Paper no. 6 – The Panama Canal Expansion Project Complexities and Lessons Learned

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ABSTRACT: One of the world's greatest engineering achievements, the Panama Canal celebrated its 100th anniversary while preparing to meet the challenges of growing traffic demand, particularly by containerships, LNG and bulk carriers, plying the route between Northeast Asia and the U.S. East Coast, and also to accommodate post-Panamax ships by means of the Panama Canal Expansion Program. The program includes two new lock complexes that have established a new size standard, the Neo-Panamax class. This paper explores the complexities of the studies, decision-making process, integration of multidisciplinary expertise and program execution. At present, with most civil works near completion, the commissioning of electrical, mechanical and control systems are being carried out by the ACP to ensure sucessful operations once the waterway opens to commercial traffic in April 2016.

1 INTRODUCTION

Since its opening to international sea trade in 1914, the Panama Canal has served as an important link to bring markets closer by reducing distance and shipping cost of goods crossing the Pacific and Atlantic Oceans to and from the Americas, Europe and Asia.

The Panama Canal transited 327 million tons of cargo in 2014, near its full capacity, after a century of operations. In order to prepare to continue serving its clients and the maritime industry, the ACP prepared a Master Plan (2005-2015) to expand the Canal and double its capacity to over 600 million tons a year.

The navigational channels were widened beyond 218 meters and were deepened to accommodate 15.2 meters draft ships. This effort required excavation and dredging of over 150 million cubic meters of rock and earth.

The greatest challenge was to build two Post-Panamax locks, one each, at the Atlantic and Pacific ends of the Canal. Each lock structure has three lift with nine water-saving basins and eight rolling gates in order to accommodates ships of up to 170,000 tons.

This paper discusses the challenges, complexities and lessons learned throughout the different phases of the project study and execution.

2 CHALLENGES DURING THE DIFFERENT PROGRAM PHASES

2.1 *Study phase*

The study phase is the most critical phase as it defines the objectives and analyzes the different options that best meets them. Decisions made at this time are more difficult to change as work progresses. But a balance has to be made on completeness of the study versus time spent developing it. One way of accelerating this process is to avoid working in a linear manner and developing the studies in parallel, making early decisions and revising previous premises and decisions as new information or study results come in.

For example, one of the first program model inputs was defining the future Panama Canal demand, the type of cargo, ship sizes and types, frequency, shipping routes. Concurrent with these studies by the marketing group, the engineering group started looking at the different channel improvement configurations and also the different lock options to accommodate the different ship sizes. Once the market target and ship dimension and type were defined, the navigation channels and lock sizes were decided upon.

Multidisciplinary groups including marketing, engineering, operations, environmental and cost-assessment experts were formed to review studies and evaluate the different options and perform sensitivity analyses.

Early group decisions were brought up to a managerial group for review and discussions to start deciding on best parameters for the project. For example, the new locks will have three consecutive chambers so that ships are raised as a water ladder. This was a result of a multi-parameter decision matrix mainly as it contributed to mitigate saltwater intrusion from the oceans to the fresh water of Gatun Lake.

The new locks will operate with rolling gates versus traditional miter gates mainly for ease of maintenance and design issues. The use of tugs versus traditional locomotives will also provide operational and technical advantages.

Three water saving basins per chamber were incorporated to save 60% of water to optimize the use of this critical resource, while the locks filling and emptying (F-E) system will use longitudinal main culverts with secondary culverts and side ports to improve F-E symmetry and for optimum operational times and water slopes.

All placed together resulted in a robust design that has become a new reference for the maritime locks of Post-Panamax dimensions with multiple lifts, rolling gates, tug assistance, incorporating water-saving basins and a novel F-E system. All these decisions were integrated in a Master Plan discussed in the next section.

2.2 *Master Plan*

A Master Plan (2005-2025) for the expansion project was prepared to serve as a roadmap first to present a plan for approval and then to serve as a high level guide throughout the program.

This document first presents the historical background of the existing infrastructure, operations and customer base, followed by trends and an outlook on international trade of goods and raw material, focusing then in the maritime logistic chain that benefits from the Panama Canal route, its growth, needs and other potential markets.

One of the key success factors for the plan was working with multidisciplinary groups gathered in the same physical location to collaborate in reviewing and enriching the document. The main risk was to balance the tendency to work toward perfection versus the deadline to complete the document. Good support was received from higher management who reviewed partial drafts of the Master Plan as the chapters progressed and were integrated. The end product had to tell a story where the reader could follow the arguments and supporting data to reach the same conclusions of the Master Plan.

The main conclusion was the need to expand the present Canal to accommodate larger ships to meet maritime-industry demand and take advantage of the economies of scale. This vessel size now dubbed as a Neo-Panamax, with dimensions shown in the following figure.

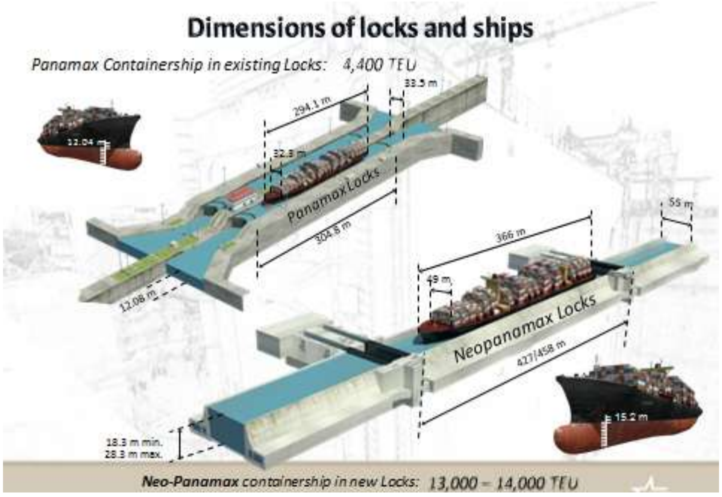

Figure 1: Neo-Panamax ship and lock dimensions.

The design vessel has a maximum 49-meter beam, 366-meter length, and 15.2-meter draft, and capacity for 170,000 tons or 13,000 TEUs. The lock dimensions are 55 meters wide, 458 meters long, and 18.3 meter minimum water depth.

The Master Plan discussed the construction, estimated costs, time, risks analysis, environmental mitigation measures, water requirements, financial scheme, employment and economic impact of the program, with an estimated budget of $5,250 million and eight years execution time.

The Master Plan was synthetized in a 79-page document and presented to the Panamanians as the base of information of the program, which should be approved by referendum in October 2006 and was passed with 75% of acceptance.

2.3 *Tender phase*

The expansion program was executed in different project phases and areas by feature of work and geography. The first project to be carried out were excavation and dredging to widen and deepen the navigational channels to accomodate the Neo-Panamax vessels in Gatun Lake and both Atlantic and Pacific Ocean entrances. The minimum channel dimensions were 218 meters wide at the bottom prism with a 16.3 meter minimum water depth requiring the removal of 150 million cubic meters of rock and dirt. Geological explorations were concluded and geotechnical designs were carried out, specification and documentation were prepared for international tender. The ACP has a strong

Engineering division which was supported with highly-qualified external consultants for the completeness of studies and robust designs.

The main and most complex contract was for the design and construction of two new Neo-Panamax lock complexes. To achieve this, the ACP chose the FIDIC Plant and Design-Build Contract with one single contractor/consortium to allow for standardization of design, construction, operations and electrical/mechanical components, with the advantage that it is a well-known international standard contract form for employers and contractors. The complexity of the project involves the civil construction and also the mechanical and electrical work, and this contract transfers an adequate amount of risk to the contractor. This required well-defined performance specifications by the Employer, who was assisted by technical, contracting and program management consultants who, added to the 100 years of experience of the ACP in successfully operating, maintaining and improving the existing Panama Canal, incorporated the best features of work and improve in others for optimum program results.

A market search was conducted in 2007 to survey interest from potential contractors. The next step was to pre-qualify interested consortia based mainly on their proven experience, expertise, financial soundness and personnel availability. The final phase required a year-long communication process with all parties involved; which appeared to be a lengthy exercise, but in the end proved to be advantageous to adequate and clarify the tender documentation providing for a transparent and competitive bid. Bids for this fixed-price tender were received and thoroughly evaluated technically and financially before choosing the wining consortium.

2.4 *Design and construction phase*

After awarding of the contract in July 2009, the contractor began working on the design while simultaneously setting up the plant and beginning excavations. The contract required that the contractor and employer design teams worked in a collaborative environment with close communication to achieve a design that combined innovation, effectiveness and efficiency while complying with contract terms.

The contract required the construction of two lock complexes – one on the Atlantic and one on the Pacific side - with three consecutive lock chambers to reduce the amount of water required to lift the vessels from ocean level to Gatun Lake level, at an average of elevation of 26 meters, a configuration thant also helps mitigate saltwater intrusion. To further conserve water resources, each chamber would have three water-saving basins - nine per lock - to save an additional 60 percent of water. To optimize the filling and emptying times, large lateral culverts measuring 8.30 meters wide by 6.50 meters high would be built along the chamber walls with sideports for a symmetrical water flow. This innovative design required numerical modeling and validation with a physical model to optimize the lock F-E times and provide for smooth transits through the lock chambers.

Figure 2: Three lift locks with nine water saving basins

Excavation of the lock footprint began when the large 4-cubic meter bucket excavators and 96-ton haulers arrived on site. Rock had to be blasted on a daily basis, the sound basalt was sent to a 3,000-ton per hour crushing plant for production of aggregate and fill material, with a total required of over 20 million tons for both the Atlantic and Pacific locks. Basalt was quarried at the Pacific locks site and 6 million tons were barged accross Gatun Lake for the construction of the Atlantic Locks. Total excavation amounted to 50 million cubic meters of material.

Civil works progressed with the main feature being the structural concrete placement, of which a total of 4.4 million cubic meters were requied. At its production peak 100,000 cubic meters of concrete were placed in a month per site. The contract required a concrete with durability of a 100 years and strength reaching 35 megaPascals. A total of 192,000 tons of structural steel grades 60 and 75 were imported for the works in sizes no. 4 to 14 and lengths of 12 and 24 meters.

Panamanian labor laws requires a minimum of 90% of hired personnel to be local. Labor force peaked at 10,000 workers, providing a strong injection to the local economy. The Panama Canal Authority together with government institutions had previously trained and certified workers in different trades in preparation for the construction work, including heavy-equipment operators, mechanics, electricians, carpenters, plant operators, plumbers, and other crafts for support work.

The world's heaviest locks rolling gates were manufactured in Italy and shipped to Panama across the Atlantic Ocean on board large semi-submersible vessels. The gates measure 57.6 meters in length, their width ranges between 8 and 10 meters and their height between 22 and 33 meters, and weight between 2,500 and 4,200 tons each. A total of eight gates were fabricated for each lock, for a total of 16 gates. The gates go in pairs in each of the lockheads for redundancy to allow for safe operations and ease of maintenance. The gates were installed in the dry using special wheeled vehicles.

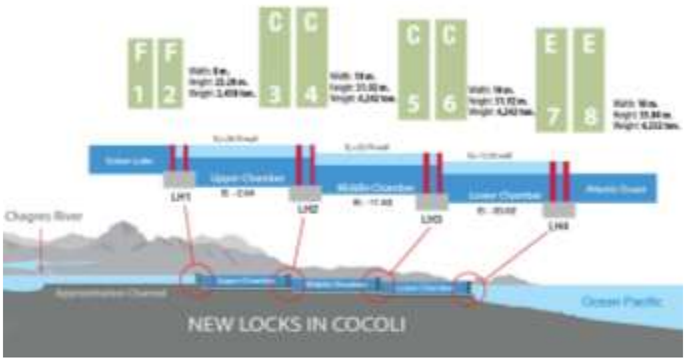

Figure 3: Locks rolling gates

Each lock requires 74 valves (148 total plus spares) for the control of water flow from Gatun Lake into the lock chambers and to/from the water-saving basins. The wagon-wheel design valves fabricated in South Korea, bench tested and shipped to Panama. Additionally, bulkheads were fabricated to isolate the valves and culverts to allow for maintenance and repairs with minimum impact to lock operations.

The work has been carried out with strict adherence to international environmental standards with inspections and meetings to ensure compliance. A workplace health and safety program was also implemented and prioritized throughout all phases and features of work, through close monitoring and corrections made as needed to protect personnel and equipment in the worksite.

Now, with the civil works over 95 percent complete, the main tasks being carried out are the installation of the electro-mechanical elements and commissioning of the locks, which are discussed in next section.

3 FLOODING AND COMMISSIONING

At present, electrical, mechanical and control components are being installed and systems and subsystems are being commissioned. Flooding of the Atlantic and Pacific locks started in June 2015 with equipment being tested.

As the locks fills, rolling gates are floated and tested to optimize opening and closing cycles, their drive mechanism, sensors and safety devices. Leakage tests are carried out to ensure proper sealing of the gates.

All hydraulic actuators for the lock valves are being installed and tested to raise and lower the valves, including tests to ensure water tightness and performance.

A central control house was built at each lock and all wiring, fiber optic, electrical and electronic controls are being installed and tested for proper and flawless automated operation, while problems are being identified and resolved.

Training for operations and maintenance of the new locks for all the complexities of the integrated systems are being carried out through theorical and field explanations.

The lock commissioning phase is scheduled to finish by January 2016. Then, the ACP plans to conduct trial transits to further train its pilots and vessel crews, and conduct hands-on training on the locks machinery that control the systems prior to opening the new locks to commercial traffic in April 2016.

4 CONCLUSION

Many lessons learned can be shared from our experience in executing the Panama Canal expansion program. Pre-feasibility studies have to be made to identify needs, investigate and, if possible, visit similar projects and talk to the owners to learn from their experiences and the different solutions implemented.

For the study and planning phase, it is vital to assemble a team of young and senior professionals in various disciplines and from a wide range of experience/expertise and base them at a central office so that they have informal day-to-day discussions and formal meetings are held where information is exchanged, plans are prepared and progress is discussed. It is important at this stage to train your personnel for the required knowledge and abilities that are needed at the time and for the future; since there will not be time for that as work progresses.

Revise and validate your conclusions and decisions as you go along and prepare a Master Plan. Proper planning is the most critical element and needs to be established early in the project. The project must be supported by sufficient studies and, if resources allow, validated by another team of experts.

At all phases of the work, it is vital to reach out for expert advice in different areas, including project management, engineering, hydraulic, construction, design, legal, contractual, and so on.

PIANC was a good source of information and peer contacts for the program. The ACP got involved in its activities, congresses and participated in many work groups which enriched its knowledge and provided for a robust program design.

Main stakeholders must be consulted, be it higher management, clients, government authorities, particular-interest groups, the general public and/or affected parties and kept informed, and a communication matrix and plan must be developed and implemented.

Assess project risks, prepare a risk register and review and update it frequently, as they change with time and as events unfold.

For the execution phase, have a good engineering team on board for the review of the project design; this team also needs to work hand-in-hand with your quality field inspectors.

A good scheduling team is also a must to plan, monitor, make changes as needed, particularly when project payments are based on earned value.

Keep records and documents of all phases of project and ensure a proper closure of the project and secure the documentation at the end of the project. Include the lessons learned provided by the main team members prior to their departure from the project.

Always keep a global view of your project and objectives. Enjoy your project management, it is a rough ride, but in the end you will come out wiser, more experienced and with good friends who have shared your load. And please, value your family and God for they keep you sane, balanced and centered.

Figure 4: Conceptual view of finished Third Set of Locks for the Panama Canal

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