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The Panama Canal: operations and traffic

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Abstract

In a previous paper on Canal management we examined the treaties and regulations underpinning firstly American and later Panamanian administration of the Canal. We also looked at the transfer of the Canal into Panamanian hands, including the management models used, ending with a review of toll structures and results. The subject of this paper is the operation of the Canal and the heated debate surrounding its modernisation, with a view to determining the adequacy of projected plans, as well as any future requirements, for maintaining its capacity in the 21 century. This paper seeks to analyse the Canal's operation, modernisation programmes and traffic systems as well as its key element: human resources.

Keywords: Panama canal; ACP; PCC

1. Introduction

The Panama Canal (PC) has been operating under Panamanian administrative control since mid-day on 31 December 1999. We continue to see the positive results of the transfer and an appreciable climate of trust within the international maritime community, which, in some cases, reserved judgement until the successful stewardship of the canal by the new administration had been established. Four years later, we can see for ourselves how canal operations are proceeding effectively and efficiently, and this is reflected in the operating results.

In one of our earlier papers on the Panamanian Maritime Sector [1], we described the physical characteristics of the interoceanic waterway following the latest improvement programmes.[1] Further details can also be learned from other documents of interest such as those used by Canal pilots [2], and with reference to PC entry and access, those used by captains intending to transit it [3–4]. In another study we conducted on the management and administration of the Canal, we clearly demonstrated that the fundamental success of its operations lay in the professionalism of its operators and the increasing participation of Panamanians in its operation and management, in conjunction with the timely implementation of administrative rules and procedures including the creation of the new Panama Canal Authority (ACP) to substitute the United States' federal agency, the Panama Canal Commission (PCC) [5].

For now, this paper would like to present the results of our research into PC operations in order to determine the primary factors that enable the interoceanic waterway to operate at full capacity, namely its water resources, infrastructures, dry and floating mobile equipment; and the relevant maintenance, operational safety and modernisation programmes. Subsequently, we will be taking a look at the key element to this system—its human resources—, paying particular attention to maritime positions and capacities. Finally, we will present our findings in respect of vessels and cargos in terms of the Canal's recent history; and based on the current situation, general trends and future forecasts, we hope to conclude with an analysis of whether the PC will

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[1] The widening of the Culebra Cut completed in 2001and commencement in 2002 of works to increase the depth of the Gatún Lake and the Cut itself by 1 m.

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be in a position to meet the demands of world maritime traffic in the future.

2. Panama canal operation

As can be observed from Fig. 1, the physical structure of the PC extends from the port of Cristóbal on the Atlantic side to the port of Balboa on the Pacific. The Canal itself includes the approach canals, three sets of locks, Gatún, Pedro Miguel and Miraflores, two man-made lakes, Gatún and Miraflores and the Culebra Cut, a narrow channel carved through the rock of the Continental Divide. The system also includes the man-made Alhajuela lake and Madden Dam built upstream of the river Chagres and designed to control the water flow into the Canal and prevent navigational problems for vessels in transit, as well as acting as a water reservoir for the dry season [6].

Owing to its geographical position, Panama has high levels of rainfall, which serve to facilitate the use of lock compartments. The dam built at the mouth of the river Chagres created the Gatún Lake, some 26 m above sea level, a large body of water essential for the operation of the lock system (Fig. 2). The set of locks at Gatún connect the Atlantic Ocean to the lake via an approach canal. At the other end, the Pedro Miguel lock chamber can lower ships 9.5 m down into the Miraflores lake, where less than a mile away the likewise named Miraflores locks allow access to the Pacific Ocean.

2.1. Water resources

A basic element in the functioning of the canal is the requirement for sufficient water to permit the entry and exit of vessels from the locks, hence the importance, as a basis for future canal expansion, of the canal watershed and its water resources. These are regulated by the new Constitutional Title XIV [7], which states that the "*administration, maintenance, use and conservation of the water resources of the Panama Canal watershed*" shall be the responsibility of the ACP. Following the creation of the ACP [8], its Board of Directors was authorised to propose the boundaries of the canal watershed and required to ensure that any regulations adopted should consider, among other matters, the following: "*the protection, conservation and maintenance of water resources…*", "*…of the environment*", "*the clean-up of Canal waters…*" *and* "*supervision of the quantity and quality of water in the Canal watershed…*". Then followed the approval of a regulation [9] on the management of water resources of the Canal watershed with a view to conserving the water resource for navigational and other uses, for the generation of

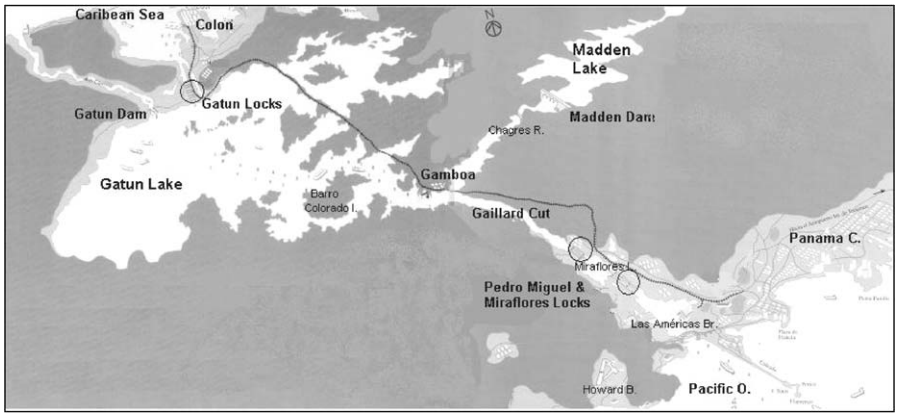

Fig. 1. The Panama Canal overview. *Source*: [6].

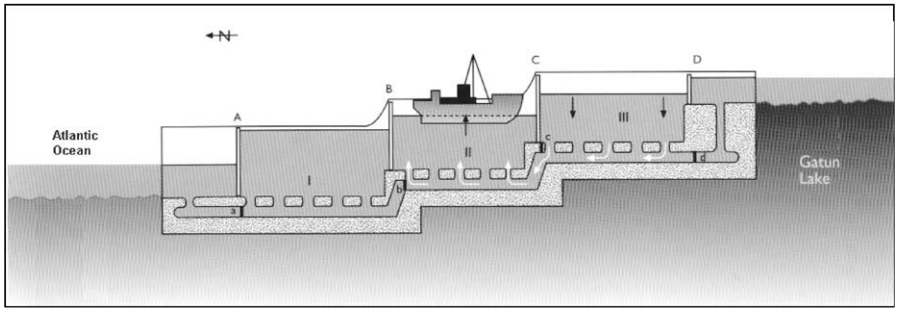

Fig. 2. Gatún lock. Miter gate B and valve b are closed. Opening valve c the ship is raised by equalising Chambers II and III. *Source*: [6,15].

hydroelectric power, etc. and, relating to lake water management, for the regulation of Canal operations and maintenance and the creation of an Interinstitutional Commission for this purpose.

The PC watershed has a surface area of 553,000 ha and perhaps one of the most pressing concerns in relation to the future expansion capacity of the Canal, is to determine the potential of the watershed in terms of meeting the future demand not only of canal operations but also as a resource for drinking water, given that it supplies Panama City, Colon and other communities. The water management system consists of the following dams: the Gatún Dam, 2.5 km in length controlled by the use of 14 remotely activated drum gates in the dam spillway, each just under 6 m in height. The Madden Dam, 290 m in length and 67 m tall, its spillway containing four main drum gates, two needle valves for minor discharges and six safety gates. The smallest of the dams is the Miraflores dam, with a spillway similar in construction to the one at Gatún. Gatún Lake covers an area of 436 km^2 at 26.7 m above sea level with a mean water storage capacity of 776,000,000 m^3. Alhajuela Lake covers an area of 50.2 km^2 at 76.8 m above sea level with an active storage capacity of 651,000,000 m^3. Miraflores Lake covers an area of 3.94 km^2 at 16.5 m above sea level with an active capacity of 2,500,000 m^3 [6]. A complex system allowing automatic measurements at remote stations to be transmitted to a central station ensures the availability of detailed information based on constantly updated readings for rainfall statistics and changes in river, tributary and lake elevations [10].

2.2. Infrastructures and equipment

The lock system is by far the most complex component of canal operations. The three sets of locks contain a total of 250 valves and 88 gates, and have relied on electronically operated mechanisms since operations began. Each of the lock chambers is 330 m long × 33.5 m wide. Water is not pumped into the locks. Instead, ships are raised or lowered within the chambers using the effects of gravity as valves open and close to connect the locks, lakes and sea through a system of main culverts. The Gatún locks have three sets of chambers which spill 100,000 m^3 of water from the lake into the sea in under 10 min during the raising or lowering process. A loaded Panamax vessel can transit the Gatún locks in approximately 2 h. Depending on the size of vessels up to two or three vessels can transit simultaneously in a procedure known as relay or tandem lockages. This procedure is not practical for ships transiting the Pedro Miguel Locks which having only one step, does not yield any savings on time [6].

The lock gates, which were traditionally gear operated, were converted in 1998 to a hydraulic system with 82 dual motor computerised hydraulic strut arms, each operating with fibre optics technology and programmable logic controllers and offering low maintenance costs.[2]

The locomotives are essential for steering the ships in the locks and allow the pilot to manoeuvre the ship into position for correct passage through the lock. The engines move on parallel tow tracks running along each side of the lock. The original locomotives used, known as mules, weighed 43 tonnes and had a maximum pull capacity of 111 kN at a towing speed of 3.2 km/h. As of 1964, they were replaced by more powerful engines towing up to 311 kN at 4.8 km/h [11]. The new generation of locomotives,[3] in use since 1999, operates with two 290 HP traction units and offers reduced lockage time. The 26 new units added to the fleet are 50% more powerful and offer a 66% increase on return time compared to previously used models [12].

The tugboat fleet provide an invaluable service to transiting ships, mainly in the entrances and exits to the locks and through the Culebra Cut. In 2002, two new tugboats were acquired to complete a 24 strong fleet. The modern models benefit from a stern azimuthal propulsion system and a 4400 hp engine.

2.3. Maintenance, modernisation and safety

Given that one of the defining features of the Canal is its non-stop operation 365 days a year, maintenance plans are a major part of ACP's budgeting policies, as indeed they were for earlier American administrations, and represent about 25% of the operating budget. The specific features, often one-off designs, of much of the equipment used in the Canal require high levels of preventative maintenance. The areas requiring ongoing maintenance are the Gatún, Madden and Miraflores dams; the navigable waterway; the three sets of locks and their associated equipment; floating equipment such as tugboats, launches, cranes and dredges and all electrical power, telecommunication and drinking water systems [7].

A number of modernisation studies were initiated well ahead of the transfer of the Canal. 1985 saw the creation of a Tripartite Commission[4] to study alternatives to the Canal with a view to taking the best possible advantage of Panama's geographical position [13]. Several proposals were put forward:

[2] The design and manufacture of the new system was awarded to Rexroth Corporation of Pennsylvania USA at a cost of 22 million dollars.

[3] Twenty-six units have already been manufactured by General Electric, NY, at a cost of 2 million dollars each. Full replacement of the fleet is expected by 2005.

[4] Agreement between Panama, Japan and USA, signed on 26th September.

(a) the widening of the Culebra Cut,
(b) the creation of a 'Centre-port',
(c) a second, sea-level canal,
(d) a third set of locks,
(e) the promotion of alternative systems of transport such as railroads, pipelines, etc.

The Tripartite Commission was charged with undertaking studies for the latter three proposals. The first proposal fell to the PCC and the second to the Ministry of Planning and Economic Policy in conjunction with the National Port Authority. With the exception of the second, sea-level canal, the other two alternatives evaluated by the Tripartite Commission, that is the construction of a third set of locks (at a then estimated cost of 5.4 million dollars) and the improvement of alternative transport systems to complement existing Canal facilities, would require the widening of the Culebra Cut [14].

As a result, the proposal to widen the Culebra Cut was planned for the short term and by 1987 the PCC had concluded its technical, environmental and financial feasibility studies. The viability of the works was confirmed. The total cost of the widening had been estimated at between 350 and 400 million dollars and the works were expected to take between 6 and 11 years. The first phase was initiated in 1992 at a cost of 200 million dollars, which was considered a valuable contribution towards the reconstruction of the Panamanian economy. The project consisted of widening all 9 miles of the Culebra Cut, from 152 m to at least 192 m along straight stretches and 222 m in the curves in order to allow the simultaneous transit of Panamax-size vessels. On the 3 May 1999 two Panamax vessels passed each other in the Cut for the first time in history.

The channel was carved through rock and shale from most of its length. It was here that the largest excavation volume was required and where the largest landslides occurred during the construction of the Canal, just after the opening the waterway as well as in many subsequent instances. The last blasting was performed on July 4, 2001, thus ending the drilling and blasting portion, while on August 16th, the excavator Liebherr lifted the last shovelful of the wet excavation work from land. The major widening work ended on November 2001, when the dredge Christensen removed the last portion of rock and shale from Culebra Cut. The strategy of dividing the widening programme into 19 contracts generated an intense competition among local and foreign contractors, which resulted in substantial savings in the dry excavation costs. A grand total of 23.2 million m^3 of dry material and 12 million m^3 of underwater material were removed.

The works completed in November 2001, at a cost of 1 billion dollars, have facilitated the transit of up to 16,000 ships a year, a 20% increase on previous levels and have reduced total transit times from 32.9 h in 1999 to 24 h today [15].

The Tripartite Commission's projects were considered to be long-term projects due to the complexity of the proposals both on a technical and political level. In addition, they would require their own feasibility studies and a national consensus would have to be reached. This would have necessitated the involvement not only of the government but also of the National Assembly.

In respect of the sea-level canal, studies were begun on two previously identified potential routes. In the case of the first route, it was envisaged that the new canal would operate jointly with the existing canal whereas, in the second, the current canal would cease to operate. Either option would facilitate the transit of vessels up to 150,000 or 250,000 dwt under controlled conditions. In 1987, the cost for building such a canal was estimated at between 15 and 20 billion dollars, a serious obstacle given that such high costs would undoubtedly affect canal users negatively with the inevitable and substantial increase in toll rates. In any case, it is unlikely that such increases would be sufficient to fund the multi-billion dollar investment required.

In relation to the increase in size of the locks, alternative studies were undertaken at the time with a view to expanding the then current limits by building a third and larger set of locks parallel to the two at Gatún and Miraflores [13]. Two major proposals were put forward in respect of this option both of which included the elimination of the Pedro Miguel locks, the widening and deepening of the canal bed and the construction of new locks. The cost was estimated at 5 billion dollars and construction time at between 5 and 10 years [16].

The Tripartite Commission also considered improvements to the other alternative interoceanic transport links such as roads, rail and additional pipelines with a view to complementing existing facilities. This option was considered unviable in the medium term given that it relied on improvements to infrastructure at a national level (road, rail, etc.) and would require high investment. It should be pointed out that since the coming into force of the Torrijos-Carter Treaties in 1979 the PCC invested over 2.5 billion dollars in modernisation programmes. Some recent major improvements include the installation of lighting to facilitate round-the-clock transit operations; the commencement of works on the Culebra Cut, already mentioned; a new fully computerised Maritime Traffic Control Centre; a transit reservation programme; signalling and radar identification systems for use at Cristóbal and the updating of buoyage and signalling systems in compliance with International Association of Lighthouse Authorities (IALA) regulations. In terms of safety, new fire-fighting systems for the locks were installed as well as improved security systems to guarantee the safety of PC facilities and ships in transit.

The results of ACP's new management strategy of applying a business perspective to Canal management, which we described in an earlier paper [5], have certainly not been long in coming. Two years into the new strategy, and the Canal's contribution to the country's economy has doubled, encouraging and enabling new modernisation programmes. These include the Channel Deepening Project to increase the depth of the navigable canal in the Gatún Lake and Culebra Cut by 1 m, which will mean a significant 25% increase in water storage capacity. Works started in March 2002 and should be completed by 2009 at a cost of 190 million dollars.

A new 360° full bridge, a 150° full bridge and a tug simulator have been integrated into the Canal's Maritime Simulation, Research and Development Center (SIDMAR), at the forefront of interactive systems in Latin America, making it possible for operators to pilot two vessels and control a tugboat simultaneously. An automatic identification system was recently integrated into the vessel tracking system and traffic management operations (EVTMS) ensuring more reliable data during transit.

In terms of security, a 24 h Security Control Centre for Incident and Emergency Management has been set up, with greater fixed and mobile support capabilities, in compliance of IMO Regulations [17]. This has been in response to the events of September the 11th which has led the ACP, and the maritime sector in general, to implement major steps for the improvement of its security and protection systems.

In terms of future improvements, a total of 200 studies have been commissioned for completion by 2004. These include market studies based on various traffic forecasts and the bunker business; feasibility studies for the third set of locks which if implemented would undoubtedly affect the future of cargo vessel design; and further studies on the economic impact of the construction project. The decision on whether or not to build the third set of locks will be taken after the 2004 elections. It is important to understand that such a decision would have to weigh up the estimated investment cost of 4–5 billion dollars against future demand for use of the Canal. Another point for consideration is that the transit of postpanamax vessels will require new and larger lock dimensions: 425 m in length, 60 m wide and 15.2 m deep. This in itself would require detailed studies into structures and configuration [18] and above all, given the increased water requirements (between 2.5 and 8 times higher) into the possibility of a water recycling system to avoid the total drainage to sea that occurs at present.[5]

If Canal extensions were to be approved, the Pacific entrance to the canal would require immediate improvements. The entrance depth would have to increase from the existing 12.5 m to allow access to postpanamax vessels into the port of Balboa. Facilities would also require modernisation in line with the blueprint for a new and ambitious 'Centre-port' system integrating the two ports at either end of the Canal into an all-encompassing maritime service centre [19–21]. Indeed, there are 5000 ha of land earmarked for development and investment on the Atlantic side, and another 3000 ha on the Pacific side [22–23]. The plan would be to develop these areas and in conjunction with the new Panama Canal Railroad Co operating as a 'dry canal', turn the Canal into an international containerised shipping centre [24].

Alongside the decisions to be made about the future of the canal and measures to be adopted is the open debate surrounding its modernisation which, by and large the experts agree, is an issue more concerned with market factors than engineering solutions [25–26].

There can be no doubting the benefits to maritime safety at the PC brought about by improvements in support equipment available to ships in transit [27]. Current figures are extremely positive, reporting the lowest ever maritime accident averages. The number of accidents occurring in the PC in 2001 and 2002 was 17 per annum, representing a 40% reduction from the two previous years [15]. During 2003 a total of 12 accidents once again set a new lowest record, which could have been even lower given that three of these accidents occurred on the 30th September, the last day of the fiscal year[6]. Since the total number of transits for the year 2003 was 13,154 (excluding port entrance manoeuvres) this represents a 0.09% accident rate, a considerable improvement on the 0.12% rate for the year before.

3. Human resources

At the time the PCC was created, Panamanians represented 69.2% of the labour force, with only 7% in managerial or executive roles. In September 1990, there were 8279 employees, of which 86.2% were Panamanians, 7232 of which were permanent staff (87.4%) and 1047 temporary staff (12.6%) [28]. By 1999, Panamanians represented 97% of the PCC labour force. Table 1 shows the composition of the PCC's labour force as it changed between 1979 and 1999, showing the increasing participation of Panamanian nationals against a reduction in American staff from 26.4% to less than 4%.

[5] Today, a vessel uses 200 million litres of water per transit. With a water recycling system in place alongside the new set of locks, water usage would increase by only 1.5 times.

[6] The continued training programmes, in which the author is an active participant, initiated by the PCC for pilots, engineers and captains help to keep personnel in touch with maritime safety issues.

Table 1
PCC permanent labour force, by nationalities

Year	Total	Panamanian	%	USA	%	Others	%	Total foreign
1979	7976	5521	69.2	2105	26.4	350	4.4	2455
1985	7538	5999	79.6	1358	18.0	181	2.4	1539
1988	7532	6323	83.9	1093	14.5	116	1.6	1209
1990	7232	6231	86.1	927	12.8	74	1.0	1001
1993	7420	6529	87.9	828	11.1	63	1.0	891
1995	7577	6819	89.9	710	9.4	48	0.7	758
1997	8073	7441	92.1	592	7.3	40	0.6	632
1999	7149	7136	96	270	3.8	13	0.2	283

Years 1979–1999.
Source: [7,21,28].

Increased Panamanian participation in the Canal was one of the priorities of the Torrijos-Carter Treaties, as mentioned earlier. To this end, an ongoing programme of training in the areas of administration, management and technical projects, in particular those of a nautical nature, was set up. It is difficult to determine which of the activities undertaken is the most important, although the work of pilots does stand out, with a training in the majority of cases exceeding 16 years for piloting deep draught vessels in transit through the Canal. Another challenging area is that of the Canal engineers responsible for surveying the stability of the banks and earthen dams, given the local geology and its variety of rock structures, as well as the permanent dredging activities designed to prevent accidents and transit stoppages. Another special interest area is that of measuring and managing water levels, essential for protecting the facilities against flooding and conserving the Gatún and Alhajuela watersheds which provide all of the water for the canal and it hydraulic systems.

Positions requiring nautical expertise were of particular interest to the directors of the PCC and the Panamanian authorities responsible for the transfer, in particular the Panamanian Department for Treaty Affairs (DEPAT),[7] given that any potential candidates, especially those wishing to enter the pilot force, would require careful selection and a sound nautical background. For this reason, one of the main activities of the IMO/UNDP projects which we managed in Panama focused on promoting the training of Panamanians in specialist maritime roles to facilitate their employment in the Canal [21]. Thus, we verified that the main positions requiring nautical expertise in the PCC could be classified as follows:

- Maritime transport operations, position of assistant officer to marine operations requiring the applicant to hold a Third Deck Officer license.
- Lock towing locomotive operations, responsibilities related to the operation and maintenance of the locks and the manoeuvre of vessels through the locks.
- Minor vessel operations, by basic position of seamen.
- Maintenance of mobile transport equipment, position of Chief Engineer on tugboats, land stations and fleet engineers. These posts to be occupied by personnel holding the license of Merchant Marine Engineer/ Chief Engineer issued by the Board of Local Inspectors, the agency responsible for investigating maritime accidents in the Canal area.
- Piloting Division, undoubtedly one of the most important divisions. The selection and entry process has been improved since 1983. There are three tracks for entry into the pilot in training (PIT) programme. Once accepted onto the programme aspiring pilots must meet the following requirements [29]:
  - Seven months theoretical and practical training on vessels not over 68.6 m in length.
  - Served at least 1 year as a Pilot on vessels not over 160.3 m in length.
  - Prior to receiving license as Pilot of Vessels of any size an applicant must pass a prescribed onboard examination.

The most direct entry into the "PIT" programme was for applicants who have served 3 years as a licensed deck officer in charge of a deck watch with experience at sea on vessels of 1000 grt or over, 1 year of which must have been as a chief mate.

Another way in is through the "Tugboat Programme" for officers in training and masters. For entry into the scheme, applicants must have graduated from a recognised Nautical School or have completed the 3 year PC apprentice program for Mate Trainee, Tugboat; or have at least 260 eight-hour watches of experience as a licensed officer in charge of deck watch on vessels over 23 m in length and hold an appointment as Master of Tugboat by the PC authorities, with 2 years experience.

Perhaps the most popular entry route was through the Pilot Understudy Programmer (PUP) for graduates from Nautical School with 2 years experience at sea as a deck officer on vessels over 1000 grt (up to 1 year experience could be substituted for cadet service instead); or 3 years experience as second or higher-ranking officer on vessels of over 1000 grt (experience at sea could be validated by time spent in-training onboard vessels over 1000 grt). The training period for this programme was between 24 and 36 months [30].

In Article I, paragraph 3 of the Treaty [31] it states that "*The Republic of Panama shall participate increasingly in the management and protection and defence of the Canal…*" Consequently, after its entry into force, the authorities began to develop mechanisms for complying with treaty stipulations as seen in the increased number of Panamanian nationals employed by the PCC [32–33].

[7] Dependent on the Ministry of Foreign Affairs and charged with issues relating to the transfer of the canal.

However, although a high proportion of key roles were occupied by Panamanians, the number of permanent senior nautical positions held by nationals was low. In 1979, for instance, out of a total of 228 pilots, only 4 were Panamanians. By 1985, out of 232 pilots, 29 were Panamanian, still considered low and the subject of a great polemic on whether there would be enough Panamanian pilots in service by the year of the transfer. It is worth pointing out that during these years Panama's Nautical School (ENP) received large numbers of applicants for the graduate programme for deck officers, practically all of which were intending to find subsequent employment not at sea but as a Canal employee. In 1999, 233 out of 287 pilots (81.2%) were Panamanians [34]. Currently, all positions are covered and intakes and promotions have been temporarily frozen.

In terms of other key nautical positions occupied by foreign nationals, excluding pilots, in 1991 the figure stood at 267, including 248 Americans and 19 other foreign nationals [33]. In 1979, out of a total of 116 senior posts, only 8 were Panamanian nationals. By 1985, the proportion had increased to 42 out of 143 and just prior to the transfer, out of a total of 146 senior personnel, 98 were Panamanian, a total of 78% [7].

Given the future requirements for business personnel to manage the Canal once it had reverted into Panamanian hands in 2000, we designed, established and directed jointly with the University of Panama [35] the first ever postgraduate degrees in maritime studies in Central America: A Master Course on Maritime Development, with a specialty in Maritime Business Administration and another in Port and Canal Business Administration (1993). The course proved to be a great success boasting an initial intake of over 100 Panamanians, many of whom occupy key posts in the AMP and ACP today [36].

4. Panama canal traffic development

The PC is a place where several of the world's principal trade routes converge. This is largely because of the strategic savings on time and distance afforded to users of the Canal. Using statistics from the period 1979–1999, published in the PCC's Annual Reports, as well as ACP statistics on vessels, routes and cargoes to 2003, we have identified the principal trading routes for analysis.

Table 2 includes information on vessel transits, total cargos and toll amounts within this period. During the 1980s, 1982 stands out as a particularly successful year for transits of oceangoing vessels: 14,142 transits and a total of 188.7 million mt in shipments. This was an extraordinary year in terms of number of canal transits and yet to be repeated. A decisive factor in obtaining such high figures was the passage of some 1500 tankers from the Alaska North Slope as well as coal and grain traffic [7]. The following year reported a sharp decline in traffic to 11,846 vessels and 148.2 mt, due to the world economic recession and the commissioning of the Panama oil pipeline in October 1982, which proved to be the end of Alaska North Slope traffic. The decline continued until 1985 where a slow recovery was recorded to 1989. The decade ended with an average of 12,535 vessels per year, a total of 1573 mt and 3121 million dollars in toll revenue.

Table 2
PCC & ACP Traffic, Cargo and Tolls. 1980–2003

Fiscal year	No. transits	Million mt	Million dollars tolls income
1980	13,614	170.3	293.4
1982	14,142	188.7	325.6
1984	11,384	143.0	289.2
1986	12,023	142.4	322.7
1989	12,075	154.3	328.8
1990	12,052	159.8	329.8
1992	12,636	162.2	368.7
1994	12,478	173.6	419.2
1996	13,721	201.7	486.7
1999	13,132	222.7	568.9
2000	12,303	196.8	573.0
2002	11,860	190.8	587.6
2003	11,725	191.3	664.7

Source: Author, adapted from [7,39–42].

The beginning of the 1990s was marked by the effects of the economic slowdown in the USA and Japan and the changes made in the transport of oil, grain and, in particular, cars. This is reflected in canal traffic which reported a transit of 12,052 vessels and 159.8 mt. The effects of the Gulf War were also felt. 1996 marked the high point of the decade reporting 13,721 transits and 201.7 mt. For the 1990s, the annual average was recorded at 12,885 transits per year with a total of 1828 mt and 4451 million dollars in toll revenues. Total toll revenues in this decade increased by 42.6% against toll revenues for the previous decade and by 16% compared with transited loads.

It is important to point out that the figures reported for 1999, the year in which the canal transfer into Panamanian hands took place, were the highest in terms of tonnes of cargo, at 222.7 mt. Since then, tonnage figures have experienced a downturn reaching 191.13 mt according to the figures for the 2003 fiscal year,[8] although record revenues at 664.7 million dollars have also been reported, as a result of the new toll structures mentioned above [37]. Canal traffic has always been determined by global economic and maritime commercial factors as well as the development of new transport

[8] The Canal's fiscal year ends on 30th September.

Table 3
Main cargoes transiting the Panama Canal

Products	1980–1989	1990–1999	Variation (%)	2003
Grains	316.5	370.4	17	34.4
Petroleum and products	356.1	281.6	21	21.4
Containerized	151.0	247.3	64	47.7
Nitrates and Phosphates	107.9	149.1	38	10.6
Coal and coke	129.5	97.2	−2%	6.7
Ores and metals	95.4	112.8	18	11.1

1980–2003 in million of mt.
Source: Author, adapted from [7,39,40–42].

technologies (such as pipelines and the design and commissioning of postpanamax vessels) [38].

Table 3 shows details of the principal commodities shipped through the Canal in the periods of interest. So, during the 1980s, the transport of oil and derivative products reached its highest point in 1982 with 62.5 mt, with a dramatic drop to 34.2 mt reported for the following year, for the reasons explained above. The decline continued up to 1989 where the reported figure was 22.3 mt. In this period, the total traffic figure for this commodity was 356.1 mt. 1989 registered a total of 1539 oil tanker transits of which 1137 were laden and 402 in ballast. The highest figures in terms of direction for laden vessels were reported for the Atlantic to Pacific route with 674. For ballast traffic the Pacific to Atlantic route prevailed with 402. During the 1990s this commodity suffered a significant 21% drop to 281.6 mt.

Grain transport is one of the major sources of traffic through the Canal. During the 1980s, it was the second most important segment, starting off at 30.9 mt, and following a decade of minor fluctuations, remaining at 30.4 mt by 1989. In that year the transit of grain carriers in ballast along the Pacific to Atlantic route increased considerably, nearing Atlantic to Pacific traffic levels. Worthy of note is the low number of vessels travelling in ballast along the Pacific to Atlantic route, particularly in 1986. During the 1990s, grain traffic reached 370.4 mt, a 17% increase on the previous decade with 1995, in particular, experiencing a sharp increase to 44.7 mt.

Container traffic, which totalled 151 mt in the 1980s, experienced strong growth during the decade from 10.6 mt in 1980 to 20.2 mt in 1989 [39]. During the latter half of the decade movement along the Pacific to Atlantic route remained prevalent for laden vessels. This traffic represented 14.5% of total participation, and it is significant that an average of only 2% of ships transited in ballast, a factor which should be borne in mind [40]. During the 1990s, the growth in container traffic consolidated its position as third largest [41], reaching 247.3 mt, having experienced a dramatic 64% increase. It is worth noting that with the exception of 1993 which saw a 2.6% decrease, steady growth has been maintained year after year [7].

The fourth biggest market segment during the 1980s was the coke and coal sector at 129.5 mt, starting off at 17.3 mt and steadily increasing until 1983, after which it experienced a decline following reduced demand from the USA. The following decade saw a decline of 25% to 97.2 mt, moving to seventh position behind manufactures of iron at 87.9 mt and mineral and metal cargo at 112.8 mt, which had increased, respectively, by 23% and 18%. It would be impossible to finish off this analysis without mentioning that chemicals and petroleum chemicals experienced the most spectacular growth from 54.5 to 95 mt, an increase of 74% [42].

Recently obtained figures, relating to 2003, report a total of 191.3 mt with containerised traffic in first place, as expected, reaching 47.7 mt or 25% of total transit traffic, distributed equally along both trade directions. Grain traffic was reported at 34.4 mt, or 18% of the total, of which 95% travelled along the Atlantic to Pacific route marking a downward trend since 1999. Oil and derivatives reported 21.4 mt, representing 11% of the total, of which 62.5% moved along the Atlantic to Pacific route, and is in decline following the temporary upturn in 2001 which reported 30.5 mt transits. Minerals and metals reported 11.1 mt, or 6% of the total, of which 59% travelled along the Pacific to Atlantic route, figures having remained stable during the three preceding years. Nitrates and phosphate traffic reported 10.6 mt, or 5.5% of the total, 89% transiting the Atlantic to Pacific route. Chemicals and petrochemicals exceeded 10 mt, or 5% of the total, slightly lower than 1999 and 2000 figures, in this case 83% of cargo moved along the Atlantic to Pacific route [43].

4.1. Commodity movement by origin and destination

In 2003, 108.3 mt worth of commodities were shipped along the Atlantic to Pacific route, representing 56.6% of all cargo transits during that year, mainly as follows:

1. In first place, traffic originating on East-Coast America (E-USA) totalling 70.9 mt, 65.5% of the total for this route. The main destination was Asia, with 54.5 mt or about half of the cargo shipped along this route, with grain and containerised traffic representing the largest segments at 48% and 21%, respectively. The second largest destination was West Coast of Central America (W-CA) with 6.8 mt and the third largest was West Coast of South America (W-SA) with 5.8 mt. A notable 10% increase was reported on 2002.[9]
2. In second place, traffic originating on the East Coast of South America (E-SA) from which 12 mt of goods departed, representing 11.1% of the total figures for

[9] Since the beginning of the 1990s, the figures have remained fairly stable with only minor fluctuations.

this sea-route. The most important destination was W-SA receiving 4.9 mt of shipments of which 1.9 mt were oil and oil-derivatives.

3. In third place, traffic originating in European ports with a total of 11 mt, representing 10.2% of the total for this route, split between W-SA with 3.8 mt, of which 1.1 mt was containerised cargo, and W-USA with 3.7 mt of which 2 mt was also containerised cargo.
4. The total distribution of shipments moving over the Atlantic to Pacific route in terms of destinations can be broken down as follows: Asia 57.6%, W-SA 16.1%, W-CA 12.5% and W-USA 9.7%, with the remaining 4.1% going to other Pacific destinations.

In 2003, 83 mt of commodities were shipped over the Pacific to Atlantic route, representing 43.3% of total canal transits, principally:

1. In first place was traffic originating in Asia which increased to 33.1 mt or 40% of the total for this route. Its major destination was E-USA receiving 26.4 mt, 40% of the cargo shipped over this route, containerised traffic standing out at 13 mt worth of goods. The second most important destination was E-CA, at 3 mt.
2. In second place was traffic originating in W-SA at 27.1 mt or 32.7% of the total for this route. The main destination for this traffic was E-USA at 10 mt, mostly mineral cargo at 4 mt, followed by oil and oil-derivatives at 1.6 mt.
3. In third place, and lagging far behind the first two, is Traffic originating in W-USA totalling a mere 6.7 mt, or 8% of total for this route. Its primary destination was Europe which received 4.1 mt, mainly from oil and oil-derivatives (1.6 mt) and containerised cargo (1 mt).
4. The total distribution of shipments moving over the Pacific to Atlantic route in terms of destination can be broken down as follows: E-USA 51.1%, Europe 24.5%, West Indies 8.1%, E-CA 7.4%, E-SA 4% and the remaining 4.9% going to other Atlantic destinations.

Table 4 shows the five top countries by origin and destination of cargo. Between them they represent 59% of the shipments loaded and 56.3% of shipments unloaded during 2003. Of particular importance are USA ports, originating 40.5% and receiving 27.6% of commodity movement through the Canal. The second largest country in terms of origin of cargo was Chile with 6.5% and in terms of destination of cargo, Japan with 13.2%.

Table 5 shows the five major Flag States in terms of number of transits and cargo, providing 47% of all ships and 54% of the total commodity movements through the Canal in 2003, representing 50% of toll revenues. In first place is Panama with 23.4% of total transits and 45.3 mt of cargo, representing 23.7% of total commodity movement. In second place Liberia, under whose Flag 11.5% of transits and 11.2% of commodity movement was made.

Table 4
Top 5 by origin and destination of cargo transiting the Panama Canal

Country	Origin	Destination	Total
USA	77.6 (40.5%)	52.8 (27.6%)	130.4
Japan	5.9 (3%)	25.3 (13.2%)	31.2
China	11 (5.6%)	16.6 (8.7%)	27.6
Chile	12.6 (6.5%)	5 (2.6%)	17.6
South Korea	6.6 (3.4%)	8.1 (4.2%)	14.7
SUB-TOTAL	113.7 (59%)	107.8 (56.3%)	221.5
GRAND TOTAL	191.3	191.3	

2003 in million of mt.
Source: Author, adapted from [42].

Table 5
Traffic by Flag transiting the Panama Canal

Flag	No. transits	Cargo moved	Tolls
Panama	2740	45.3	171.2
Liberia	1347	21.4	76.2
Cyprus	697	13.4	35.3
Hong Kong	401	12.1	25.8
Greece	344	11.4	24.8
SUB-TOTAL	5529	103.6	333.3
GRAND TOTAL	11,725	191.3	664.7

2003 in number of transits, cargo moved in million of mt and tolls in million dollars.
Source: Author, adapted from [42].

5. Conclusions

The establishment of the structural and legal framework of the Canal ahead of the transfer into Panamanian hands was essential for addressing the problems faced by the Canal in terms of maritime transport today. Operating results clearly demonstrate that operations are proceeding efficiently thanks to the skill and commitment of Panamanian nationals in successfully responding to current needs. Particularly worthy of note is the significant contribution that the Canal is making to the nation's economy, which doubled in the first 2 years of Panamanian administration of the canal.

The nature of shipping use of the Canal is constantly changing and the ACP has responded well to these changes by implementing several modernisation programmes based on the results of rigorous research and needs analyses [44]. Since it was built, the Canal has continued to adapt itself to such changes, but it is now facing fundamental questions to be considered ahead of possible extension plans which, given their scope, are

inextricably linked to the specifications of ships using the waterway in the near future and beyond.

Whatever the outcome, it is clear that the widening of the Culebra Cut has marked the beginning of a dynamic modernisation process which has meant a considerable increase in the capacity to accommodate transiting vessels and a reduction in transit times. This process continues with the Channel Deepening Project together with the improvements to canal facilities and new equipment thanks to sound budgetary and investment policies. Any plans for a future extension of the Canal will be closely linked to the availability of sufficient water which, unless adequately managed, could mean an increase in water consumption of up to eight times current usage.

Any works which may be undertaken to extend canal capacity require the support of numerous studies, some of which have already been concluded, including market studies on dry and liquid bulk carriers and on liner-container shipping. The aim is to develop an investment-grade market demand forecast in order to assess revenue flows and risks associated with possible fluctuations in demand. Such a model would allow the determination of different operational alternatives for the Canal based on the new dimensions and depth specifications. The decision on whether or not to build the third set of locks, for instance, requires a detailed assessment of possible alternatives. ACP has therefore commissioned two firms[10] to carry out two independent 'conceptual' designs for the new locks in order to guarantee an optimum technical and financial solution for any works ultimately undertaken.

The number of ships transiting the Panama Canal is in decline, but tonnage figures are on the increase. Patterns in canal traffic over the next few decades will depend on such factors as the development of commercial stability between the areas of economic influence, the development of new products, consumer trends, technological advances as they relate to vessel design and, of course, any engineering works undertaken in the Canal. Nevertheless, it is still useful to consider geographical service areas by producers and consumers and traffic segments.

There are four main economic areas directly linked to the future of the Canal. They are the Asian Pacific, North America, Latin America and the EU. Due to its low operational costs, China has become the country of preference for foreign investments with 55 billion dollars worth of direct foreign investments reported for year 2002, in excess of USA figures, and 400 million dollars worth of exports in terms of mechanical and electrical equipment, cutting-edge technology and textiles [45]. Growth figures have been maintained at 8% and we consider its entry into the World Trade Organisation essential. 10 years ago, economic studies of China referred to it as the Sleeping Dragon [46–47] whilst not questioning Japanese supremacy. Today, its public sector represents less than 30% of GDP and it has just overtaken Japan to become the third largest exporter in the world after USA and Germany [48]. Likewise, Japanese companies depend less on American imports, generally exporting to Asia where growth figures exceed joint figures for USA and Europe [49]. The Japanese will continue to open new markets and transfer their plants abroad. In view of this outlook, it seems that the general policy, not only of China and Japan, but also of the other countries in the region, will be focused on increasing exports to the North American and European markets. Japan is the second largest user of the Canal, and China the third with 31.2 and 27.6 mt worth of origin and destination loads, respectively.

North America is the second largest economic group with the USA holding the dominant position. Factors such as rapid growth and economic dynamism in recent years favour the Growth Theory on Asia, also based on the weakening of the American economy, in recession at the end of 2001, but experiencing 3.1% growth in 2003 [49]. Economic indicators are indeed improving and effects of tax cuts have stimulated growth, despite the very high levels of national debt. A reduction in American trade deficit, given that its trading with Asia is three times greater than with Europe, has resulted in the weakening of the dollar against Asian currencies. The outlook for the USA is positive but still very fragile. In 2003, this country was the leader in cargo by origin and destination with 130.4 mt.

Latin America's position will depend on its capacity to address US anti-deficit measures, as well as other factors such as foreign debt and political instability. It is considered that 2004 will be a positive year with the following standing out as the main users of the Canal: Chile, the fourth largest user in 2003 with 17.6 mt of origin and destination loads, Peru in sixth position and Ecuador in eighth with promising prospects.

EU figures have stabilised and a recovery is expected in Germany and France for 2004. Nonetheless, European countries feature low on the list of countries in relation to classification by origin and destination. Germany is in sixteenth position, Belgium in eighteenth and Italy in nineteenth position, each one with some 4 mt worth of origin and destination loads transited.

In 2001, maritime transport, following 15 years of continuous growth contracted to 5830 mt of goods loaded. The figures for 2002 present a similar picture, 5880 mt, with a modest growth of 0.8% [50]. In terms of traffic segments, the indicators point toward the continued gradual decline of grain traffic since the year 2000. Grain exports from E-USA to Asia continue to dominate this type of traffic, at 48% of the total. The potential for deeper draught vessels in the bulkcarrier

[10] US Army Corps of Engineers and a Franco-Belgian Consortium.

segment could have a considerable effect on Canal operations in the future. There were 82 mt worth of dry bulk transits in the year 2003.

Oil and oil derivatives transport in general should continue to experience a slight decline, in the last year transit figures were reduced by 4 mt. Figures remain stable mainly thanks to Ecuadorian exports to East Coast of North and Central America. Taking into account the time frames established for the phase-out of single-hull tankers in Europe in 2005 and 2010, it is likely that some of them could be used in the Canal routes. If the third set of locks is built, Aframax tankers could transit.

Container traffic, as the largest segment, will play an important role in Canal operations though much will depend on the reception, storage and service or handling capacities of the entrance ports at Balboa and Cristóbal. The stabilisation of traffic volume along the Atlantic to Pacific route and vice versa, will continue with large increases expected in both directions, in the last year these were reported at 8 mt. There is no doubt of the effect that a future increase in Canal depth would have in terms of allowing passage to postpanamax vessels up to 12,500 TEUs capacity, and of the greatly significant impact of this on Canal operations. The 'conceptual' design for the new set of locks considerer containers ships with the above mentioned capacity, although at the moment, container vessels transiting PC have a maximum capacity of 4500 TEUs and only a few vessels up to 9600 TEUs are being built.

Given the characteristics and complexity of the projected expansion plans, the legal framework of the Canal may have to be reviewed in view of the possible international financing requirements for a project on this scale. This may call for changes to legislation or indeed Title XIV of the National Constitution.

Depending on the results of the numerous external studies in progress, expected to be completed in the coming months, and the ACP's own critical analyses, a series of final recommendations will emerge to form the basis of a national debate and perhaps even a referendum which will determine how and when, if at all, such an ambitious programme of works should be undertaken.

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