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DYNAMIC PLANNING FOR FLEXIBLE PORT INFRASTRUCTURE AFTER PANAMA CANAL EXPANSION: A REAL CASE STUDY

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ABSTRACT

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 dynamic planning and flexibility in engineering design is presented for a new port terminal in Barranquilla, Colombia. Furthermore, this paper presents the results of a stochastic method for quantifying opportunities from containerized traffic using Dynamic Forecasting, Real Options Analysis and Monte Carlo Simulation, within the framework and spirit of Adaptive Port Planning under uncertainty.

Keywords: Dynamic planning, adaptive, uncertainty, opportunities, flexibility, Dynamic Forecasting, Real Options, Monte Carlo Simulation.

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. Methodology and findings

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 and dynamic planning of flexible infrastructures whereby ports can deal with the vulnerabilities and seize new opportunities.

The paper carries out a Real Options Analysis throughout its basic and yet transparent steps i.e., definition of project-specific flexibilities; definition of strategies and scenarios; definition of screening models with built-in “rules for exercising flexibilities”; quantitative assessment of flexible real options *vis-à-vis* the base fixed alternative; and ranking and comparative evaluation of most-promising strategies.

Throughout a worked out numerical example, it was demonstrated that incorporating flexible options can result in a more robust project. Making the value of flexibility visible in such a “user-friendly” manner, makes it easily digestible by upper management and decision-makers.

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.

2. IMPACTS AND UNCERTAINTIES AFTER PANAMA CANAL EXPANSION

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

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 (Clarksons Research, 2017). Accordingly, it has been also estimated in this research that expanded Panama Canal, may reach its full capacity around year 2030 (Soto Reyes, 2017).

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.

3. ADAPTIVE PORT PLANNING: THEORETICAL FRAMEWORK IN A NUTSHELL

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.

The basic steps of the Adaptive Port Planning methodology were followed during the development of the real case study, as defined and thoroughly depicted by (Taneja, 2013)**:**

- Step 1: Definition of the project objectives and success criteria
- Step 2: Definition of the basic plan and assumptions
- Step 3: Proactive incorporation of flexibility and robustness
- Step 4: Evaluation and selection of alternatives (strategies)
- Step 5: Contingency planning (incorporation of adaptive elements)
- Step 6: Implementation and monitoring

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, 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.[1]

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.

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.[2]

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.

4.2. Identification of project uncertainties

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

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

Table 2 summarizes the "unknown" project uncertainties and the conceptual responsive actions to either hedge vulnerabilities or shape the future, accordingly.

4.4. Monitoring, contingency and implementation plans

Table 3 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.

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[1] 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. For the purpose of this paper, the latter capacity has been calculated following the best practice and, under the 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.

[2] Ibid.

Table 1. 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.	SZ: 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 (NPX) LNG/LPG vessels.	SZ: 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.	SH: Foster and establish cooperation agreements with Panama Canal and/or with Caribbean transhipment hub ports to manage their overflow in the long-term. SH: 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.	MI: 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. SH: Investing in inland waterway terminals and/or "dry port" (Woxenius, Roso, & Lumsden, 2004) facilities.

Source: Adapted from (Soto Reyes, 2017)

Table 2. 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.	HE: Design and build NPX-enabled port infrastructures. SH: Negotiate with minor shipping lines to continue deploying Panamax vessels in their feeder services.
Vulnerability: Development of new container terminal at Urabá-Antioquia, Colombia.	SH: 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.	SH: 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.	SH: To design and build LNG/LPG importing/storage/bunkering terminals, which are also enabled for Neo-Panamax carriers.

Source: Adapted from (Soto Reyes, 2017)

Table 3. Monitoring thresholds and triggers

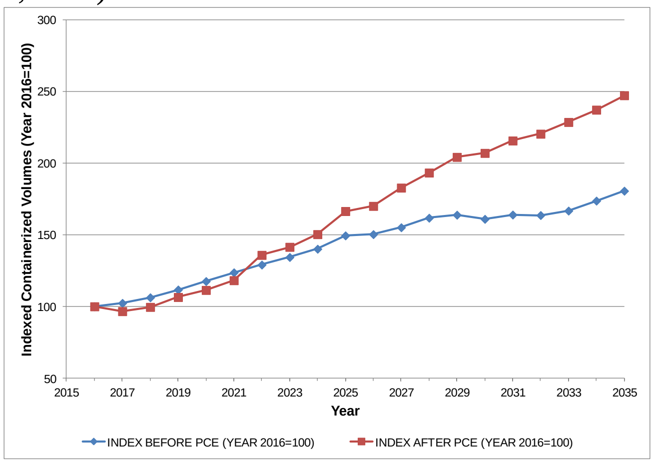
Vulnerabilities / Opportunities	**Monitoring & Thresholds**	**Actions: Reassessment (RE) or Corrective (CR) or Defensive (DE) or Capitalizing (CP)**
Opportunity: To gain share in existing demand that would otherwise go to another port.	Demand / Capacity ratio equal or greater than 0.95 for two (2) consecutive years.	CP: 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.	CP: 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: 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 1, 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 1. Indexed Caribbean containerized port traffic, before and after PCE (1-run estimate)

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.

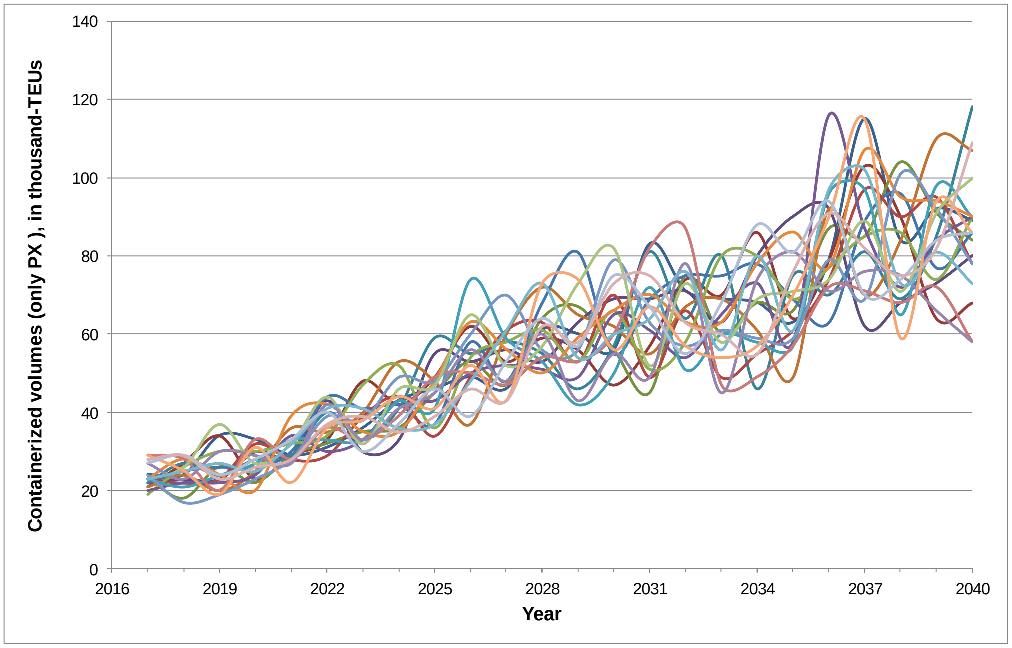
Further assumptions were superimposed on the dynamically forecast Caribbean port traffic to convert it to the demand for the case study port. Accordingly, randomly and gradually-varied market shares were assumed, as shown in Table 4.

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 2; 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 3.

Table 4. Market share assumptions for screening models

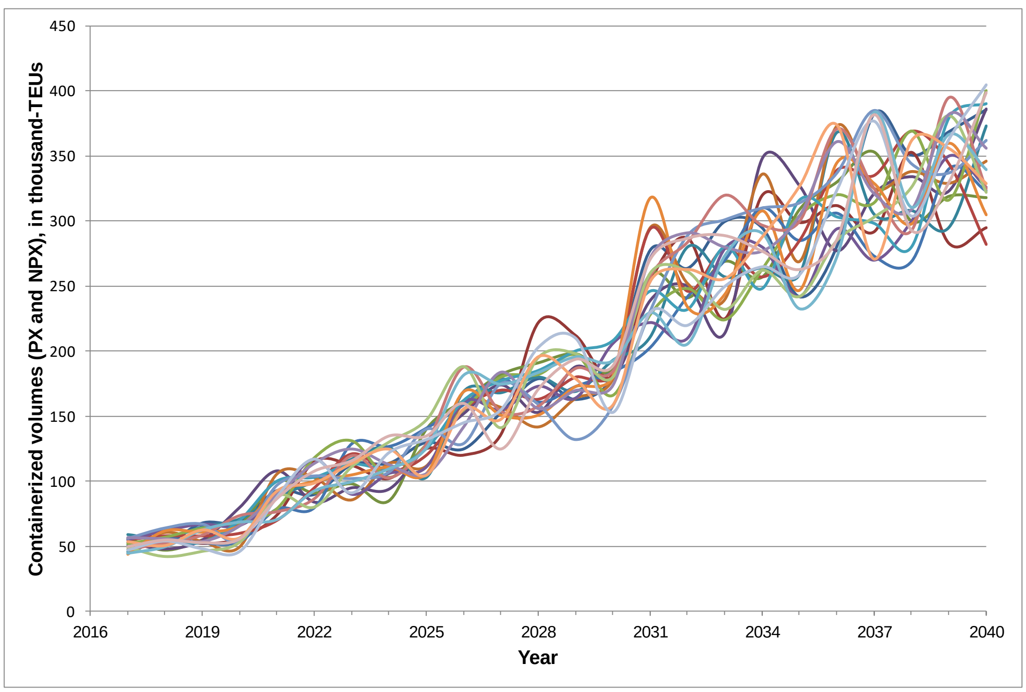
Year	2017		2040	
Range	Min	Max	Min	Max
PX-borne traffic share, PX	40.0%	50.0%	20.0%	30.0%
NPX-borne traffic share, NPX	50.0%	60.0%	70.0%	80.0%
Colombian Caribbean share (of Caribbean Port System)	18.0%		22.0%	25.0%
Rest of Caribbean System ports	82.0%		75.0%	78.0%
Barranquilla share (of Colombian Caribbean)	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 2. Dynamic forecasting for case study port: PX-borne only (20-future sample)



Source: Excerpted from (Soto Reyes, 2017)

Figure 3. 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.

The five (5) different flexible real options (Flexibilities 1 to 5) assessed along with the base case (Flexibility 0) are summarized in Table 5, and depicted in terms of quay wall length, area of container handling yards, and scope of dredging works; as well as the corresponding (non-) capability of the terminal to handle Neo-Panamax vessels, and added throughput capacity.

5.2.2. Definition of real option strategies and screening models

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 6 summarizes the basic descriptions of strategies in terms of the flexibilities incorporated in each instance.

Table 5. 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)

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).

Table 6. 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)

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

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

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.

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

Revenues: 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.[3]

TEU-factor: 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)

Analysis period: 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 7 summarizes infrastructural features and capabilities for the different analyzed strategies.

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).

5.2.3. Quantifying flexibilities by Monte Carlo Simulation (MCS)

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).

[3] 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 7. 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)

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

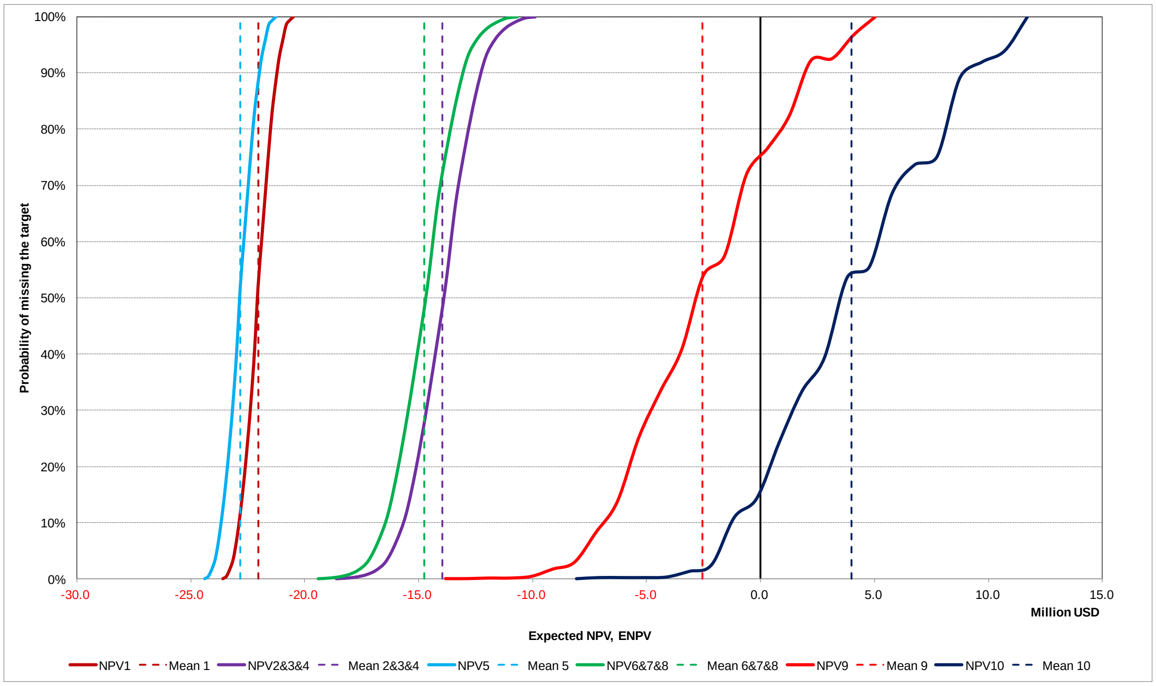
5.2.4. Ranking and selection of promising alternatives

(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 5 compiles the results for such assessments.

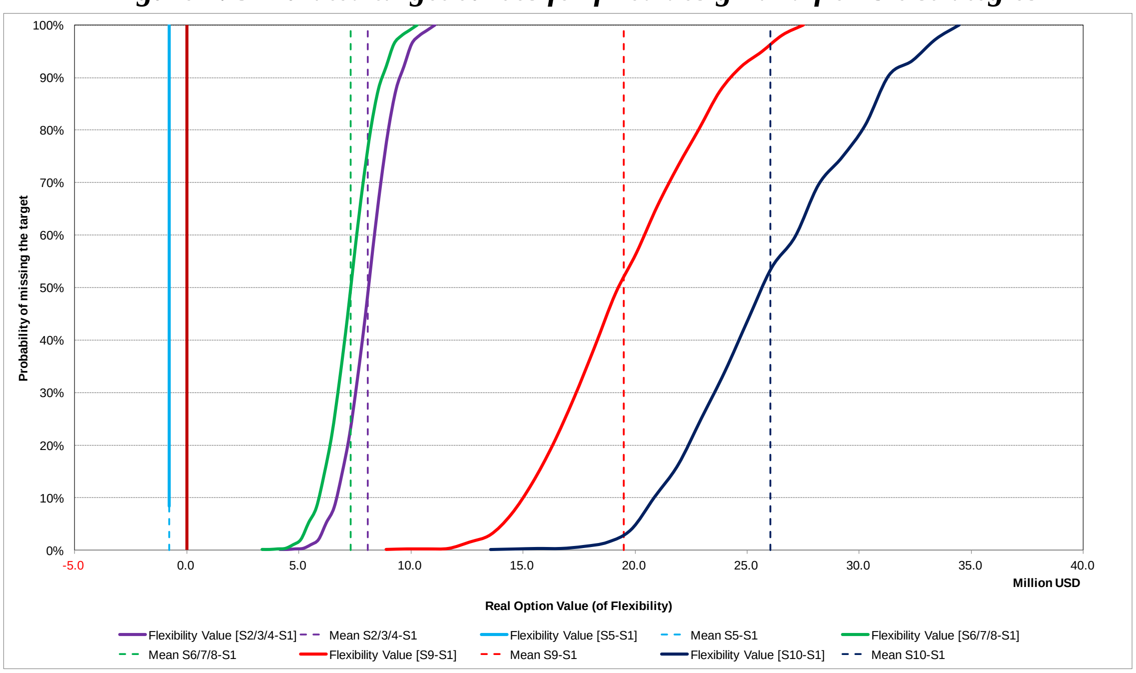
To a great extent, Real Options Quantifying reconfirmed the behaviours observed while generating individual simulated target curves for the ten (10) analyzed strategies.

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).



Source: Excerpted from (Soto Reyes, 2017)

Figure 4. Simulated target curves for fixed design and flexible strategies



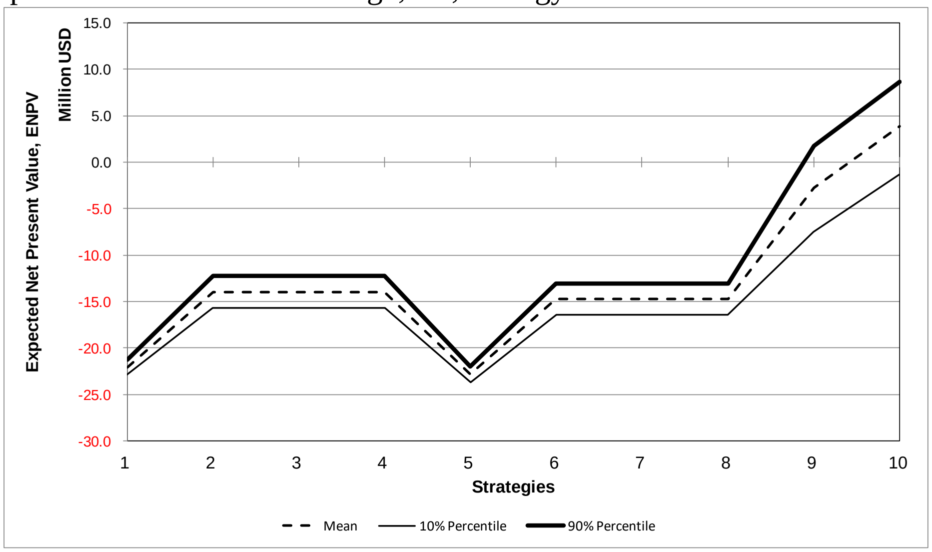
Source: Excerpted from (Soto Reyes, 2017)

Figure 5. Real Option Values of flexible strategies

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).

For instance, as it can be seen in Figure 6, 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.

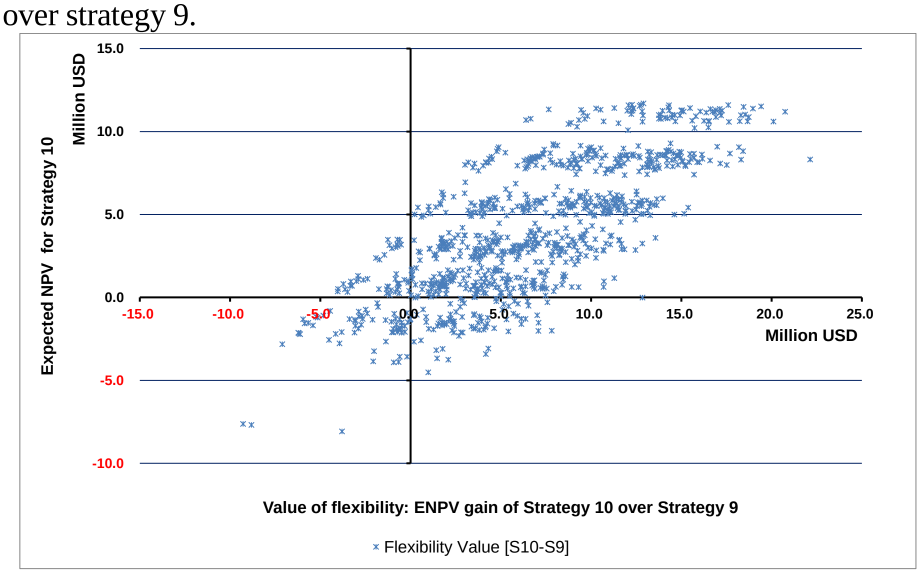


Source: Excerpted from (Soto Reyes, 2017)

Figure 6. Upside-Downside curves for flexible strategies

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.



Source: Excerpted from (Soto Reyes, 2017)

Figure 7. Regret plot: Strategy 10 versus Strategy 9

Finally, from Figure 7 the following qualitative analysis may be pointed out: Strategy 10 outperforms strategy 9 in most of the cases, despite some instances where Strategy 10 shows negative ENPV, since more than 80 percent of the simulation points are plotted rightward of the Y-axis.

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, dynamic, 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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