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Estimating the emissions potential of marine transportation using the Kra Canal

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ABSTRACT

The Panama and Suez canals greatly reduced pollutant emissions from shipping through much reduced sailing distances. Another possible future canal is across the Kra isthmus in Thailand, reducing sailing distances for ships travelling from East Asia to Europe that sail around the Malacca straits. Much literature considers the economic and political viability of the Kra Canal and notes the adverse environmental impact of the canal's construction. Yet, this literature also highlights the decarbonizing potential of the canal through reduced sailing distances and emissions. In this paper we critically consider this potential through the specific type of calculations in the study (ship emissions, etc.) and qualitative data consisting of the perspectives of experts (n = 20) from China (n = 5); Thailand (n = 5); Singapore (n = 5) and Taiwan (n = 5) gathered through semi-structured interviews. This data shows that, in fact, the canal might offer negative decarbonizing and emissions potential. This is due to a number of factors: the shorter reductions in sailing distances it affords compared to the Suez and Panama Canals; the economic models and political requirements to finance it, and; the currently available technologies. Nevertheless, the canal does offer potential for reducing distances and traffic in the Malacca straits if these factors change, and we outline and discuss these changes here.

1. Introduction

As Table 1 below outlines, both the Panama and Suez canals led to huge reductions in Greenhouse Gas Emissions from Shipping and continue to do so increasingly, especially with the expansion of the Panama Canal in 2016 and the widening of the Suez Canal to allow for two way shipping traffic in 2019. This is a highly significant factor given the amount of GHG emissions and fuel consumed by shipping. Although shipping is one of the most environmentally efficient ways to transport cargo, and although GHG emissions remained constant in the early 21st century according to IMO estimates (IMO, 2020), predictions for the future are ominous. Indeed, mid-range forecasts of emissions are predicted to grow by between 90 and 130% by the year 2050 depending on economic growth (IMO, 2020), with global freight demand predicted to triple by 2050 (Maritime Executive, 2019). Even though emissions from shipping are calculated currently at only 3% of total global emissions, this nevertheless represents a huge increase, and emissions from shipping are predicted to increase to constitute 10% of the global total by 2050 (Shipping and Environment, 2021). Moreover, these predictions and forecasts should be seen in the context of the fact that by the year 2050, the United Nations has set a goal of the world becoming Carbon Neutral (UN, 2020). Admittedly, technology may develop for carbon capture (e.g. Elias et al., 2018) and for greener production

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Table 1
Distance and emissions reductions from the Suez and Panama Canals.

Canal	Distance saved	Emissions reduction(NOx, SO2, CO2, HC, and PM)
Suez canal	3120 km (Fletcher, 1958)	674.74 tons
Panama canal	4251 km (Huebner, 1915)	918.68 tons

of areas and generation that will offset (through foldable containers for example (Goh, 2019)) or counterbalance the emissions from shipping (Gössling et al., 2021). Nevertheless, when put side by side, the potential increase in emissions of 250% by 2050 from shipping and the goal of the United Nations for Carbon Neutrality by 2050 sit together uncomfortably. It is in this context that any initiatives set to reduce GHG emissions from shipping should be seen, and in this context that the reduction of sailing distances is key. One possible way to reduce these distances is through the introduction of canals such as the Suez and Panama canals, and a canal across the Kra isthmus is one such possible canal.

Based on Tai and Lin (2016), one 7000 TEU containership with 10 knots[1] speed would emit 173.01 tons emissions (including NOx, SO_2, CO_2, HC, and PM) per day. Thus, the Suez canal and the Panama canal could reduce 3.90 (=3120/1.852/18/24) days and 5.31 (=4251/1.852/18/24) days sailing time. Consequently, for one 7000 TEU containership, the Suez and Panama canal can reduce about 674.74 (=173.01 × 3.90) tons emissions and 918.68 (=173.01 × 5.31) tons emissions, respectively compared to traditional routes (via Cape of Good Hope and Cape Horn) (Fletcher, 1958; Huebner, 1915) (see Table 1).

The Kra Canal (also called the Carat Canal) in Thailand[2] has long been considered as an alternative sailing channel for the Asia-Europe route, and more recently as part of China's Belt and Road initiative and the Maritime Silk Route (Zeng et al., 2017). The canal could cut 1200 km or approximately 27 h of sailing time and increase ship utilization (Rahman et al., 2016) between the East Asia-Middle East area, bypassing Singapore and the congested Malacca Straits (Lau and Li, 2016). Taking Yang Ming container shipping company (Asia-Middle East) as an example,[3] the route is rotated as Shanghai-Ningbo-Xiamen-Shekou-Port Kelang-Jebel Ali-Hamad-Umm Qasr-Hamad-Jebel Ali-Singapore-Shanghai (Fig. 1).

If Port Kelang is bypassed (W-Bound) and Singapore port is bypassed (E-Bound) and replaced by the Kra Canal, the route will be rotated as Shanghai-Ningbo-Xiamen-Shekou-Kra Canal-Jebel Ali-Hamad-Umm Qasr-Hamad-Jebel Ali-Kra Canal-Shanghai. Since the sailing distance and time is reduced, the ship utilisation can be increased during the port rotation.

Not for nothing has the emissions reduction potential of the Kra Canal been commented on in studies focusing on elements such as its viability, suitability for specific countries, and for specific ship types (Sulong, 2012; Kontovas, 2014; Rahman et al., 2016; Heng and Yip, 2018; Tseng and Pilcher, 2021). Some studies have also compared the Kra Canal route to that of the Northern Sea Route (e.g. Zeng et al., 2017), highlighting the significant reductions in sailing distances and GHG emissions such routes can create (Lasserre, 2014; Meng et al., 2017; Aksenov et al., 2018). Some studies even describe the Kra Canal as being 'the oriental Panama canal' (Zeng et al., 2018).

However, although the Kra Canal has been discussed since the fifteenth century, through to Japanese interest in the 1980s and more recent interest from China (Sulong, 2012), it remains unconstructed. Moreover, in September 2020, it was said that the government is considering a rail link rather than a canal (Maritime Executive, 2020). There are many reasons suggested as to why the canal remains unbuilt, one being that the finance for the canal would be too great for the Thai government to fund (Sulong, 2012). What is more, although the emissions reduction potential of the canal is often highlighted in the literature, it has not to date been considered critically. This is key, given that one comparable project for a canal in Nicaragua that would have similarly slight sailing distance reduction benefits is currently paused, with one challenge being huge opposition to "its potential to inflict environmental and societal damage" (Chen et al., 2019, p.79). Arguably, the motivation for any initiative to build a Kra Canal needs to critically consider its emissions reduction potential, and to do so in the context of both political factors and the economic goals that may underpin funding any canal, and the potentially negative impact these may have environmentally. We consider such factors below drawing on both quantitative data in the form of calculations and projections and qualitative data in the form of perspectives of experts ($n = 20$) from countries who would undoubtedly use any canal were it constructed: from China ($n = 5$); Thailand ($n = 5$); Singapore ($n = 5$) and Taiwan ($n = 5$) gathered through semi-structured interviews.

The remainder of the paper is organised as follows. Section 2 presents the development background of Kra Canal in Thailand, considering past studies into the canal and the potential impacts the canal has been said to have in the short term (during its construction) and the medium to long term (after construction and during its use) with regard to emissions reductions in shipping. Section 3 outlines the methods we have used to gather our data. Section 4 then presents the quantitative and qualitative data and results and in Section 5 these are critically discussed in light of the potential of the canal to contribute to decarbonizing and emissions reductions in both shipping and ports. Finally, key issues and policy suggestions are provided in the conclusion in Section 6.

[1] 10 knots=10 nautical miles/hour=18.52 (=10 × 1.852) km/h. The fuel consumption and emission were consulted by experts in Yang Ming Maritime Corp. and the figures are acceptable.

[2] This canal connects the Gulf of Thailand with the Andaman Sea across southern Thailand (Yuan et al., 2020).

[3] After consulting experts in Yang Ming Marine Corp., a 7000 TEU container ship is suitably used in the Kra canal if this canal is finished in the future.

Fig. 1. Shipping routes in Asia-Middle East
https://www.yangming.com/.
Source: Yang Ming Marine Corp.

2. The Kra Canal in Thailand, its development and past studies

With regard to its historical progress, since being first presented in Siam (Thailand) in 1677 (Min, 2015; Rahman et al., 2016) as a potential passageway to connect the Indian Ocean, the Andaman Sea, and the Gulf of Siam in Thailand, the Kra Canal has been much debated, but never constructed. Political issues in Thailand reportedly prevented this in the 1980s, although it was supported by the Thai government in the 1990s as a means of boosting the economy after the Asian crisis of 1997 (Sulong, 2012). Yet, at this time, the cost of the canal was put at approximately US$20 – 28 billion by Japan's Global infrastructure fund (Thongsin, 2002; Billington, 2011; Rahman et al., 2016), and in the early 2000s internal political conflicts in Thailand again put paid to any plans to build the canal (Sulong, 2012). More recently, China and Thailand have planned to cooperate on this project (Sulong, 2012; Heng and Yip, 2018), although the Thai government has still not committed and is said to be now considering a rail link instead (Maritime Executive, 2020). China would benefit from the canal as it would form an integral part of any Maritime Silk Route and its One Belt One Road initiative, and at the same time provide military benefits by minimizing the threat of any US blockade of the Malacca Straits. However, Beijing requires Thailand to go ahead with the canal and cannot independently decide to build it (Er, 2018).

Such a high estimated cost for the Kra Canal underlines both its large-scale nature as an infrastructure project, the challenges that the Thai government would face in funding it, but also the significant negative impact its construction could have on pollutant emissions and on the environment. Indeed, multiple reasons are noted for the failure of the canal to be constructed, such as the lack of funds, technological capability, indecisive political leadership, and geo-political issues (Lau and Lee, 2016).

The scale of funding required becomes apparent once the scale of the canal's construction is considered. The proposal for the Canal is for it to be approximately 102 km long, 400 m wide, and 25 m in depth to allow for the passage of any type of cargo vessel, including ultra large crude carriers (300,000 deadweight tonnage) (Rahman et al., 2016; Heng and Yip, 2018). Understandably, creating such a canal represents a huge financial investment; Thailand does not have sufficient funds itself (Lam, 2018) and there is also a lack of well reputed international investors to support this canal. Although the World Bank, Asian Development Bank or Chinese companies might have interests to provide funding for the canal, these still have not been confirmed (Lau and Lee, 2016). The amount of money required to build the canal is often cited as being at least US$ 20 billion (Sulong, 2012; Lau and Li, 2016), possibly US$ 28 billion (Er, 2018) or even up to US$ 36 billion (Heng and Yip, 2016). Any costings should also be seen in the context that project budgets often overrun, and that in the comparative case of the Panama canal its original construction had a "limitless budget" (Waltham, 2018, p.218) and its recent expansion witnessed significant "cost overruns" (Chu and Ledermann, 2017, p.3). From a decarbonizing and emission reductions perspective such costings have a number of indirect implications. Firstly, it is possible that to gather the funding necessary any investors will need to significantly develop the economic income generating capacity of surrounding ports, enforce significant tolls on ships passing through the canals, or implement other income generating measures. Indirectly, the need for such measures may require activities that increase GHG emissions or are damaging in some way to the environment. This is not necessarily the case, but if, for example, significant infrastructure needs to be constructed, this may require significant encroachments on the natural landscape, and significant amounts of GHG emissions in its construction.

Technologically the construction of the canal is highly complex and could require much time. Indeed, American scientists have been said to suggest the use of nuclear explosives in order to ease the construction process and to save up to 40% of the costs (Lau and Lee, 2016). Such a suggestion may seem radical but becomes entirely understandable in consideration of the scale of the canal, being 55 nautical miles in length, 30 m in depth and almost 400 m in width, and taking 10 years to build (Zuhdi and Turan, 2021). Comparatively, although undoubtedly different in topology and length, the 44 nautical mile long Panama Canal (Waltham, 2020) took 10 years to build in its original format, and required the American military to build it after a failed attempt headed by Ferdinand de Lessops (Waltham, 2020). Admittedly, De Lesseps had previously built the Suez canal with great success and the topology there was very different, as was the length of the canal and its width and depth (Ismailia, cited in Nusantara, 2005), but this nevertheless

underlines the unique nature of the topography for each project. This uniqueness makes each project a sizable technical challenge, as arguably evidenced in the case of the Kra Canal by the suggestion to use nuclear explosives to speed up construction (Lau and Lee, 2016). From a decarbonizing and emissions perspective, this too may be highly negative. The amount of fuel required for the machinery to build the canal could well require the release of significant amounts of GHG emissions. Similarly, any nuclear explosives could impact on the environment negatively, despite their technological innovation and ability to reduce GHG emissions (cf. Lovelock, 2010).

Politically as well the canal presents many issues, and these have played a role in its failure to materialize. Political instability in Thailand (Sulong, 2012) and violence issues over the years (Bjarnegård et al., 2017) have made it difficult to attract foreign investors (Sulong, 2012). Specifically, the geographical location of the Kra Canal in Thailand is enmeshed with political implications; the Muslim population in the south of Thailand would be physically separated from the Buddhist north. This may potentially aggravate the violence that has occurred over many years from Muslim separatists (Croissant, 2007) by creating a physically separate geographical area. High political risks arguably make investors worry about the government's ability to provide a safe investment and operation environment. In addition, politically, the rerouting of shipping could prove disadvantageous to those areas that stand to lose out if shipping moves from its current routes. The ports of Klang in Malaysia, and Singapore could lose business and income if shipping reroutes through Thailand (Rahman et al., 2016). Malaysia and Singapore could therefore be opposed to the canal and its construction may have a destabilising effect on the political body of the Association of South East Asian Nations (ASEAN[4]) group. Indeed, some argue that it would destabilize the region by physically dividing maritime Southeast Asia from mainland Southeast Asia, ultimately resulting " in an economic, cultural and political divide of ASEAN itself" (Sulong, 2012, p. 109). From a decarbonizing and emissions perspective, any military or political tensions would arguably result in increased emissions of GHG through military activity, and increased damage to any surrounding environment.

Nevertheless, in economic terms, the canal offers much potential. For the Thai authorities, the Kra Canal offers the potential to provide benefits from the canal tolls, navigation charges, port facilities charges and the development in the surrounding area. It also is beneficial for the tanker market, creating significant cost-benefits compared to traditional routes, particularly in times when the tanker market is in an unfavourable position and fuel prices are high (Heng and Yip, 2018). In addition, the canal will lead to development of any hub ports along its route (Zeng et al., 2017, 2018), thereby creating economic benefits for countries such as Vietnam. Some studies also suggest that compared to routes such as the Arctic Sea routes, the Kra Canal offers greater benefits for container shipping as it presents more navigational certainty (Yuan et al., 2019). Nevertheless, there may be some economic and practical disadvantages with the canal for shipping companies, and also for some individual ASEAN countries. For example, although the Kra Canal can offer an alternative route in lieu of the congested Strait of Malacca and reduce sailing distances, large containerships may not obtain economic benefits since they must miss calling at some important ports in Southeast Asia (e.g. Port of Singapore, Port of Klang, etc.).

Indeed, many studies have focused on the economic impact of the canal on specific ASEAN countries. For example, in the case of Malaysia, in studies of the impact of the canal, suggestions have been made for refocusing the country's maritime business should ships be diverted away from Malaysia (Rahman et al., 2016). If seen from a decarbonizing and emissions reduction lens such activity can appear positive or negative. For example, an economic loss to Singapore and the port of Klang may be negative from an economic perspective, but from an emissions perspective, if this loss of economic potential is due to the increase in economic potential of the Kra Canal, then it is a positive impact from a decarbonizing perspective. This is because ships would be sailing much reduced distances and thereby be producing far less GHG emissions. Concomitantly, whilst the positive economic impacts of the canal for Thailand may be said to align well with positive decarbonizing and emissions reduction impacts, if they are doing so on the basis of an economic gain, then traditionally such gain is being sustained in an economic system that is based upon a principle of growing by 5% per annum (cf. Graeber, 2012). Thus, the economic system to set up a future of decarbonizing and emissions reductions and sustainability may be invalid in that its successful operation is at loggerheads with the environmental goals it seeks to achieve (cf. Meek, 2021).

In terms of the canal's decarbonizing and emissions reduction impacts, in the short term, and by short term we mean from the start to completion of the canal, the ecological impacts of this canal will bring negative environmental externalities. For example, construction explosions might bring ground shock, air blast, dust cloud, air pollution, and so on. Moreover, the use of machinery and materials will inevitably bring increased GHG emissions through the production of these materials themselves, through the extraction of any natural resources required to build them, through the use of machinery to transport and construct them, and through the damage to the environment that construction of the canal may cause. Arguably, it is of fundamental importance to investigate what these impacts may be in any consideration of the decarbonizing and greening potential of the Kra Canal. Yet doing so is highly complex, and below we outline how, mathematically and philosophically, what considerations this may involve.

In the medium to long term, and by this we mean from the inception of the canal after its construction to the future, the canal is generally considered to potentially have significant positive decarbonizing and greening benefits. It will reduce sailing distances by approximately two to three days through ships bypassing the Strait of Malacca (Lam, 2018). This sailing benefit is noted in previous literature (our own included), and thereby either concluded or assumed, to significantly reduce pollutant emissions, and at the same time avoid the threat of pirates, congestion and potential accidents in the Strait of Malacca[5] (e.g. Rahman et al., 2016; Heng and Yip, 2018), all of which could have negative environmental impacts. Again however, it is of fundamental importance to critically consider exactly what these gains may be, and to discuss these in light of complexities such as increases in shipping worldwide, the responses of

[4] The Association of South East Asian Nations includes Brunei Darussalam, Myanmar/Burma, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam.

[5] It is estimated that about 70,000–80,000 vessels have passed Strait of Malacca annually (Rhoden, 2015; Heng and Yip, 2018).

competitors, and the difficulties of measuring any impacts. As with attempting to measure any short term impacts, measuring any medium to long term impacts is also highly complex, and we describe the attempts we have made, and also what considerations there are, in attempting to do so.

3. Methodology

The quantitative calculations we undertook focused on generating data related to the medium and long term impacts of decarbonising and emissions production from the introduction and use of the Kra Canal. This involved defining what pollutant emissions are, and defining what activities would be involved. Concomitantly, we also needed to consider what pollutant emissions and impacts on the environment could be involved with aspects such as port operations.[6]"

We note that in terms of the short and medium to long-term calculations for emissions there are a number of aspects it is necessary to consider which we do not do here, but highlight them and later discuss these in more detail below. In the short term, related to construction, it is necessary to consider how much pollutant emissions and what the environmental impact would be both from particular machinery given the emissions from the construction industry (cf. Qian et al., 2017). In the medium to long term, and in light of the qualitative data below, it is necessary to consider the emissions from the production and refining of oil (cf. Jing et al., 2020), were any hub ports along the canal to develop such facilities. As we note, we do not calculate these aspects here, but we highlight them as we consider them necessary considerations in relation to emissions, and discuss them in more detail below the presentation of the quantitative and qualitative data.

The qualitative data that we draw upon to complement the quantitative calculations we took from primary data gathered from 20 experts we interviewed using semi-structured interviews. We adopted a snowballing process (e.g. senior expert's recommendation) to select potential qualified Taiwanese interviewees working in Thailand, China, Singapore, and Taiwan. These interviewees were considered as suitable experts based on the fact that they needed to have a minimum of 10 years experience working in port, shipping and canal related fields and also have a strong grounding in knowledge of Kra Canal issues. These interviews were focused on the Kra Canal's construction overall to gather a wide range of data that we could discuss and to allow for dialogue. There were 20 interviewees, with five from Thailand, China, Singapore and Taiwan. We interviewed almost equal numbers of government officials (9) and shipping operators (11) and an appropriate range of interviewees in different positions and roles (Division director (8); Manager (4); Engineer (3); Captain (3); Port Official (1); Shipping Operator (1)) to reduce sampling bias (Winship and Mare, 1992).

Their experience averaged 18 years for China (from 16 to 25); 20 years for Singapore (from 16 to 25); 17 years for Thailand (form 10 to 21); and 20 years for Taiwan (from 16 to 23). They worked as shipping operators or government officials, and engineers, managers, captains, and port officials. Sampling was done based on the interviewee's length of experience. Half of the interviewees were consciously selected from countries in ASEAN (Thailand and Singapore) and half from areas who would potentially use any Kra Canal (China and Taiwan). In order to allow ease of communication and prevent any communication barriers and potential bias in distortion of meaning, all interviews were undertaken in Chinese. This was the native language of the participants, and their language of choice for the interviews (Cortazzi et al., 2011). Due to the COVID-19 situation, the interview method was online using Skype software and took place during 1st–31st March 2021. Interview transcription by the authors started the process of analysis (Bird, 2005) and increased validity through ensuring anonymity as possible. All interviews were in line with the relevant institutional ethics guidelines and are presented here entirely anonymously (Christians, 2011).

4. Results

Our results are organised to first present the quantitative mathematical calculations and to follow these with the qualitative interview data. Following this we discuss these results as a whole in a separate section before drawing together the main points and making conclusions in relation to the decarbonizing and greening potential of the Kra Canal.

4.1. Quantitative results

In order to estimate emission reduction effect when Kra Canal exists for Europe-Asia shipping routes or East Asia-South Asia shipping routes, one 7000 TEU containership with 10 knots, one handymax containership (approximately 2000–2500 TEU), and one handy type containership (approximately 1000–2000 TEU) are taken as comparisons. From the heavy oil consumption perspective, it is assumed that fuel consumption of one 7000 TEU container ship is higher than 1.36 times and 1.40 times for one handymax type container ship and one handy type container ship, respectively (Tai and Lin, 2016). We assume with pollutant emissions there exists a direct ratio with fuel consumption. It is estimated that the Kra Canal could reduce the sailing distance by 722.2 nautical miles (about 1337.5 km) for ships when bypassing the Strait of Malacca (Yuan et al., 2020). Assuming the sailing speed of containership is 10 knots, the container ship from the east side of Kra Canal to the west side of Kra Canal could reduce the ship's sailing time by 72.2 (=722.2/10) hours which is approximate to 3.0 days (=72.2/24). It is estimated that one 7000 TEU containership, one handymax type container

[6] GHG emissions is defined by the IMO GHG emissions study 2014 (IMO, 2015) as: "For the year 2012, total shipping emissions were approximately 938 million tonnes CO_2 and 961 million tonnes CO_2e for GHGs combining CO_2, CH_4 and N_2O. international shipping emissions for 2012 are estimated to be 796 million tonnes CO_2 and 816 million tonnes CO_2e for GHGs combining CO_2, CH_4 and N_2O. international shipping accounts for approximately 2.2% and 2.1% of global CO_2 and GHG emissions on a CO_2 equivalent (CO_2e) basis, respectively.

ship, one handy type container ship with 10 knots speed would emit about 173.0, 127.3, and 123.6 tons emissions (including NOx, SO_2, CO_2, HC, and PM) per day, respectively.[7]

Regarding the container ship's emission in the Kra Canal, we follow the estimation method for the Panama canal (Tai and Lin, 2016). One container ship passing through the Panama canal will experience through manoeuvring (1.67 days), canal-time (0.59 days), and port-time (7.39 days) periods.[8] The emissions of the three type ships in the canal are shown in Table 2.

The length of the Kra Canal is 102 km (Rahman et al., 2016) which is 1.275 times than Panama canal (=102/80).[9] It is assumed that a direct ratio exists between the volume of emissions and the length of the canal. Thus, the container ship's emission in the Kra Canal can be obtained in Table 3 when multiplying 1.275 times for figures of Table 2. Results show ship's emissions in manoeuvring is major pollution source, followed by canal-time, and port time. For one 7000 TEU container ship, the total emissions of the Kra Canal is 556.8 tons.

It is clear that the true emission reduction effect of Kra Canal could be obtained when ship's reduced emissions on the sea (173.0 tons) deducts ship's emission when passing the canal (556.8 tons). Therefore, taking one 7000 TEU container ship as a case, the result shows that the Kra Canal cannot bring emission benefit (−383.8 tons emissions=173.0–556.8) from the pollution emission perspective. The main reasons are the reduced sailing distance of the Kra Canal is limited (1337.5 km) compared to the Panama canal (4251 km) and ships will emit additional significant emissions during the canal sailing period. Also, slow steaming has made ships emit less emission during the sailing period compared to traditional sailing speed. Thus, short distance reduction for Kra Canal cannot bring significant decarbonizing effect.

4.2. Qualitative results

Much of the qualitative data also suggests that the Kra Canal will have an adverse impact on decarbonizing and greening. For example, many of its benefits were considered to related to transportation of oil. When asked about the benefits of the Kra Canal, many participants spoke of how the canal would help China ensure its supplies of Oil were safe. In the words of one government official and division director based in China: *"Oil suppliers (e.g.….Arab countries) might sell more oil to China and get the benefit from oil exports."* Similarly, a government official and division director from Singapore said *"China… can reduce the operation risk of oil imports."* Notably, one government official and division director in Taiwan also commented that the canal would be successful if its surrounding hub ports could be developed into oil refining centres, similarly to the facilities offered by Singapore: *"Singapore is a famous oil refining centre in the world. If the ports near the Kra Canal also can develop oil refining… and become key oil filling centers for shipping operators, I think it can indirectly enhance the competitiveness of the Kra Canal."* In addition, benefits were felt to be economic or military, as succinctly put by this shipping company captain based in Taiwan: *"This canal offers military strategic value and brings economic value."* In other words, such noted benefits are ones that, rather than promote decarbonizing and greening, would do the exact opposite.

Further, rather than have the decarbonizing advantage of reducing emissions through ships switching from the Malacca Straits to the Kra Canal, the Kra Canal was often felt to be advantageous as providing *additional* shipping space once the Malacca Straits were full. One shipping company manager based in China commented that it was irrelevant how much the distance reduced was and that the key thing was that the canal could provide passage for shipping once the Malacca Straits were overly congested. They commented that, even if *"the volume of Straits of Malacca achieves saturation, the value of the Kra Canal will exist even if the user quality of the Kra Canal is worse compared to the Straits of Malacca since the Kra Canal could reduce the operation risk of shipping for shipping operators."* In line with the quantitative results (see above), respondents commented that the canal was also only effective in reducing distances by a short amount and would not really be worth building as a result. In the words of a government official and division director based in China, the: *"value of shortening sailing distance is limited. I think the economic effect of the Kra Canal cannot be very significant."* Here then, it appears that, rather than reduce GHG emissions, it is possible the canal may counterintuitively increase them; not only is its reduction of distances only slight, but it would allow for additional shipping space once the Malacca Straits become overly congested. Here, rather than work to decarbonize, the canal would have the directly inverse impact.

With regard to the construction cost of the canal, participants' oft-quoted construction figure was that of US$ 30 billion, a figure which would arguably involve much emissions producing activity to create. One shipping company captain in China commented, *"the money is huge."* This huge cost had two implications: one, Thailand would have to charge compensatory tolls, navigation fees, maintenance fees and so on to recoup the cost; and two, it meant that Thailand alone could not fund it, rather, the canal would need to be funded by more than one player. In the words of this Thai-based shipping company port engineer: *"Thailand must ask for fund from other countries and their debit conditions* (e.g. *interest, load time)."* Thus, on the one hand the canal would involve the requirement for significant economic activity to create the money to fund it and keep the canal working. On the other though, it may well require Thailand to seek help from other countries to fund it successfully. Thus, whilst the initial idea of the canal's financing may be negative from a decarbonizing perspective as it creates significant economic activity, from another perspective it suggests the need for countries to work together, and as we will argue below, this has the potential to offer positive decarbonizing driven goals.

In the context of the need to work together, when asked what the political implications and challenges of building the canal were, participants spoke of the possible divisive effects of the canal on ASEAN but also of its opportunity to allow countries to work together. Any divisive effects related to the potentially negative economic impact the Kra Canal may have on other ports in the Malacca Straits

[7] The figures were consulted by experts in Yang Ming Maritime Corp. and acceptable.
[8] The lock-time is not considered in the Kra canal.
[9] The length of Panama canal is 80 km. Panama Canal Authority. https://www.pancanal.com/eng/general/canal-faqs/physical.html

Table 2
Pollutant emission in the Panama canal (unit: tons).

Ship type	Period	NOx	SO_2	CO_2	HC	PM	Pollutant emissions
7000 TEU container ship	Manoeuvring	6.6	5.5	325.8	7.0	15.7	360.6
	Canal-time	0.9	0.8	45.6	0.1	0.1	47.5
	Port-time	0.7	0.8	35.1	0.0	0.0	36.6
	Sub-total	8.2	7.1	406.5	7.1	15.8	444.7
2000–2500 TEU container ship	Manoeuvring	4.9	4.0	239.6	5.1	11.5	265.1
	Canal-time	0.7	0.6	33.5	0.1	0.1	35.0
	Port-time	1.9	0.6	25.8	0.0	0.0	28.3
	Sub-total	7.5	5.2	298.9	5.2	11.6	328.4
1000–2000 TEU container ship	Manoeuvring	4.7	3.9	232.7	5.0	11.2	257.5
	Canal-time	0.6	0.6	32.6	0.1	0.1	34.0
	Port-time	0.5	0.6	25.1	0.0	0.0	26.2
	Sub-total	5.8	5.1	290.4	5.1	11.3	317.7

Source: Based on similar methods to those used by Tai and Lin (2016).

Table 3
Pollutant emission in the Kra canal (unit: tons).

Ship type	Period	NOx	SO_2	CO_2	HC	PM	Pollutant emissions
7000 TEU container ship	Manoeuvring	8.4	7.0	415.4	8.9	20.0	459.7
	Canal-time	1.1	1.0	58.1	0.1	0.1	60.4
	Port-time	0.9	1.0	44.8	0.0	0.0	46.7
	Sub-total	10.4	9.0	518.3	9.0	20.1	556.8
2000–2500 TEU container ship	Manoeuvring	6.2	5.1	305.5	6.5	14.7	338.0
	Canal-time	0.9	0.8	42.7	0.1	0.1	44.6
	Port-time	2.4	0.8	32.9	0.0	0.0	36.1
	Sub-total	9.5	6.7	381.1	15.6	14.8	418.7
1000–2000 TEU container ship	Manoeuvring	6.0	5.0	296.7	6.4	14.3	328.4
	Canal-time	0.8	0.8	41.6	0.1	0.1	43.4
	Port-time	0.6	0.8	32.0	0.0	0.0	33.4
	Sub-total	7.4	6.6	370.3	6.5	14.4	405.2

Source: estimated by authors.

route. For example, one shipping company port engineer in China commented that, *"Generally, people will say the Kra Canal will bring a threat for Singapore port. Maybe Singapore will be directly affected by the Kra Canal."* Another government official and division director in Singapore also noted that the canal may affect both Singapore and the port of Klang in Malaysia, but added that this may not be an issue as, *"these two ports have huge shipping volume; the impact of the Kra Canal might be limited."* Conversely, the opportunity the canal presented for countries to work together was noted by a number of others, for example by this Thai-based shipping company senior engineer: *"Thailand might cooperate with these neighbour countries. However, Thailand also worry they will lose the leading position in this canal."* Indeed, that the canal may never reach fruition if countries did not work together and agree on its progress was noted by one government official and division director in Taiwan, who commented that, *"under the entanglement between different countries, I think it cannot offer an effective long-term project at this moment."* As a shipping company captain in China noted, the success of the canal required, *"support from the Thailand, attitude from other neighbour countries."* Globally, participants felt the canal could have an impact on South East Asia and also on shifting power from the USA to China. The same shipping company captain in China felt smaller countries such as Myanmar and Cambodia may lose their independence, as *"these countries' finances are weak. They are easily intervened in by China."* This respondent further commented that on a wider global stage it could impact on the reallocation of military resources, saying, *"if this canal exists, for India and the USA, the military strategies will be reallocated in the Asia-Pacific area."* One government official and division director in Taiwan noted that the key thing was to approach the construction and planning from a sustainability perspective: *"It is necessary to think about many factors to promote the Kra Canal… it must review this thing from the perspective of sustainable development."* Here then, there may be a need for countries to come together to work on the canal, and if this is done from a sustainable perspective, the canal could offer the opportunity for an international green focused partnership that attempted to avoid any environmental impact and at the same time help decarbonise and green the shipping industry.

With regard to the environmental impact, and thus the decarbonizing and greening potential of the canal, respondents commented on short-term construction related impacts and medium and longer term impacts as well. Almost all short-term related comments spoke of the negative environmental impact, from a range of different angles. For example, one government official and division director in China commented on a number of potentially negative environmental impacts such as, *"air pollution, water pollution, waste treatment, roosting ecology, negative impacts on animals and plants, living quality as well."* Another port official in Singapore also spoke of a range of negative impacts: *"The explosives will be used when constructing the canal. The materials will bring damage for the environment. The excavators and trucks also bring noise, air pollution, waste during round transportation. The negative impacts are significant for the environment."* This respondent was one of a few (e.g. also a shipping company senior manager based in Taiwan) who commented that what was required was the need for a survey and *"environment impact evaluation"* before commencing construction. Despite these negative

fears, other respondents felt that the construction would be sensitive and environmentally sound as it would follow existing regulations. For example, one shipping company senior manager from Thailand commented that a number of regulations would mean that the environment was protected, for example, *"MARPOL (International Convention for the Prevention of Pollution from Ships), IMDG (International Maritime Dangerous Goods Code) Code."*

In the medium to long term, some commented on negative impacts as well that any authorities would need to monitor. For example, this government official and division director in Taiwan noted that *"besides general ship pollutions (*e.g. *water, fuel, garbage, waste), potential ship accidents should be a concern… since they might bring terrible ecological damage when oil spillage occurs."* However, in the medium to long term most commented on the positive impacts of reducing sailing distances and reducing fuel consumption. For example, one government official and division direcrtor in Taiwan noted that the *"Kra Canal could offer short sailing distance and indirectly reduce fuel consumption"* Similarly, this government official and division director in Singapore commented that, *"the purpose of constructing Kra Canal is to shorten the sailing distance."* Another government official and division director in Singapore commented similarly that *"it is estimated to reduce 2–5 days sailing distance."* However, this respondent (and others we add) did note that the reduction in sailing distance when compared to the Panama Canal was significantly less, and that the *"Panama canal can reduce by 10 times the sailing distance (if ships pass the South of America). If we compare this ratio, the Kra Canal has less economic benefit."* Much was felt to do with the need to emphasise the value of the canal and to focus on the synergistic impact of a good result leading to further positive results. As one government official and division director in Taiwan commented: *"If the values can be emphasized, I believe more and more people will pay attention to this canal."* Also, in the words of another government official and division director based in China: *"If the effect is good, then it will continuously attract more shipping operators to use it."*

5. Discussion

Much of the literature related to the Kra Canal discusses it in terms of its economic potential and viability (Sulong, 2012; Kontovas, 2014; Rahman et al., 2016; Heng and Yip, 2018; Tseng and Pilcher, 2021). For example, Tseng and Pilcher (2021) adopted a PESTELE/SWOT analysis to evaluate the Kra Canal and estimate overall potential cost benefits of the canal using crude oil transport as an example case. Whilst such studies often have a focus on aspects other than the environment, for example politics (e.g. Sulong, 2012) or the impact on a particular country (e.g. Rahman et al's, 2016 focus on Malaysia), many studies comment on the canal's potentially adverse environmental impact through its construction. Based on the best knowledge of the authors, there is no study to date that has estimated the potential emission impacts when comparing the traditional route (via Strait of Malacca) and the new route (via Kra Canal). Here we complement the existing literature by using East Asia-South Asia shipping route as a case to do precisely this. This is important, as it is either assumed, or concluded in the literature that in the medium to long term, the fact that the canal will shorten sailing distances by cutting out the need for ships to sail through the Malacca Straits (e.g. Rahman et al., 2016; Sulong, 2012; Heng and Yip, 2018). Indeed, it is observed by some that the Kra Canal is described as the oriental Panama Canal (Zeng et al., 2017) and, we note that we ourselves (the authors of this paper) have argued that the canal has benefits for the environment in the medium to long term (Tseng and Pilcher, 2021). Nevertheless, as the above shows, upon closer examination, these assumptions or conclusions transpire to be false. The quantitative data shows that the canal will only reduce distances by a relatively short amount if shipping reroutes from the traditional routes around the Malacca Straits. This relatively short distance, coupled with the emissions produced by ships whilst travelling through the canal means that the Kra Canal cannot bring reduced emissions benefits. What is more, the qualitative data indicates more worrying impacts from a decarbonizing and greening perspective. Firstly, the qualitative data confirms the quantitative data in showing the limited impact of the canal due to its ability to reduce distances by only a small amount. In addition, however, the qualitative data suggests that rather than allow for shipping to switch from the Malacca Straits route, in actual fact the canal may provide overspill capacity space for shipping once the Malacca Straits become too congested. This would only increase pollutant emissions. What is more, the qualitative data suggests that in order to succeed, the canal may need to develop hub ports with oil refining capabilities, which in itself would involve the creation of activities with significant carbon production (Jing et al., 2020). Further, the immense cost of the canal would require funding on a very large scale, and this in turn could only come from activity which in itself may be creating more carbon through a need to be continually growing to pay off any debt (Graeber, 2012) and at loggerheads with an environmentally focused agenda (Meek, 2021). The fact that the qualitative data suggests canal could create tension in the region itself and on a global scale that may potentially lead to military activity with an inevitable carbonizing impact compounds the matter further. Similarly, there are a number of indirect carbonizing activities that we have not investigated here that we argue require further work. On the one hand there is the need to estimate what the GHG emissions would be from any potential oil refining activity (cf. Jing et al., 2020), and on the other hand there is a need to estimate the pollutant emissions from the construction of the canal (cf. Qian et al., 2017). This is beyond the scope of our paper here but not only is it critically important to include in any consideration of pollutant emissions, but it would undoubtedly add to the total of emissions produced by the canal. This total can only indicate that at the moment, from a decarbonizing and greening perspective, contrary to the assumptions and conclusions in much of the literature, the Kra Canal would be an unmitigated disaster. The fact that these assumptions exist would, moreover, allow for those championing the canal to do so (either consciously or not) from a standpoint that would be 'greenwashing' (de Freitas Netto et al., 2020) its potential as being environmentally beneficial when the precise opposite is the case.

A key question resulting from this data and discussion is: Should the canal then be written off in terms of its decarbonizing and greening potential? The answer is arguably 'yes' if the following is carried out under current technology and conditions. However, if technology does develop, and if cleaner production methods evolve for construction and running of ships, then the picture changes quite dramatically. Whilst on the one hand this may suggest the Kra canal would have no impact and is not needed from a decarbonising perspective, it would still have advantages in reducing traffic in the Malacca Straits, and it may have political benefits for

some of the countries involved in building it, and for China also. Indeed, if the canal is approached as an opportunity for countries to work together, as suggested by one respondent in the qualitative data, then it does have decarbonizing potential. The reduction of emissions, and tackling climate change itself, is something that requires joint and global coordination. If the canal is approached in this way, and done so under cleaner technologies, then it does indeed have the potential to decarbonize and green the shipping industry. It is essential though, we argue, that this be undertaken only after a thorough and careful forecast that shows that the conditions for decarbonizing and reducing GHG emissions are present. In addition, trees, flowers and other plants might bring decarbonising effects if these are planted around the Kra Canal, although this issue was not mentioned by interviewees. It is suggested that canal authority in Thailand could think of carbon off-setting plant cultivation projects in order to align with the green shipping trends from the perspective of greenhouse effect reduction. Finally, the conflict of South China sea might indirectly affect the shipping operators' routes planning near the Kra Canal due to any sovereignty infringements and economic jurisdiction issues between countries in the region and increased potential military activity from the US (Financial Times, 2021). Also, the development of the Kra Canal directly relates to increasing securing for China's energy security policy (e.g. oil and gas transportation) (Weimar, 2013) and its Maritime Silk Road (Zeng et al., 2017). It is therefore possible China may seek to drive development of the canal regardless of its impact on emissions, although this would still require cooperation from the Thai government.

6. Conclusions

Despite its being considered for centuries as a way to reduce sailing distances, a canal across the Kra Isthmus in Thailand has not to date materialized. Further, although studies focusing on its feasibility from an economic and practical perspective have been undertaken, and these studies invariably assume or conclude it has positive environmental impacts, a critical consideration of its decarbonizing and emissions reducing potential has not been undertaken. We have undertaken a first attempt at doing this here through the use of quantitative estimations and qualitative interview data. These data show that, in contrast to any assumptions or conclusions (including our own) that the canal will have positive decarbonizing and emissions reducing impacts in the medium to long term, this is far from being the case. Not only will the canal not reduce emissions, but its construction, and the construction of hub ports and their activities (potentially including oil refining) will adversely impact upon pollutant emissions as well. Nevertheless, we argue that when technology evolves to become far greener, and countries work together with a focus on decarbonization, then the canal does indeed offer significant potential for decarbonizing and greening the shipping industry. We suggest that before any canal is started, if the focus is going to be on its decarbonization and emissions reducing potential, then a thorough and careful forecast of this needs to be made. We also suggest that future research focus on the pollutant emissions that may be produced by the construction of the canal and also by the activities (and construction) of any hub ports that may be developed to support the canal.

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