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Moving international shipping containers at seaports: A case study for Melbourne

by
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Abstract

Moving international shipping containers "the last mile" into seaports in prime real urban estate has been a challenge. A review of key trends finds that the exponential growth of seaport infrastructure is unsustainable. The ability to achieve accurate scheduling of rail and road resources is frustrated by multipurpose infrastructure needed to accommodate both people and freight frequency of movements which also requires land for storage capacity close to the port. A response to these challenges is addressed by the innovative approach of Container Freight Technologies (CFT) with ambitious plans to shake up the international logistics industry. The core innovation of CFT proposes a revolutionary new system for transporting shipping containers. A first attempt is made to evaluate CFT designs and processes. Different scenarios of truck replacement are examined for optimal outcome. The proposed CFT innovation suggests economic feasibility when it replaces 20% or more container freight trucks, warranting further work.

Introduction

This submission presents a work-in-progress study of applying Container Freight Technologies (CFT)[2] to Australia's largest container port, the Port of Melbourne.

Capacity at many Ports around the world has grown well beyond the design specifications that were relevant when the ports were first established. This manifests as congestion and reduced throughput, as well as increased land consumption. In many cases, this expansion is creating conflict with surrounding communities, and growth has become unsustainable. Land consumption is due to two factors – space required to store shipping-containers, full or empty, between transport stages, and also the need to provide maneuvering room to accommodate intermodal transfer activity.

[1] The University of Melbourne Cost-Benefit Analysis (CBA) study results partly reported in this paper are by Masters Students: Kai Hong Cavell Khoo (813506), Theng Yuan Lim (789920), and Jason Lee (780322) under the supervision of Assoc. Prof. Russell Thompson, Civil Engineering.
[2] CFT is protected by a world patent (Allen & Norman, 2021).

As a result, moving international shipping containers “the last mile” into seaports in prime real urban estate presents a challenge. The ability to achieve accurate scheduling of rail and road resources is frustrated by multipurpose infrastructure needed to accommodate both people and freight frequency of movements. The consequential unavoidable new infrastructure adversely impacts both funding and land use. A response to these challenges can be addressed by the innovative approach of Container Freight Technologies (CFT). CFT is an Australian technology start-up with ambitious plans to shake up the international logistics industry. It has designed a process to meet the following five aims to achieve frequent landside freight movement while being sustainable in the future.

The five design objectives of CFT aim for: (1) a single purpose landside infrastructure; (2) improved connection to current long-distance modes of transport (rail and road); (3) a scheduling mechanism to minimize contiguous sea and landside storage while achieving minimum ship turnaround time; (4) an end for the need for fossil fuels in the operations of the landside infrastructure; and (5) to achieve sea – land freight exchange which does not intrude upon residential society.

This submission presents a first attempt for evaluating CFT designs and processes. The evaluation results reported are based on a case study performed in the School of Engineering Graduate Program of the University of Melbourne. Different scenarios of percentage truck replacement by the proposed automated system are examined for optimal outcome. The proposed CFT innovation is shown to be economically feasible when it replaces 20% or more container freight trucks. The **base case** of the analysis refers to the current two-way heavy road trucks transport of containers from the Port of Melbourne to the Truganina container hub fifteen kilometers away. As discussed below, the **project case** replaces percentages of currently used road trucks by the CFT twin tunnels innovation.

Engineering and description of CFT

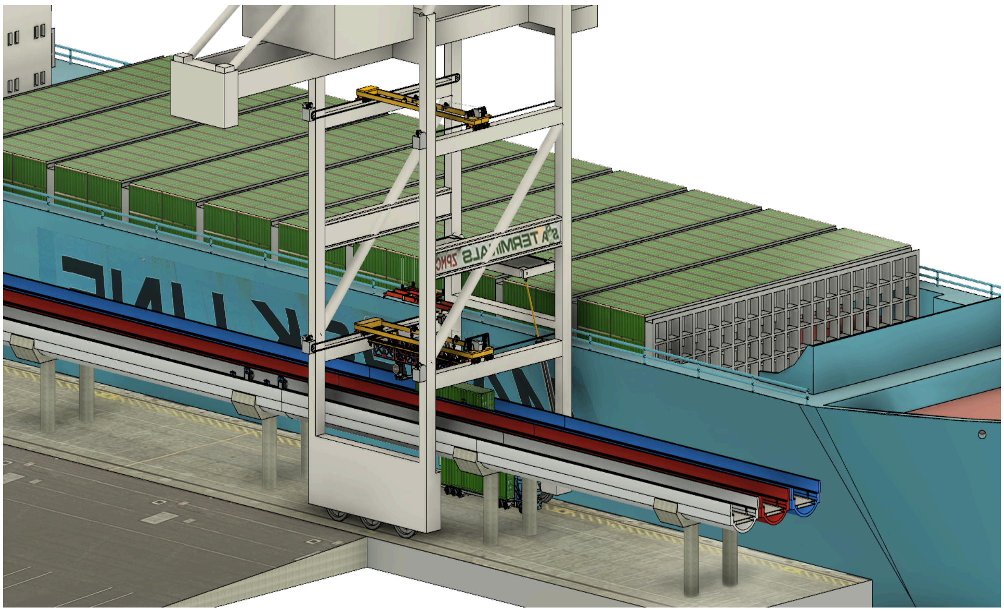
The best long-term solution to any issue is obtained by matching ongoing and long-term requirements with a solution that is flexible, and able to scale efficiently and cost-effectively into the future as the landscape changes. The core of the single purpose infrastructure proposed to meet these criteria is demonstrated in Figure 1. The CFT innovation proposes a revolutionary new system for transporting shipping containers whereby sets of electrically powered-wheels are attached to containers so they temporarily become semi-autonomous 'Container Vehicles'. Central control of these vehicles leads to unprecedented levels of efficiency. They run on rails within pipes, which also house the power lines. The electric detachable drive unit holds the container (either 20 feet or 40 feet) and the container vehicle is encompassed in a pipe/tunnel of about six metre outer diameter.

CFT Infrastructure will allow for volume growth at the port without increasing land consumption. Container storage will be neither at the port nor its precincts. Trucks will not create congestion nor road deterioration around the port or its nearby suburbs, and Rail sidings and shunting-yard infrastructure are not required at the Port. This will allow the logistics hub to transfer containers to and from the port efficiently, cleanly, and unobtrusively.

In addition, the CFT system eliminates the costly multiple handling of containers at both the ship load-unload and railhead or truck depot sites by its design and smart crane operations. By combining the ship load-unload process directly with the land-transport mechanism, the CFT system slows real-estate consumption at ports while minimizing pollution and traffic congestion. CFT ensures established world-class seaports can remain competitive. Figures 2 and 3 illustrate how specifically designed or modified cranes can feed the existing gantry cranes to load and unload vessels. These smart cranes can simplify the movement of containers by eliminating double handling between the ship to land and land to rail/road interfaces.

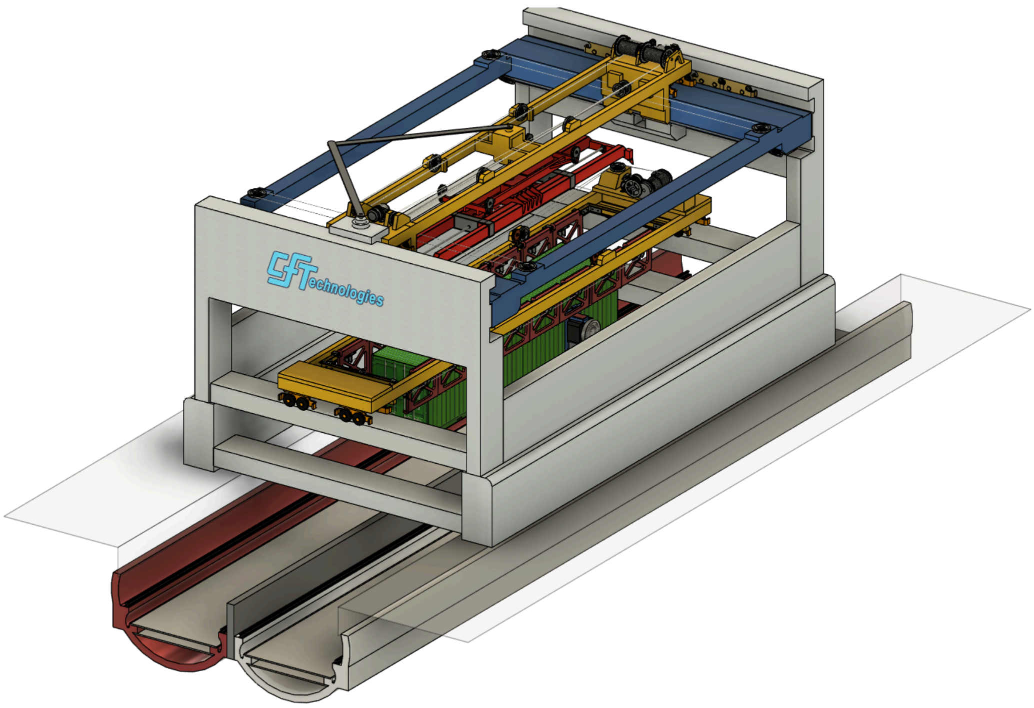
Figure 1: CFT semi-autonomous components

Figure 2: A modified ship Gantry Crane connecting to the CFT system



Container Vehicles can travel through pipes just over five metres in internal diameter, and can be routed above ground, at ground level, or underground in tunnels less than six metres in external diameter. In a normal configuration, twin pipes would be required to accommodate transit in both directions between port and logistics hub. Pipes allow for travel in either direction, and can switch directions to handle unusual traffic conditions. In addition, this bidirectional ability provides a degree of redundancy should an incident occur in one of the pipes. At both the port and the hub ends there is an additional section of pipe-channel used to store the Detachable Drive Units - DDUs (without containers attached), and feed them to the transit pipes as required. DDUs are capable of moving independently without necessarily being attached to a container. Pipes are fitted with power-supply rails, and also communication lines to keep the vehicles in constant communication with a central command station. Ample allowance is made for drainage in the bottom of the pipes, which also includes room for self-driven cleaning robots, if these are deemed necessary.

Figure 3: Transfer Unit that robotically moves containers and DDUs between transit channels and other transportation devices



The core advantage of the CFT system is its ability to transport containers in near-continuous flow between a port and a logistics hub. Bottlenecks and double handling are reduced to a minimum. The hub can be situated many kilometres away from congestion and valuable real estate. Twin tunnels and pipes can deliver containers in both directions, securely and on time.

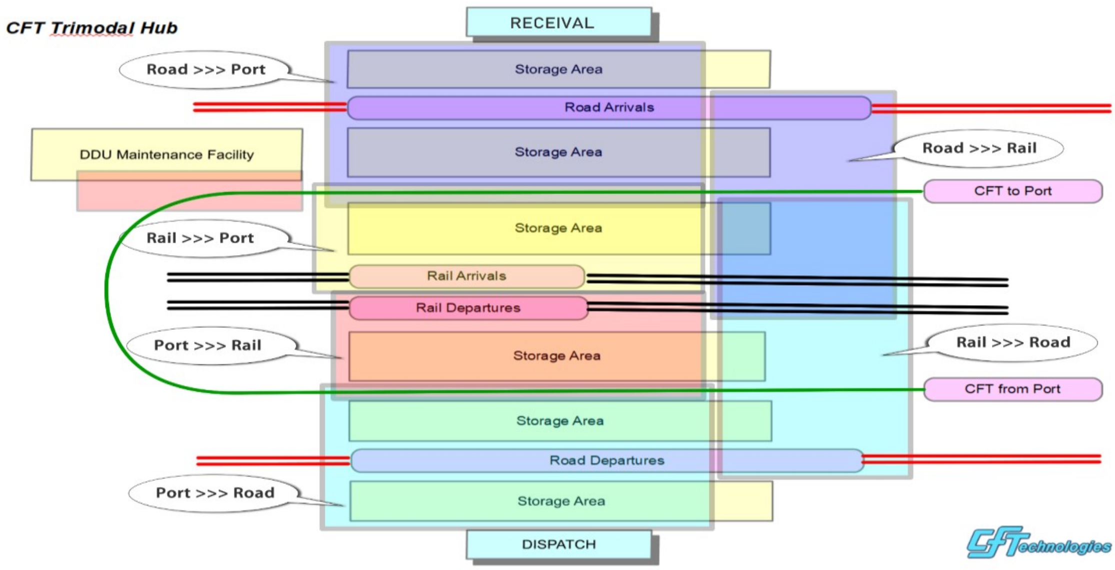
Trucks will not have to travel on congested roads in and out of the port, increasing their efficiency, while reducing pollution, road maintenance, and time-delays for motorists. Rail freight train paths will not have to cross domestic rail-lines; a potential cause of schedule failures. The predicted increase in shipping volumes will no longer require consequential land expansion in the port or nearby suburbs for stacking containers, and turning trucks, cranes, and forklift vehicles. These activities can now be assigned to the Logistics Hub, possibly many kilometres away.

A possible CFT facility can defer or even avoid having to build a new port. An example of where this might apply is the planned port of Hastings in Victoria. A standard installation of the CFT system will have a capacity of millions of container movements per annum. The capacity of the standard CFT system can be sufficient to cater for fifteen years of growth in the case of the Port of Melbourne. Another application example can be the planned relocation of the Port of Fremantle to Kwinana in WA. Finally, road use will decrease over time, thus proportionately reducing road maintenance, congestion, incidents, and a need for new road infrastructure, while positively reducing environmental impacts. Potential savings on expenditure for new road construction projects can result in a significant reduction in capital costs.

Modelling and scheduling (Port and precinct inventory capacity) via a Logistics Hub

Figure 4 presents a schematic representation of the expected streamlining of the current Port-Hub-Port system of scheduling by replacing it with a CFT system. The Logistics Hub is sited on the current rail freight infrastructure, road freight infrastructure and resources to service customers (importers and exporters) of the port. The current requirement to store containers at the ports some days before the ship arrives is achieved. A “just in time” scheduling process such as the capacity planning element of MRPII (Materials Requirement Planning software) will enable port inventories currently held at the port and its precinct now be held at the Hub with a say 6-hour inventory rather than the current minimum of 56 - 72 hour inventory; subject to negotiations with shipping companies. The scheduling success can be demonstrated through trials, as the shipping operators will require proof and confidence to reduce port inventory. When

Figure 4: Tri-Model Hub 20 to 50 kilometres from the port



looking at manufacturing industry over the last 40 years this scheduling process has been remarkably successful. The objective to remove the inventory at the port is imperative to minimize the consumption of land as port volume growth continues.

Case Study Location

Based on the information from Victoria State Government Department of Transport (VSGDT) (2019), freight volumes in Victoria in 2014 were around 360 million tonnes annually. This is expected to increase to about 900 million tonnes annually by 2051. Currently, there is no intermodal terminal in Melbourne that is capable of accommodating the rapid increase in freight volumes, hence the Victorian government has put forward a business case to deliver new intermodal terminals in Melbourne to cope and support the expected growth in freight volumes (VSGDT, 2020). Two prospective intermodal terminal locations have been suggested; one is situated in Truganina, Melbourne's West, which is referred to as the Western Interstate Freight Terminal (WIFT). While the second one is located in Beveridge, Melbourne's outer north, which is referred to as the Beveridge Interstate Freight Terminal (BIFT) (VSGDT, 2020). These intermodal freight precincts are also expected to replace the existing Dynon precinct (Port of Melbourne, 2019).

From Google Maps (2020), it was found that Truganina is approximately 18km to the West of the Port of Melbourne (see Figure 5). As most of the freight activities for import and export (UoM 2020, Appendices A & B) are found to be in the West of Melbourne area, Truganina has been selected as the setting for this case study. Based on the Port of Melbourne's Container Logistics Chain Study, CLCS report (2009), the total trade volume in the Port of Melbourne was then approximately 1.5 million TEU, while in 2020 the estimate is around 3 million TEU (Port of Melbourne, 2019), a doubling of the trade volume reported in 2009. Most (around 95%) of the total container movements are via the existing road freight network. About 60% of this represents import containers, with the remaining 40% exports.

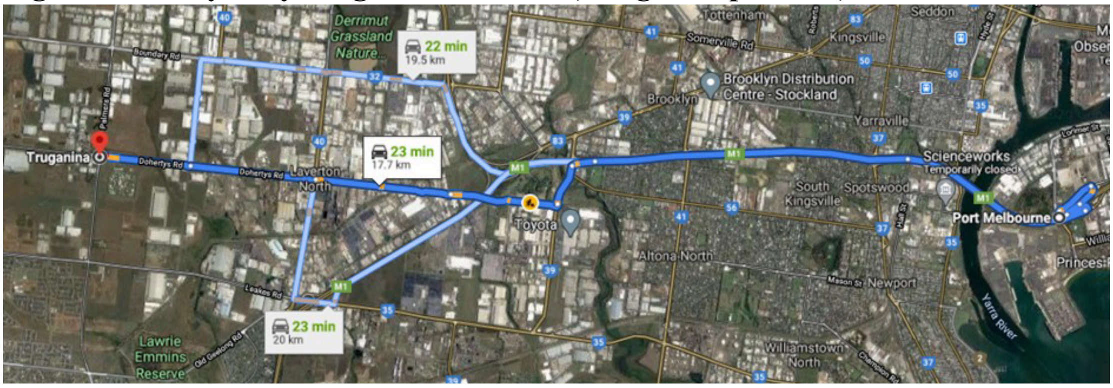
The UoM (2020) estimated the total container movements between Truganina and the Port of Melbourne to 2.1 million TEU per year. The peak hour demand reported in the CLCS report (2009) was found to be around 222 TEU for imports and 92 TEU for export containers, which corresponds to approximately 320 TEU per hour of container movement.

Business as usual (BAU) – base case

The business as usual (base case) to transport shipping containers to intermodal terminals is through road freight networks. Heavy-duty diesel engine trucks achieve high efficiency, reliability, durability, and low operating cost for highway operations but cause air and noise pollution, congestion, and accidents in slow urban operations (Ibrahim et al, 2014). As the volume of freight is expected to increase exponentially, the truck freight system acting as the intermodal transport system cannot be sustainable.

For heavy-duty freight trucks to travel between the Port of Melbourne and Truganina, the shortest road distance found is 17.7km (Google Maps, 2020). From Figure 5, it is noticeable that the West Gate Freeway (M1) serves as the main road connecting the Port of Melbourne to the west areas of the city.

Figure 5: Heavy-duty freight truck route (Google Maps, 2020)



An alternative approach (project case)

As already mentioned, the alternative to BAU is the potential of the CFT innovative solution. Figure 6 displays a straight distance of about 15 kilometres tunnel for the CFT between the Port of Melbourne and Truganina.

Figure 6: CFT tube run location (Google Maps, 2020)

Economic Analysis (A Cost-Benefit Comparison)

By January 2021, our preliminary CFT costing analysis was complete. The economic feasibility of CFT requires appropriate evaluation techniques. Lifecycle cost-benefit analysis (LCBA) is one of the most objective and widely used project appraisal methods for large-scale public infrastructure investments (Nickel, Ross & Rhodes, 2009). According to Ninan, K.N. (2008), a whole of life Cost Benefit Analysis (CBA) is considered a formal regulatory process. The method allows decisionmakers to compare alternatives (Jones, H., Moura, F., & Domingos, T.,2014). For the purposes of this study a standard CBA (for the assumed 50-year useful life of the project) is conducted to investigate the economic appraisal of the proposed CFT concept. Four different scenarios of percentage truck replacement by CFT are described in Table 1.

Table 1: Scenarios for CFT utilisation analysis

Scenarios of container truck replacement	% of freight trucks to be replaced by CFT
Scenario 1	10%
Scenario 2	20%
Scenario 3	30%
Scenario 4	40%

The research framework for CBA in this report includes 50-year useful project life cash flows identification and estimation, followed by calculation of the key economic measure, Net Present Value (NPV) using the following formula (Equation 1), which is an adjusted Equation (19) of the UoM (2020) study.

$$NPV = PV(B) - PV(C) = \sum_{t=0}^{n} [\frac{(B_t - OC_t)}{(1+i)^t} - \frac{IC_t}{(1+i)^t}] \qquad (1)$$

Where, **PV(B)** and **PV(C)** denote the present values of the benefits (net of operating and maintenance costs) and the capital (investment) costs of the project respectively; **Bt** is the benefits; **OC_t** denotes the operating costs; **ICt** is the investment (capital) costs; **n** is the project's useful life in years; and **i** is the discount rate used to compute the present values.

If the proposed CFT freight system has a positive NPV, then it is economically feasible and the scenario with the highest NPV should be implemented, as it would be the most beneficial. The benefit cost ratio (BCR) of the CFT freight system can also be calculated for each scenario by computing the ratio of present values of benefits and costs as shown in Equation (2) which is an adjusted equation (20) of the UoM (2020) study. If the BCR is equal to one or greater, then the CFT freight system is economically feasible. The scenario with the highest ratio is deemed to be the best.

$$BCR = \frac{PV(B)}{PV(C)} = \sum_{t=0}^{n} [\frac{(B_t - OC_t)}{(1+i)^t} / \frac{IC_t}{(1+i)^t}] \qquad (2)$$

In this analysis, the expected project life of the CFT freight system is 50 years, and the real (excludes inflation) discount rate to be used is 7% as recommended by Infrastructure Australia (2018) to reflect the benefits in the long term. Tables 4.1 to 4.4 as reported in UoM (2020) provide the estimation of the major costs and benefits of the CFT freight system, where the associated unit costs used are based on relevant case studies and quotes using the CFT design, which may vary for different designs/ applications. [Note that for this analysis, there will be no intermodal terminal land and development cost considered since there is already an ongoing business case for the Truganina intermodal terminal by the Australian Government].

Table 4.1 Capital Costs (Initial one-time costs) Preliminary costings	
Tunnel construction cost for fully completed tunell ready to be fitted	Cost of boring, excavation, and concrete linings to construct the tunnel for pipeline installation. A preliminary estimate of the cost (Feb 2020) of constructing the required tunnel is A$42,000,000 per km. Thus, considering two 15 km length tunnels for the project to and from the Port of Melbourne, the total tunnel construction cost is about A$1.3 billion. By September 2021, the authors would add a contingency to recognise the cost of potential toxic soil disposal.
Pipeline cost (fitting of tunell)	Cost of a pipeline for the semi-autonomous freight system as quoted by the CFT representative is approximately A$5 million per km, which gives a total estimated pipeline cost of A$150 million for two 15 km pipelines.
Control system and equipment cost	Based on CFT design, the estimated cost of control systems and mechanical equipment such as motors and Detachable Drive Units (DDUs) required for the operation of the semi-autonomous freight system is A$700,000 per TEU. Thus, assuming the semi-autonomous system is to cope with the peak freight transport demand of 320 TEU per hour as found by a study by the Port of Melbourne (2020) and depending on the scenarios of percentage truck replacement in Table 2 in UoM (2020) the total estimated control system and equipment cost is as per Equation (3).
% transported by CFT × 320 TEU × A$700,000 per TEU (3)	

Table 4.2 Operating and Maintenance Costs (Annual recurring costs)	
Tunnel operation and maintenance cost	A study by Zhang et al. (2005) which analysed the lifecycle cost of tunnels found that the average cost of tunnel maintenance and repair was 1.5% of the initial cost per year. Since the tunnel in this analysis is used to accommodate an semi-autonomous system, its maintenance cost may be slightly higher and can be assumed as 2% of the initial cost, hence the tunnel operation and maintenance cost is about A$25.2 million per year.
CFT system power use cost	Uni of Melb students data shows the semi-autonomous freight system is expected to transport approximately 2,100,000 TEU per year by replacing trucks completely, and the power consumption is 0.043 kWh per km per TEU. Assuming the average electricity price in Victoria is 23.47c per Wh (Brendon O'Neil 2020) and depending on the scenarios of percentage truck replacement in Table 1 above, the estimated annual CFT system power consumption cost can be calculated as per Equation (4). (Large users of electricity can expect price discounts). % transported by CFT × 2,100,000 TEU per year × 0.043 kWh per km per TEU × 15 km × A$0.2347 per kWh (4)
CFT system maintenance cost	To ensure the high performance and efficiency of operation, periodic inspection and maintenance of the semi-autonomous freight system are required. For this analysis, the maintenance cost for the CFT system on an annual basis is assumed to be 5% of the system's initial cost, hence can be calculated as per Equation (5). % transported by CFT × 320 TEU × A$700,000 per TEU × 0.05 (5)

Table 4.3: Major benefit components of a CFT freight system

<table>
<tr><td>Freight truck operating cost saving</td><td>According to Freight Metrics (2020), the estimated freight truck operating cost is A$43.56 per tonne for a 15 km distance travel. Hence, by implementing an automated freight system to replace freight trucks and assuming each loaded TEU weighs 12 tonnes (Shipping MRV Monitoring Sub-group, 2017), the annual saving of freight truck operating costs can be calculated as per Equation (6).</td></tr>
<tr><td colspan="2">% of freight transported by CFT × 2,100,000 TEU per year × 12 tonnes per TEU × A$43.56 per tonne (6)</td></tr>
<tr><td>Carbon footprint reduction</td><td>According to Transport and Infrastructure Council (2020), the mid-range estimate of the social cost of carbon dioxide equivalent emission in Australia is A$60 per tonne CO_2-e. Hence, the estimated annual benefit from carbon footprint reduction can be calculated as per Equation (7).</td></tr>
<tr><td colspan="2">% of freight transported by CFT × _tonne CO_2-e reduced per year × _A$60 per tonne CO_2-e (7)</td></tr>
<tr><td>Air pollution reduction</td><td>According to Transport and Infrastructure Council (2020), the mid-range estimate of air pollution cost in Australia is A$0.227 per vkm. For a 15 km distance travel and assuming 2,100,000 TEU per year each to be transported by a freight truck, the estimated annual benefit from air pollution reduction can be calculated as Equation (8).</td></tr>
<tr><td colspan="2">% transported by CFT × 2,100,000 vehicles per year × 15 km × A$0.227 per vkm (8)</td></tr>
<tr><td>Noise pollution reduction</td><td>According to Transport and Infrastructure Council (2020), the mid-range estimate of noise pollution cost in Australia is A$0.041 per vkm. For a 15 km distance travel and assuming 2,100,000 TEU per year each to be transported by a freight truck, the estimated annual benefit from noise pollution reduction, can be calculated as per Equation (9).</td></tr>
<tr><td colspan="2">% transported by CFT × 2,100,000 vehicles per year × 15 km × A$0.041 per vkm (9)</td></tr>
<tr><td>Traffic congestion reduction</td><td>According to Laird, P. (2005), the mid-range estimate of traffic congestion cost in Australia is A$0.001 per ntkm. For a 15 km distance travel and assuming 2,100,000 loaded TEU per year each weigh 12 tonnes (Shipping MRV Monitoring Sub-group, 2017), the estimated annual benefit from traffic congestion reduction can be calculated as per Equation (10).</td></tr>
<tr><td colspan="2">% transported by CFT × 2,100,000 TEU per year × 15 km × 12 tonnes per TEU × A$0.001 per ntkm (10)</td></tr>
<tr><td>Accident reduction</td><td>According to Laird, P. (2005), the mid-range estimate of accident cost in Australia is A$0.006 per ntkm. For a 15 km distance travel and assuming 2,100,000 loaded TEU per year each weigh 12 tonnes (Shipping MRV Monitoring Sub-group, 2017), the estimated annual benefit from accident reduction can be calculated as per Equation (11).</td></tr>
<tr><td colspan="2">% transported by CFT × 2,100,000 TEU per year × 15 km × 12 tonnes per TEU × A$0.006 per ntkm (11)</td></tr>
</table>

UoM (2020) CBA Results

Table 4.4 indicates that the initial tunnel construction cost is the highest contributor to the cost of the CFT freight system for all of the scenarios. This is followed by the tunnel lining and the control system and equipment costs. There is also a significant system operation and maintenance cost.

Table 4.4: Present Values of Costs & Benefits

COSTS		BENEFITS				
Cost Components	**PV of costs (A$ million)**	**Benefit Components**	**PV of Benefits (A$ million)**			
% Truck Replacement			**10%**	**20%**	**30%**	**40%**
Tunnel construction cost	1,260	Freight truck operating cost saving	1,515	3,030	4,545	6,060
Pipeline cost	150	Carbon footprint reduction	2	4	6	8
Control system and equipment cost	45	Air pollution reduction	10	20	30	39
Tunnel operation and maintenance cost	348	Noise pollution reduction	2	4	5	7
System power use cost	1	Traffic congestion reduction	0.5	1	2	2
System maintenance cost	31	Accident reduction	3	7	9	13
Total cost	1,835 (for Sr 2)	Total Benefit (Cost)	1,532 (1,796)	3,064 (1,835)	4,597 (1,873)	6,129 (1,876)

Air pollution[3] and accident reductions are the major social benefits of the CFT freight system in all scenarios. Other external costs such as social amenity and road damage are not included in this case study. Furthemore, wider economic benefits induced by major innovations like the CFT proposal cannot be easily captured in a standard CBA. Finally,

[3] Air pollution costs will change over a period of a 50-year useful project life, as less truck polluting technologies (e.g., electric vehicles) enter the industry. The rate of adoption of electrified trucks may be delayed for short haul port operations, which opt to use older polluting trucks (not just air and noise pollution).

it is noted that project benefits estimates do not include a residual value beyond the 50-year useful life of the project, which could be of considerable end value. The estimated UoM (2020) study NPV and BCR values of the system for each scenario are shown in Table 4.5.

Table 4.5: Summary of the cost-benefit analysis results obtained

Percentage Truck Replacement	NPV (A$ million)	Rounded BCR[1]
10%	-264	1
20%	1,229	2
30%	2,724	2
40%	4,253	3

[1] BCRs in this table are reported as per UoM (2020), which are estimated by treating the operating costs of the project as part of the capital costs. However, by applying the theoretically correct formula (Equation 2) above, somewhat greater estimates will be reported (e.g. 40% will give a BCR of close to 4).

Sensitivity analysis

The BCR of a CFT system is sensitive to both the tunnel construction cost and the freight truck operating cost-saving. The results are less sensitive to changes in the discount rate (UoM 2020).

Control Mechanisms

In the CFT case the signalling systems, GPS and scanners within the pipes are not new technology. The scheduling procedures and tracking of movements are used in rail, airline, and manufacturing. The CFT pipes and semi-autonomous container vehicles being 'different' to current practice will require considerable monitoring of success and understanding of any opportunities to fail.

Summary and Conclusions

This paper suggests a more detailed business case is warranted. The innovative approach of Container Freight Technologies (CFT) presented is well placed to respond to current challenges faced by an exponential growth of seaport infrastructure that is unsustainable. Transporting shipping containers by road in the vicinity of ports in urban areas is expensive and intrusive to communities causing congestion, road crashes, harmful air and noise pollution, GHG emissions, and serious degradation of community amenity and road infrastructure. CFT is an Australian start-up with ambitious plans to address these challenges and improve international freight logistics efficiencies. CFT's design is best suited to help solve many of the 'last mile' inefficiencies in transport network interfaces such as seaports and railheads. Scheduling of rail and road resources is frustrated by multipurpose infrastructure needed to accommodate passenger and freight frequency of movements, which also requires prime land for storage capacity close to the port. Traditional new infrastructure adversely impacts both funding and land use.

The core innovation of CFT proposes a system for transporting shipping containers using powered wheels attached to the containers, temporarily making them semi-autonomous 'Container Vehicles'. By combining the ship load-unload process directly with the land-transport mechanism, the CFT system slows land consumption at ports, while minimizing pollution and traffic congestion. CFT ensures established world-class seaports become more competitive by improving ship turnaround via better scheduling of operations; increasing efficiency of road and rail movement, as the ‘last mile’ travel on congested infrastructure to the Logistics hub and serious double handling are minimised; and reducing maintenance expenditure of road infrastructure. The automated CFT system is unobtrusively available on a 24 hours a day basis generating cost and time saving for both shipping companies and customers. The single purpose CFT infrastructure (tunnels and pipes) is enabling increased biosecurity safety in the transport task, and is removing ‘container parks’ in valuable real estate and the need for shunting yards and truck bays at the port, as well as the use of older polluting trucks.

A case study completed within the Engineering Graduate Program of the University of Melbourne (UoM, 2020) was set to evaluate the CFT designs and processes. The area of study is the container freight corridor from the Webb Dock of the Port of Melbourne to the Truganina freight hub. Different scenarios of percentage truck-replacement by the CFT system are examined for establishing an optimal outcome for substantially reducing the operating as well as the social and environmental costs of container freight transport. The standard cost-benefit analysis (CBA) methodology used in the UoM (2020) study stands to compare the existing road freight system using trucks (BAU) with the proposed automated CFT system. The proposed CFT innovation is shown to become increasingly competitive as it replaces 20% or more of container-freight truck movements. The results of the CBA show that a CFT application can effectively reduce the carbon footprint, traffic congestion, accidents, noise, and air pollution. The two highest benefits of implementing CFT are freight truck operating cost savings and air pollution reduction.

Abbreviations

Abbreviation	Description
AADT	Annual Average Daily Traffic
ANZSCO	Australian and New Zealand Standard Classification of Occupation
BAU	Business as Usual
BCR	Benefit Cost Ratio
BIFT	Beveridge Interstate Freight Terminal
BITRE	Bureau of Infrastructure, Transport, and Regional Economics
CLCS	Container Logistics Chain Study
CFT	Container Freight Technologies
DDU	Detachable Drive Unit

ECTA	European Chemical Transport Association
GDP	Gross Domestic Product
GHG	Greenhouse Gases
MRPII	A Planning IT enabling the JIT concept – Calculates Inventory based on an opportunity to fail
nBL	Number of Bottom Lines
NPV	Net Present Value
NTI	National Transport Insurance
ntkm	Net Tonne-Kilometres, i.e. 1 tonne of goods over 1 km
SBTC	Skill-Biased Technological Change
TEU	Twenty-Foot equivalent Unit
VSGDT	Victorian State Government Department of Transport
vkm	Vehicle-kilometre (of traffic flow)
WIFT	Western Interstate Freight Terminal

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