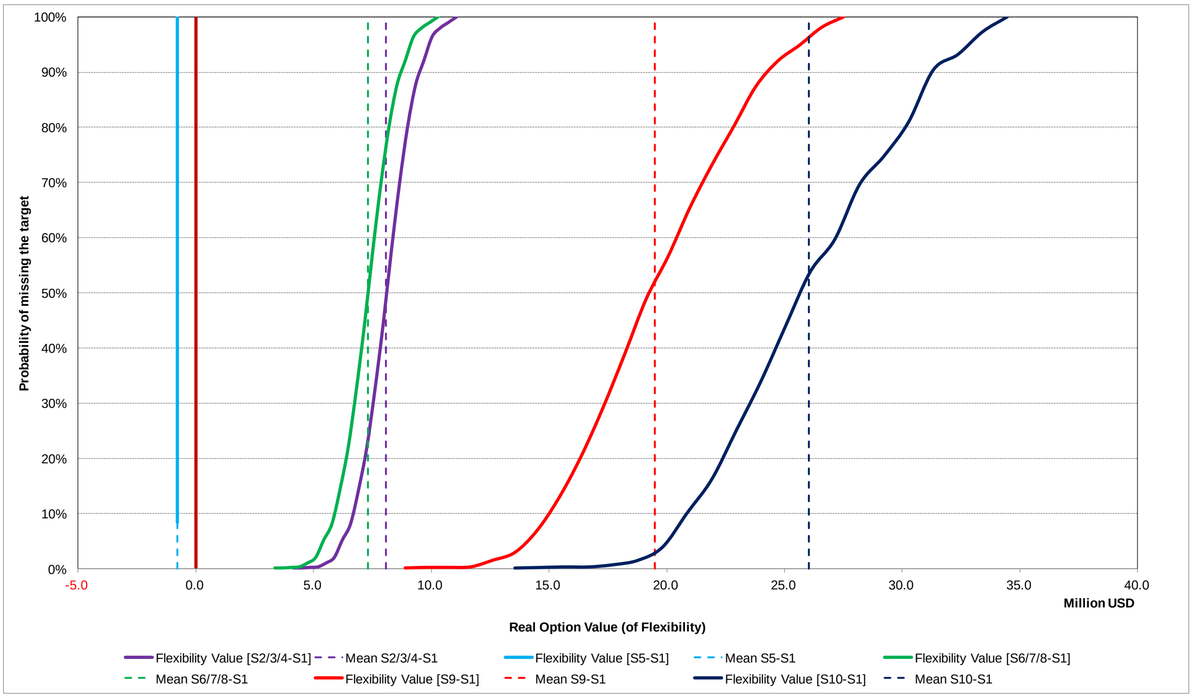
(Rivey, 2007) has concisely defined the term Real Option Value as the difference between the Expected Net Present Value of any given flexibility less the Expected Net Present Value of the traditional fixed base case.

Therefore, after having assessed their individual Expected Net Present Values (ENPV) for each of the ten (10) strategies analyzed, it becomes necessary to assess such Real Option Values as the nine (9) flexible strategies (from 2 to 9) *vis-à-vis* the non-flexible Strategy 1. Figure 10 compiles the results for such assessments.



Source: Excerpted from (Soto Reyes, 2017)

Figure 9. Simulated target curves for fixed design and flexible strategies



Flexibility Values	[S2/3/4-S1]	[S5-S1]	[S6/7/8-S1]	[S9-S1]	[S10-S1]
Mean, in USD	8,083,474	-781,575	7,301,898	19,502,776	26,042,771
Max, in USD	11,063,946	-781,575	10,282,371	27,514,598	34,459,608
Min, in USD	4,138,186	-781,575	3,356,611	8,902,564	13,562,139
10% Percentile, in USD	6,688,408	-781,575	5,906,833	15,051,033	20,836,378
90% Percentile, in USD	9,478,686	-781,575	8,697,111	24,282,797	31,271,956

Source: Excerpted from (Soto Reyes, 2017)

Figure 10. Real Option Values of flexible strategies

To a great extent, Real Options Quantifying reconfirmed the behaviours observed while generating individual simulated target curves for the ten (10) analyzed strategies.

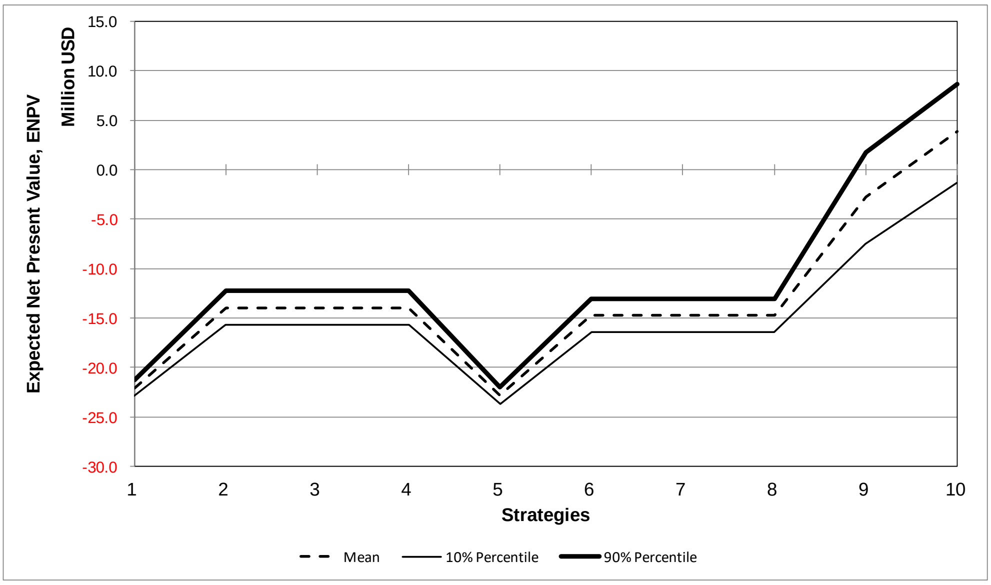
Complementary to the Real Option Quantifying, two useful managerial tools for decision making are the *Upside-Downside curves* and, the so called *Regret Plots* (De Neufville & Scholtes, 2011).

Upside-Downside curves are especially useful to trade off uncertainty, denoted by spread and standard deviation, against Expected Net Present Values (De Neufville & Scholtes, 2011) for the full range of different promising alternatives or strategies.

Regret Plots are useful tools to compare pairs of promising alternatives, upon their reciprocal Real Options Quantifying, i.e., to cross-check how much better –or worse – it is, and in which proportion may a first alternative perform over the second one and vice versa (De Neufville & Scholtes, 2011).

As it can be seen in Figure 11:

- Strategies 1 and 5 show relatively small spreads[12] in the order of USD 1.7 million, with 80% chance of ENPV falling between USD 21.2 million and USD 23.7 million, always negative.
- Strategies 2, 3, 4, 6, 7 and 8, present a moderate spreads of USD 3.4-3.5 million, with 80% chance of ENPV falling between USD 12.3 million and USD 16.5 million, always negative
- Strategy 9 show a wider spread of USD 8.7 million, with 80% chance of ENPV falling between positive USD 1.8 million and negative USD 7.0 million.
- Strategy 10 has the widest spread of USD 10.1 million, but with 80% chance of ENPV falling between positive USD 8.8 million and negative USD 1.3 million.



Source: Excerpted from (Soto Reyes, 2017)

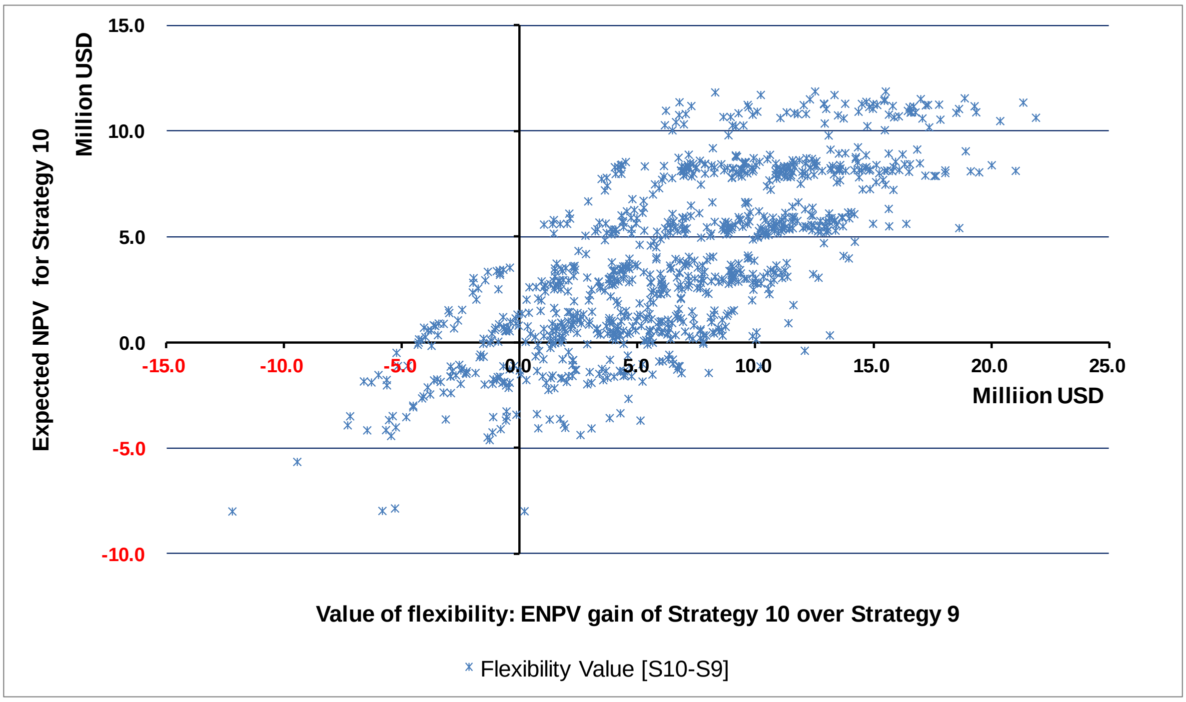
Figure 11. Upside-Downside curves for flexible strategies

At this point, it has been observed that, despite their largest spread and hence larger uncertainties, strategies 9 and 10 appear to be the best performers in terms of Expected Net Present Value, Real Option Value of flexibilities and Upside curves. It may be also observed that both strategies 9 and 10 clearly outperform fixed base case design, i.e., strategy 1.

Therefore, not only strategies 9 and 10 should be shortlisted as the most promising alternatives but, they should also be assessed one against the other in order to provide a rationale and comparative framework for the sake of future decision making.

Thus, the regret plot becomes a useful tool to achieve this objective. More specifically, the plot evaluates the cross-performance of the ENPV for strategy 10 *vis-à-vis* the value of flexibility of strategy 10 over strategy 9.

[12] Spread may be simply defined as the difference between 10-percentile and 90-percentile, for each instance.



Source: Excerpted from (Soto Reyes, 2017)

Figure 12. Regret plot: Strategy 10 versus Strategy 9

Therefore, from Figure 12 the following qualitative analysis items may be pointed out:

- Strategy 10 outperforms strategy 9 in most of the cases, despite some instances where Strategy 10 shows negative ENPV: More than 80 percent of the simulation points are plotted rightward of the Y-axis (1st and 2nd quadrants).
- Strategy 10 yields positive ENPV, even if Strategy 9 would perform better if chosen: Less than 10 percent of simulation points are plotted leftward of the Y-axis and above the X-axis (4th quadrant).
- Strategy 9 performs better than strategy 10 in less than 10 percent of the simulations: Points plotted leftward of the Y-axis and below X-axis (3rd quadrant).

6. CONCLUSION

We should move from risk management to uncertainty management and from static strategic planning to dynamic adaptive planning. Accordingly, uncertainty management and dynamic planning should be deemed as essentially interlinked and contemporaneous. Adaptive port planning is a comprehensive, coherent and integrated methodology to incorporate flexibility into port infrastructure projects.

The Panama Canal expansion will certainly bring cascading impacts on the ports and logistics platforms of the Caribbean region. Initially, this may lead to the decrease of transhipment containers volumes, lost to the new direct services deploying Neo-Panamax vessels. The accelerated scrapping of old Panamax vessels will also have its effects. The eventual capacity constraints of the expanded Panama Canal around year 2030 may however contribute to the recovery of the container transhipment business in the Caribbean port system.

Hence, uncertainty is omnipresent as far as this point, especially when many of the estimations are based on uncertain assumptions of different alternatives for sailing patterns, mergers and alliances, innovative technologies, and global economy´s outlooks.

We demonstrated through a specific research case study that incorporating flexible options can result in a more robust project.

Overall, the Adaptive Port Planning methodology, as applied in this research work, proved to be an innovative and yet pragmatic methodology to tackle the somehow tricky task of Quantifying Flexibility, accomplished by means of the simple and transparent tools such as dynamic forecasting, Real Options Analysis and Monte Carlo Simulation.

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