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Prospect of Emission Reduction Standard for Sustainable Port Equipment Electrification

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ABSTRACT

Despite efficient carbon monitoring system and the commercialization of battery technology for intra-port transportation, port management are found not deploying environmental equipmentsmainly due to high cost. Port authority who regulates environmental policies lacks leverage to impose tangible reduction standards on emission through concession. This model integrates sustainability into port equipment expansion theory by quantifying viable equipment electrification profile while still observing threeconstraints of operation, cost and environment. A benchmark emission reduction standard (ERS) is surveyed by Delphi method as environmental demand indicator thatsimulates for the electrification of port equipments. The results from Port of Tanjung Pelepas case study suggest an ERS implemented lower than 4% reduction a year is viable to retrofit and replace all electric rubber-tired gantries and prime movers. The simulation model allows informed decision for all port agents to establish viable environmental policies for sustainable port operations.

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NOMENCLATURE

wt_{std}	standardized ship waiting time	t_{op}	time of operation (hr)
n_b	number of required berth unit	cef	carbon emission factor (CO_2 kg/L).
cf	congestion factor	$\bar{X}_{i,j}$	average distance (m)
ets	estimated ship service rate	foc_i	fuel oil consumption (kg CO_2/L)
n_i	units of equipments type i	$NPV_T, NPV_{ZEE}, NPV_{CA}$	types of net present value
$\bar{Q}_{month}$	monthly TEU throughput	C_0	initial investment
f	TEU factor	R_t	port revenue
MPH_i	move per hour of equipment type i	E_t	port expenditure
r_i	handling ratio coefficient	ir	discounted rate
t_s	time of operation service	pth	planning time horizon
n_{ei}	units of new electrical equipment	**Greek Symbols**	
$CO2$	weight of CO_2 emitted	ρ_{std}	standardized berth utilization rate
pr_i	equipment power rating	λ_{ship}	mean ship arrival rate
lf_i	load factor of equipments	μ_{ship}	average service rate of ships

1. INTRODUCTION

In greening container terminal operationally, attention goes to introducing electrification of cargo handling equipment. It is estimated to have energy savings at about 30% [1]. Although clean truck protocol such as Euro 1, 2, 3, 4, 5 & 6 aims to phase out old diesel trucks replacing cleaner engines, these new engines still emit minimal environmental pollutants [2]. Electric truck or prime mover (PM) promises not only higher energy efficiency but also zero-emission with lower operation cost. Pilot testing phase has already commenced in Port

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of Los Angeles (POLA) and Port of Rotterdam (POR) since 2004.

Huge success in port electrification is the retrofitting of ERTGs was reported to yield energy savings of 86.6% was reported, equivalent to 67.79% CO_2 reduction, and 2.2 payback years without compromising operation performance [3]. As for PM, in 2007, POLA launched the MX30 model electric prime mover (EPM) that currently travels at 40 mph for 60 miles on a full charging time of only 6 hours [4]. Electrification by zero-emission equipment is widely studied on its feasibility of deployment. Systematic deployment for zero-emission truck enables optimum zero-emission truck procurement while satisfying the demand throughput and economic performance [5]. Yet some argued that electrification setup and operation of electrical vehicles emits more harmful pollutants in its' life-cycle analysis [6] and does not eliminate the emission but rather merely shifting it indirectly up-stream to its power generator. Nevertheless, port authority and operators should adopt port sustainability of any form under its own authority, jurisdiction and not beyond. CALSTART [7], a strategic consultant of electric truck, has laid out key milestones for electric truck rollout in US starting from pilot test to commercialization and marketing, along with the breakdown of its subsidy and funding.

Last but not the least, technical zero-emission equipment transformation cannot succeed without successful stakeholder management, where strategies for involvement of all relevant parties in the policy-making and execution are properly carried out. Lam and Notteboom [8], who highlighted various green port management keystones, found that Port of Los Angeles (POLA) and Port of Rotterdam (POR) both adopt similar tangible emission reduction standards under California's Carbon Warming Solution Act and Rotterdam Climate Initiative. Each port respectively cutting greenhouse gases at 80% to pre-1990 levels by 2050 and 50% to 1990 levels by 2025. However, these environmental commitments are voluntary and are not in form of legal sanction or standardised operating procedures.

We created a model to simulate zero-emission equipment expansion that not only meet operation and financial performance but also integrates prospective emission restriction. This proposed model adopts a tangible ERS from port survey and simulates the long term zero-emission equipment expansion. This research background assumes the imminent establishment of emission reduction standard, probably by local port authorities under national policy. The simulation foresight will influencethe long-term master port plan moving forward to consider electrification as port plans for expansion.

2. METHODOLOGY

2. 1.Primary Port Equipment Expansion This model simulates the zero-emission equipment expansion along a long-term planning time horizon with the sustainable constraints of (1) operation performance, (2) net present value (NPV) performance and (3) emission reduction standard (ERS).

Priority of port operationconstraint starts where standardized berth utilization rate (ρ_{std}) and standardized ship waiting time (wt_{std}) is observed. These standards are normally instituted at port concession between port authority and port operator agreement [9]. Berth expansion requirementhas to meet the aforementioned two operation key performance index which will in turn simulate forthe primary equipment expansion requirement of quay cranes units and the supporting units of RTGs and PMs.

The basic calculation of berth utilization rate to check against standardized berth utilization rate, ρ_{std}, is checked against performing berth utilization, $\rho_{\text{std}} > \rho$, where ρ is expressed in Equation (1). The equation is in function of the mean ship arrival rateλ_{ship} (ship call/day) and the average service rate of ships, μ_{ship}(ship/day):

$$\rho = \frac{\lambda_{ship}}{n_b \cdot \mu_{ship}} \quad \text{,where } \rho_{\text{std}} > \rho \tag{1}$$

where $n_b$is number of required berth unit. Then, the calculation of waiting time constraint for $\text{wt}_{\text{std}} > wt$, can be expressed as Equation (2):

$$wt = cf \cdot \frac{1}{\mu_{ship}} = cf.ets \quad \text{,where } \text{wt}_{\text{std}} > wt \tag{2}$$

where cf is the congestion factor according to queue type of $E_2/E_2/n$ of Erlang 2, generally used for transhipment port type [10] and ets is the estimated ship service rate (ship/h). One berth is added when the waiting time for ship exceeds the standard time, until constraints$\rho_{\text{std}} > \rho$ and $\text{wt}_{\text{std}} > wt$ are satisfied.

Here, berth productivity after expansion is sustained by the supply of horizontal transport equipments, $n_i$where i represents equipment of quay crane (QC), rubber-tired gantry (RTG), prime-mover (PM). The unit requirement of equipments can be calculated by Equation (3):

$$n_i = \frac{\bar{Q}_{month}}{f \cdot n_b \cdot MPH_i \cdot r_i \cdot t_s} \tag{3}$$

where, f is the TEU factor; n_b is the number of berth (unit), n_i is the units of equipments type i, (unit), MPH_i is the move per hour of equipment type i (move/h), (QC = 32 MPH, RTG = 10 MPH, PM = 6 MPH), t_s is the time of operation service (hours = 24 ××30 days) in monthly interval, r_i is the handling ratio coefficient of equipment, type i.

These will be the primary equipment expansion upon which the model simulates for a systematic electrification of existing port equipments. Rubber-tired gantries (RTG) and prime movers (EPM) are phased-out and replaced with electric models according to the electrification axiom flow chart is described in Figure 1.

2. 2. Port Equipment Electrification Model RTGs will be the primarychoice and first to be electrified as it has conclusive economic benefit. Then, the next key interest is to phase-out conventional diesel PM that contributes the bulk of ports emission and replace them with full EPM. The MX30 electric model is the study subject [4], instead of PM with cleaner engine. The life-cycle of PM and scrap or trade-in value is disregarded in this modelling. Also, the operation disruption of electric bus-bars, recharging station and necessary installation is considered a non-factor. This study concerns only with the relationship of a viable equipment electrification pattern to the change in ERS percentage. Optimization of equipment electrification amount is modelled only within the operation standard constraint.

The electrification is projected on the basis of meeting the estimated emission restriction level at every planning phase of 5 years (monthly interval) as with common port master plan phase. CO_2 constraint by ERS is calculated to determine the amount of emission to be mitigated, ΔCO_2. Then, the required number of equipment electrification, n_{ei} (ei = QC, ERTG and EPM) is simulated by Equation (4).

$$n_i - n_{ei} = \frac{\Delta CO2}{pr_i . lf_i . t_{op} . cef} \quad (4)$$

where n_i is the total number of equipment type i, n_{ei} is the sum of the new electrical equipment of primary expansion and the electrification of old equipment, $pr$is the equipment power rating, lf is the load factor of equipments, t_{op} is the time of operation (hr), cefrepresents the carbon emission factor (CO_2 kg/L).

Activity-based method [11] of estimating emission is adopted to estimate emission. Emission can be expressed as a function of number of equipment, n_i. The electricityconsumption of the electrified equipments can be simulatedto account for operation cost. Geerling formula [11] by distance approach can also provide mathematical verification to the emission calculation by activity approach as expressed in Equation (5):

$$CO2_{\ t} = \sum_{i=1}^{3} Q_t(\bar{X}_{i,j} \times foc_i \times cef) \quad (5)$$

where Q_t is the total throughput handled by diesel equipments, at year *t*, $CO2_{\ t}$ is the weight of CO_2 emitted by total port equipment fleet (kg CO_2), $\bar{X}_{i,j}$ is the average distance (m) for equipment *i* = QC, RTG, PM, route *j* (calculated by first order Minkowski Distance metric of designated ports' route), foc_i is the fuel oil consumption per km (or interchangeably with electricity consumption, ecc_i), cef is the carbon emission factor in kilogrammes of CO_2-emission per lit diesel (= 2.65 kg CO_2/L).

Since literature on carbon emission reduction by quantified percentage is absent, a built scenario of ERS is surveyed. While voluntary commitment of emission reduction by POLA and POR stands at 2.3% and 5% carbon reduction a year, this study takes a simple Delphi survey as case study to assume the emission reduction standard (ERS). The results yield an average ERS of 6% annual CO_2 reduction,where 20 experts from various Malaysian ports' health, safety and environment officers were involved in a two-stage Delphi survey. The first stage solicits a ERS percentage suggestion based on the disclosure of POLA and POR commitment and APM's carbon reduction success cases [12]. Then, the second stage feedbacks the preliminary findings to the participants to reach the consensus of 6% ERS.

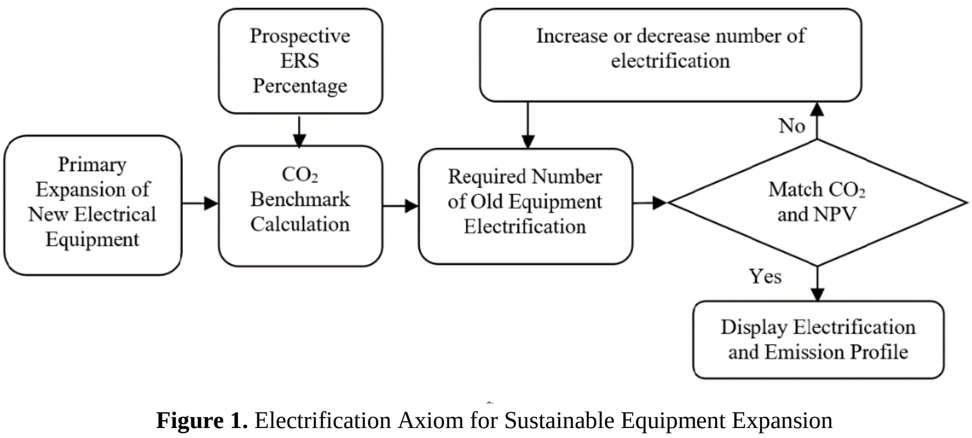

Figure 1. Electrification Axiom for Sustainable Equipment Expansion

After the model simulates the zero-emission equipment profile within the environmental constraint of the surveyed 6% ERS, the model goes on to simulate the financial feasibility of the intended electrification profile. The electrification will be capped at a positive NPV performance constraint described by NPV_{ZEE}> NPV_{CA}, where NPV of zero-emission expansion (ZEE) must exceed NPV of conventional approach (CA). Conventional approach refers to the equipment expansion planning by using diesel equipments. Simulation reiterates for a lesser electrification profile of electrification should NPV of intended electrification profile be lesser than the conventional equipment expansion choice.

Project NPV calculation at phase t, NPV_t, applied in the costing constraint can be expressed in Equation (6):

$$NPV_T = -C_0 + \int_1^T [R_t - E_t] \exp(-ir.pth)\, dt, \quad where,\ NPV_{ZEE} > NPV_{CA} \tag{6}$$

where C_0 is the initial investment, R_t is the port revenue from ship docking charges and container lifting works, as decreed in port concession, while $E_t$is the port expenditure from labour cost, overhead cost and operation cost that comprises fuel, electricity andalso maintenance cost. The cash flow, $CF_t = R(t) - E(t)$, is discounted at rate of 8% along the planning time horizon, pth, usually at 20 years which is the life-span assumed for port equipment.

The two main differences in calculating NPV_{ZEE}andNPV_{CA} is in the varying initial cost for the equipment type, where (1) electric vehicles are more expensive than conventional diesel equipment; and (2) the offsetting of operation cost savings in electricity consumption over fuel consumption. Essentially, sufficient savings from using electricity in the long term must offset the high initial investment on electric equipment to fulfil NPV_{ZEE}> NPV_{CA}. Nevertheless, in practice port managers may see other obstacles that come along with electrification and opt not to execute electrification, regardless of the positive NPV performance. The rate of electricity tariff and fuel oil price are taken from local energy commission.

Other aspects of recurring do not affect the comparative NPV performance. However, for clarity, labour cost and overhead cost adopts the methodology from Nam et. al. [13]. They assumed a two shift labour of two drivers, two signal persons, and one clerk per quay crane, and 1.5 persons for other equipment and a foreman. Overhead cost includes port administration cost, port due to local port authority (for leased land), utilities, maintenance cost per TEU for all equipments and other supporting services. For lack of some confidential data, back-estimation for overhead cost is done from available data of total revenue, labour cost and operation cost for the simulation forecast.

2. 3. Sensititivity Analysis of Emission Reduction Standard Since the interest of this paper is to evaluate the impact of prospective ERS on sustainable equipment expansion, the electrification sensitivity to ERS is analysed. The ERS established by Delphi method yields preliminary consensus of 6% and a sensitivity deviation of ±2%. So, one standard deviation of ERS of 4% and 8% analysed.

Understanding that not all ports are institutionally ready for the deployment of zero-emission equipment, this study runs the simulation under the assumption of port making sustainability a priority and has transitioned along the sustainability path. This green transition, also termed as regulative port institution by Notteboom [14], is state of port governance imposing punitive measures such as retracting operating license of ports who fails to observe environment restrictions. Though some argued that it is unrealistic for underdeveloped or developing countries to adopt sustainability without the leadership of global superpowers, literatures are centred on methodologies that justifies environmental policies implementation for even developing countries [15-17].

3. RESULTS AND DISCUSSION

3. 1. Simulated PTP Case Study Result The model is simulated with Port of Tanjung Pelepas (PTP) as the case study subject. PTP is the world's top 10 and fastest growing transshipment hub situated in Johor, South of Malaysia (Diagram 1).

Diagram 1: Location of PTP

Confidential data of operation and environmental collected that will not be disclosed here and results are also discreetly displayed. Coefficients of operation follows the practice of Johor Port Authority; emission data for verification are solicited from PTP; while financial data are adapted from various sources and are all cited in Table 1.

A prior throughput forecast by univariate method, a simple forecasting of throughput history without considering external and economical factor, is done to determine the equipment demand.

TABLE 1. Specification of Expansion Input Data for Port Equipment Electrification

Parameter	**QC**	**RTG (ERTG)**	**PM (EPM)**	**Reference**
Average Handling Capacity(MPH_i)	30 move/h	11 move/h (11 move/h)	4 move/h (6 move/h)	[18] [19]
Diesel Usage (foc_i)	*N/A*	2.0 L/move (0.25 L/move)	1.7 L/move* (*N/A*)	[20]
Electricity usage (ecc_i)	6 [kWh/move]	(*N/A*) (3 [kWh/move])	(*N/A*) (6.57 [kWh/move])*	[11]
Power Rating (pr_i)	750 kW	450kW (450kW)	75 kw (80 kw)	[21]
Load factor (lf_i)	-	0.2	0.51	
Equipment Cost**	RM 27 Million	RM 4.8 Million (Rm 4.8 Million)	RM 300,000 (RM 861,650)	[4] **PTP
Diesel Fuel Price	RM 2/L	**[22]		
Electric Tariff	RM 0.336 / kW	[23]		
Emission Factor (cef)	1.64 kg CO_2/L	[11]		
Standardised Utilization Rate (ρ_{std})	0.7	PTP		
Standardizied Wating Time ($W_{t,std}$)	2 hours	PTP		
Congestion Factor (*cf*)	0.003355	[10]		

* estimated distance for PTP from GIS by first order Minikowski distance metrics
** converted from USD to RM, at an approximate exchange rate 1:3.88 (Note: RM = Ringgit Malaysia)

For PTP, a projection of an average 3% yearly increment was simulated along a planning time horizon of 40 years from 2014 throughout 2053. The model totals up a lump sum 5-year-expansion requirement over 8 phases. In 2013, PTP has all diesel-powered equipment count of QC = 44, RTG = 148 and PM = 277, where electrification of RTG and PM have yet to be executed. The results omit quay crane expansion because quay cranes are generally electric-powered but its' costing calculation are still included in the NPV evaluation.

This model is encoded in NETLOGO for this discrete-event simulation. The results that show the zero-emission expansion of each the electrical equipment for 4%, 6% and 8% ERS implementation are as in Figures 2 and 3. As this is a simulation of future electrification, the results do not necessary reflect the actual expansion planning set by PTP itself. The model simulates PTP with similar retrofitting pattern for its' RTGs within the first 5 years (phase 1) in all ERS cases (Figures 2, 3 and 4).

Similarly in actual practice, PTP has completed its ERTG electrification in 2016. PTP is a member of APM terminal, a global terminal hub, that has directive to execute ERTG electrification [12].

This white paper is an extensive calls for sustainable port practice with Malaysia southern region ports [24]. Then, RTGs are retrofitted into ERTG (Hybrid ERTGs) that uses bus bar for electric energy but still relies on diesel driving across container blocks. Hence, the residual emission in phases 5, 6, 7 and 8 in Figure 5 attributes to these retrofitted ERTGs. The model simulates not the scraping of equipment but in reality those will have been replaced by new fully electric ERTGs at equipment end-of-life after 4 phase period (20 years). The simulated results for new EPM expansion starts only at secondphase after the electrification of all RTGs.

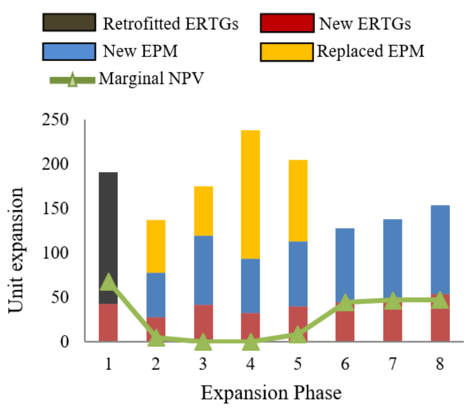

Figure 2. NPV difference at 4% ERS

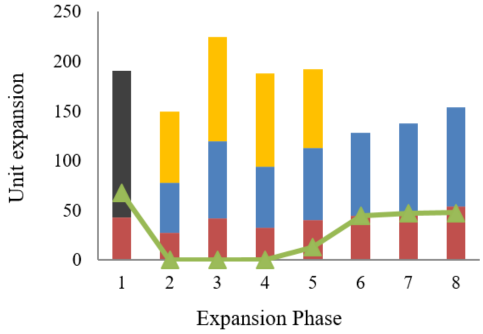

Figure 3. NPV Difference at 6% ERS

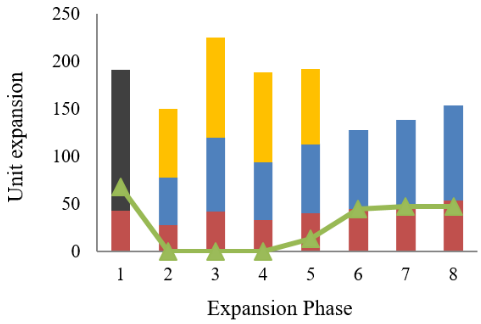

Figure 4. NPV Difference at 8% ERS

Figures 2, 3 and 4 all show again similar pattern of diesel PM being phased out and replaced by new EPM throughout all phases 2, 3, 4 and 5. For cases of 6% ERS (Figure 3) and 8% ERS (Figure 4) which set higher emission limit, by cumulative 30 and 40% reduction over one phase. Therefore, this leads to the fall short of meeting the emission performance at 6 and 8% ERS as seen in Figure 5. Viable electrification can only meet the 4% ERS.

Even though the overall cost of retrofitting RTGs is higher, it yields higher difference in NPV performance from high saving benefits. Soon, as EPM commercializes, EPM will yield lesser savings due to the relatively expensive purchase. Consequently, all Figures 2, 3 and 4 simulates NPV_{ZEE} having small positive margin over NPV_{CA} during the phasing out of diesel-powered PM. After port fully functions on E-PM, it then can reap the benefit of increased NPV value in future. So, only during the phasing out of existing PM the model simulates no improvementin NPV performance. The best option for port authorities is to enter a regulative institution by enforced sustainability without delay for an early recovery of NPV performance, which requires a span of 20 years for PTP case study.

As for emission performance, Figure 5 shows the reduction pattern that flats out and remains constant from phase 5 onwards. This is due to the retrofitting all hybrid ERTGs and EPM. Figure 5 also shows the futility of imposing high and unrealistic ERS, where electrification progress can only meet the 4% ERS standard requirement. For 6 and 8% ERS execution, extra electrificationcould notbe simulated for phase 2 and beyond to reduce emission limited by the positive NPV performance constraint.

Inference drawn on viable zero-emission equipment expansion is the prospect of ERS implementation at lower than 4%. This validates and proof viable the voluntary commitment of POLA and POR to reduce emission at 2 to 5% annually. Although, lower ERS implementation may delay the realization of zero-emission port but environmental policies should be sensible to encourage port operators to collaborate on sustainability to reach a win-win scenario. Furthermore, negotiations for such environmental policy must account the interest of all port agents in respect to ERS suitability. Availability of technology and development of green market, the punitive system should ERS be reasonable. Even with ports getting larger and more competitive,demanding higher efficiency and to be more economical, such environmental policies are certainly still ingrained with port fundamentals which is now an inevitable trend.

Nevertheless, any tools to enhance the decision-making of ERS must be consolidated tomake more informed policies that promises success.Nevertheless, risk of high ERS execution may burden port managers to sustain port revenue and competency. It risksa back fire when port managers find the ERS impossible to achieve and abandon such environment conserving endeavour. Even hard tax on exceeding CO_2 emission performance may not be the solution to electrification. "Green paradox", a term coined by Edenhofer [25] suggesting that an increased energy tax will only inflate the commodity, thus, worsening global warming and the economy instead.

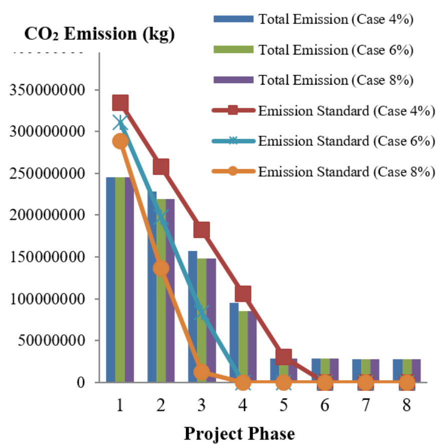

Figure 5. Total Emission Performance vs Planning Phase at ERS4%, 6 and 8%

Therefore, it will be more appropriate to first introduce the energy-efficient measure and then disseminate the know-how before implementing any punitive measures [26].

As is the case of Australia and state of Maryland, USA, which are examples of repealed carbon tax for being unsustainable to business [27]. Carbon tax aims to motivate carbon emitters to pay for externalities of their manufacturing or industrial service.However it requires bilateral adjustment of the policy-makers and industrial players to reach anequilibrium that satisfy the company's profit whileabsorbingthe externality cost. Further incorporation and analysis of various technique such as pareto optimization [28], game theory andneural network with swarm particle optimization [29, 30] are needed to enable managers option adjustment base on their own parametric preference.

3. 2. Discussion of Model Limitation One of some limitations of the model is the assumption of port sustainability transition, in which PTP and its affiliated port agents are ready for green port execution. Notteboom explains that port governance takes three institutional forms in 'cultural cognitive', 'normative' and 'regulative' where in the latter port governance has evolved to be compliant to environmental rules [14]. Socio-technical changes in a group of actors can be modelled computationally to understand port sustainability transition [31]. As a result, such modelling of discrete-event system will become an agent-based system that simulates equipment electrification based on higher tier decision-making from port agents' interaction. It will be interesting to simulate how smaller and conventional ports with different sustainability transition fare in deciding for its equipment electrification.

Without the juxtaposition of risk assessment, this model is not complete without accounting economical factor such as the stability of fuel price that greatly affects the outcome of equipment electrification. Since electricity is the energy source for electrical equipment, comparative NPV_{ZEE} to NPV_{CA} is based on the savings of fuel price over electricity tariff, a crash in fuel price will tip the decision to refrain electrification for a more economical operation by fuel. Though electricity tariff deflation is possible from the depreciation of oil commodity, the interest of port operators should be guaranteed under environmental policies made through port concession.

4. CONCLUSION

We have developed a sustainable model that integrates prospective ERS into port equipment expansion planning without compromising operation and financial performance. Not only does the model simulates for zero-emission equipment instead of cleaner engines, it also re-evaluates feasible ERS percentage execution to spearhead electrification without burdening port managers. The long term equipment expansion simulation with sustainable approach gives insight to electrification requirement with comparative NPV performance. The simulation results from PTP case study infers a viable ERS implementation at 4% (a year) or lower to reduce emission without violating the emission standard and avoid legal consequences. ERTGs and EPMs can be in full deployment after 5 phases (25 years) of short-term planning under standardized expansion parameters. In short, higher expansion NPV can be achieved after all equipments are electrified.Realistic equipment expansion should also include the simulation of port sustainability transition that affects the timing of electrification implementation. Further risk assessment is also necessary to ensure the success of ERS implementation by port master plan, now that electrification of port equipments is imminent.

5. ACKNOWLEDGEMENT

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6. REFERENCES

1. Davarzani, H., Fahimnia, B., Bell, M. and Sarkis, J., "Greening ports and maritime logistics: A review", ***Transportation Research Part D: Transport and Environment***, Vol. 48, (2016), 473-487.
2. Dedinec, A., Markovska, N., Taseska, V., Duic, N. and Kanevce, G., "Assessment of climate change mitigation potential of the macedonian transport sector", ***Energy***, Vol. 57, (2013), 177-187.
3. Yang, Y.-C. and Chang, W.-M., "Impacts of electric rubber-tired gantries on green port performance", ***Research in Transportation Business & Management***, Vol. 8, (2013), 67-76.
4. Adams Lopez, T., *Electric truck demonstration project fact sheet*. 2008, Port of Los Angeles.
5. Hartman, B.C. and Clott, C.B., "An economic model for sustainable harbor trucking", ***Transportation Research Part D: Transport and Environment***, Vol. 17, No. 5, (2012), 354-360.
6. Lucas, A., Silva, C.A. and Neto, R.C., "Life cycle analysis of energy supply infrastructure for conventional and electric vehicles", ***Energy Policy***, Vol. 41, (2012), 537-547.
7. Calstart, I., *I-710 project zero-emission truck commercialization study final report*. 2013, Pasadena.

8. Lam, J.S.L. and Notteboom, T., "The greening of ports: A comparison of port management tools used by leading ports in asia and europe", ***Transport Reviews***, Vol. 34, No. 2, (2014), 169-189.

9. Novaes, A.G., Scholz-Reiter, B., Silva, V.M.D. and Rosa, H., "Long-term planning of a container terminal under demand uncertainty and economies of scale", ***Pesquisa Operacional***, Vol. 32, No. 1, (2012), 55-86.

10. Tsinker, G.P., "Port engineering: Planning, construction, maintenance, and security, John Wiley & Sons, (2004).

11. Geerlings, H. and Van Duin, R., "A new method for assessing co2-emissions from container terminals: A promising approach applied in rotterdam", ***Journal of Cleaner Production***, Vol. 19, No. 6-7, (2011), 657-666.

12. Moller), A.A.P. *Apm terminals to retrofit and electrify rtg fleet worldwide*. 2011.

13. Nam, K.-C., Kwak, K.-S. and Yu, M.-S., "Simulation study of container terminal performance", ***Journal of Waterway, Port, Coastal, and Ocean Engineering***, Vol. 128, No. 3, (2002), 126-132.

14. Notteboom, T., De Langen, P. and Jacobs, W., "Institutional plasticity and path dependence in seaports: Interactions between institutions, port governance reforms and port authority routines", ***Journal of Transport Geography***, Vol. 27, (2013), 26-35.

15. Newell, R.G., Pizer, W.A. and Raimi, D., "Carbon markets 15 years after kyoto: Lessons learned, new challenges", ***Journal of Economic Perspectives***, Vol. 27, No. 1, (2013), 123-146.

16. Bridge, G., Bouzarovski, S., Bradshaw, M. and Eyre, N., "Geographies of energy transition: Space, place and the low-carbon economy", ***Energy Policy***, Vol. 53, (2013), 331-340.

17. Pearce, D., Barbier, E. and Markandya, A., "Sustainable development: Economics and environment in the third world, Routledge, (2013).

18. Loke, K., Saharuddin, A., Ibrahim, A. and Rizal, I., "Container handling efficiency", in Proceedings of the 4th International Conference on Marine Technology. (2004).

19. Saanen, I., "Mega ships: Positive asset or terminals' worst nightmare", ***Network***, Vol. 3, (2013), 86-106.

20. Longo, F., Bruzzone, A., Nicoletti, L., Massei, M. and Spadafora, F., "An advanced and flexible simulation tool for environmental impact evaluation and sustainability enhancement in marine ports", ***International Journal of Engineering, Science and Technology***, Vol. 6, No. 3, (2014), 70-84.

21. Browning, L., "Current methodologies in preparing mobile source port-related emission inventories", ***In Final Report for US Environmental Protection Agency***, Vol., No., (2009).

22. World Bank. *Pump price for diesel fuel*. 2014.

23. Mekhilef, S., Barimani, M., Safari, A. and Salam, Z., "Malaysia's renewable energy policies and programs with green aspects", ***Renewable and Sustainable Energy Reviews***, Vol. 40, (2014), 497-504.

24. JPA. *Johor port authority green port policy 2014-2020*. 2014.

25. Edenhofer, O. and Kalkuhl, M., "When do increasing carbon taxes accelerate global warming? A note on the green paradox", ***Energy Policy***, Vol. 39, No. 4, (2011), 2208-2212.

26. Vera, S. and Sauma, E., "Does a carbon tax make sense in countries with still a high potential for energy efficiency? Comparison between the reducing-emissions effects of carbon tax and energy efficiency measures in the chilean case", ***Energy***, Vol. 88, (2015), 478-488.

27. Taylor, R. and Hoyle, R., "Australia becomes first developed nation to repeal carbon tax", ***Retrieved from The Wall Street Journal website: http://www. wsj. com/articles/australia-repeals-carbon-tax-1405560964***, (2014).

28. M., Z., J., R. and Shokoufi K., "Pareto-based multi-criteria evolutionary algorithm approach for parallel machine scheduling problem with sequence-dependent setup times", ***International Journal Of EngineeringTransaction C: Aspects***, Vol. 30, No. 12 (2017), 1437-1446.

29. Delkhosh, M. and SAADAT, F.M., "Multi-objective optimization of hybrid electric vehicle equipped with power-split continuously variable transmission", ***International Journal of Engineering (IJE), Transactions C: Aspects***, Vol. 29, No. 3, (2016), 368-377.

30. Ghasemi, J. and Rasekhi, J., "Traffic signal prediction using elman neural network and particle swarm optimization", ***International Journal of Engineering-Transactions B: Applications***, Vol. 29, No. 11, (2016), 1558-1564.

31. Markard, J., Raven, R. and Truffer, B., "Sustainability transitions: An emerging field of research and its prospects", ***Research Policy***, Vol. 41, No. 6, (2012), 955-967.

Prospect of Emission Reduction Standard for Sustainable Port Equipment Electrification

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چکیده

علیرغم سیستم مانیتورینگ کربن کارآمد و تجاری سازی تکنولوژی باطری جهت انتقال درگاه داخلی، مدیریت درگاه بدلیل هزینه بالا عموما در تجهیزات محیط زیست مورد استفاده قرار نمی گیرد. مسئولین درگاه که سیاست های محیط زیست را قانون گذاری می کنند از کمبود قدرت نفوذی رنج می برند که کاهش محسوس استانداردها را از طریق امتیازی که دارند بر روی انتشار تحمیل کنند. این مدل، نگهداشت پذیری را با تئوری توسعه تجهیزات درگاه از طریق سنجش پروفایل تجهیزات الکترونیکی موفق ادغام می کند در حالی که همچنان سه مانع شامل اجرا، هزینه و محیط زیست را پیش رو دارد، یک استاندارد کاهش معیار برون ریزی ERS بوسیله روش دلفی مورد نظرسنجی قرارگرفت به عنوان شاخص درخواست های محیط زیستی که الکترونیکی کردن تجهیزات درگاه را شبیه سازی کند. نتایج از درگاه مورد مطالعه تانجونگ پلپاس یک ERS را نشان می دهد که باعث کمتر از 4 درصد کاهش سالانه شد که این امر تایید کننده توانایی کارکردن موفق و تکمیل و جایگزینی تمامی بست های الکترونیکی پلاستیکی خورده شده و جابه جا شونده های اصلی می باشد. این مدل شبیه سازی شده اجازه تصمیم تغییرشکل داده شده برای همه عوامل درگاه را می دهد و سیاست های موفق زیست محیطی را جهت اجرای درگاه پایدار بنیان می گذارد.

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