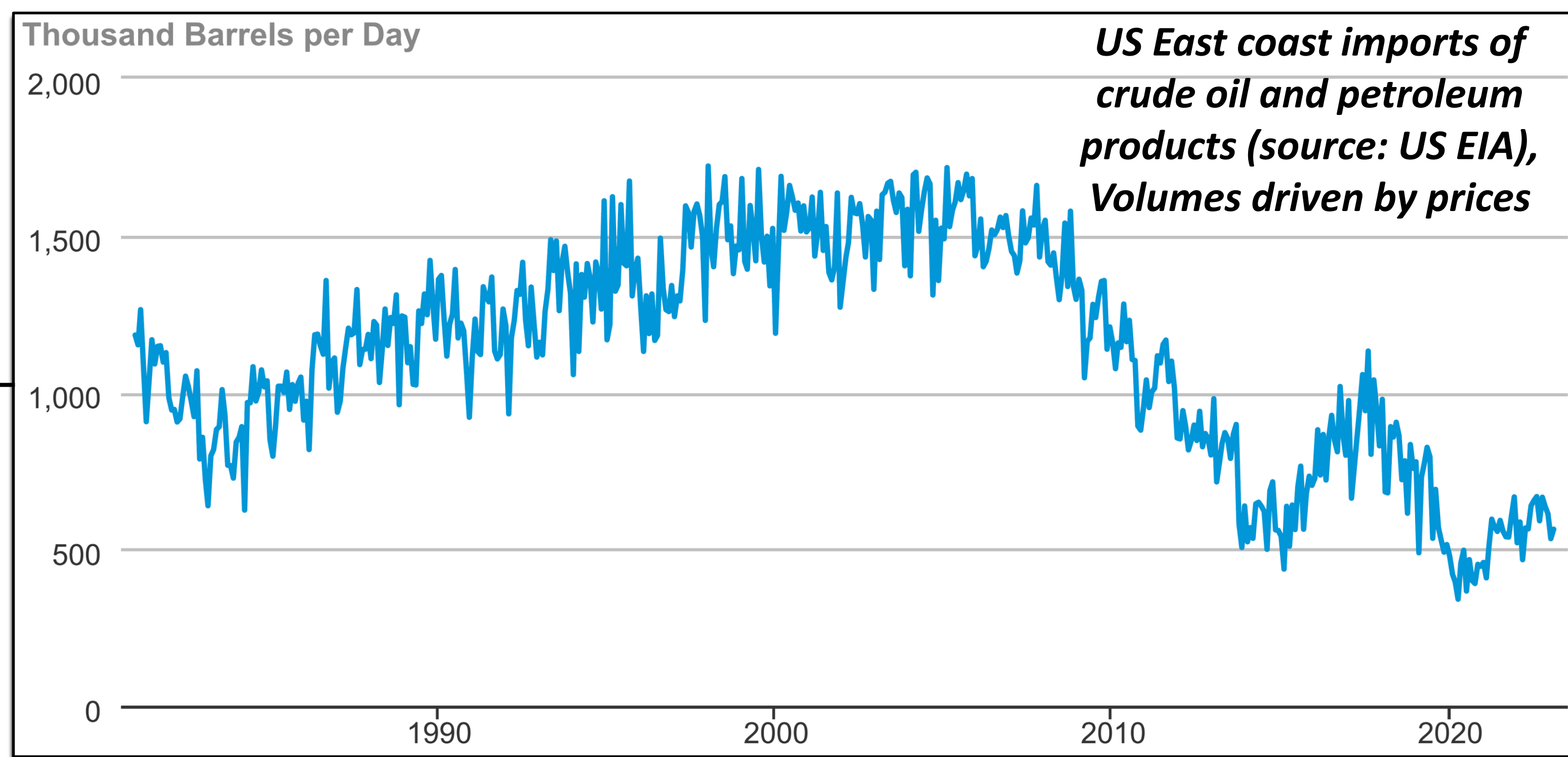


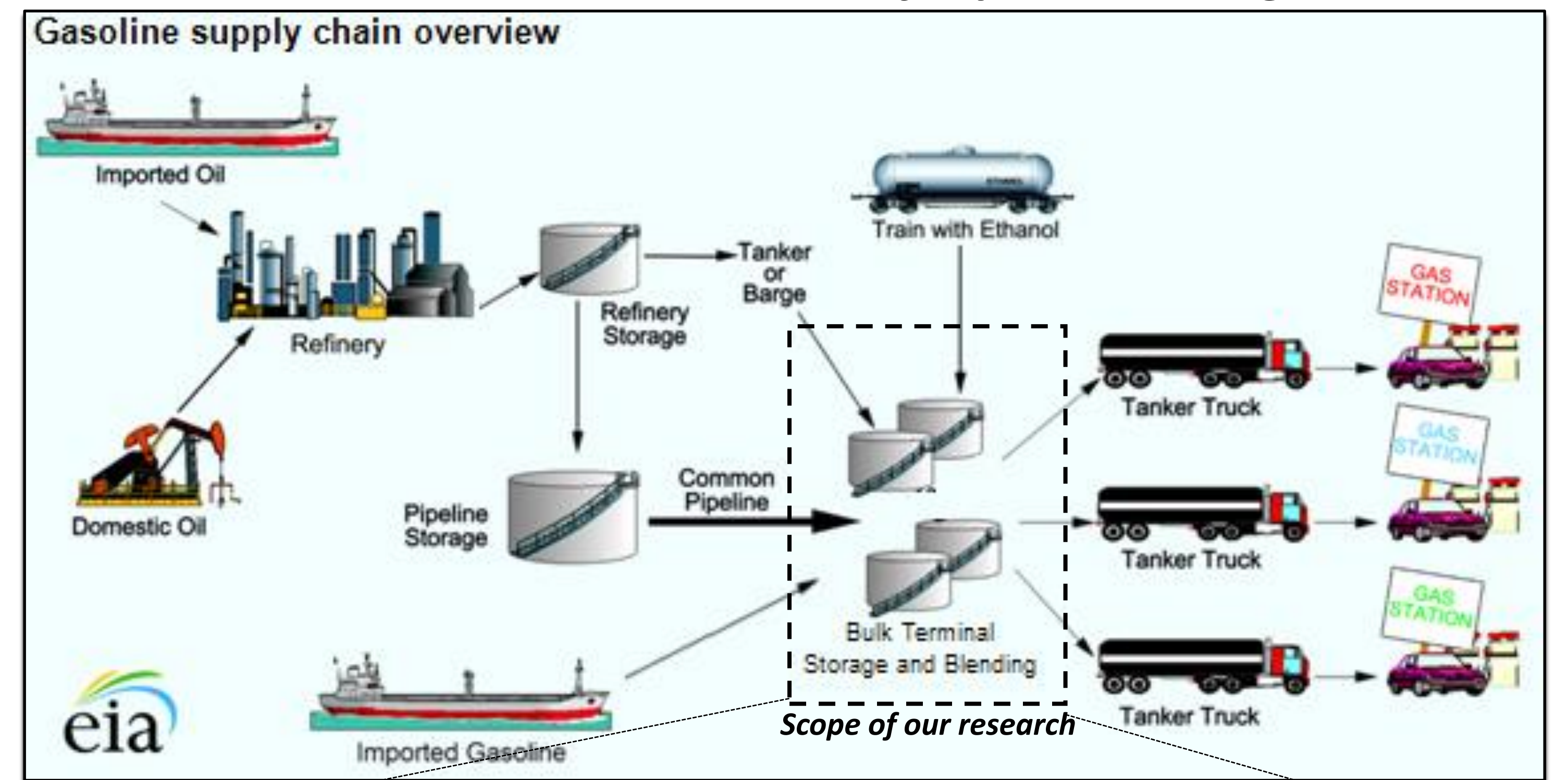
Debjit Roy*, Werner Scheinhardt*, Jan-Kees van Ommeren*

*Indian Institute of Management Ahmedabad

•University of Twente



Tankers handled 3.2 billion tons of liquid bulk cargo in 2019



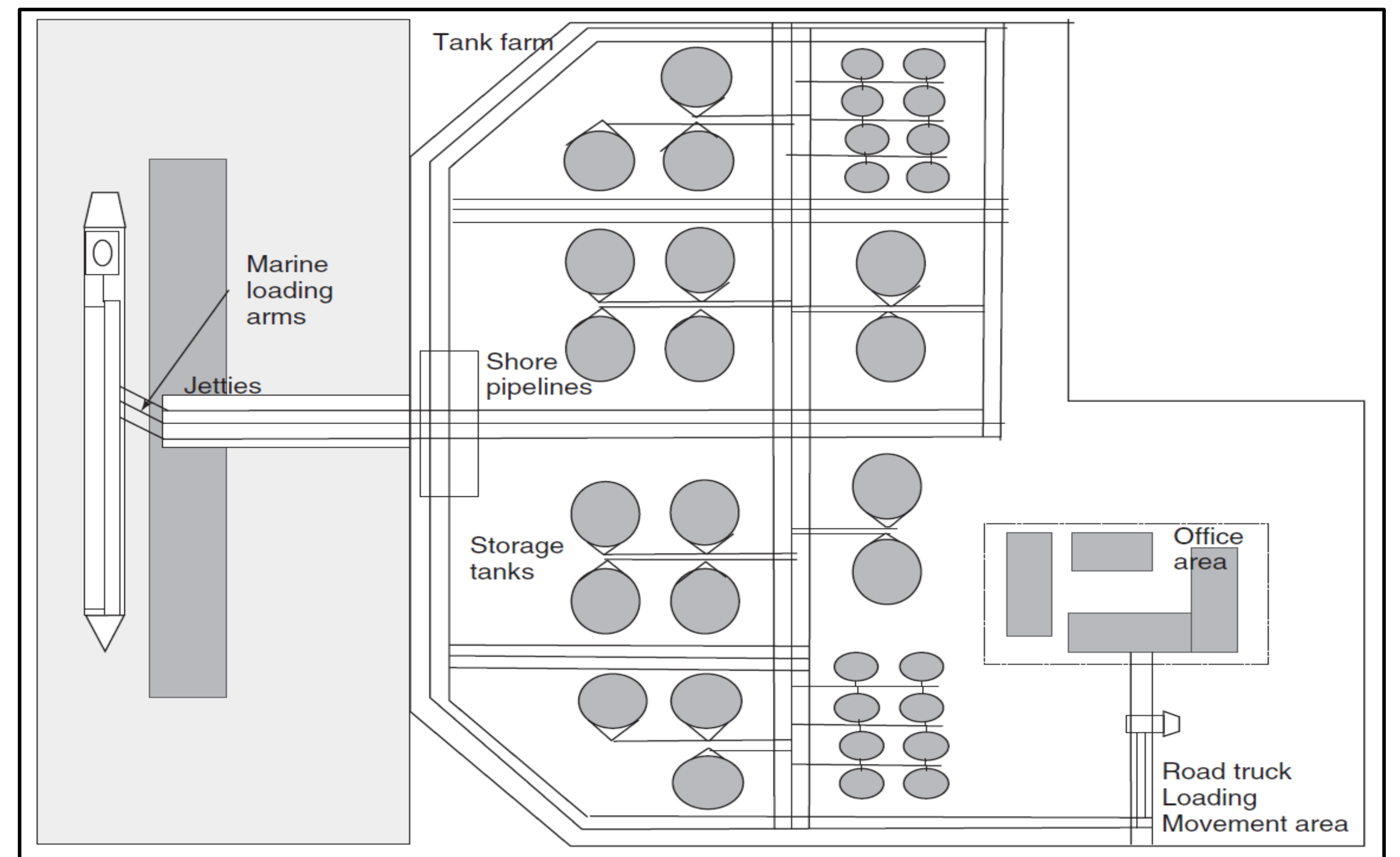
The Logistical Puzzle

Terminal Operators

- Efficient use of terminal equipment
- Design choices: Tank farm storage capacity, loading arms (dedicated or pooled), capacity of loading arms, discharge rate from storage tanks, bunching of vessels

Vessel Operators

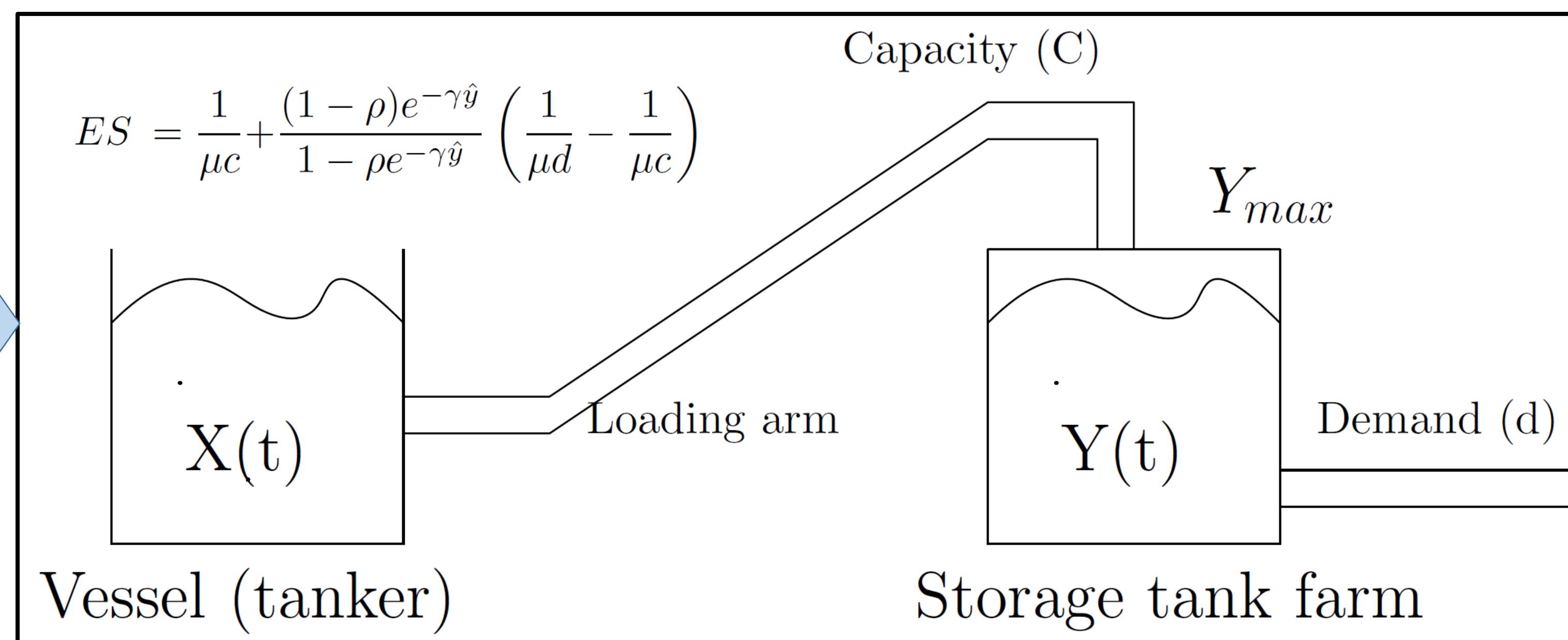
- Reduce turnaround times
- Manage variability (long-term as well as short-term) in vessel arrivals, oil types, tides, pilot availability, vessel size, parcel size



Inputs

parameter	meaning
α	arrival rate of vessels (average)
μ^{-1}	size of vessel load (average)
\hat{y}	size of storage tanks (total)
c	capacity of (un)loading arm
d	demand for oil (average, landside)

Integrated Model



Measures

performance measure
average sojourn time of vessels
average sojourn time per m^3
(variance of sojourn time of vessels)
probability of blocking
probability of (partly) slow unloading
throughput
prob. of empty storage upon arrival
throughput

Model Variants

Model	Vessels	Stor./Feedb.	Loading Arms	Analysis
Single fluid, basic model	1	$< \infty$ / yes	1	direct approach
Single fluid, extended model	≥ 1	$< \infty$ / yes	1	FFQ
Two fluids, no feedback	≥ 1	$= \infty$ / no	≥ 1	FQ, block matrices
—, Exhaustive	—	—	—	—
—, FCFS	—	—	—	—
—, FCFS look ahead	—	—	—	—
Two fluids, partial feedback	≥ 1	mixed	≥ 1	FFQ, block matrices
Two fluids, approx. feedback	≥ 1	approx.	≥ 1	iterating model above

Vessel bunching as a strategy helps?

Storage tanks capacity: 120,000 KL, All times are in hours
Loading arm capacities for two oils are 1400 m^3/hr and 2800 m^3/hr



Arrival rate	Bunching size	E[Bunching time]	E[Berth wait time]	E[Discharge time]	Arm ute.(%)
0.05/day, 0.09/day	1	0.0	187.1	95.9	54.9
	2	177.2	255.5	101.9	58.5
	5	705.6	539.3	120.2	69.3
	10	1600.4	998.8	130.6	74.8
0.06/day, 0.11/day	1	0	187.1	95.9	73.3
	2	140.6	601.7	107.4	77.2
	5	567.8	1451.6	122.3	87.7
	10	1274.2	3587.1	132.9	95.2