PERFORMANCE INDICATORS IN BENCHMARKING OF MARITIME LOGISTICS CHAINS

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ABSTRACT

A benchmarking study is a useful tool for a shipping company to measure and compare the performance of alternative logistics chains in order to find a way to provide better logistics service. The selection of a set of key performance indicators (KPIs) and identification of the interrelationships between the input parameters and KPIs are two important parts of a benchmarking study. In this paper, we investigate different performance measures relevant in the benchmarking of alternative logistics chains, which include cost, time, environmental efficiency, flexibility and reliability. This correspond to a set of detailed metrics to be used as KPIs, such as the total cost, the estimated delivery time, CO_2 emission, spare capacity, service frequency, deviations of schedule, and insurance cost. The relationship between different input parameters and those KPIs are analyzed and described in the cause-and-effect analysis chart. In the illustrative example, we use a simulation model to capture the logistics activities for the alternative chains from which the relevant KPIs can be derived. We further analyze the impacts of different input parameters on emission performance in a maritime shipping chain to identify the key variable(s) based on this simulation model.

Key words: performance measurement, key performance indicators (KPIs), benchmarking, maritime logistics chain, simulation.

1. INTRODUCTION

For many shipping companies, today's competition not only takes place in the traditional sea transportation area, but also in the hinterland transportation. Some shipping companies have already extended their service to cover the whole logistics chain to gain competitive strength since they have some degree of choice how to deliver cargos between locations. In order to handle the increasing competition, it is vital for a shipping company to achieve a continuous and sustainable improvement. Among many of the improvement tools, benchmarking has been become an increasingly popular and useful tool since Xerox Corporation used this method to regain their market shares in 1980s (Camp, 1989).

In this paper we discuss how a shipping company can use benchmarking to measure and compare their alternative logistics chain performances both in economic and environmental perspectives in order to help the company find a way to provide better logistics service and also to achieve continuous improvement in the long term. The suitable and sensible selection of key performance indicators (KPIs) is the basis and one of the significant parts of the performance measurement and benchmarking study.

The main focus in this paper is on the selection of KPIs, and the general interrelationships between input parameters and those KPIs for the measurement and benchmarking. The paper is organized as follows: in Section 2, we discuss this selection of suitable KPIs for benchmarking of maritime logistics chains. The interrelationships between model inputs and KPIs are identified and illustrated based on the cause-and-effect analysis chart in Section 3. An illustrative example is presented based on the simulation model in Section 4. We give our conclusion and future work direction in Section 5.

2. THE SELECTION OF KEY PERFORMANCE INDICATORS (KPIs)

2.1 LITERATURE REVIEW

The process of benchmarking starts with choosing what to benchmark and proceeds through selecting parameters to measure, data gathering and analysis, the determination of the suitable best practice and ends with finding ways implementing the selected best practice. Choosing the parameters to be measured is one of the critical parts of the whole benchmarking project.

From the literature research, we find that, as a general trend, organizations increasingly focus on non-financial factors, including product quality, flexibility and reliability, product variety and innovation, instead of only on financial metric (Beamon, 1998; Bititci, Suwignjo et al., 2001; Andersen and Fagerhaug, 2002). However, many performance indicators used in supply chains or logistics chains are derived from manufacturing practice. We also can find that some of those metrics are proposed for specific logistics functions, such as port operation, warehousing management. However, among all of those indictors, we can find some are relevant and useful to the delivery performance in maritime logistics chains. For instance, lead time, the percentage of goods in transit, the number of faultless notes invoiced, the flexibility of delivery systems, total distribution cost are suggested to be used to measure the delivery performance (Gunasekaran, Patel et al., 2001). In the project concerning benchmarking inter-modal freight transport in UK, the metrics including vehicle utilization, empty running, fuel consumption, deviation of delivery schedule are used to be the KPIs to measure and compare the performance of food logistics chain (OECD, 2002). Cost and quality are regarded as the performance metrics for an intermodal transportation system where cost is divided into different parts including: operating cost in terms of various transport modes, cost in terminals, infrastructure charges, cost of infrastructure-related services, intermodal loading unit costs and chain management costs etc, while quality is measured by time, flexibility and reliability (Vrenken, 2005). Delivery performance, flexibility and responsiveness, logistics cost and asset management are identified as key factors to the logistics chains excellence (Wong, 2008). From this, we can conclude that in terms of the performance measurement of maritime logistics chains, cost, flexibility and reliability are the metrics we should draw attention to.

Traditionally the focus has been on cost vs. service level in terms of performance metrics. In recent years, energy efficiency and emissions have gained importance. With respect to green performance measurements, environmental impact is taken into account besides time, cost, quality, volume, flexibility (Andersen and Fagerhaug, 1999). In particular, they divide the green performance indicators into three levels: strategic, tactical and operational levels. We can look into the metrics they use for operational level. The main dimensions of performance at this level include the amounts of waste or pollution produced the energy or irreplaceable consumed with the business process. Air emissions, energy recovery and recycling are used to measure the environmental performance in the green supply chain management and performance measurement system (Hervani, 2005). In (Rothenberg, 2005), they discuss the performance indicators used to do environmental benchmarking in the automobile industry. The metrics they use include regulatory, gross emission efficiency and life cycle. We see that those metrics discussed above are still mostly from the perspective of manufacturers rather than the logistics providers themselves. When designing the metric for measuring the environmental performance for a maritime transport chain, we should consider more about the characteristics of shipping activity itself. In the shipping area now, one of the most common metrics for environmental efficiency is various kinds of the air emission, especially the CO_2 emission (IMO, 2000; MARINTEK, 2010).

In this study, we design the set of performance indicators from the viewpoint of a shipping company. We include such parameters as, CO_2 emission, flexibility and reliability as a part of KPIs to measure the chain's environmental efficiency and capability of handling future uncertainty.

2.2 THE SELECTION OF KPIs

2.2 (a) Cost and time performance

The cost and time performance is measured by KPIs as follows:

- Total Cost ($/Ton-Km): Only operational cost is covered in this case. Hence the total cost here refers to the sum of the fuel cost of different vehicles and handling cost in various terminals. This KPI is a financial metric. We measure the total cost based on the activities in the transport process (Brown 1996). This helps the shipping company to know which part of the process might be the bottleneck in the whole logistics chain and then they can have a better control on the real operational costs.

- Estimated Total Delivery Time (Hour): Delivery Time is a key process measure for a transport task since it is not only relevant to the cost, but also it is always about the customers' needs. The total delivery time includes transport time, handling time, and waiting time.

2.2 (b) Environmental efficiency performance

In this paper we focus on CO_2 emission since it is a main part of greenhouse gas (GHG) and the emissions from other GHG can be achieved in a similar calculation method. In transportation, fuel consumption is one of the primary sources of CO_2 emission. Better cargo-handling gear, ability to cruise efficiently at different speeds, schedule optimization, and ballast optimization are all operational methods to reduce emissions and improve the energy efficiency, which provide many options for improvement. The emission is divided into 3 scopes in the GHG protocol initiative (GHG Protocol Initiavite 2004). In this paper, it mainly refers to Scope 1 emission which directly comes from sources controlled by a shipping company itself, for instance, the emission caused by fuel consumption used by all vehicles. The KPI selected for environmental efficiency is:

- CO2 Emission (Kg/Ton-Km): It refers to the CO2 emission from the fuel consumption used by vehicles and handling equipment in the whole transportation process.

One problem is how to assign the cost and emission with multiple cargos and transport modes, since it is far from obvious how cost or emission should be allocated when we have complex multi-stage movements with numerous different service players and transportation modes. A brief summary of a potential way to do it is given in Table 1. We only consider one cargo which is container in the illustrative example. Therefore we simply assign the cost and emission based on cargo weight and transport distance (ton-km). As concerned to the varying loading factor and return transportation, we initially assume the utilization of container lines general is 50%-100% one way and 20%-70% the other way and for the truck transport, we consider 100% one way and 50% the other way (Asbjørnslett, Lindstad et al. 2010; Lindstad, Mørkve et al. 2010; MARLEN Project Team 2010). We can change those values in the simulation model directly in order to check their impacts on the different performance in the example.

Table 1: Cost and Emission Assignment

Transport Mode / Cargo Type	Single Mode	Multiple Modes	Return Route
Single Type of Cargo	Cargo Unit* for example: General Cargo/Container: per TEU-km/ per ton-km; Vehicle: per Vehicle-km; Passanger: per passanger-km	the smallest "non-divisible"loading unit or Cargo Unit*	Considering the average capacity ulitization
Multiple Cargos	Cargo Unit**	Loading Unit***or Cargo Unit ** if needed	
*: based on the dimensions of cargo (weight, volumn)			
**:based on the dimensions of cargo (value or freight rate)			

2.2 (c) Flexibility performance

Shorter lead time and higher demand variance are making logistics flexibility increasingly important. A flexible service is the one which is able to handle the unforeseen fluctuations in demand or circumstance (Vrenken 2005). A flexible transport chain should be ready to satisfy the dynamic cargo demand in the market. Flexibility is one of the metrics used to measure and benchmark the service quality of a logistics chain. Because of numerous service players on different levels of chains and the various characteristics of transport modes, it is a big challenge and a potential success factor for a shipping organization.

- ❖ Spare capacity (Ton): It refers to the difference between the available capacity of a given logistics chain and the given specific cargo demand in one shipment. This tells in a given logistics chain, if there are sufficient vehicle fleets to cope with the dynamic markets.

- ❖ Service Frequency (/Week): high frequency logistics schedule decrease response time. It is easy to change the transport plan in case of the cargo priorities and demand fluctuations. This KPI shows how often the transport service is provided in every week.

2.2 (d) Reliability performance

Like flexibility, reliability also can be regarded as the measurement of service quality. Increasing number of manufacturing companies is pursuing the Just-in-Time (JIT) strategy for their supply chains. Because of this kind of time compression strategy, if the goods in the logistics chain are delayed, or damaged, there is not enough time to fix the issue which causes the extra cost. Hence, it is vital for a shipping company to provide a reliable logistics service in order to decrease the risk of such kinds of failures. Logistics services can be considered reliable if the cargos are collected and transported at the right time and arrive in the accepted condition. Hence we develop different KPIs to measure the reliability of logistics chain:

- ❖ Deviations from schedule (Hour): we use this indicator to check the punctuality of the delivery service. It shows the difference between the real time used to finish the delivery and the customer's requirement. In our case, any deviations could be caused by congestion at different terminals, lack of vehicles.

- ❖ Insurance cost ($/Ton-Km): for long transport process, we also can measure the reliability in aspect of cargo safety and security since the insurance cost can directly reflects high risks and accident (Vrenken 2005).

3. THE RELATIONSHIP BETWEEN INPUT AND OUTPUT PARAMETERS

3.1 INPUT AND OUTPUT PARAMETERS

We outline the analysis framework of benchmarking and the input and output metrics in the figure below:

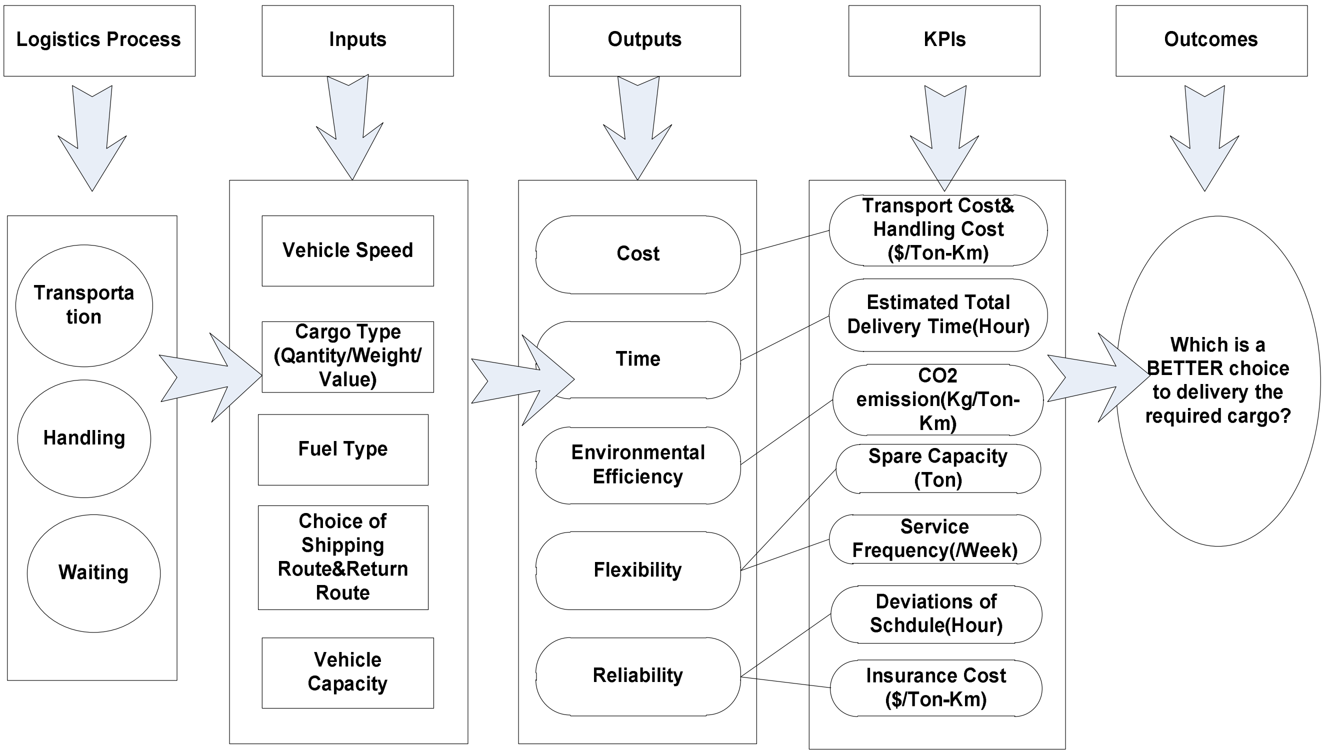

Figure 1: The analysis framework of the benchmarking process

We can achieve different measurement or benchmarking results if we change the values of those input parameters. In Figure 2, we list the more specific inputs. In the illustrative example in the next section, we investigate how each of those inputs such as loading factor, vehicle speed and handling rate influences the emissions.

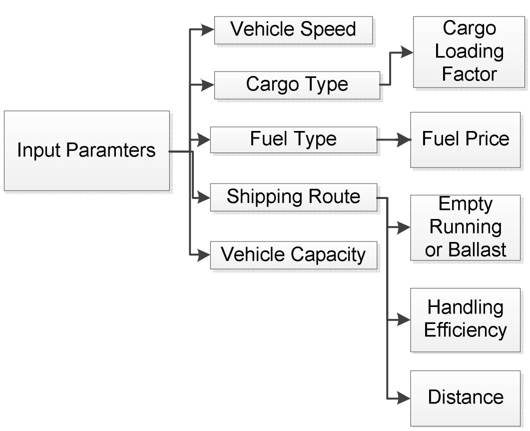

Figure 2: Input parameters

In the following part we give the specific formulations to measure all KPIs according to the discussion in Section 2:

- ❖ Cost – Total Cost:

$$TC = f(\text{TransportationCost}, \text{HandlingCost}) = \frac{\sum_{i\in K}\sum_{j\in K}\sum_{v\in V} C_{ijv}^{T} + \sum_{i\in K}\sum_{v\in V} C_{iv}^{H} + \sum_{j\in K}\sum_{v\in V} C_{jv}^{H}}{(\sum_{i\in K}\sum_{j\in K} d_{ij}) * Q}$$

- ❖ Delivery Time - Estimated total delivery time:

$$TT = f(\text{TransporationTime}, \text{HandlingTime}, \text{WaitingTime}) = \sum_{i\in K}\sum_{j\in K}\sum_{v\in V} T_{ijv}^{T} + \sum_{i\in K}\sum_{v\in V}(T_{iv}^{H} + T_{iv}^{W}) + \sum_{j\in K}\sum_{v\in V}(T_{jv}^{H} + T_{jv}^{W})$$

- ❖ Environmental Efficiency - CO_2 emission:

$$TE = f(\text{EmissionTransport}, \text{EmissionTerminal})$$

$$= \frac{\sum_{\mathrm{i}\in \mathrm{K}}\sum_{\mathrm{j}\in \mathrm{K}}\sum_{\mathrm{v}\in \mathrm{V}}\sum_{\mathrm{f}\in \mathrm{F}} \mathrm{E}^{\mathrm{T}}_{\mathrm{ijvf}} + \sum_{\mathrm{i}\in \mathrm{K}}\sum_{\mathrm{f}\in \mathrm{F}} \mathrm{E}^{\mathrm{H}}_{\mathrm{if}}}{(\sum_{\mathrm{i}\in \mathrm{K}}\sum_{\mathrm{j}\in \mathrm{K}} d_{ij}) * Q}$$

❖ Flexibility – Spare Capacity:

$$\mathrm{TF}^{\mathrm{SC}} = f(\text{VechicleCapacityMax,CargoDemand})$$
$$= \mathrm{Min}\{\mathrm{q_{ij}}\} - \mathrm{Q}\ , \qquad \mathrm{i,j} \in \mathrm{K}$$

❖ Flexibility – Service Frequency:

$$\mathrm{TF}^{\mathrm{SF}} = \mathrm{N}$$

❖ Reliability - Deviations of the schedule:

$$\mathrm{TQ}^{\mathrm{D}} = f(\text{DeliveryTime,RequriedTime})$$
$$= \left|\frac{\mathrm{TT}}{\mathrm{P}} - \text{RequiredTime}\right|$$

❖ Reliability – Insurance Cost:

$$\mathrm{TQ}^{\mathrm{IC}} = f(\text{ChoiceOfShippingRoute})$$
$$= \sum_{\mathrm{i}\in \mathrm{K}}\sum_{\mathrm{j}\in \mathrm{K}} \mathrm{C}^{\mathrm{I}}_{\mathrm{ij}}$$

Where,
TC – Total Cost
TT – Estimated total delivery time
TE – Total CO_2 emission
$\mathrm{TF}^{\mathrm{SC}}$ – Spare Capacity
$\mathrm{TF}^{\mathrm{SF}}$ – Service Frequency
TQ^{D} – Deviations of the schedule
$\mathrm{TQ}^{\mathrm{IC}}$ – Insurance Cost
i K, j K, K-logistics nodes
f F, F - fuel type
v V, V - vehicle type
C^{T} – Transportation cost
C^{H} – Handling cost
C^{I} – Insurance cost
T^{T} – Transportation time
T^{W} – Waiting time
T^{H} – Handling time
E^{T} – CO_2 emission from transportation
E^{H} – CO_2 emission from handling
Q – Cargo demand
$\mathrm{d_{ij}}$ – Arc distance , i, j K
$\mathrm{q_{ij}}$ – Arc capacity , i, j K
P – the Probability of punctuality
N – the Number of service finished in one week

We know that there exist some trade-offs among those metrics. In order to have a good time performance, air or pure road transportation is preferred which, on the other hand, cause high CO_2 emission and increase the cost. The same could happen when we want to keep or improve the flexibility, also leading to high cost. Flexible service typically implying large spare capacity, frequent service, or multi-choice logistics routes, always calls for good quality infrastructure with intensive investment. Thus, the final decision needs to take the preference structure of the individual customer into account.

3.2 CAUSE-AND-EFFECT ANALYSIS

If we look into the inputs list in Figure 2 in detail, we find there are more root causes which lead to different outputs, in other words, different performance of alternative logistics chains. In order to improve the operational performance in effective and efficient way, it is helpful to know which input parameter has larger impact on the specific outcome. Hence, we use cause-and-effect diagram here to list all important inputs of the operational performance for the maritime logistics chains. It also illustrates the relationship between the input and output parameters in more detail (See Figure 3).

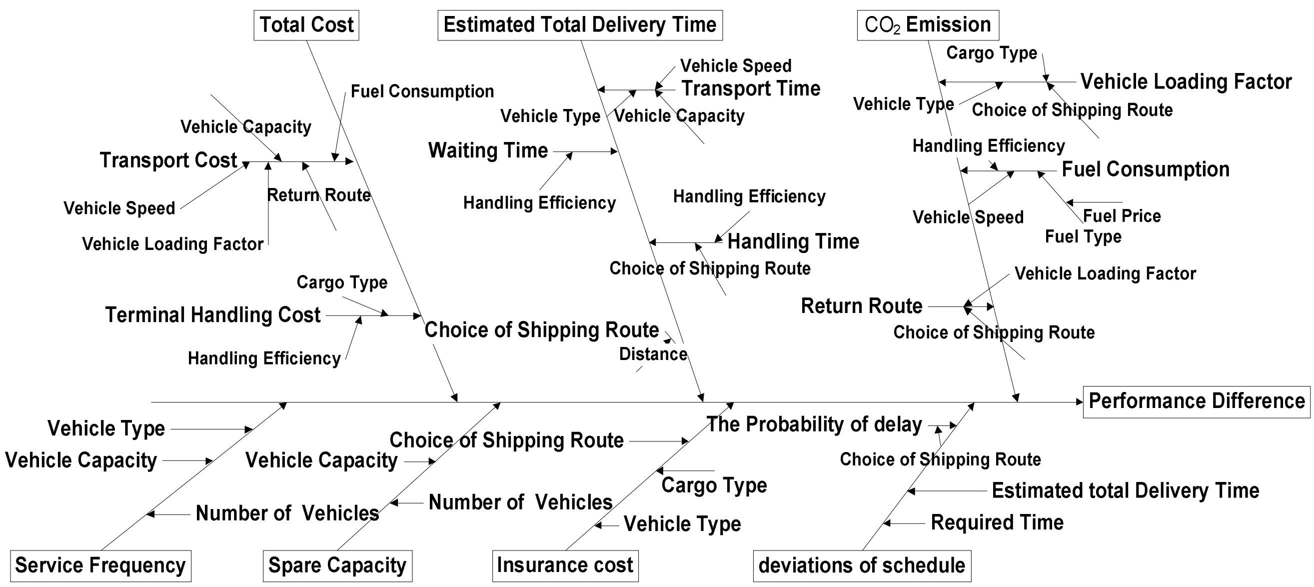

Figure 3: Cause-and-Effect analysis for benchmarking

We take cost performance as an example. It depends on transport cost and terminal handling cost. The transport cost here is regarded as the function of fuel type, vehicle capacity, vehicle speed and cargo type. Also it is relevant if a return route is included or not. Similarly, we can get the different possible causes for all the different performance or outcomes we want to measure. Based on this analysis, we can go further to discuss which input among all of the parameters has more impact. This helps us know, for instance, if it is more sensible to change the vehicle speed or increase the vehicle capacity in order to achieve better cost performance.

3.3 ILLUSTRATIVE EXAMPLE - EXAMPLE DESECPTION

We provide an example here that shows how a simple logistics chain can be captured by a simulation model from which both the KPIs and the relevant interactive effects can be determined. We assume a shipping company frequently transports one container with 20-ton cargo in one 20 TEU container from Trondheim (TRD) to Bergen (BEG) in 2 working days according to cargo owner's requirement. The shipping company has two options: one is to deliver the container combined by truck and short-sea, which needs transfer in Ålesund (ALE) while the second is by truck from TRD to BEG directly. The shipping company now wants to determine which one is better. In this example, we compare and benchmark the performance of those two solutions based on five aspects of performance we mentioned above. We use simulation tool to derive all relevant KPIs except the insurance cost since it is a short distance delivery task. We assign the cost and emission according to the cargo weight and distance.

We use the simulation toolbox ExtendSim to model the whole logistics process and get the results of performance measurement. Parts of the model are illustrated in Figure 4 and Figure 5.

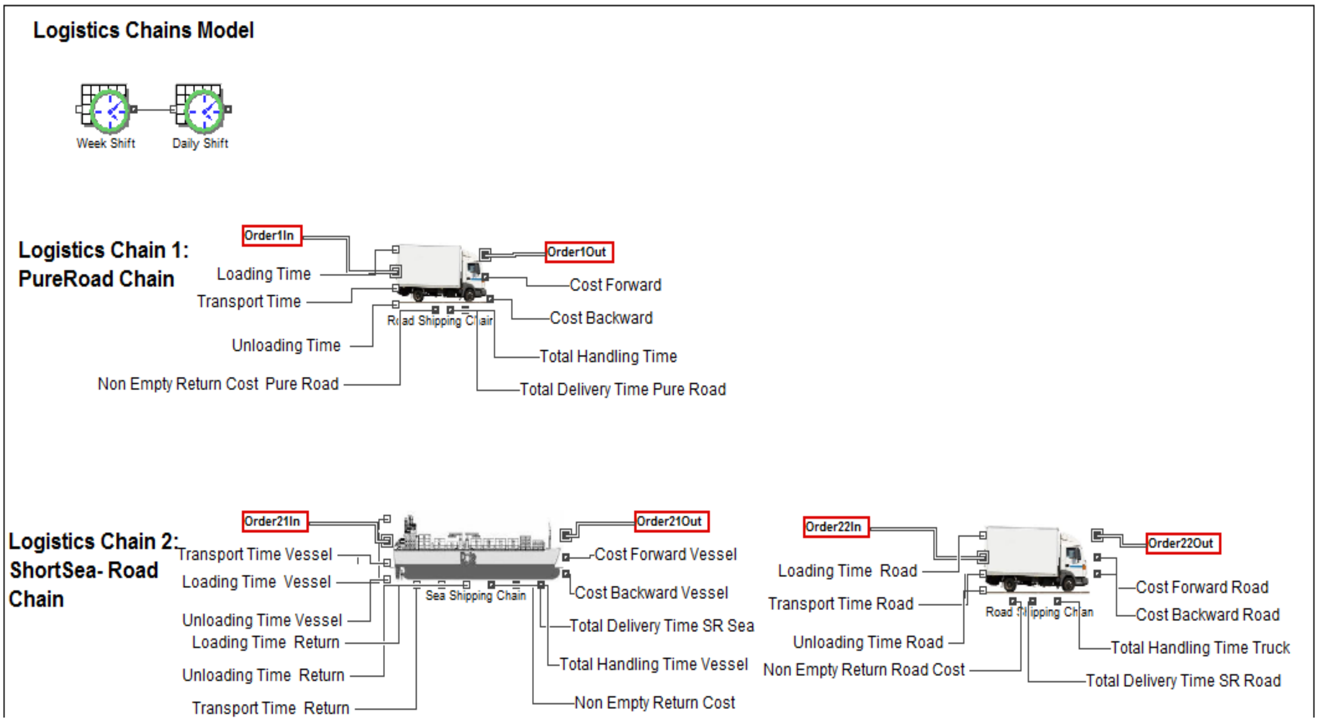

Figure 4: Simulation model for the alternative chains

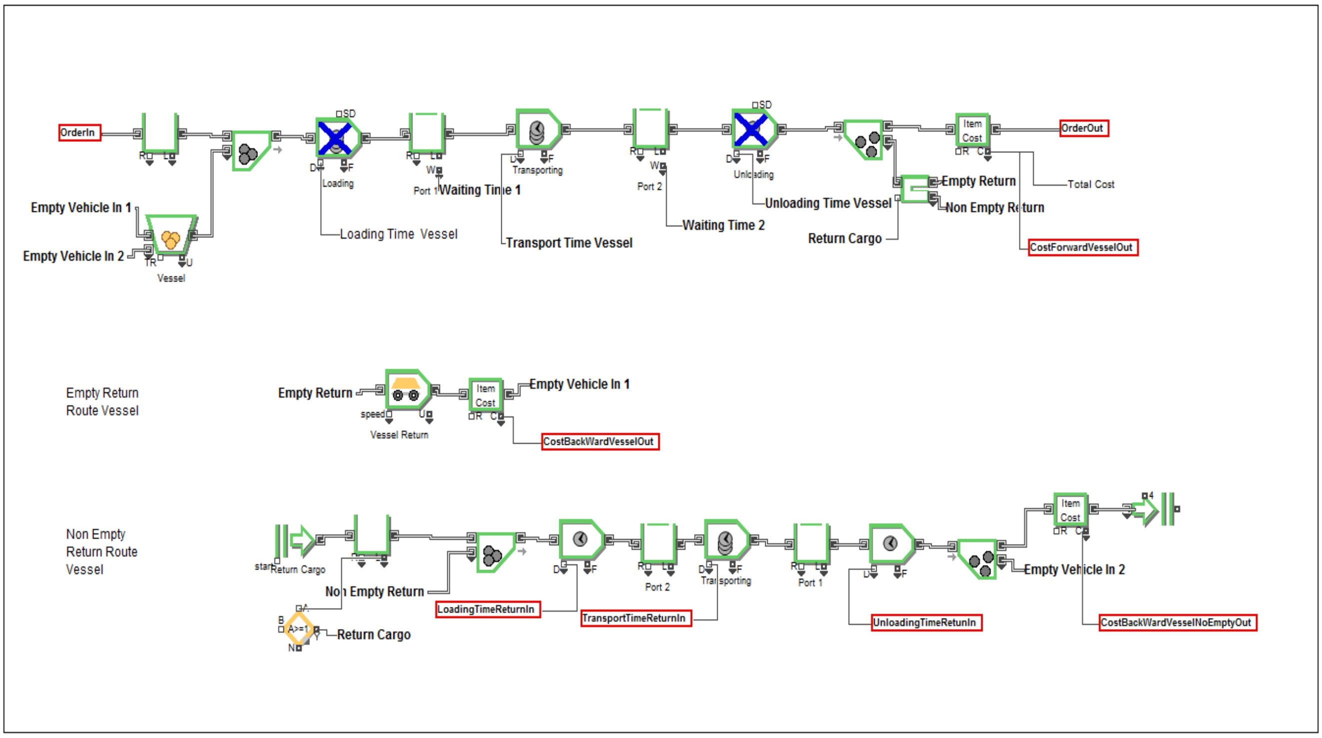

Figure 5: Simulation model for one logistics chain

3.4 SIMULATION RESULTS

We set the initial parameters as shown in Table 2 and the results are summarized in Table 3. We find that, in terms of cost performance, the intermodal chain is a little better than the pure road chains while the pure road chain emits less emission than the intermodal one.

Table 2: Initial setting for input parameters

	Logistics Chain		Distance	Vehicle	Vehicle Speed	Handling Rate
1	Pure Road Chain	TRD-BEG	663 KM	Truck (40 Ton)	70 Km/H	TRD: 300 Ton/H
2	Road-Sea Chain	TRD-ALE	163 NM(or 301 KM)	Vessel (2000 TEU)	20 Knots	BEG: 400 Ton/H
		ALE-BEG	386 KM	Truck (40 Ton)	70 Km/H	ALE: 300 Ton/H
	Logistics Chain		Fuel Type	Fuel Price	Emission Index	Ave.Loading Factor
1	Pure Road Chain	TRD-BEG	IFO 380	$ 650/Ton	3,2 Ton/Ton fuel	75 %
2	Road-Sea Chain	TRD-ALE	Diesel Oil	$ 3,2/L	2,75 Ton/Ton fuel	55 %
		ALE-BEG	IFO 380	$ 650/Ton	3,2 Ton/Ton fuel	75 %
Baseline of fuel comsumption: 100 Ton/Day@21 knots for 2000 TEU container vessel; 0.35 L/KM@Truck						

Concerning the flexibility, there is 20-ton spare capacity in both chains to handle extra cargo demand. Also with respect to weekly service frequency, the shipping company can finish 6 round trips weekly by both chains. For reliability performance, from the deviations from schedule, we know that the intermodal chain is more punctual than road chain. But since delivery by both chains can finish the task in the required time, this kind of deviations is accepted in this case. In this study since we are more concerned about environmental performance we regard the pure road chain as a benchmark.

Table 3: Simulation results based on initial settings

Performance Measurement		Total Cost	Time	Environmental Efficiency	Flexibility		Reliability
KPIs		Total Cost ($/Ton-Km) (Per week)	Estimated Total Delivery Time (Hour)	Total CO2 Emission (Kg/Ton-Km) (Per round trip)	Weekly Service Frequency	Spare Capacity (Ton)	Deviations from schedule (Hour)
Chain 1	Pure Road Chain	16,73	9,59	0,025	6	20	-38,41
Chain 2	Road-Sea Chain	16,31	13,91	0,027	6	20	-34,09

3.5 SENSITIVITY ANALYSIS

From the above we know that there is a trade-off between cost and emission in sea-road chain. Therefore in this part, we check if the emission emitted in intermodal chain can be decreased while its cost performance still does better than pure road chain. This first step of analysis is to identify which one is a more important driving metric among various input parameters on the emission performance. It helps to know the root causes affecting the overall emission performance. From the cause-and-effect chart, we know there are quite a few input parameters which have an impact on the emission performance, such as vehicle speed, fuel type, and handling efficiency, return route as shown in Figure 6. We look into the vehicle speed, handling rate and loading factor for the intermodal chain.

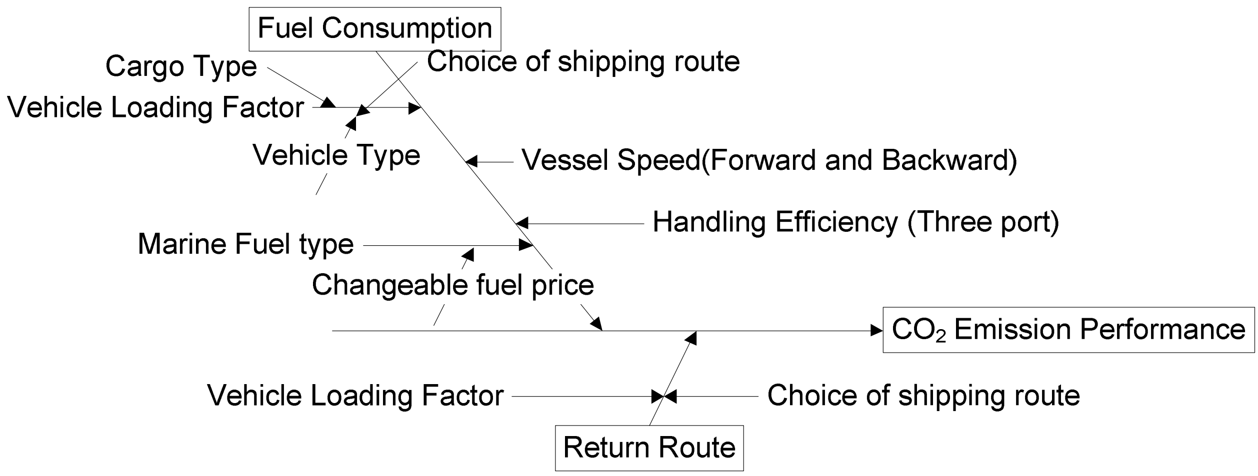

Figure 6: Cause-and–Effect analysis for the emission performance

We create a couple of different scenarios in which the input parameters are changed from the initial settings. We change every parameter by the same percentage and keep the other two constant when we investigate one of them. We summarize all the changes in the table below. We find that among these three parameters, the vessel speed has a more positive impact on the emission performance compared to handling rate in ports and loading factors. This implies that if we want to improve the cost performance of sea-road chain, it is more sensible to adjust the vessel speed. Based on this analysis, if we decrease the vessel speed in forward route to 16-17 knots from 20 knots; the emission of the whole chain is less than that from pure road chain. Meanwhile its operational cost is still lower than that of pure road chain. This speed reduction inevitably increases the total delivery time to around 15 hours, but still within the required time.

Table 4: Identification of key parameters of the emission performance

Handling Rate (Ton/Hour)	TRD	BEG	ALE	Total Emission (Kg/Ton-Km)	Decrease Rate
Original	300	400	300	0.0268	
Scenario A1	350	400	300	0.0268	0.00%
Scenario A2	400	400	300	0.0268	0.00%
Scenario A3	400	450	300	0.0267	0.12%
Scenario A4	400	450	350	0.0267	0.34%
Scenario A5	400	450	400	0.0266	0.50%
Vessel Speed (TRD-ALE) (Knots/Hours)					
Original	20			0.0268	
Scenario B1	19			0.0262	2.07%
Scenario B2	18			0.0257	4.03%
Scenario B3	17			0.0252	5.89%
Scenario B4	16			0.0247	7.63%
Scenario B5	15			0.0243	9.27%
Vesse lLoading Factor (TRD-ALE)					
Original	0.60			0.0268	
Scenario C1	0.63			0.0265	1.01%
Scenario C2	0.69			0.0260	2.77%
Scenario C3	0.80			0.0253	5.32%
Scenario C4	0.96			0.0246	7.98%

From the above analysis, we know that in this case the vessel speed has the highest influence among various input parameters. We also find that these parameters affect the performance more or less. Hence in order to improve the environmental performance of sea road chain to larger extend, we set different values to those input parameters: handling rate (TRE, BEG and ALE), vessel speed (forward route and return route if have), vessel loading factor (forward route). They are grouped them into 250 different scenarios. We use the sensitivity analysis function in ExentdSim for this investigation directly and find the best practice for this delivery. Two options are given in the Table 5: one is with minimum emission and the other is with minimum cost. In this case, the Run#30 is the best practice among all the options, which emits least and costs less than before. From Table 6, we can see the comparison among those three logistics solution. With the new intermodal delivery solution, we can decrease both cost and emission in the road-sea chain by acceptable increased total delivery time and one less weekly service frequency.

Table 5: The options for best practice

Run #	Vessel Speed	Vessel Speed Return	Handling Rate TRD	Handling Rate ALE	Handling Rate BEG	Loading Factor	Total Emission	Total Cost
30	14	14	500	500	500	0,69	0,020	15,75
45	14	20	500	500	500	0,96	0,023	15,74

Table 6: Performance improvement by new solution

Performance Measurement		Total Cost	Time	Environmental Efficiency	Flexibility		Reliability
KPIs		Total Cost ($/Ton-Km) (Per week)	Estimated Total Delivery Time (Hour)	Total CO2 Emission (Kg/Ton-Km) (Per round trip)	Weekly Service Frequency	Spare Capacity (Ton)	Deviations from schedule (Hour)
Chain 1	Pure Road Chain	16,73	9,59	0,025	6	20	-38,41
Chain 2	Road-Sea Chain	16,31	13,91	0,027	6	20	-34,09
New Chain 2	Road-Sea Chain	15,75	17,32	0,020	5	20	-30,68

4. CONCLUSION

In this study, we discuss the selection of KPIs for benchmarking of maritime logistics chains. The following factors: low cost, short delivery time, low emission, high flexibility and reliability are considered as key objectives for a logistics service provided by a shipping company. Accordingly, we choose total cost, estimated total delivery time, CO_2 emission, spare capacity, service frequency, deviations from schedule, and insurance cost as KPIs to measure the achievement of the overall objective. We also investigate the cause and effect relationship between different input parameters and those KPIs. From this cause-and-effect diagram, we get important causes for various outputs in general. By using the simulation model we find that vehicle speed, choice of shipping route, vehicle capacity, return route, fuel type and cargo type are regarded as the major causes for the different performance levels of maritime logistics chain. We discuss in detail about the possible specific reasons for poor emission performance in the illustrative example. We find that the vehicle speed change has more positive impact on the improvement of emission performance than port cargo handling rate and vessel loading factor on the forward route in this case. By slowing down the vessel speed and increase handling rates and ship loading factors at the same time we can improve the cost and environmental efficiency performance to some extent.

Some implications for future work can be suggested. In this report, when we choose the benchmark, we only focus on the emission performance instead of considering all the KPIs comprehensively. Therefore the discussion of the multi-criteria decision based on multiple KPIs should be an interesting topic included in future work. And also we simplified the whole logistics process, for instance port or inland terminal operation, return cargo operation. One of the future topics is to capture those processes in the simulation model to make the illustrative example more real-life. Last but not least, by using simulation model, in the future work, we can try more scenarios or use Optimizer block in ExtendSim in order to find an optimal solution with minimum emission as objective function.

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