WHITEPAPER

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METRICS FOR CONTINUOUS IMPROVEMENT OF THE SUPPLY CHAIN PERFORMANCE

LEAN & GREEN EUROPE

Metrics for continuous improvement of the supply chain performance

This paper introduces the result of the development work of the Lean & Green logistics community. In the last three years recent standards and concepts on carbon reporting for transport have been tested in practice by them.

The community felt that metrics should be in the spirit of Lean & Green, focused on the Lean & Green performance of the supply chain:

- on how to stimulate cooperation that leads to a better utilization rate of the resources
- to an increased effectiveness of the trips
- and as a result more value for customers, less non-value added costs and less emissions.

Most companies have already applied common rules-of-thumb for increasing effectiveness and productivity. The challenge is to go beyond these rules, to dig deeper, which requires a deeper understanding of the business to be able to predict the result of the improvement. It requires better models, better indicators and better data.

The aim was to develop metrics that have:

- indicators that are comprehensive, easy to interpret and consistent on both effectiveness and emissions;
- definitions and methodologies on how to measure and calculate the indicators that are both practical and rigorous.

Comprehensive indicators include all emissions and all effects of reducing emissions by optimization of the supply chain. Repositioning trucks, maintenance trips, empty trips and all these kind of necessary but indirect types of transport must be accounted for to get a comprehensive picture. The benefits of such metrics are clear:

- a common methodology and definition makes it easy to compare and exchange vital information, accelerating innovations and improvements;
- good indicators allow for daily or weekly operational tracking of the performance;
- good indicators allow for high-level or detailed analysis of unexpected deviations;
- good indicators allow for modelling and ex-ante estimates of the effect of non-trivial changes in a supply chain.

This report introduces the Lean & Green metrics, derived from the EN 16258 standard and tested in practice.

Lean & Green: the road to true sustainability

Since the publication of the first edition of the Greenhouse Gas Protocol (GHG Protocol) in 2001 a growing number of companies involved in logistics started to measure and report their carbon emissions as part of their social responsibility efforts. The same social responsibility drive has led to a variety of projects and programs to reduce the CO_2 emissions in logistics.

Over the years more and more companies noticed that their efforts to reduce the emission footprint of the transportation of goods aligned with increasing the competitiveness of their company. Sustainability in the long run is a combination of a thriving business and a minimal footprint.

A thriving business continuously:

- invests in improving the value delivered to customers while reducing the non-value-added waste in its processes,
- invests in consuming as few (non-renewable) natural resources as possible while maintaining our ecosystem.

Experience shows that efforts to improve the one reinforces the other: Lean is a natural partner of Green. Lean & Green has become the name of a successful European program of Connekt that supports its members in applying the Lean & Green vision to sustainability. Initially funded by the Dutch Ministry of Transportation it has diversified into Logistics, Personal Mobility and Solutions.

Lean & Green Logistics is a community driven program of companies in logistics that share this vision and strive for continuous improvement, each at its own level. The diversity in logistics is huge and ranges from competitive landscape to technology, from size to distance, from time-insensitive bulk to high value JIT items. Some businesses see zero emission logistics as a goal that can be reached for their purposes within a decade and have set their mind on it. Others are limited by technology and their competitive environment and focus on reducing waste.

Regardless of the circumstances, all of them share the focus on continuous improvement. The Lean & Green community members:

- Share the vision of how Lean reinforces Green and vice versa.
- Challenge each other to keep on improving and raise the bar.
- Celebrate the efforts and the improvements made by members of the community.
- Innovate to push the envelope, by sharing best practices, inventing new ways of cooperation, and try new technologies.
- Improve their data to strengthen evidencebased decision making and tracking of their progress.

Within the community the members meet their peers to exchange experiences: local meets local, international meets international. Together they discuss how complex international supply chains, in which they all participate can be improved.
The cornerstone of the Lean & Green Program is a certification framework to support its members in formulating and achieving their ambitions, and recognizing them both inside and outside the company. In short this framework consists of the following three key phases:

1. **Award/Star Phase:** A 20% CO_2 emissions reduction within 5 years (relative to one's own reference measurement).
2. **2nd Star Phase:** A harmonized language for analysis and further improvement.
3. **3rd star and beyond:** Absolute benchmarks on CO_2 efficiency and effectiveness toward zero-emissions.

Award and Star: getting started is making the difference

To implement continuous improvement in a business is easier said than done, especially if sustainability is to be changed from a social responsibility to a business driver. The Lean & Green Award and first Star program assist companies in focusing their efforts on achieving tangible results, and on injecting the experience into the culture of the organization. Companies learn how to identify and reduce waste, and how to measure and enjoy the beneficial effects of reductions in waste and emissions.

The challenge of reducing 20% CO_2 emission within 5 years (relative to one's own reference measurement) requires a bit more than simply a implementing painless wins. Changing the driving style of drivers to reduce fuel consumption is merely a first step. The extra reductions are usually found in increasing the utilization rate, the effectiveness of a trip, rather than changing the technology of vehicles to reduce emissions.

Measuring the reference point, developing an audited plan on how to reduce 20% and tracking the progress helps to focus the efforts and increase awareness. The direct pay-off is reduced emissions and reduced costs, thereby strengthening the competitiveness of the company. An audited and accepted plan is celebrated with an Award and the right to proudly advertise this milestone. When the 20% goal is met the first Star is awarded and celebrated.

More than 350 companies have started on this path and many report reductions that go beyond their targets. Other than the internal benefits, they report recognition in the market for their continuous improvement efforts. The value of meeting like-minded companies and people, and sharing information on best practices and experiments is recognized.

Second Star: a common language for analysis and improvement

Having seen the results and gained their first Star, some of the leading companies that had tasted the results and had reached their first Star expressed their desire for a new challenge. They felt that the new challenge should be focused on the performance of the supply chain:

- how to stimulate cooperation that leads to a better utilization rate of the resources an increased effectiveness of the trips
- Resulting in more value for customers, less non-value added costs and less emissions.

As many examples in and outside the Lean & Green community have shown, there is a lot to be gained by taking a wider view and cooperating within and between supply chains. Examples include:

- re-using empty containers by another shipper in the neighbourhood who needs them for export
- combining high frequency deliveries (and therefore less-than-full truckloads) from separate shippers to the same FMCG warehouse,
- combining delivery runs in zero-emission city delivery trucks to get a high utilization rate for these advanced resources.

All are examples of value gained while emissions are reduced: Lean & Green.

Beyond rule-of-thumb with good data

Most companies have already applied the common rules-of-thumb for increasing effectiveness and productivity. The challenge is to go beyond these rules, to dig deeper. All the examples above require a deeper understanding of the business to be able to predict the result of the improvement. It requires better models, better indicators and better data.

Harvesting this potential requires also wider view over a larger part of the supply chain. It requires effective communication in the supply chains between the partners (and sometimes competitors), and a win-win cooperation model.

Last but not least these efforts give the best results when they are supported by hard data that are a good measure of what you want to achieve. The drive of these companies to improve communication within the supply chain coincided with their desire to be able to compare themselves better with their peers. A supply chain consists of many individual service providers and operators, all trying to deliver the best possible service to their various customers while optimizing their own overall performance. How to compare your own efforts to improve with others, how to identify and learn about best practices from each other and how to align the various (commercial) interests?

The need for a common 'language' on the Lean & Green supply chain performance is clear.

Effective Indicators

There is large body of work being done on measuring and reporting CO_2 emissions for transport, each party focusing on their own indicators and methodology fit for the purpose. Although there is much that can be used from already developed norms, standards and concepts, the Lean & Green community has identified from experience that Lean & Green indicators should:

- Align Lean with Green, meaning they should align business value indicators with emission profile; improvement in the one should mean improvement in the other, fitting with common sense observations.
- Be simple but useful for both internal analysis and for communication with other parties
  - for analyzing supply chains in total and form analysing specific parts;
  - for comparing and benchmarking;
  - in as much or as less detail as a party sees fit.
- Incorporate all the effects on the real utilization of resources such as
  - slowly emptying trucks (100% to 0% load) in a delivery run, or kilometres driven for repositioning of resources, or combining deliveries.

Working with existing norms and indicators the community found that:

- A single performance indicator (KPI) is inadequate for the purpose. Multiple KPI's are needed, as no single KPI can do justice to the complexity of supply chains and the different roles and responsibilities.
- In most cases short-cuts are taken in the measurements and calculations that unfortunately lead to large errors in the KPI, and even worse obscure the effect of improvements.[1]

So we took the existing standards and developed indicators that did satisfy the needs.

Two interdependent perspectives of the supply chain

There are two supply chain perspectives that are interdependent. One perspective is the shippers' perspective: a shipper wants to deliver its products to customers through a supply chain that is built by multiple LSPs (including terminals, storage and warehouses).

This perspective can be expressed in a KPI that indicates the 'translocation' effectiveness. Translocation is defined here as moving the goods closer to your customers. The handling on a terminal, such as moving a container off a ship and unto a waiting barge, or the temporary storage in a warehouse are both part of the translocation.

This perspective of emissions[2] per unit product translocated will be referred to as 'supply chain performance'. This indicator of the total emission added to a product 'translocated' by the supply chain (like CO_2 per ton, or CO_2 per m3) is a good indicator of the effectiveness of the supply chain.

Another perspective is that of an LSP optimizing its own business: combining for his customers parts of several independent supply chains. Its business is optimizing the combination of multiple products, delivery addresses, routes and transport modes and transport equipment. This perspective can be expressed in a KPI that indicates the effectiveness of the transport by the LSP in quantity of emissions per unit.km (ton or m3)[3]. This perspective will be referred to as 'carrier performance'.

The indicator of the effective utilization rate of resources (CO_2 per ton.km or CO_2 per m3.km) shows clearly how few kilometres are driven or sailed empty or partly empty, and how effectively resources are utilized. For terminals and warehouses an equivalent indicator is used, such as CO_2 per TEU, or CO_2 per unit.day.

[1] Common shortcuts are a.) neglecting kilometers driven while empty and b.) using theoretical routes, instead of real distances driven with the associated fuel consumption

[2] Emissions (foremost the greenhouse gas CO_2 but also other types) is currently a good proxy for the energy input that is used for the transport and its effects on the environment. Other inputs could also be used in the future, such as electrical power (kWh), or others.

[3] Or in the case of terminals and warehouses, equivalent indicators, like CO_2 per TEU for a container terminal, or CO_2 per unit.day for a warehouse.

The combination of the two is very informative.

- A supply chain that is constructed poorly overall may very well be supported by an LSP that is doing an excellent job for its part. The carrier performance indicator will show that the LSP is top-of-class, the supply chain performance indicator will show that overall something is wrong.
- In the last-mile distribution the interaction between supply chain performance indicator and the carrier performance indicator will show immediately if the ordering behaviour
- of end-customers (the shippers customers) is changing. More smaller orders that mean the same volume but more drops will show up immediately.

The combination gives valuable information on how improvements can be identified and measured. These two related indicators can be applied in a wide variety of supply chain and service portfolios. They can be used for a very detailed operational analysis trip by trip, or for high level reporting of the emissions effectiveness of a supply chain over a year.

The simple solution to measuring the indicators of effectiveness

Having identified the right indicators the next step is to collect the operational data and calculate them. Many claim that collecting data is too complicated therefore one should refrain from trying. We shall show that collecting the data and calculating the indicators is very simple if based on the primary business data.

Let's first start with some of the arguments that are used to substantiate the claim of complexity. For example: a delivery run can start with 100% load, but any drop of cargo reduces the load for the remainder of the run while fuel consumption and therefore emissions hardly change. A fully loaded truck that drops everything at the destination and drives back empty is on average 50% utilized as far as cargo carrying capacity is concerned. Trucks have to be repositioned between cargo assignments, and have to be maintained.

The amount and type of cargo seldom matches the available capacity perfectly. But even when a vessel is fully loaded there can be wasted capacity: a ship can be fully loaded with containers but are the containers fully utilized or partly empty? Don't forget that empty containers have to be repositioned in the network. One could even argue that due to the packaging of products transport capacity can be wasted: for instance if the protective packaging of a product takes excessive space, or if due to irregular forms products cannot be stacked neatly.

Some standards and methodologies evade the subject, or take quick-and-dirty shortcuts in the practical application.

It turns out that the solution to this conundrum is astonishingly simple in its basic form. Don't try to measure utilization rate per vehicle by looking at load factors, but:

> Relate the effective result (translocation of goods) with the primary input (fuel) that is used to get this result.

The rationale is that the demand is driven by the need to transport goods from one place to another. The value is created by that move, that translocation from A to B. Nobody is interested in what route is followed or how it is done, what car or barge or even drone is used. The value is the translocation, everything else does not add value.

The LSP[4] uses resources to supply the service, as demanded. The 'cost' of using the resources is expressed as the greenhouse gas emissions[5], derived from the fuel or energy consumption. The fuel consumption integrates all choices made by the LSP to optimize his performance, given the demand.

This means that when the pure basic data of the business is available (amount of fuel used, what cargo is moved from A to B or C, for whom) the indicators can easily be calculated with high accuracy and confidence. No need to know what route has been taken, no need to know what truck or vessel was used, no need to know in what sequence the drops have been made. Just the basic data of the business, either analyzed in detail per trip, or integrated per year.

This very effective and elegant method requires that the party who transports[6] collects the data and converts it into the indicators.

- One KPI is the carrier performance, the other is the supply chain performance. They monitor the effects of actions taken to increase the effectiveness of the use of resources, indicated by the reduction of the CO_2 footprint of the company. In a later stage such KPIs may also be used to benchmark and compare with peers.
- The second step is the attribution of the CO_2 emissions to shippers and shipments. When an LSP combines shipments of various shippers to various locations, each shipper would like to know the CO_2 emissions of his particular shipments so each shipper can determine his own supply chain effectiveness.

[4] Or terminal or warehouse. The term LSP is used in the document to denominate all steps in a supply chain.

[5] As effective indicator

[6] Or terminal or warehouse or subcontractor.

For the attribution of emissions to shippers there is a large body of work available, as can be found in the EN16258 norm and in work done by COFRET. This will be explained later in this paper. Again, the level of detail is a conscious choice made by each party, fitting to the purpose. An LSP may need a detailed analysis to understand what the potential for improvement is, and at the same time give a shipper aggregated data which is useful for a supply chain analysis. Analysis may be performed down to a level of a trip, or indicators may be generated on a monthly basis for a set of vehicles.

In practice not all data is always available in its pure and basic form. In the next chapter we elaborate on the methods of calculation and on ways to estimate data that is missing.

The basic method for the calculation of KPIs

The starting point of our approach is the determination of resources used. This is achieved by calculating the total greenhouse gas emissions associated with the logistic operation for which the KPI is to be determined. It is paramount that all relevant emissions are accounted for, also e.g. those associated with intermediate trips. In a second step the carrier performance needs to be determined to which these greenhouse gas emissions are attributed. Appropriate definitions are needed for both in order to make sure that the resulting KPI value can be used in a meaningful way to monitor the impacts of measures taken.

To better explain the thinking behind the definition of the KPIs used in the 2nd Star of Lean & Green, let's first have a look at the KPI for carrier performance. This perspective is that of an LSP (transport operator) optimizing its part within several combined supply chains by optimizing multiple products, delivery addresses, routes and transport modes and transport equipment.

Carrier performance

At the highest aggregation level the KPI for the carrier performance of a transport company (or part of its operations) is defined as total CO_2 emitted divided by the total transport performance expressed in unit.km, with the transported units expressed in either metric tonne[7] or m3.

The CO_2 emissions ECO_2 in the numerator are all the greenhouse gas emissions caused by the transport of the goods.

$$KPI_{carrier} = \frac{total\ greenhouse\ gas\ emissions}{total\ transport\ performance} = \frac{E_{CO_2}}{\sum_i U_i \times d_i}$$

[7] Other indicators like containers, trolleys or pallets can be converted to tonne or m3 using conversion factors fitting to the industry.

The transport performance is the value added to the goods by transportation i.e. moving the goods from the origin to the destination. This is expressed as the amount of goods per shipment (in volume or weight) times the shortest distance (di) over the earth's service (also known as 'birds-flight distance' or 'great circle distance') between the locations of origin and destination.The actual pathway along which the goods are transported is not relevant as it does NOT add value to the translocation. Ui is the amount of goods in tonne or m3 transported between a given origin and destination[8]. The total carrier performance is the sum of the carrier performances per shipment over a given period.

For example: 2 tonne of cheese is transported from the warehouse to droplocation A (distance[9] 65 km between warehouse and A) and 5 tonnes of cheese is transported from the same warehouse to droplocation B (distance 85 km between warehouse and B). The transport performance is (2 x 65 + 5 x 85) = (130 + 425) = 555 ton.km. The fuel used for the round trip is 30 litres of diesel. A conversion factor of 3.17 kg CO_2 per litre well-to-wheel leads to a total of 94 kg CO_2 emitted. The KPI is 0,17 kg CO_2/ton.km.

This KPI can be calculated both at a high aggregation level, such as for the total operations of a carrier over a longer period (e.g. a year), or at a detailed level for each transport, or any period in between. The KPI remains valid at each level. A carrier can choose for instance to record and analyze KPIs in detail to optimize its own operation, yet report externally aggregated KPIs.

The CO_2 emissions ECO_2 in the numerator are all greenhouse gas emissions, from well-to-wheel and expressed in CO_2 equivalents, resulting from the energy consumed by all vehicle movements and other activities that are associated with the transport activities of the carrier. These include the emissions associated with empty return trips, trips to maintenance locations, etc.

The reason to include all emissions in the KPI, including those associated with empty return trips and e.g. maintenance trips, is that reducing the amount of empty trips by optimised routing or increasing the load factor, is an important means of increasing effectiveness while reducing the CO_2 footprint of a carrier's operation.

[8] Other units used in transport such as pallets can be converted to volume or weight, using standard conversion factors applicable to the type of goods. Containers units such as TEU can be used as such, calculating emissions per TEU for a supply chain of containerized goods.
[9] Great circle distance, the direct flight distance between two point on the earth.

Value generated is expressed by Great Circle Distance

The kilometres di in the denominator are the indicator of the value added by transport. These distances are the so called Great Circle Distances (GCD) between the origin and destination of the transported goods. A GCD is the distance in a direct line, travelling over the curved[10] earth in birds flight.

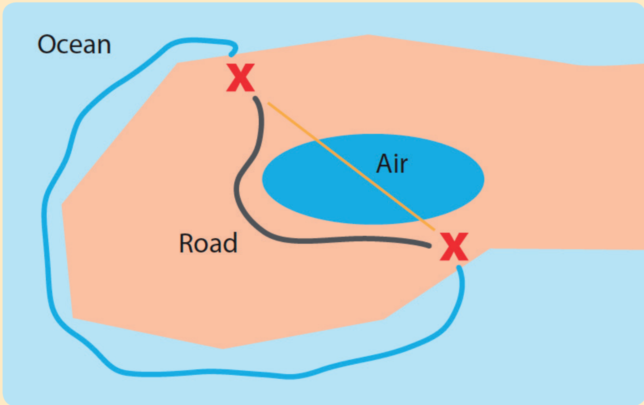
Again, this is seen by most experts as the best approximation and indicator of the value added by the transportation, independent of the means of transport and the route taken.

The reasons for using the GCD for the kilometres in the denominator are:

- The purpose of transport is to bring goods from a to b. The route along which this is done does not add value to the transport performance.
- By separating the value added (direct line) distance from the actual travelled distance (road, water, rail, air) one can immediately identify and measure the effects of better planning and more cooperation. Better planning leads to the same value (goods from A to B) with less use of resources (less kilometres driven, less energy used, less emissions).
- In various other carbon foot printing schemes the kilometres in the denominator are based on shortest feasible distance. If the KPI were to be used for a single mode of transport only, this option could be acceptable. However, using shortest feasible distance ceases to be an appropriate parameter as soon as using other modes of transport is considered as a means for improving the carbon footprint of a shipment. If a trip from a to b could be done by road, rail or inland waterways (or a combination of these) the shortest feasible distances for the three modes are never the same. Choosing a mode with low emissions per actual driven kilometres only yields a net reduction of the CO_2 footprint of a shipment if the alternative mode does not involve a large increase in the actual driven distance.
- Another reason for not using the shortest feasible distance for the kilometres in the denominator is that reductions in the shortest feasible distance are also a means to reduce the carbon footprint of transport. Although building new roads, rail- or waterways that allow more efficient transport routes is not a decision made by carriers or shippers, the transport sector is a stakeholder with influence in governmental decision making processes on infrastructure investments. Furthermore actual driven distances can be directly influenced by shippers and carriers e.g. through optimized location of warehouses and terminals.

[10] The fact that the earth is a globe makes it necessary to calculate the distance taking in account this curvature. The effect is most pronounced at larger distances, as airlines know.

Fig. 1: The mode of transport determines the pathway, but the value delivered as in translocation of the goods between origin and destination is the same.



So in the KPI for carrier performance the numerator is dependent on the mode of transport as it is defined by the actual traveled distance and the energy consumption or CO_2 emission of the mode used per km. The value of the denominator is not dependent on the mode of transport as it is defined by the net translocation of the goods being the great circle distance between origin and destination.

Calculating the KPI from direct and indirect data

Calculating the KPI for carrier performance at the highest aggregation level requires little monitoring effort and can in principle be fully based on data that is already available to the carrier.

- The numerator in equation (1) is determined from the total fuel consumption over the monitoring period of all vehicles and resources used in that period.
- Calculating the denominator only requires information for all shipments in the monitoring period : the shipment weight or size and the locations of the origin and destination.

There can, however, be situations in which especially the total fuel consumption is not, or not exactly, known. This may e.g. be the case when part of the transport is performed by subcontractors. In such cases one may need to estimate the total fuel consumption which converts to the resulting unknown CO_2 emissions.

The estimate of total fuel consumption is based on estimated actual driving[11] distances and estimated specific fuel consumption per kilometres of the resource (vehicle, barge, train) used. At this point a common misunderstanding should be clarified.

- In the denominator the value added is calculated using the great circle distance, ignoring the actual driven kilometres.
- In the numerator the CO_2 emission may need to be calculated from an estimated amount of fuel consumed, using the actual driven distance and average fuel consumption.

These two types of distances are easy to mix up. The best way to understand the difference is that in the denominator the demand from the shipper is indicated ('bring goods from A to B'), in the numerator the operational execution of fulfilling the demand is characterized, or how well the LSP performs in meeting the demand. It shows how this KPI involves both the shipper and the LSP.

The Lean & Green carbon footprint methodology also contains a set of criteria on which approximation methods offer sufficient accuracy. (See the addendum).

The same data is used for attribution of the CO_2 emissions to individual shippers.

Calculating the shippers perspective and the carbon reporting

The shippers' perspective looks at the products that have to be delivered to the customers through a supply chain that could be built by multiple LSPs, several inventory facilities, or other logistics network decisions. This perspective can be expressed in a KPI that indicates the quantity of carbon emissions per unit (ton or m3) delivered. This perspective is referred to as the KPI for supply chain performance.

$$KPI_{supply\ chain} = \frac{total\ greenhouse\ gas\ emissions}{total\ network\ performance} = \frac{E_{CO_2}}{\sum_i U_i}$$

The network performance is the total amount of goods shipped, expressed in weight or volume. Note the difference with transport performance as is used for the carrier: network performance just counts the amount shipped, not the distance. The total amount of units shipped and their weight or volume is obviously known to the shipper, so that determination of the denominator in equation (2) is straightforward.

This indicator tells in a straightforward manner the level of emissions generated by the supply chain. It is the basis for carbon reporting and is affected by all efforts to reduce distances and increase effectiveness.

[11] We use 'driving' to indicate driving a truck, piloting a train or airplane, or sailing a vessel.

The challenge in determining the KPI for supply chain performance is to collect data on the CO_2 emissions in the numerator, that are associated with different parts of the supply chain network. These different parts may be operated by a large amount of LSPs, may contain various modalities and may be spread out over various countries. The long term ambition is that more and more LSPs are able to calculate their transport performance correctly, and are thus able to supply their customers with the allocated emissions. But in the short term that is not yet the case, so that the shipper itself may need to estimate a significant of part of its logistic CO_2 emissions using approximation methods. It is part of the Lean & Green program to promote cooperation between shippers and carriers in gaining experience with CO_2 attribution.

Attributing CO_2 emissions to shipments and shippers

As mentioned above, determining the CO_2 footprint of the logistics activities of a shipper or carrier requires their LSPs to be able to report the CO_2 emissions attributed to shipments transported for their clients.

An important condition for such a reporting to be meaningful is that an LSP uses a consistent methodology for attributing emission to all its clients. The sum of the emissions attributed to all clients should equal the total emissions of the LSPs logistic activities. The new European Standard EN 16258 'Methodology for calculation and declaration of energy consumption and GHG emissions of transport services' is an important step in creating a harmonized framework for such emission calculations. This standard and the additional work of the COFRET Project for allocating energy use/emissions in distribution shipments provide excellent building blocks for the Lean & Green framework.

The EN 16258 leaves some degree of freedom for the application of the standard, and therefore clear choices have to be made to give the required significance to the data. The Lean & Green framework helps to make these choices based on the practical experiences of Lean & Green frontrunners, and chooses to start with the core operational data of a logistic operation.

Principle of attribution

The principle of attribution is based on the amount of goods and the required distance that the goods should be repositioned (translocation, expressed by the great circle distance). Goods that need to be brought to a place farther away and take more space or weigh more, get a bigger part of the CO_2 emissions of that trip allocated. The consensus[12] in COFRET is that this method of attribution is fair and sends the right signals.

[12] The EN16258 standard allows in some cases the use of shortest feasible distance, the COFRET recommendation is to only use great circle distance for reasons of consistency.

Let's take an example.

A parcel delivery service provider uses a subcontractor for the last mile. The subcontractor picks up 50 packages at the local warehouse and tries to deliver them. 30 are accepted at the first call, 10 at the second call and 10 are brought back to the local warehouse. There is no direct measurement of the fuel used, so an approximation is necessary. The track and trace system shows that a total of 185 km are driven from picking up the packages and bringing the last 10 back. Added to that are 2 x 11 km from the location of the subcontractor to the pickup point and back. A grand total of 182 + 22 = 204 km, which with this vehicle means on average in a city 18 litres of diesel. The well-to-wheel factor for diesel is 3,135 kg CO_2/litre meaning an emission of 56,4 kg CO_2.

Either the subcontractor or the distributor now can do all the calculations needed. The output is the 40 packages delivered to the customer. Let's assume all drop locations are known, so the GCD[13] distance between the warehouse and each drop location is known: 40 distances, each for every packet.

The distributor does not need a correction for the weight of the package as they are all small in weight. The package is the unit . So it is easy to allocate CO_2 emissions to each package based on the distance (GCD between warehouse and drop location). The subcontractor can assess its own effectiveness by calculating his carrier performance: CO_2 per unit.km. Another example is a distribution run. In one round trip beer and cheese are transported from a warehouse to 3 drop locations.

Tonnes Beer	**Tonnes Cheese**	**Location**	**km GCD**	**Beer ton.km**	**Cheese ton.km**		**Beer % allocated**	**Cheese % allocated**
2	3	A	25	50	75		14,49	21,74
	2	B	35	0	70		0,00	20,29
5		C	30	150	0		43,48	0,00
				200	145	345	57,97	42,03
				Beer total	**Cheese total**	**total**		

Given the weight and the GCD from the warehouse to the drop location, it is easy to calculate the attribution percentage of the CO_2 emissions to each drop and each shipper (beer, cheese). The CO_2 emission itself can be derived from the fuel consumption as measured for the trip. The same principle can be used for aggregated trips. Take for example a month's worth of distribution with various trucks used. The calculation of the attribution % as above remains the same, only now for a larger number of drops and goods. The total CO_2 emission is derived from the fuel consumption of all the trucks used in that month.

[13] Although at short distances one could use other approximations of the birds flight, it is good practice to always use the GCD.

The attribution principle is the same when round trips are made, unloading and picking up cargo at various locations, for instance barges or seafaring vessels that call on many ports. In Appendix 1 a roundtrip example can be found.

Tools

The calculation is easy to automate, once the origin and destination locations are converted to GCD. Lean & Green has developed two tools to make this easy in practice.

Barges only can load and unload at existing terminals. A list of terminals in Europe is maintained by the waterway authorities. This fact makes it easy to determine GCDs between all existing terminals, and use the results in a spreadsheet. The barge captain only has to enter fuel consumption, loading and unloading number of TEUs per customer and everything else is calculated.

Barge captains have started to use the tools that enable them to inform customers of the emissions they have caused, and to monitor their own performance. It gives them a great tracking tool of how they are doing operationally. Shippers have started to use the tool to model and predict transporting by barge.

An online GCD converter has been built. The input is a list of origins and destination addresses, optionally with the cargo that is transported. The tool converts addresses to latitude and longitudes, and converts this to a GCD. If cargo is added in the input, the attribution is calculated.

Warehouses and terminals performance indicator

The Lean & Green Program acknowledges that in addition to transport itself, the transport nodes like terminals and warehousing are also an intrinsic part of a supply chain, and add to the carbon emissions of a supply chain. These carbon emissions are generated for example by lifting equipment at container terminals, or for example by cooling equipment in warehouses. In comparing supply chain performance, whether from a business or sustainability perspective, also these emissions need to be taken into account.

The performance indicator (CO_2 per unit) can be directly applied to warehousing and transport nodes, as the amount of emissions generated can be divided by the number of units handled or stored. In the case of warehousing, an additional view is provided by a specific warehouse performance indicator (CO_2 per unit.day) which takes into account the emissions generated per unit per day. For transport nodes like terminals a specific transport node indicator can be calculated that takes into account the CO_2 emissions per single movement of a unit CO_2 per unit.movement, like CO_2 per TEU.

Benefits of using the KPIs for operational purposes

A The KPIs are very useful to:

- monitor the operations and react to anomalies;
- track the effects of improvements;
- analyse details;
- model alternative arrangements.

Here are some examples from our members.

EXAMPLE 1

A shipper is used to transport containers by road to and from the sea port. The option arises to combine container flows with a neighbor, generating a volume and frequency such that transport by barge becomes possible. Using the KPI's the two shippers can model the two different supply chains:

1. Trucking back and forth to the port terminal
2. Trucking back and forth to an inland terminal, (un)loading the containers on a barge, barging to the sea port terminal and back.

Sensitivity analysis shows what the desired operational parameters necessary in order to achieve the desired improvement in utilization and emissions. Once the new supply chain is operational, tracking the actual KPI's against the modelled parameters will give a quick and easy feedback as to whether the supply chain is performing as desired.

EXAMPLE 2

A beverage producer uses an LSP to deliver beverages to pubs in cities, and collect the empties that are returned. By tracking the KPIs over time the beverage producer notices that the performance is deteriorating. The LSP analyzes the data which shows that the pubs ordered more often, in smaller amounts, leading to more trips for the same volume. The cause of this change in behaviour turns out to be cashflow problems at the pubs.

EXAMPLE 3

A food retailer does not want his suppliers to deliver full truck loads at his warehouse. Instead, he wants only the amount that fits the daily flow of products to the retail shops which could be 25-50% of a full truck load per shipper. Instead of making milk runs delivering with the same truck to more warehouses an alternative supply chain is designed, in cooperation with other suppliers to the same retailer and an LSP. Full truck loads are delivered to the warehouse of the LSP. The LSP combines goods from various suppliers in one full truck load to one warehouse. The KPIs are an excellent method of tracking whether or not the new arrangement works as planned.

Data Accuracy

When the basic business data for the various elements is available in the source systems the indicators can be easily calculated with high confidence and accuracy. This is the case when direct operational data is available on the actual fuel consumption, the actual weight or volume per shipment, and the actual translocation (= great circle) distance per shipment.

EXAMPLE 4

In city distribution there is an ongoing push for lower emissions of greenhouse gases, NOx, PM10/2.5 and noise, and a push for less intrusion by loud and dangerous vehicles. This requires both an ongoing improvement in drive-train technology and fuels, and an ongoing improvement in how the distribution is organized, resulting in less movements. For all the stakeholders there is a need to objectively characterize best practices and compare different solutions, for many different types of distribution (building materials, waste disposal, parcel delivery, food and beverages, fashion etc.). The KPIs are objective and traceable indicators that combine both technology and organizational effectiveness, usable over a wide range of distribution types. The KPIs do not prescribe or favor how a performance level is reached, only the result.

The reality however is that this direct operational data is not always available in multiparty, multinational and multimodal supply chains. In these cases less specific data, based on conversions, averages or estimates, can still be used to calculate the same KPIs, be it with less accuracy and with less information value.

For the Second Star Program a Data Accuracy Model has been developed that indicates for each data element whether it is calculated with high, medium or low accuracy.

The accuracy model has the following purpose.
It shows what minimum level of accuracy is needed to get meaningful indicators.
Indicators are meaningful is they clearly show the effects of measures that are taken.

- If everything is derived from general standards, nothing will show up as effect.
- To judge and compare KPIs (benchmarking) it is essential to have insight in the level of accuracy with which the indicators are calculated
- It allows the Lean & Green Program to set objective minimum standards on data accuracy
- It shows companies where they are with regards to Data Accuracy, and gives them insights in how to further improve their data accuracy.
- It guides companies that do not have basic operational data available how to calcu-late their indicators in a reliable way.

To maintain practicality within the accuracy model, three levels of data accuracy are identified for each of the data elements: high, medium and low. A high accuracy is characterized by objectively defined direct values, a medium or low accuracy is characterized by an approximation based on a conversion, average or estimate. The difference between medium and low is that in the case of medium accuracy the approximations are specific to the business context, while in the case of low accuracy the approximations are based on national or industry averages. For the Lean & Green 2nd star the minimum data accuracy is medium.

Within a company combinations of different accuracy levels can often be applicable. For instance a company can have specific operational direct data (high accuracy) for the in-house operations while only generic operational data is available for the subcontracted business (medium accuracy).

Conclusion

The Lean & Green approach to improving supply chains combines simplicity with meaningful data. Relating the effective demand with the resources that are expended in fulfilling the demand has many uses, creates a common base for cooperation and can be used for many different modalities and international or local supply chains.

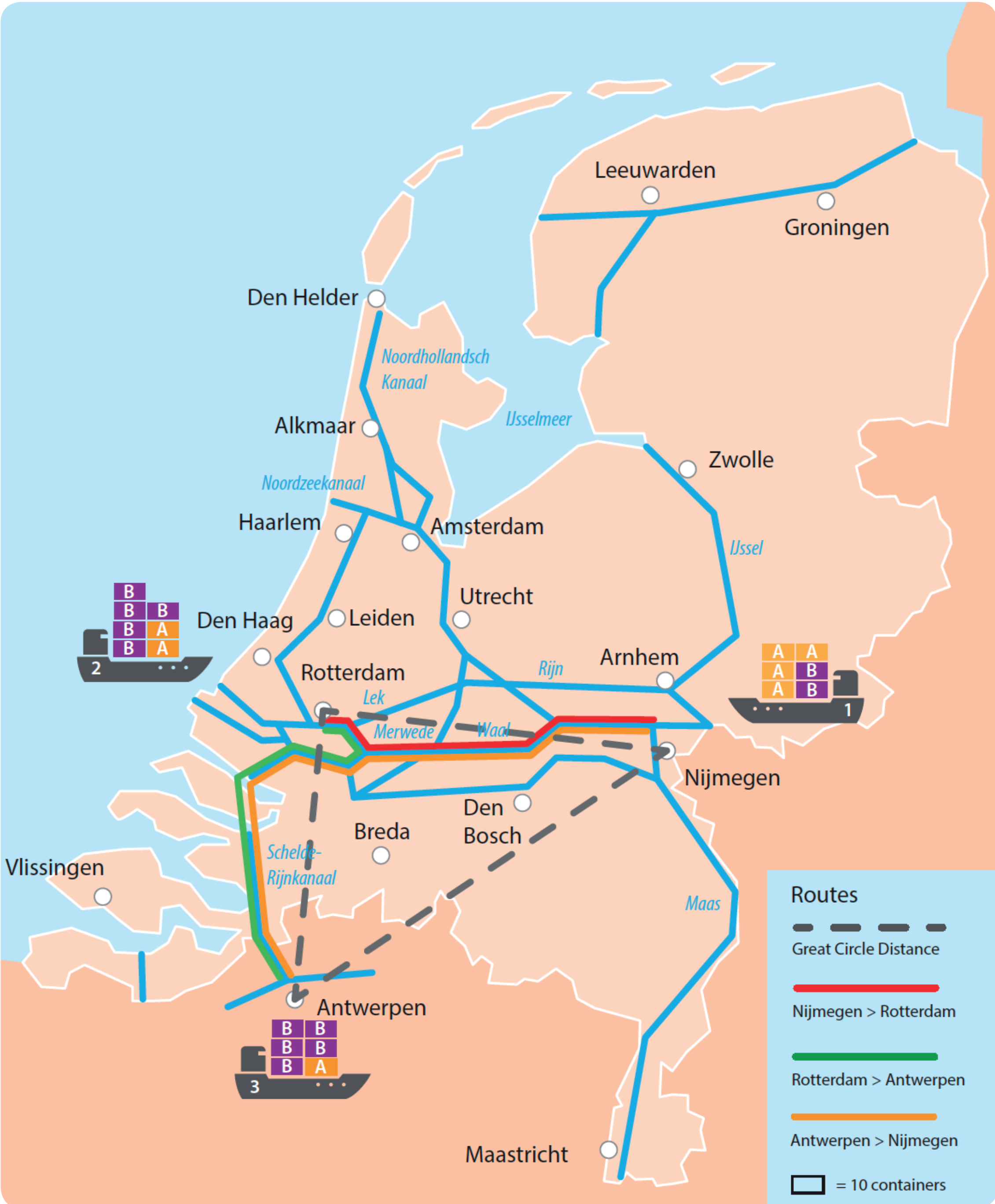
An effective attribution method allows transporters, warehouses and terminals to give their customers the data to account for their CO_2 emission and improve the supply chain together. The methodology allows for flexibility and choice in its use:

- high aggregation levels or detailed per trip
- good-enough accuracy with approximations or very fine indicators based on detailed data
- start and develop over time as required and fit to the business
- adjustable to the characteristics of the business, like the unit of cargo

The IT-tools necessary to make the repeated analysis easy are becoming available. It is expected that as more and more companies start using the methodology more detailed recommendations will be developed for special cases.

Appendix 1

A barge is shipping containers between terminals, in round trips between an inland terminal in The Netherlands (Nijmegen) and the sea ports of Rotterdam (Netherlands) and Antwerp (Belgium).



The calculation is as follows.

The total CO_2 emission is derived from the fuel consumption for a round trip. The value delivered is the transport of (full and empty) containers from one location to another.

The number of containers transported for two shippers (A and B) are as follows.

In Nijmegen:	20 TEU for A loaded	40 TEU for B loaded	Total 60 TEU on board
In Rotterdam:	10 TEU for A unloaded 10 TEU for A loaded	30 TEU for B unloaded 40 TEU for B loaded	Total 70 TEU on board
In Antwerp:	20 TEU for A unloaded 10 TEU for A loaded	30 TEU for B unloaded 30 TEU for B loaded	Total 60 TEU on board
In Nijmegen:	10 TEU for A unloaded	50 TEU for B unloaded	

This can be split into the actual performance, which is the transport between various pickup and drop locations.

FOR SHIPPER A	
From Nijmegen to Rotterdam	10 TEU
From Nijmegen to Antwerp	10 TEU
From Rotterdam to Antwerp	10 TEU
From Antwerp to Nijmegen	10 TEU
From Rotterdam to Nijmegen	0 TEU

FOR SHIPPER B	
From Nijmegen to Rotterdam	30 TEU
From Nijmegen to Antwerp	10 TEU
From Rotterdam to Antwerp	20 TEU
From Antwerp to Nijmegen	30 TEU
From Rotterdam to Nijmegen	20 TEU

GCDIST	Antwerp	Nijmegen	Rotterdam
Antwerp	-	122,8	70
Nijmegen	122,8	-	95,6
Rotterdam	70	95,6	-

GCDIST	Antwerp	Nijmegen	Rotterdam
Antwerp	-	176	108
Nijmegen	176	-	109
Rotterdam	108	109	-

Given de the GCDs the value delivered can be expressed in TEU.km

FOR SHIPPER A a total of	4112 TEU.km
From Nijmegen to Rotterdam	956 TEU.km
From Nijmegen to Antwerp	1228 TEU.km
From Rotterdam to Antwerp	700 TEU.km
From Antwerp to Nijmegen	1228 TEU.km
From Rotterdam to Nijmegen	0 TEU.km

FOR SHIPPER B a total of	11092 TEU.km
From Nijmegen to Rotterdam	2868 TEU.km
From Nijmegen to Antwerp	1228 TEU.km
From Rotterdam to Antwerp	1400 TEU.km
From Antwerp to Nijmegen	3684 TEU.km
From Rotterdam to Nijmegen	1912 TEU.km

This can be expressed as a percentage of the total of 4112+11092 = 15204 TEU.km, which gives the allocation of the emitted CO_2 during the roundtrip.

FOR SHIPPER A 27,1% divided in	
From Nijmegen to Rotterdam	6,3%
From Nijmegen to Antwerp	8,1%
From Rotterdam to Antwerp	4,6%
From Antwerp to Nijmegen	8,1%
From Rotterdam to Nijmegen	0%

FOR SHIPPER B 72,9% divided in	
From Nijmegen to Rotterdam	18,9%
From Nijmegen to Antwerp	8,1%
From Rotterdam to Antwerp	9,2%
From Antwerp to Nijmegen	24,2%
From Rotterdam to Nijmegen	12,6%

In this case the attribution has been made to standard units known in the container trade: a 20ft container of 1 TEU. No correction for weight has been made. A more sophisticated analysis could use the actual weight per container, including the weight of an empty container.

Or one can use a standard discount for empty containers. The level of detail is a matter of necessity for the purpose.

Choice of round trip versus segments

One may argue that it makes a lot of difference whether a ship travels upstream or downstream. The fuel consumption is quite different going against the current relative to with the current, so containers for a shipper that only travels downstream are punished with more allocated emissions if everything is averaged.

First of all, containers only going one way need a ship that travels to the them to pick them up. That ship will make round trips where some legs are going with the current and others against. The purpose of the Lean & Green KPIs is to incorporate all direct and indirect emissions associated with transport.

Secondly in our view it is a bit like calculating profits in financial accounting: there is some leeway in allocating costs that will influence the profit numbers temporarily. But over a longer period everything will even out, what matters is if the information is correct and the choices made are transparent so the numbers can be interpreted correctly. In this case, by cutting up the roundtrip in parts the numbers may vary. In the end, containers have to be brought up and down from the sea harbor to the inland terminal anyway so it may not matter much. The real question is if this level of detail adds to the level of knowledge needed to improve the system.

Appendix 2 The Lean & Green data accuracy model

When the basic business data for the various elements is available in the source systems the indicators can be easily calculated with high confidence and accuracy. A high accuracy is characterized by objectively defined direct values, a medium or low accuracy is characterized by an approximation based on a conversion, average or estimate. The difference between medium and low is that in the case of medium accuracy the approximations are specific to the business context, while in the case of low accuracy the approximations are based on national or industry averages.

Data elements for transport KPIs		A. High accuracy	B.Medium accuracy	C. Low accuracy
NUMERATOR	**CO_2 emission/Fuel consumption** **(CO_2 per unit and CO_2 per unit.km)**	Actual fuel consumption	Estimated fuel consumption based on a consumption factor per km or emission factor per unit.km that is specific to the actual transport conditions.	Estimated fuel consumption based on average default consumption or emissions factors
	if B		Based on driven distance, or shortest feasible distance in case of FTL, and taking into account empty kilometers.	Based on shortest feasible distance (in case of LTL) or GCD.
DENOMINATOR	**Units** **(CO_2 per unit and CO_2 per unit.km)**	Actual units per shipment (in metric ton or m³)	Estimated units per shipment based on a conversion from other unit (pallet, collo, etc.)	Estimated units per period (no information on units per shipment)
	Distance used for KPI calculation **(CO_2 per unit.km)**	GCD or Shortest Feasible Distance	Driven distance for dedicated transport (FTL)	Driven distance for shared transport
Allocation (if applicable)		Based on EN.16258 approach (unit and GCD/ SFD)	Based on unit and driven distance in case of dedicated transport (FTL)	Based on only unit or distance

Lean & Green Europe is Europe's leading community for sustainable logistics. Lean & Green Europe combines corporate responsibility for reducing footprints with continuous improvement of operational performance and value for customers. Lean & Green Europe develops community-driven practical tools and guidelines for applying international emission calculation standards. Lean & Green members include > 500 shippers, carriers, logistics service providers, ports, terminals and retailers.

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Lean & Green Europe

Ezelsveldlaan 59
2611 RV Delft
www.lean-green.eu

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please contact us at info@lean-green.eu

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