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Port development in Small Island Developing States: A case study of the Maldives

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Abstract
The Maldives is a Small Island Developing State which depends on sea-borne transport connectivity for trade and inclusive nationwide growth. The high international freight costs to its small domestic market are aggravated by deficiencies in services and capacity in the Port of Male', the sole maritime gateway to the country.

Male' City is the main hub for the distribution of goods for the whole country. It is densely populated, hence the movement and storage of goods within the city has exacerbated congestion. The gateway and distribution function of Male' port introduces bottlenecks and constraints to efficient transport and logistics in the Maldives. Moreover, due to the prevailing institutional arrangements, Maldivian ports have developed in an ad-hoc manner over the years. It is anticipated that the ports will not be able to accommodate future demand if current conditions are left to continue.

This paper aims to develop an adaptive port master plan over the time horizon of 20 years, to address the above-mentioned issues. The tools for adaptive port planning were used to address uncertainties and vulnerabilities in the development of the masterplan. The basic plans encompass the development of Male' Commercial Harbour as an efficient gateway and distributor. A distribution network was designed to connect Male' with the regional ports. The actions to increase robustness and flexibility were translated into projects with no flexibility (ad-hoc), just-in-time flexibility and just-in-case flexibility. In summary, the 20-year vision for Maldivian ports is to become an international gateway port with an efficient ship to shore operation with fast and efficient domestic distribution via a roll-on/roll-off network connecting the far reaches of the country.

Keywords: Adaptive Port Planning, Ports, Master planning, Maldives, SIDS.

1. Introduction

The Maldives is a Small Island Developing State (SIDS) in the Indian ocean. Like other SIDS, it is small in terms of land area, population and economy. The country is remote as it is separated and "sea-locked" from land masses and trade routes. It's 1190 islets are geographically dispersed over 13,423 km^2 [3].

The Maldivian economy lacks diversification and is heavily dependent on its tourism industry. The exports of this import-dependent country are limited to mainly fish products. The country has an open economy [2]. This integration with the global economy is evident from the reaction of the Maldivian economy to external factors such as volatility in food and fuel prices, terrorist attacks, natural disasters, economic crises, and epidemics.

The Maldivian population of about 400,000 is scattered over 194 islands. Due to its geography, the Maldives depends on sea-borne connectivity for its domestic and international trade needs. The small market and its spatial fragmentation introduce diseconomies of scale, low volumes and inefficiency in the movement of goods and passengers. High domestic and international freight costs are making businesses less competitive and hinder equitable, sustainable growth over the country. Studies show high transport costs as a major constraint in developing alternative industries, while also showing a significant gap in the incidence of poverty between the capital city of Male' and the outer atolls [2].

The islands of the Maldives are, on average, 16 hectares, and 80% of these are less than 1 metre above mean sea level [1]. The low-lying islands of the country are exposed to large swells, storm surges and rising sea levels due to climate change.

1.1 Transport, Logistics and Infrastructure

The Maldivian Port system can be described as a network in a hub and spoke system in which Greater Male' Region is the central hub. The Port of Male' – the sole maritime gateway of the country - is a complex of terminals spread over the islands of the Greater Male' Region. The Greater Male' Region is the economic centre of the country where almost 40% of the population currently resides. Most imports and trade transactions occur in this region. The Male' Commercial Harbour (MCH) located in Male' City, handles almost all inbound international cargo to the country. However, the limited berths and space, in addition to operational inefficiencies are causing longer dwell times and higher handling charges at MCH.

In Male', consignments are broken down for sale to local retailers, or the retailers in the outer islands. Hence Male' City is also the main hub for the distribution of goods for the whole country. Nearly 90% of all distribution to the outer atolls go via the Male' North Harbour (MNH). The mixing of passengers and cargo at MNH causes long dwell times. Male' City is small and densely populated, hence the movement and storage of goods within the city's warehouses has exacerbated congestion. The existing gateway and distribution functions of Male' Port introduces bottlenecks and constraints for efficient transport and logistics in the Maldives.

Moreover, due to the current institutional arrangements, Maldivian ports have developed in an ad-hoc manner over the years. It is anticipated that the ports will not be able to accommodate future demand if current conditions are left to continue.

In a world of uncertainties and uncertain futures, the long-term planning of infrastructure for SIDS needs a new approach; One that ensures infrastructure as well as the plans supporting them stay relevant under changing circumstances.

2. Objectives and Research Questions

This paper aims to formulate a medium-term to long-term masterplan or vision for the port system of the Maldives, over the time horizon of 20 years, where the Adaptive Port Planning (APP) framework [5] is used as a tool to address vulnerability and uncertainty in port development.

Objective: Expand capacity and improve the efficiency of the port system to meet future demand (vision of port network for 2040).

Questions:

1. How will the port system look and operate?
    a. What is the best course of action to meet future demand?
2. What will be the functions of the ports in the system?
    a. How will the ports be classified?
3. How do we reduce the vulnerability of the country through port development?
    a. How can we incorporate adaptability and address uncertainty in the adaptive masterplan?
    b. How can we reduce freight prices domestically and internationally?

2.1 Methodology

A methodology to develop the masterplan and achieve the objectives was designed based on the traditional master planning process and the adaptive port planning framework [4]. The methodologies framework that was devised, with its tools and techniques is illustrated in Figure 1.

3. Outputs and Results

The outputs and results of the steps of the methodology framework are summarised below.

3.1 Step1a - Define Problem

This step frames the problem to be solved.

- The organisation, functions and stakeholders of Maldivian ports were identified. The requirements and objectives of key stakeholders were used to help define the problem and the objectives of the masterplan. These, in turn, were used to formulate the goals, strategies and the definitions of success for the master plan.
- An assessment of the major ports and their hinterlands was conducted. The classification and functions of the ports in the Maldives are put in a hierarchy (Table 1) to answer research question Q2 and Q2a.
- A SWOT analysis was done to assess the current state of Maldivian ports.

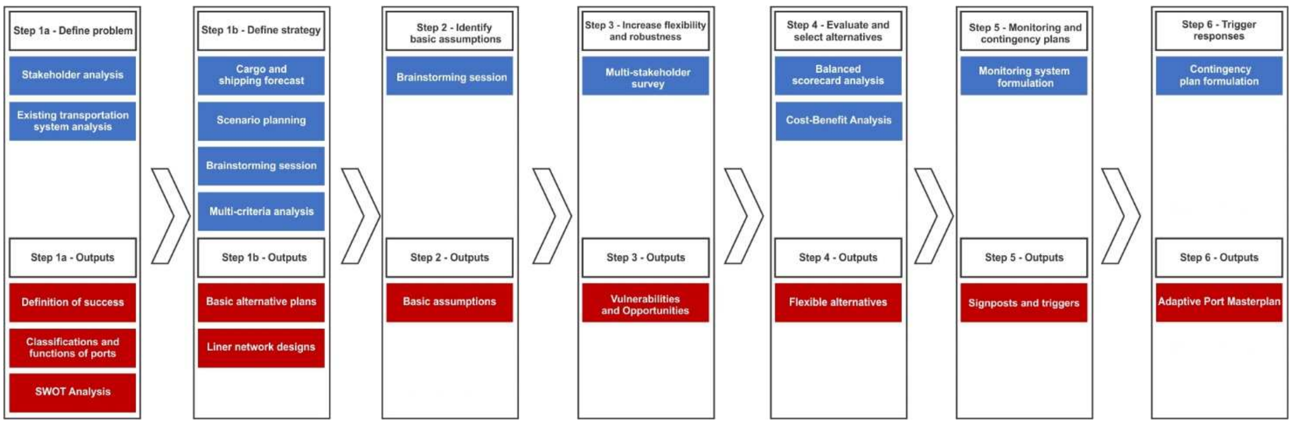

Figure 1 Methodologies of the research, developed by author

Table 1 The classification for Maldivian Ports

Class	Port Category	Type
I	International Ports	Gateway hub
II	Regional Ports	Domestic hubs
III	Domestic Ports	Collectors
IV	Private Ports and terminals	Collectors

3.2 Step 1b of APP – Define Strategy

The strategy outlines the methods, tools and means of evaluation of the masterplan. The strategy is determined by the planning time horizon.

The planning time horizon for this study is 20 years. This means the system has medium to deep uncertainties. As the objective of the study is to give a medium to long term vision for the ports of Maldives, a scenario-based approach is recommended though we cannot attach probabilities to the scenarios generated [5].

The final output of this step is the selected basic alternative plans where adaptivity or robustness have not yet been incorporated. The basic alternative plans were generated as sequenced below.

3.2.1 Forecasting

As a gateway port, most cargo flows to the Port of Male' are for local consumption and industries. These flows consist of mostly containers and general cargo.

Cargo forecasts were done by defining the hinterlands and conducting macro-economic analyses. Regression analysis was done to identify which demand drivers should be used to forecast the cargo throughput. The throughput at the port of Male' was forecasted and then distributed regionally by population. Shipping forecasts were made based on historical data of ships that have called on the port of Male'.

Forecasts were based on three likely scenarios which reflect low, medium and high throughput. This is linked to the scenario planning approach used in section 3.2.2.

3.2.2 Scenarios

Scenario planning was used to generate three realistic narratives that tell a story of how the elements and driving forces of the future interact. The scenarios generated were;

1. The business as usual case which extrapolates on historical trends where conditions were neither good nor bad. Attributed to medium throughput forecast.
2. The worst-case scenario where all elements have high negative impacts. Attributed to low throughput forecast.
3. The best-case scenario where all the elements have high positive impacts. Attributed to high throughput forecast.

Numerous scenarios can be generated where the driving forces develop differently and hence have a mix of different interactions and impacts.

One aspect of driving forces are external factors such as the global economic conditions, conflicts and the resulting volatility of oil and food prices. Analysis of historical data shows that these factors can have significant impacts on the Maldivian economy. Furthermore, how the Maldives economy reacts to the challenges by diversification of its economy and how it addresses port development are key factors in the scenarios generated (Table 2). The generation of three scenarios can be attributed to the time constraints of the study. Furthermore, it is important to note the limited stakeholder input in the formulation of the scenarios.

Table 2 Scenarios generated for the study

Driving Forces	Scenario 1: Things go wrong	Scenario 2: Business as usual	Scenario 3: Looking good
External Factors	Global economic crisis	Steady global economy	Global boom
	Protectionism	Heading toward open trade	Open trade
	Food and fuel prices rise	Steady food and fuel prices	Steady food and fuel prices
Tourism	Less investment	Steady investment	Booming South Asian Market
	New markets are not accessed	New markets accessed	Strong growth in new markets
Economic Base	No new industry	Some new industry	Numerous industries and investment
Port Reform	Slow reform	Adequate reform	Rapid reform

3.2.3 Liner Network Design

Three types of liner networks (Figure 2) were designed to distribute domestic cargo throughout the whole country. The networks span outward from the port of Male'- the gateway hub which receives international freight. It also serves as the central logistics hub that distributes cargo to the regional and domestic ports via the liner networks.

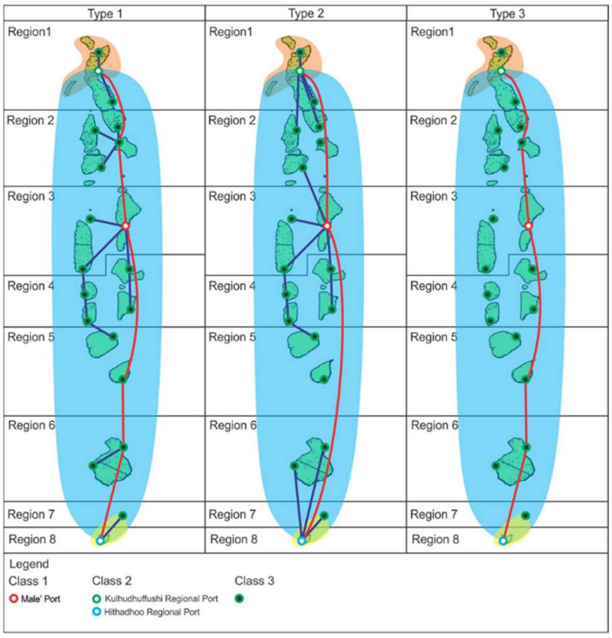

Figure 2 Shipping and distribution network types

3.2.4 Basic alternative plans

Three basic alternative plans (Table 3) were formulated to address the definitions of success and achieve the objectives of the study.

The basic alternative plans consist of layouts for the gateway port (Figure 3), a liner network and a system for movement of cargo through the gateway port, to the regional and domestic ports.

In consideration of the definitions of success for the masterplan, the basic alternative plans were formulated to enhance efficiency by reducing costs and handling time for international and domestic cargo, while also considering efficient use of space and resources available. Since the gateway function is provided at the international terminal at MCH. The design for MCH emphasised the reduction of waiting time and turnaround time. Hence all three alternatives considered the use of ship to shore cranes (STS) at the international berth. Furthermore, all alternatives, consider the use of the utilisation of Rubber Tired Gantry (RTG) cranes for stacking in the storage yard for efficient use of limited space.

L1 proposes the development of a dedicated container terminal at MCH, where reach stackers are used for horizontal transfers within the terminal. L1 focuses on efficient services to the container vessels at the international berth.

L2 Proposed the development of a container berth and a general cargo berth at MCH. This alternative focuses on cater to general cargo and containerised cargo. L2 considers the use of terminal tractors and chassis for horizontal transfer of containers.

L3 proposes a dedicated container terminal tractors and chassis for horizontal transfer of containers.

The last component of the MCH terminal design is the distribution centre - a cross-docking warehouse which also serves as the container freight station. This solution for the gateway port was then paired with a liner network design. The Type 3 network (Figure 2), which consists of a liner service operating to the far North and far South was selected owing to its simplicity and the resources and to implement it nationwide.

Though alternatives were generated for the three scenarios (Table 2), due to the time constraints of this study, only the alternatives generated for the business as usual scenario was evaluated. This approach is validated by the fact that the multi-stakeholder survey results back the assumption that the business as usual scenario is most likely to develop in the future.

Table 3 Basic alternative plans

Alternative 1 (L1)	Dedicated Container Terminal
Alternative 2 (L2)	Container + General Cargo Terminal
Alternative 3 (L3)	Roll-on Roll-off system

The basic alternative plans were qualitatively compared after which a simple weighted scoring model for multi-criteria analysis was used to analyse and choose the best alternative.

Figure 3 Basic alternative plan implementation at MCH

The selected alternative is the Roll-on Roll-off system L3. An efficient distribution system, which uses a cross-docking warehouse at MCH. The design vessel selected for distribution is larger than the current vessels used for domestic distribution and is specialized for Roll-on Roll-off transport of chassis loaded with containers. The design vessel is 50 metres long and can carry 36 Twenty-foot equivalent units. This allows for greater economies of scale. The containers can be rolled on to the vessel on chassis. Hence equipment such as cranes and reach stackers are not required at the ports receiving the containers from MCH. Only terminal tractors are required, and hence, the equipment costs and labour costs would be reduced. In this alternative, the container quay at MCH can accommodate the largest vessels and has ship to shore gantry cranes. The design of the container terminal at MCH also considers berth utilization at 60%, reducing the service time and turnaround time of the container vessels. This solution would facilitate a reduction in international and domestic freight prices hence answers Q3b. As this section has described how the port system will look and how it operates, it address Q1.

3.3 Step 2 – Identify basic assumptions

This step involves identifying the basic assumptions underlying the masterplan. This would be achieved using a brainstorming session.

3.3.1 Brainstorming session

The brainstorming session was held among student researchers, lecturers and specialists in the field of Port Planning. The participants were from IHE Delft Institute for Water Education, Erasmus University Rotterdam and the Port of Rotterdam.

The major assumptions that can be attributed to the development of this masterplan are related to;

1. The natural growth of the populations of the different regions in the Maldives, internal migration and resettlement
2. Trends of industry such as tourism and fisheries and their growth in different regions
3. Trends of containerization and shipping
4. Trade conditions between the Maldives and its trade partners
5. Port reforms agenda.

It was noted in the brainstorming session that the outcomes for the Maldives should rely on tourism-based scenarios and how it affects the Ports or their throughput. Furthermore, it was emphasised that focus should be on the efficiency of the existing ports in the Maldives, identifying processes and bottlenecks and optimising the services by use of Information communication technology-based solutions.

3.4 Step 3 – Devise actions to increase flexibility and robustness of basic alternatives

This section aims to make the basic alternative plans flexible and robust. This was done by identifying the important or load bearing assumptions underlying the basic plan through a multi-stakeholder survey.

3.4.1 Multi-stakeholder survey

The surveys were conducted using the online platform surveymonkey.com. The survey respondents were specialists in the fields of transport, management, trade and finance from stakeholder agencies relevant to this study. The responses were collected anonymously.

Plausible developments or the underlying assumptions were grouped into economic, technical, social and environmental aspects. A Likert (rating scale) approach (Figure 4) was used. The impact of the development on the plan was mapped on the horizontal axis, and the likelihood of occurrence of a plausible development was mapped on the vertical axis.

Horizontal Axis		Vertical Axis	
Impact level	Scale	Occurrence	Scale
Very Negative	-2	Very unlikely	-2
Negative	-1	Unlikely	-1
Neutral	0	Neutral	0
Positive	1	Likely	1
Very Positive	2	Likely	2

Figure 4 Rating scale for occurrence and impact

The average score in terms of probability of occurrence and the impact of the occurrence was calculated by giving points according to the categories of responses given and attaching weights to them. The important vulnerabilities and opportunities are the events that fall in the coloured areas in **Error! Reference source not found.** 6. The flowchart for transforming plausible events into actions is given in Figure 5.

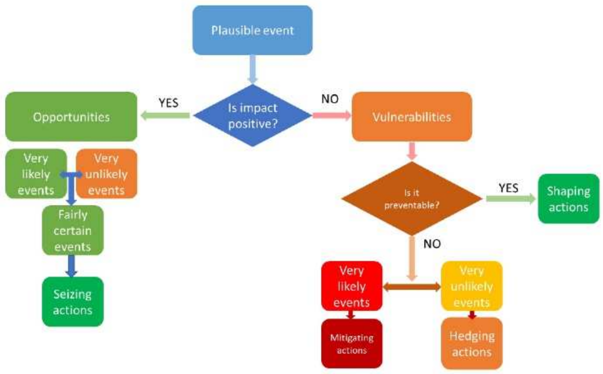

Figure 5 Generating flexibility from underlying assumption

Next, the actions for increasing flexibility and robustness were generated. These actions were used to formulate masterplanning projects under the strategic approaches to flexibility [5] as depicted in Table 4.

Table 4 Approaches to flexibility for project formulation

	Alternative 1	Alternative 2	Alternative 3
Approach	Non-flexible approach	Flexible approach (just-in-time)	Robust approach (just-in-case)

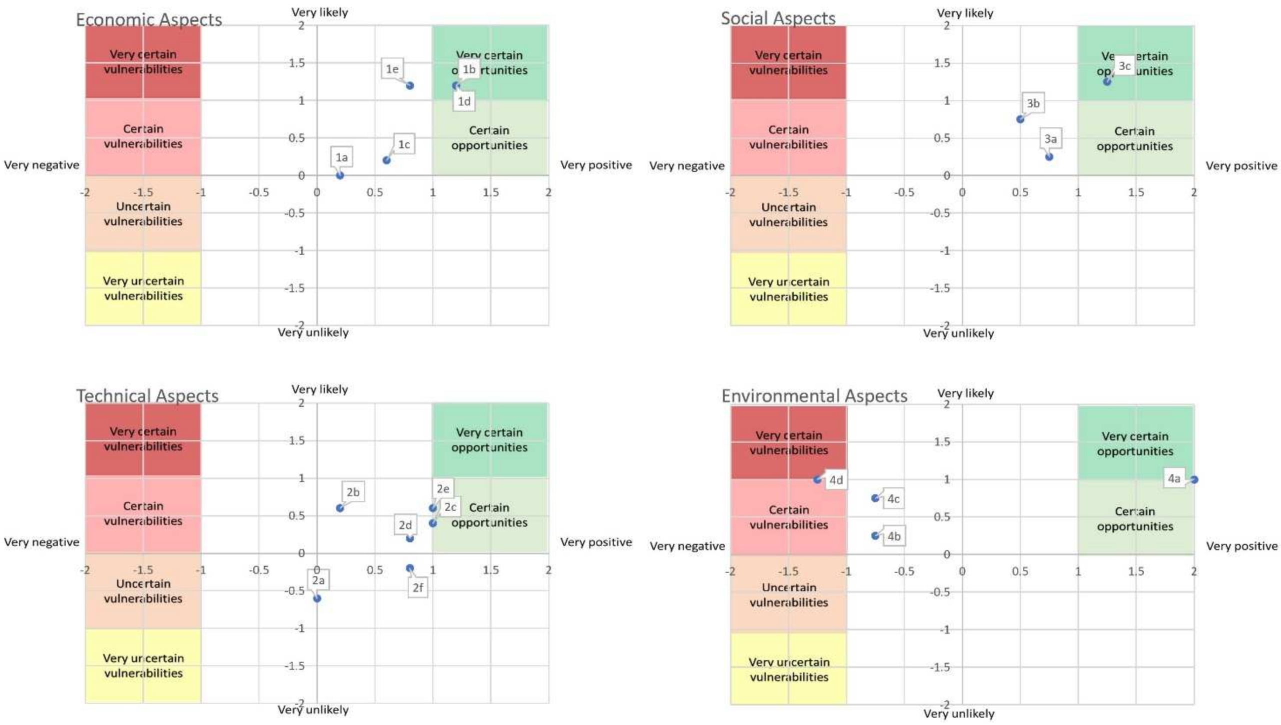

Figure 6 Generating flexibility from underlying assumptions or plausible developments

Step 4 - Evaluation and selection of alternatives

This step aims to evaluate the alternatives generated in step 3.

3.4.2 Cost-Benefit Analysis (CBA)

CBA was used to justify the projects using a discounted cash flow approach of tangible benefits versus the costs. The project alternatives were evaluated by Net Present Value (NPV) and Internal Rate of Return (IRR). One more focus of the CBA is to value the flexibility of the alternative projects. One must understand that flexibility always comes at a cost. Hence a way to value the investment in flexibility is given below [5].

$$Value\ of\ flexibility = Net\ present\ value\ with\ flexibility - Net\ present\ value\ without\ flexibility. \quad (1)$$

3.4.3 Balanced Scorecard

A balanced scorecard presents decision makers with a combination of non-financial and financial aspects to give a balanced view of the performance. In this case, the balanced scorecard (Figure 7) is used to evaluate and select the alternative for the output of step 4 of the APP.

Hence the alternatives are evaluated firstly on monetary terms using metrics such as NPV and IRR where the flexibility is valued. Then the alternatives were compared qualitatively. This aspect of evaluation makes sure that the alternative fulfils the objectives and definitions of success. The balanced scorecard shows that all the alternative projects have benefits as the domestic transport cost is reduced.

When the distribution network is implemented, the domestic transport costs for one Twenty-foot equivalent unit could be reduced to US$ 600, which is nearly half of the current distribution cost [2]. The highest NPV and value in terms of flexibility is the alternative developed with the robust approach. This approach involves building infrastructure which have margins for sea level rise and climate change. Hence over the lifetime, the maintenance cost of infrastructure is less than the other Alternatives. This means that the infrastructure in Alternative 3 would have higher platform levels and have bigger margins in terms of materials design for durability. Furthermore, as this option is focused on climate resilience, it is assumed donor funding and grants would be easier to obtain.

In conclusion, the non-flexible alternative does not perform well in comparison to the other alternatives in the balanced scorecard approach (Figure 7). By evaluating and selecting the robust approach results in a robust masterplan, which addresses Q3a and Q1a.

3.5 Step 5 - Monitoring and Contingency plan

Setting up a monitoring and contingency planning system is the last step of the APP. Signposts which are indicators that can be monitored, were assigned trigger values. Actions to be taken once the triggers values are reached or exceeded, were specified in

	Alternative 1	Alternative 2	Alternative 3
Project	• Non flexible Port Masterplan	• Flexible Port Masterplan	• Robust Port Masterplan
Description	• Deck on pile quay wall	• Modular, L-block quay wall can be phased in new quay wall • Flexible finance (lower interest rate	• Climate change resilient quay walls • Built with margins • Flexible Business model (lower interest rate)
Strategic Perspective	• Costly adaptations may have to be considered in the future	• Option to scale up or delay	• Durability and resilience of infrastructure
Stakeholder perspective	• Ad-hoc adaptations cost more and delays for port users	• Adapt to new requirements in time	• Less downtime due to storms and swells, sea level rise • Cost savings
Business Case (US$)	NPV 561,415.54	NPV 1,249,563.44	NPV 2,866,470.43
	IRR 9%	IRR 10%	IRR 14%
	Value of flexibility = 0	Value of flexibility = 688,147.90	Value of flexibility = 2,305,054.88

Figure 7 The balanced scorecard, evaluation and selection of flexible alternatives

this section. This is the last part of the monitoring system and contingency plan (Figure 8). It is designed to anticipate changes that may cause a deviation from the selected alternative. Furthermore, it must be able to detect when a plausible development becomes load bearing as it may cause the masterplan to fail. A simple monitoring system was developed to detect and address any vulnerabilities that may arise in the future.

One of the important assumptions that we make is that the business as usual scenario will continue into the future. Hence it is important to identify when there is a deviation from this scenario towards a lower or higher scenario, which would need the master plan to be re-assessed and updated.

Load bearing assumption	Monitor and Trigger	Action
Business as usual scenario	• Monitor Cargo and Shipping traffic for greater than 10% deviation	• If deviation from base scenario, update masterplan
Fisheries boom	• Monitor exports of fish products 50% higher from last annual report	• Revise forecasts
Vessel waiting time increases	• Records of vessels calling at port, if occupancy greater than 0.7, re-assess • Monitor and interact, to see if shipping lines want to increase charges	• Check assumptions in masterplan • Negotiation with shipping lines
Sea level rise and climate change	• Monitor IPCC reports and updates, if sea level rise greater than 10% in worst case scenario by 2040 • Return period of events and surge level records, 1 in 500 event greater than 10% from Detailed island risk assessment reports	• Update masterplan and new infrastructure designs to have new sea level parameter

Figure 8 Contingency and mitigation plan

4. Conclusion

- The generic framework of APP is intuitive and can be applied by Port Authorities of SIDS to address their port planning challenges.
- This framework can be used to formulate a comprehensive, adaptive masterplan with exhaustive scenarios and alternatives. The constraints, however, would be resources available and time.
- Valuations and appraisal of projects and incorporated flexibilities is a new concept in the Maldives. However, APP is equipped with the tools to assist decision makers.
- The institutional arrangements in the Maldives result in ad-hoc port development, where financial decisions, regulatory changes and planning are undertaken in different agencies.
- The main limitation of the study was subjectivity in the results due to the low response rate, and limited interaction with stakeholders.

5. Summary

Adaptive Port Planning can be applied for SIDS such as the Maldives to address its port planning challenges over the long term. It can be used to address vulnerabilities and uncertainties by introducing flexibilities and robustness into the basic plans. Furthermore, Adaptive Port Planning gives the tools to value the flexibilities incorporated to enhance the decision-making process.

The output of this paper is a 20-year vision for the ports system of the Maldives which comprises an efficient international gateway port complemented by efficient domestic distribution via a roll-on/roll-off network connecting the far reaches of the country.

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