Biofuel Compatibility Study for Next Generation Multipurpose Port Operations

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2023

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College of Design and Engineering

BACKGROUND

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- Driven by the growing and- changing industry, Jurong Port is striving to evolve into a next generation multipurpose port with improved productivity, safety & security and sustainability.

- JP's commitment towards environmental sustainability has led to many green initiatives in recent years.

- To further explore sustainable port operations, Jurong Port is teaming up with C4NGP NUS and MESD NTU under this proposed project to study the alternative energy sources for JP port operations.

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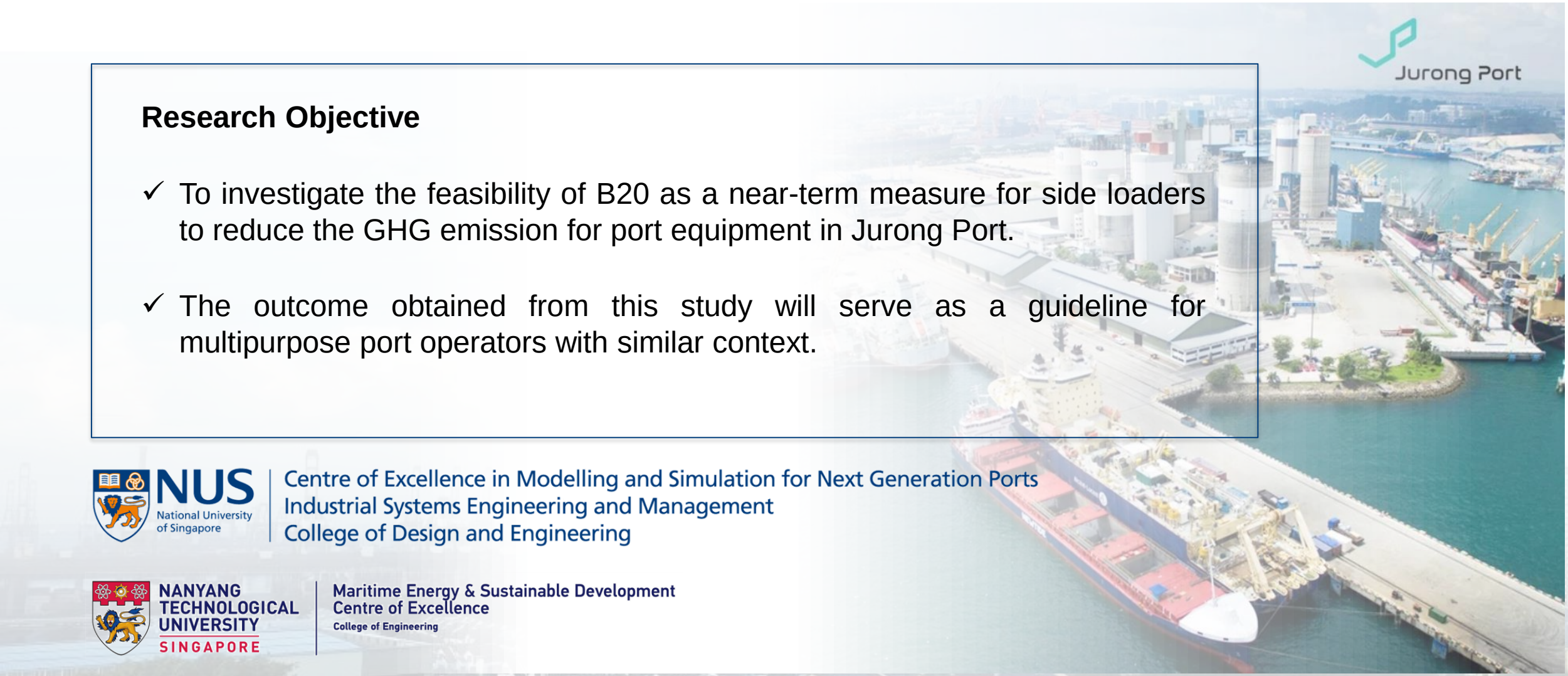
BACKGROUND

- Side loaders, forklifts, and port vehicles, are identified as the main diesel consumption or on-site Greenhouse gases (GHG) emission.
- Biodiesel is a domestically produced, renewable fuel that can be manufactured from vegetable oils, animal fats, or recycled restaurant grease for use in diesel vehicles or any equipment that operates on diesel fuel.
- B20 Biodiesel is a common biofuel blend which consists of up to 20 percent Biodiesel and 80 percent petroleum diesel.
- B20 presents a good balance of cost, emissions, cold-weather performance and equipment compatibility.

BACKGROUND



Research Objective

- ✓ To investigate the feasibility of B20 as a near-term measure for side loaders to reduce the GHG emission for port equipment in Jurong Port.
- ✓ The outcome obtained from this study will serve as a guideline for multipurpose port operators with similar context.

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DATA COLLECTION

Data Collection

OPERATION PROFILE

- Speed, Acc./Dec.
- Pick-up/ Drop-off time

FUEL CONSUMPTION PROFILE

- Diesel
- Biofuel B20

EMISSION PROFILE

- Carbon emission:CO2, CO
- Oxynitride NOx

Equipment

Camera monitoring inside driver's cabin

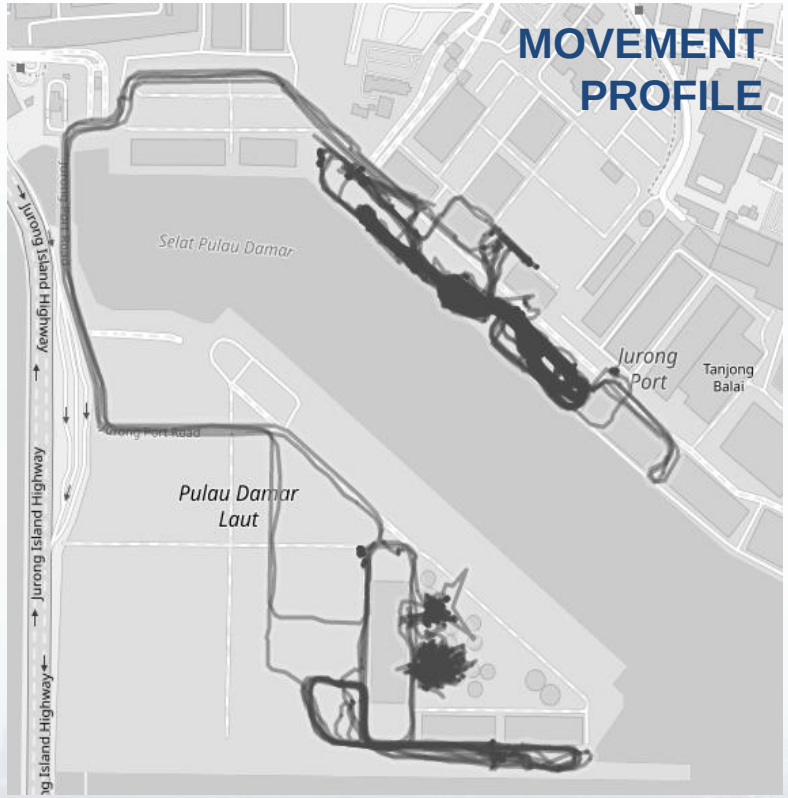
Encased GPS set on the roof of the driver's cabin

Gas analyzer control unit set secured on the back of the side loader

RH & Temps sensor attached on the exterior of the frame

Gas analyzer's probe attached to the adapted exhaust pipe

Operational Profile

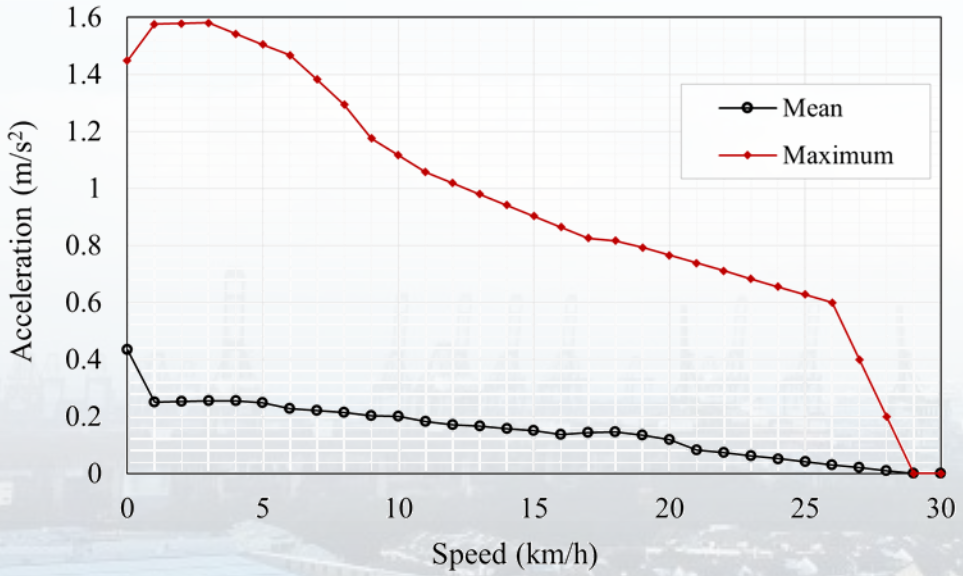


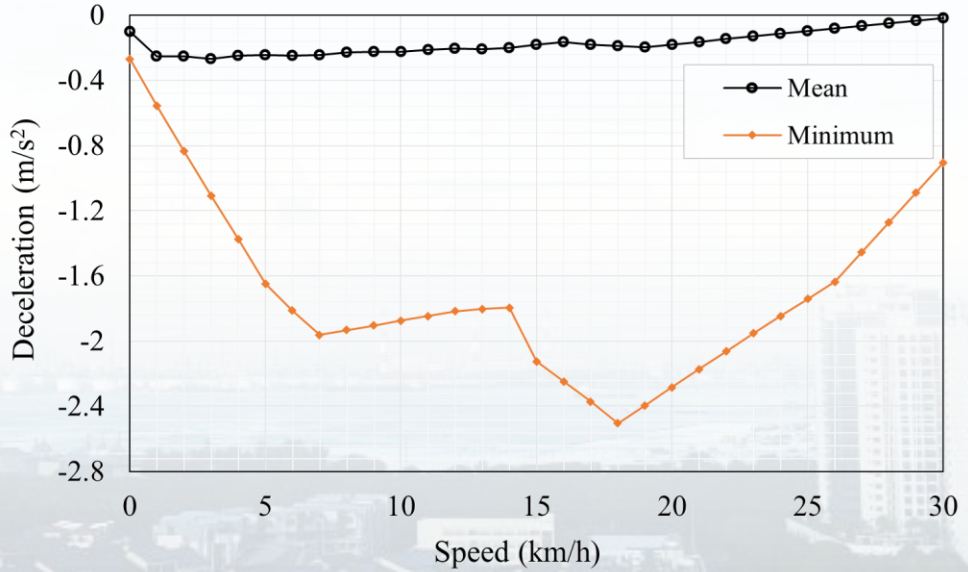
CARGO TRIPS	
Status	**Speed Range (km/h)**
Transit Speed	6 - 20
Turning Speed	6 – 8
Status	**Duration Range (sec)**
Pick Up	20 - 80
Dropoff	20 - 60

Operational Profile

Acceleration & Deceleration

- Acceleration and deceleration vary with the speed due to engine power and torque, air resistance, etc.
- We provide the acceleration and deceleration distribution of a side-loader by analyzing the speed data collected every second.

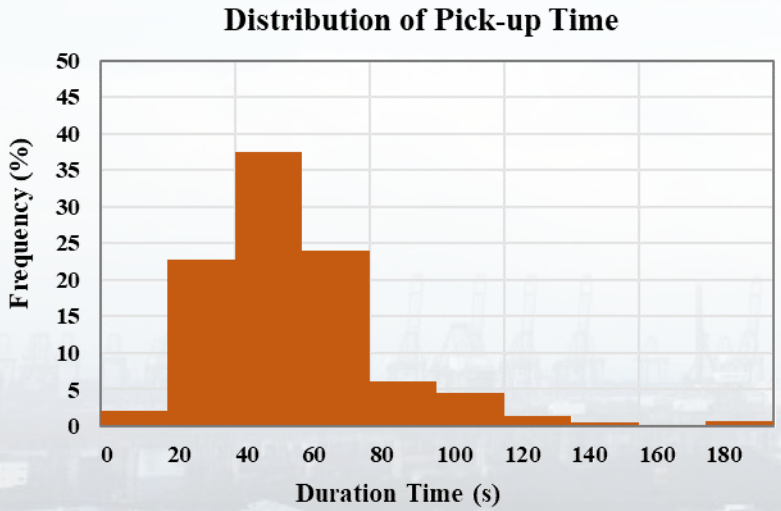


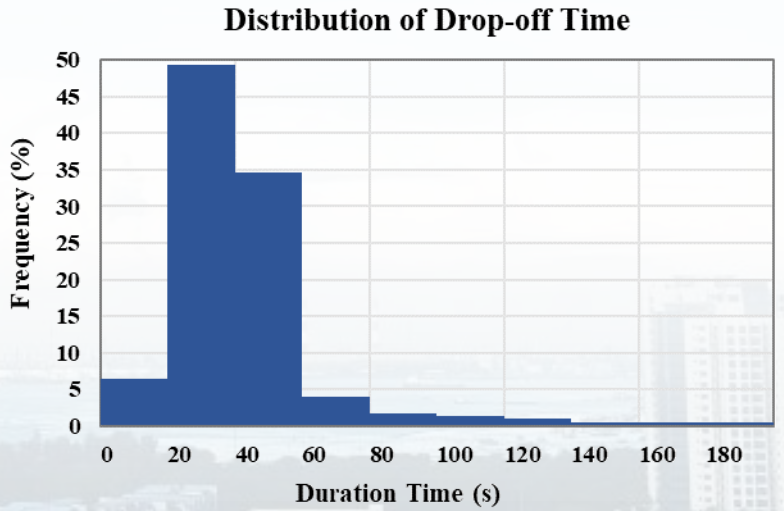


Operational Profile

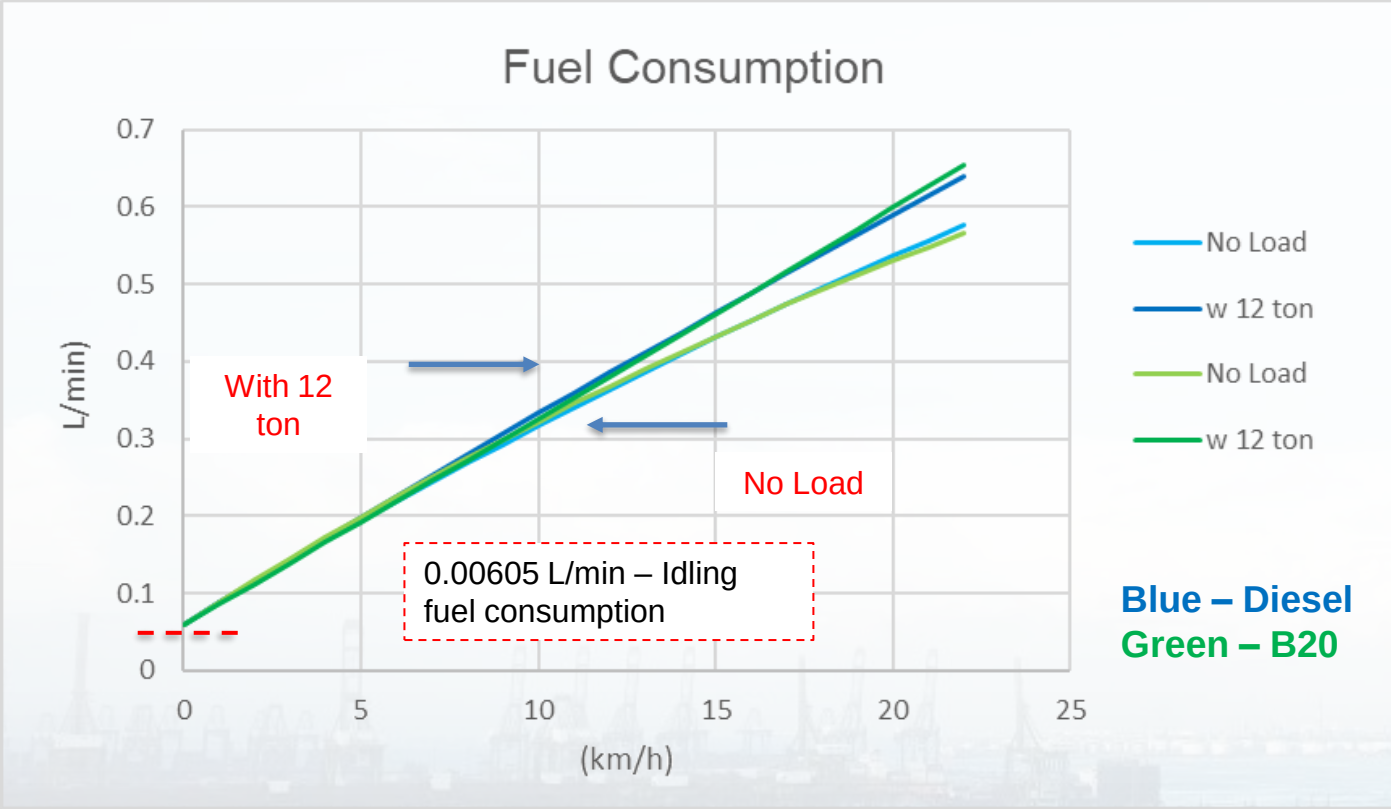
Pick-up time & Drop-off time

- According to the field survey, the pick-up and drop-off times for a side-loader are not consistent values.
- We have provided the distribution of these pick-up and drop-off times based on historical data.





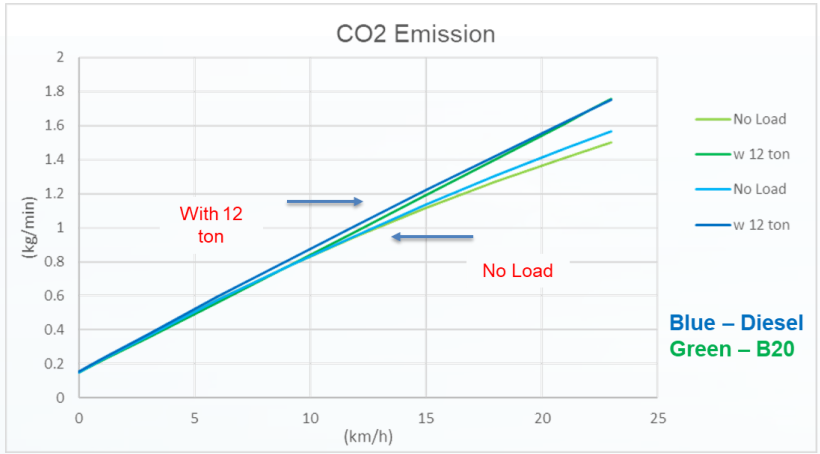
Fuel Consumption Profile

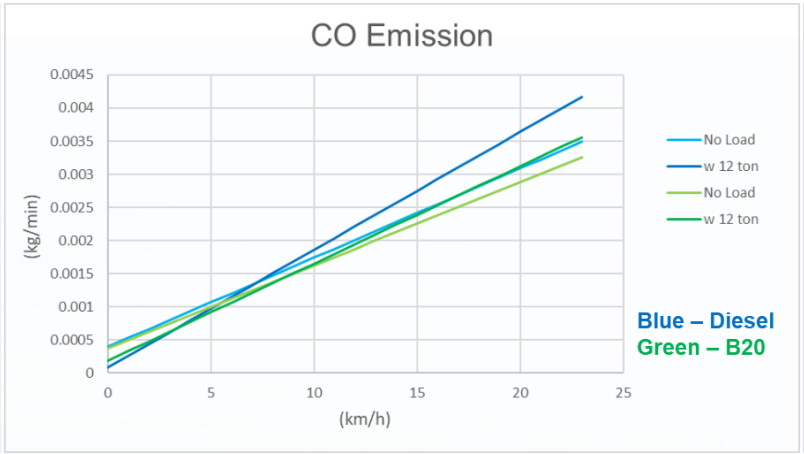


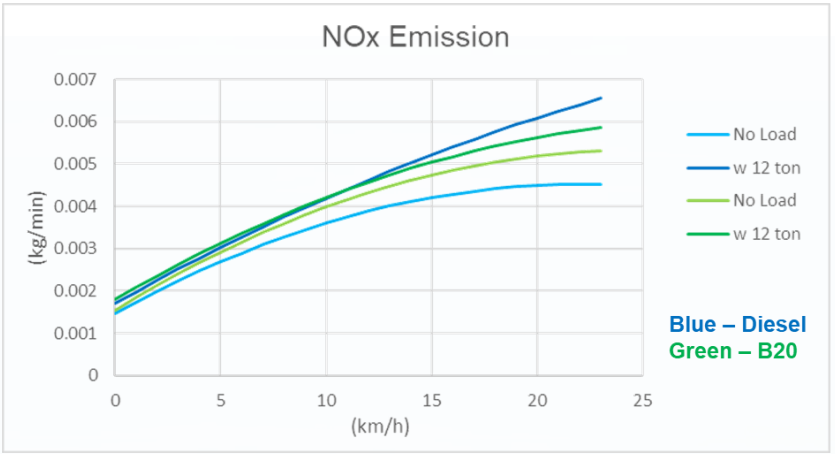
- Fuel consumption is a function of speed and added load.
- Regression shows that there is no statistical significance between Diesel and B20 fuel consumption

Diff % from 9 km/h to 21 km/h				
	No Load	**Diff (%)**	**With 12 ton**	**Diff (%)**
9~16 km/h	**B20** > Diesel	0.08 to 2.52	**Diesel** > B20	0.40 to 3.40
17~22 km/h	**Diesel** > B20	0.22 to 1.90	**B20** > Diesel	0.40 to 2.50

Emission Profile







- CO2/CO/NOx emission is a function of speed and added load.
- B20 has a statistical significance and reduction in CO2 emission rate.
- CO regression shows that it has statistical significance with B20 having lower emission.
- NOx regression shows that it does not have statistical significance between B20 and Diesel.
- NOx and CO emission relies heavily on the combustion efficiency of the engine and fuel composition.

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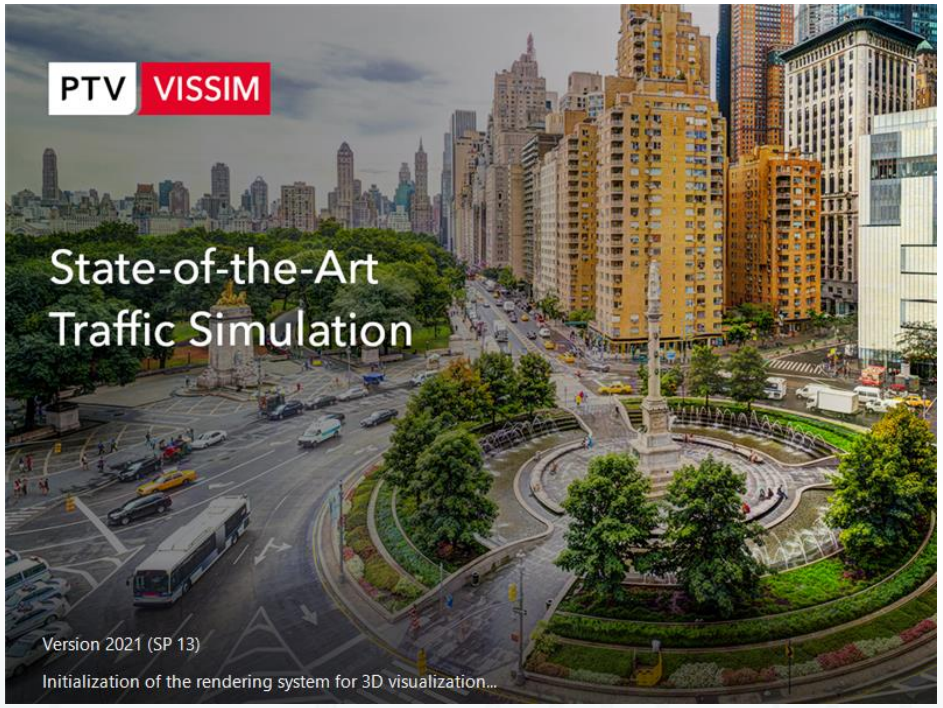
SIMULATION AND FINDINGS

SIMULATION PLATFORM



PTV VISSIM
Microscopic Traffic Simulation

- The data analysis results are statistically meaningful. But during actual operation, a side-loader will experience various accelerations, decelerations, and idling times.
- Conducting field experiments to test different operation scenarios can be time-consuming and costly.
- Replicate the side-loader operation within Jurong Port using VISSIM, based on operation profile data collected.
- Test various scenarios using different operational strategies and assessed the performance of the operation based on simulation outputs

Years of proven success
Decades of research and continuous development with customers

Simulate multimodal traffic
A single software that fully integrates all modes of transport

Flexible and seamless integration
APIs and interfaces to external software providers

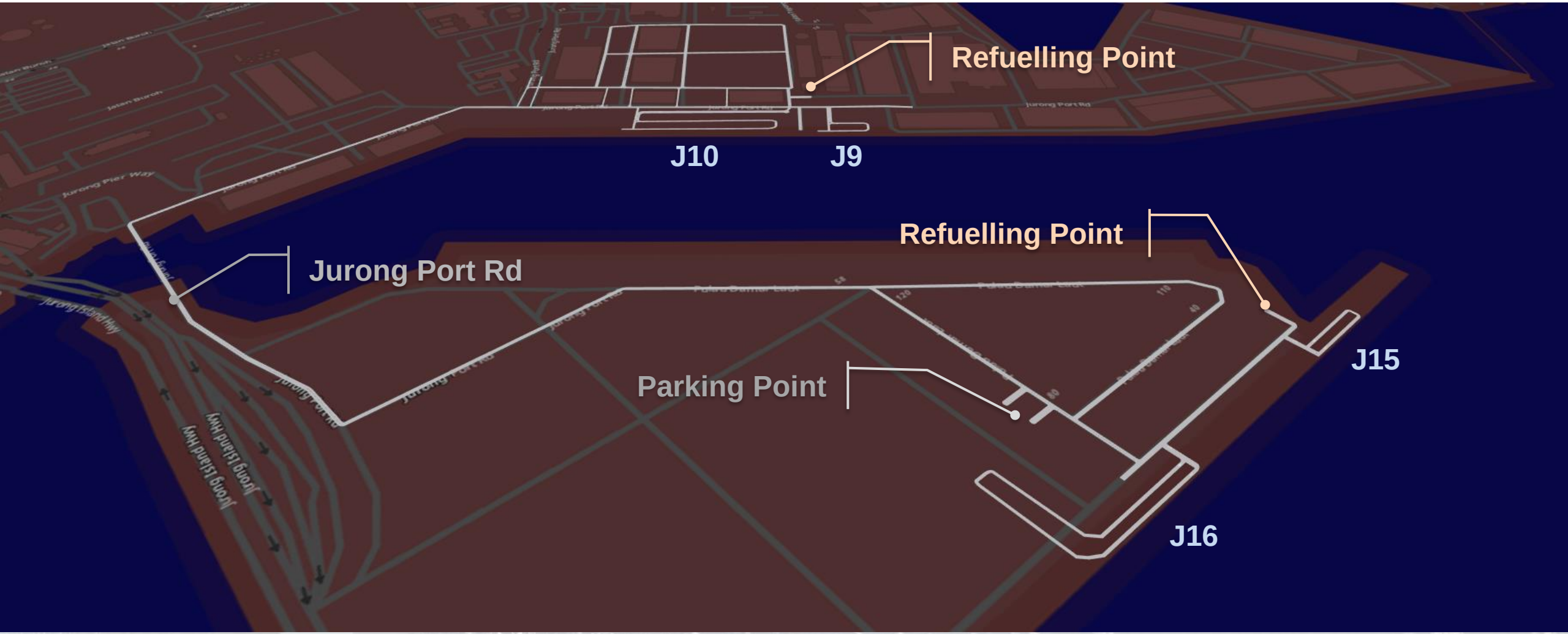
Sophisticated motion model
PTV Vissim considers regional and cultural differences

Improved traffic flow
Reduce congestion and emissions with efficient traffic planning

In-depth traffic simulations
Create microscopic, mesoscopic or hybrid simulations

No scripting
Intuitive interface that does not require scripting (though still possible)

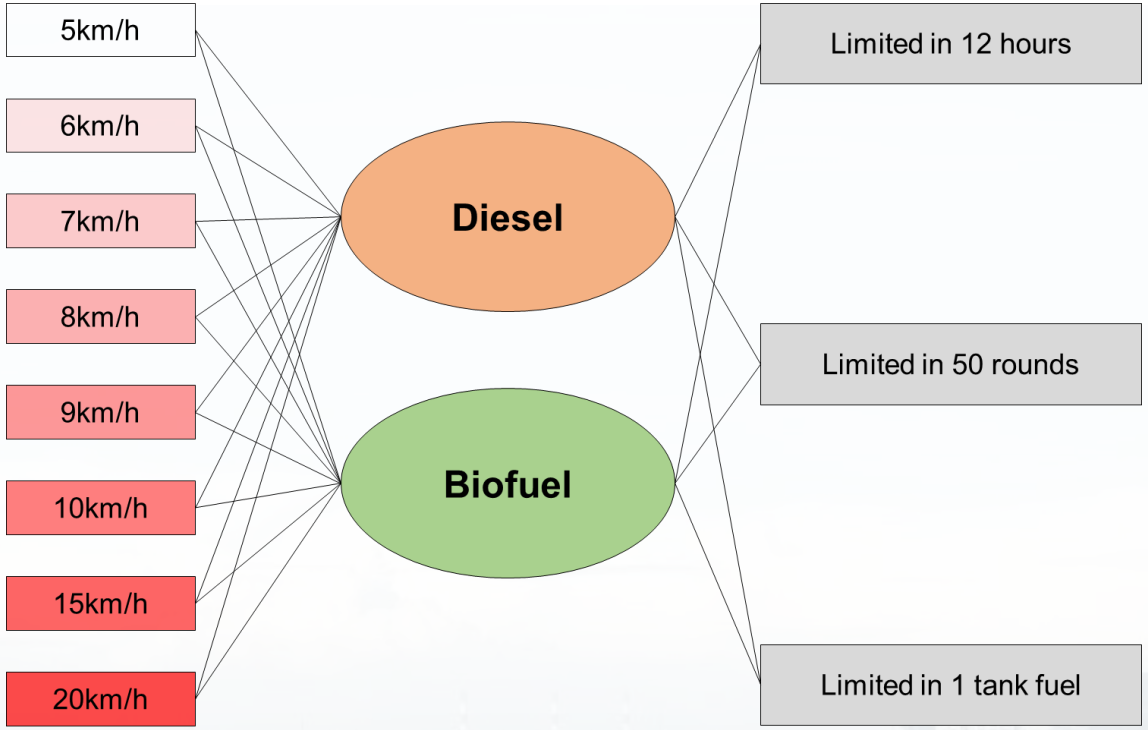
MODELLING - *Road Network*



MODELLING – *Operation*

EXPERIMENT DESIGN

- Limit the side-loader to a fuel capacity of **180 liters** and determine how many round trips it can make using different fuel sources: diesel and biofuel.
- Restrict the side-loader to **50 round trips** and measure how much fuel is consumed, as well as the emissions produced, using both diesel and biofuel.
- Allow the side-loader to operate normally for **12 hours**, then determine the fuel consumption and emissions when powered by both diesel and biofuel.

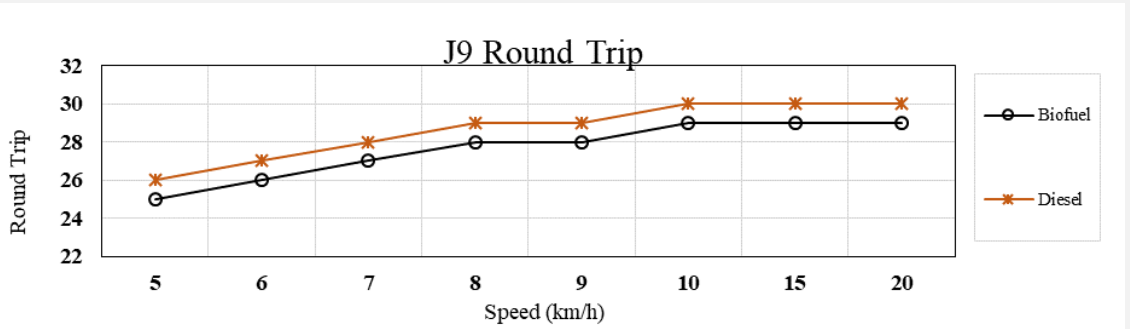


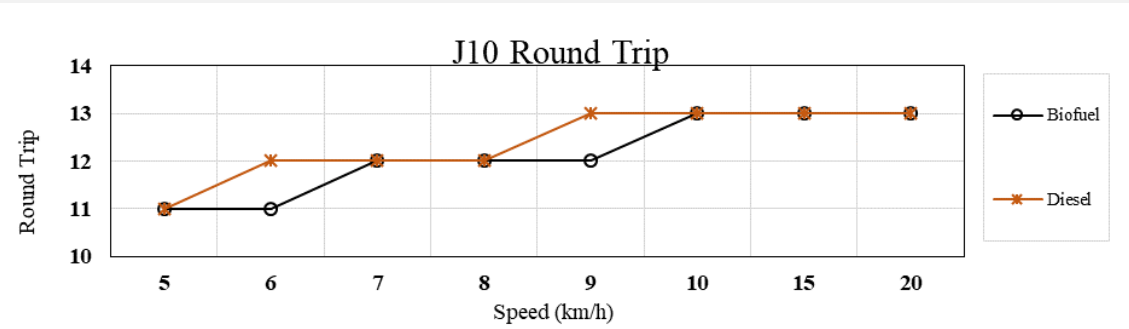
According to the fuel consumption and emission profile, a side-loader will consume more fuel and generate more emission at higher speeds. However, a higher speed will in turn lead to reduced travel time. Therefore, we have created scenarios with different maximum speeds to observe their impact on total fuel consumption and emissions.

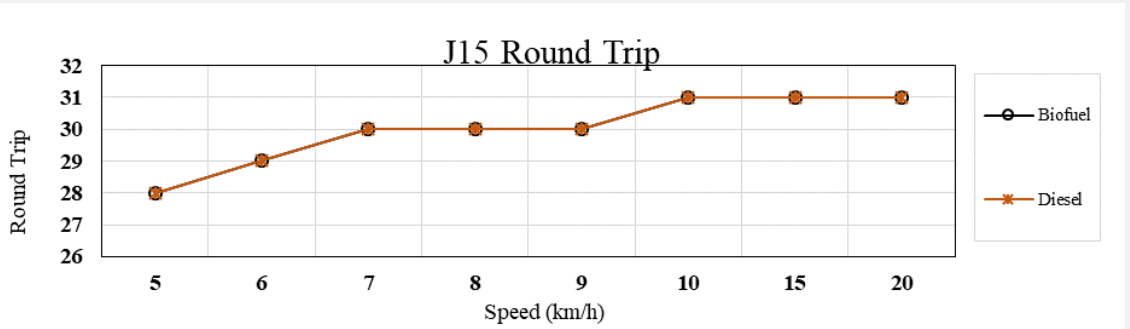
RESULT – *Fuel Consumption*

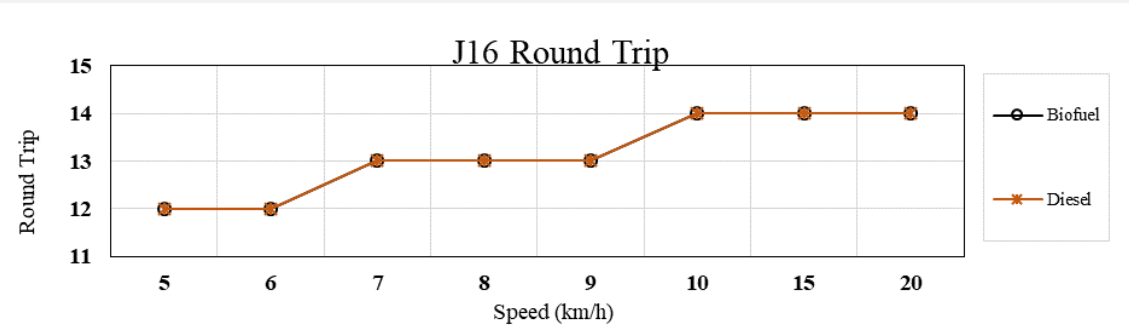
❖ Operation efficiency limited to a fuel capacity of 180 liters

- It is evident that biofuel has no significant impact on the operation efficiency of the side-loader.









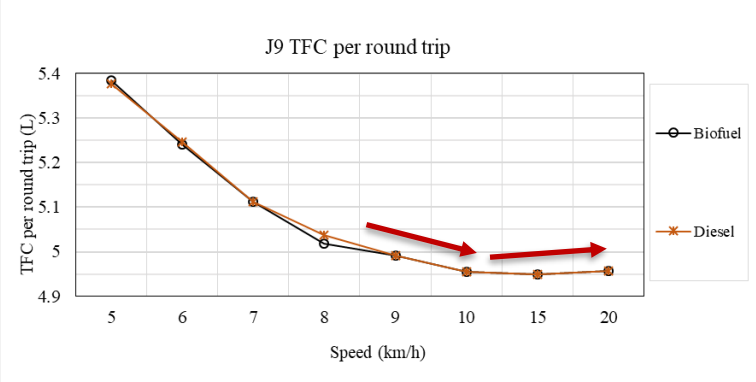
- We observed that both biofuel and diesel resulted in almost the same number of round trips with 180 liters of fuel.
- Only for berth J9, which has the shortest round trip distance, does biofuel complete one less total round trip than diesel.

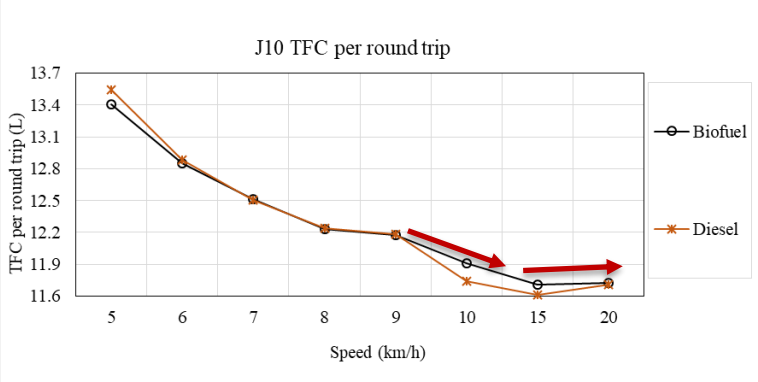
RESULT – *Fuel Consumption*

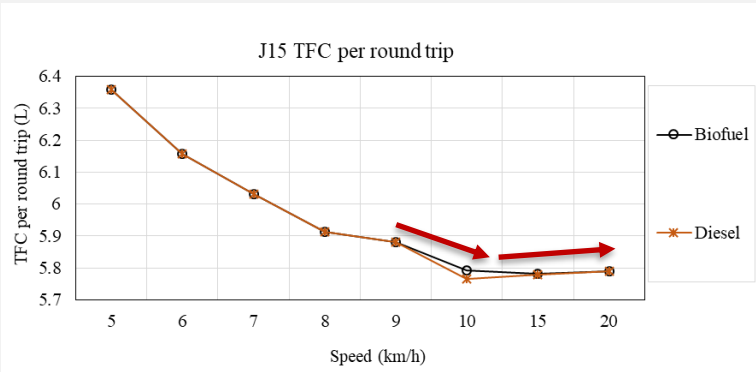
❖ Fuel consumption varies with maximum speed when operated for 12 hours

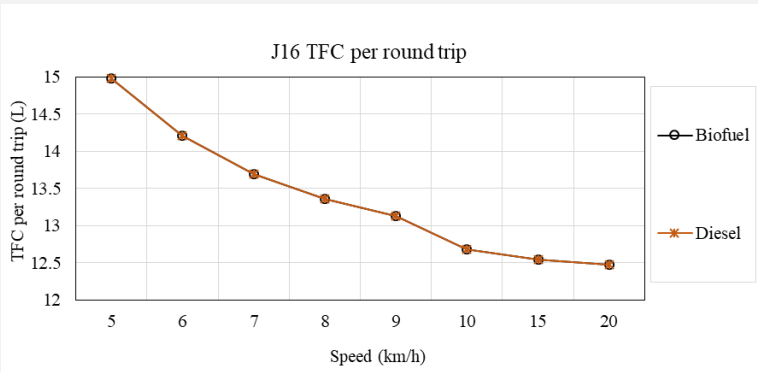
- A maximum speed of around 15 km/h may yield the best fuel savings, slightly better than increasing the speed further.
- Side-loader drivers are discouraged from driving deliberately slowly.

- We observed that the fuel consumption per round trip generally decreases as the maximum speed increases.
- Fuel consumption varies only slightly after 10 km/h.
- The minimal value may appear between 10 km/h and 15 km/h.
- After this range, the total fuel consumption experiences a slight increase.

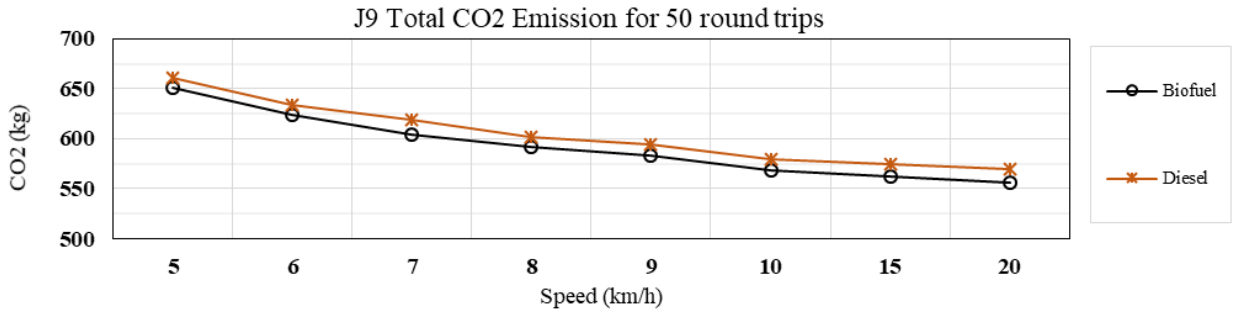


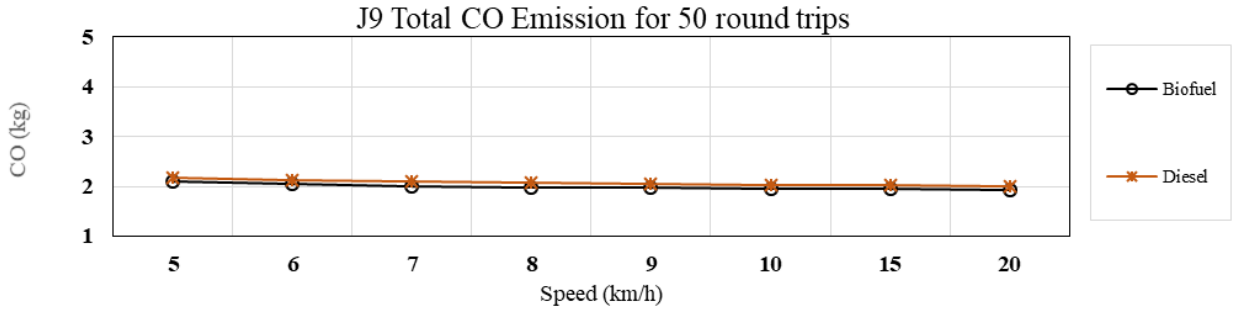


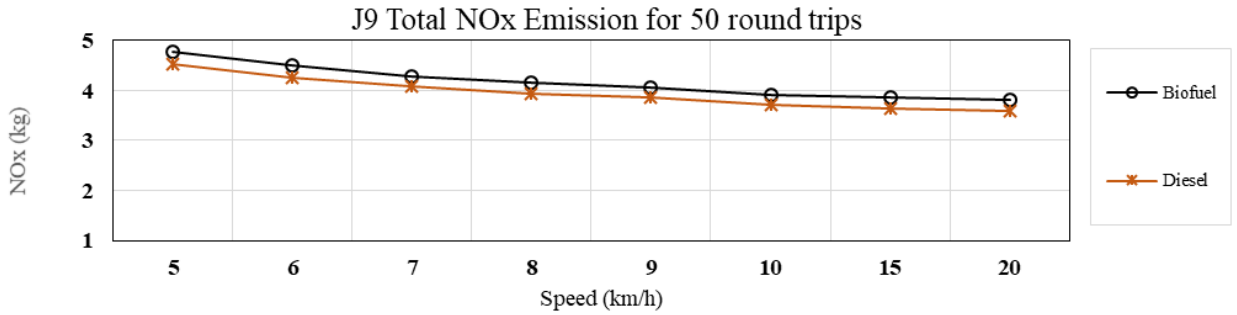




RESULT – *EMISSION*







In scenarios where vehicles complete 50 round trips and operate for 12 hours, observations at all berths indicate that using biofuel results in:

- **Reduced CO2 and CO emissions**
- **Increased NOX emissions.**

RESULT – *EMISSION*

$$\text{Percentage difference} = \frac{(Emission\,w\,Biofuel - Emission\,w\,Diesel)}{Emission\,w\,Diesel} \times 100\%$$

Examine the effects of maximum speed and operational time duration on emissions using different fuel sources.

- Biofuel could reduce carbon emission by about 4% compared with diesel.
- A longer operational duration will amplify the reduced CO2 & CO emissions, and mitigate the increase in NOX emissions from biofuel.
- Increasing maximum speed will slightly enhance the reduction in emissions.

Speed (km/h)	J15						J16					
	CO_2		CO		NO_x		CO_2		CO		NO_x	
	50 round trip	12 hours	50 round trip	12 hours	50 round trip	12 hours	50 round trip	12 hours	50 round trip	12 hours	50 round trip	12 hours
5	-3.40%	-3.52%	-3.62%	-3.69%	4.36%	4.19%	-2.39%	-2.43%	-4.39%	-4.55%	5.88%	5.55%
6	-3.38%	-3.57%	-3.99%	-4.15%	4.24%	4.02%	-2.48%	-2.54%	-5.06%	-5.28%	5.86%	5.52%
7	-3.47%	-3.65%	-4.27%	-4.47%	4.06%	3.85%	-2.55%	-2.59%	-5.55%	-5.80%	5.80%	5.47%
8	-3.39%	-3.63%	-4.48%	-4.74%	3.94%	3.70%	-2.58%	-2.64%	-5.91%	-6.21%	5.73%	5.40%
9	-3.50%	-3.68%	-4.59%	-4.83%	3.82%	3.61%	-2.62%	-2.69%	-6.19%	-6.52%	5.64%	5.32%
10	-3.71%	-3.95%	-4.67%	-4.94%	3.72%	3.46%	-2.82%	-2.89%	-6.85%	-7.21%	5.21%	4.92%
15	-3.87%	-3.97%	-4.72%	-4.89%	3.69%	3.52%	-2.97%	-3.06%	-7.06%	-7.44%	4.91%	4.64%
20	-3.92%	-4.08%	-4.71%	-4.92%	3.70%	3.49%	-3.35%	-3.46%	-7.18%	-7.57%	4.71%	4.47%

RESULT – *SUMMARY*

- Using biofuel instead of diesel will not impact the side-loaders operation of handling work.
- Using biofuel will not increase fuel consumption and may even lead to a slight decrease.
- Using biofuel will reduce CO2 and CO emissions by about 4% but increase NOX emissions.
- Side-loader drivers are advised against intentionally driving slowly.

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THANK YOU!

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