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Firms are under pressure to prove their environmental credentials. Now a win-win way of weaving 'green' considerations into business decisions is emerging

Lean and green: 'doing more with less'

RESEARCH

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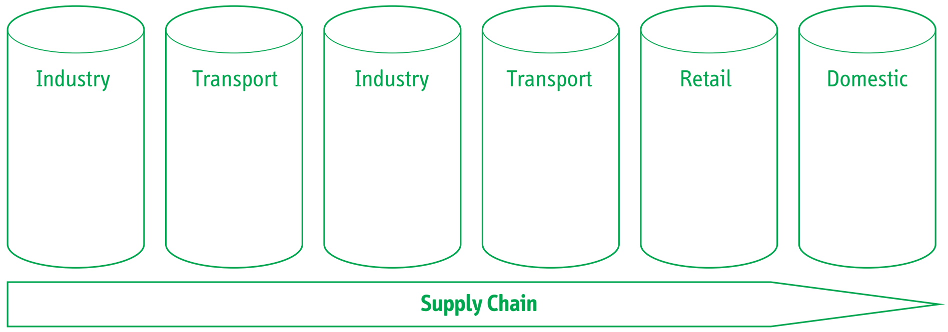
Improving supply chain performance has been at the heart of the ECR movement, enhanced recently by a growing interest in lean thinking – the Toyota-inspired route to eliminating wasteful activities in the supply chain by focusing on time compression. By taking a holistic approach to remove waste from the whole supply chain process, end-to-end, lean enterprises can deliver increased value for the end consumer while using up fewer resources. In short, they "do more with less".

One of the keys to lean is that it takes a process-centred approach, aiming to optimise the whole supply chain rather than achieve islands of improvement. Sub-optimal partial solutions are not enough. Opportunities and choices are best seen and learnt by following the value stream for representative products of a product group from the farm to the home (and maybe beyond, to complete the recycling cycle).

Value Stream Mapping[1] aims to assess and seek these opportunities, to improve the value-adding activity for this holistic value stream process. It reviews the flows of information and physical goods with the aim of eliminating waste and thereby improving quality, cost and delivery. It is based on the premise that compressing time through the value stream reveals hidden quality problems and that their resolution leads to a more efficient, cost-effective supply chain.

Value Added Time percentage is the key metric of the mapping – comparing value adding with non-value adding activity[2]. By removing waste from the supply chain, the value adding percentage

Exhibit 1: **Silo environmental legislation and the supply chain**



increases. Experience over the last decade across many industries provides mounting evidence that time compression throughout the supply chain is a leading indicator of quality, cost and delivery responsiveness.

The lean approach has delivered significant economic benefits to companies. However, companies are under increasing pressure not just to deliver profit improvement but also to do business in a responsible manner, being mindful of the activities' impact on society and the environment. Being able to demonstrate improved environmental performance and to weave environmental and ethical considerations into their business decision-making processes is becoming mainstream.

This trend is accelerating as policy makers increasingly accept that economic growth needs to be of higher quality than in the past: achieved while reducing pollution and the use of resources – "doing more with less".

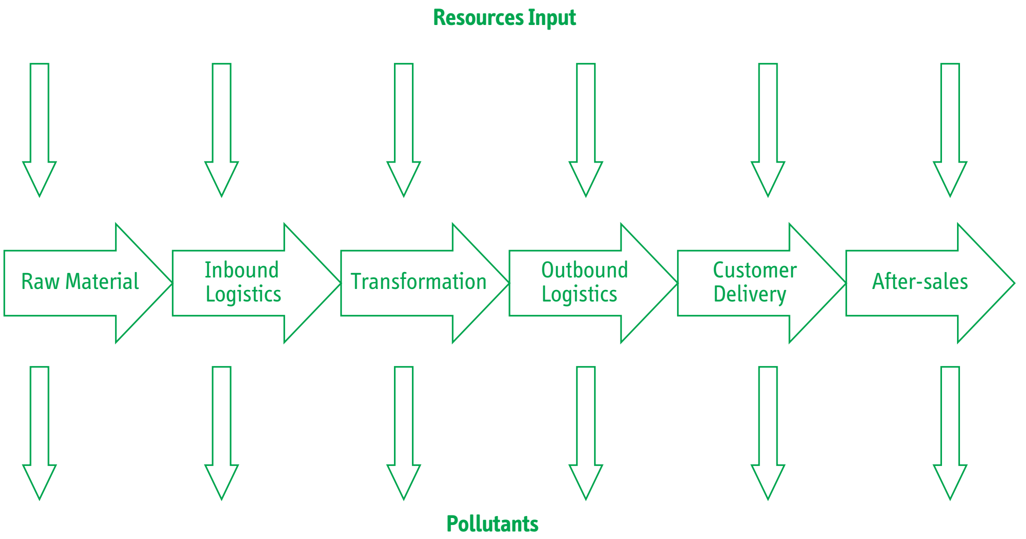
Thus governments have set environmental targets for business based on allocation of energy and emissions to different sectors. For example, in the UK, environmental objectives are set for industrial, transport and domestic sectors, and legislation and taxation regulate and incentivise corporate behaviour. One effect so far, however, is that companies are having to react to public policy via a series of "environmental silos" along the supply chain (Exhibit 1). These silo constraints can be overcome by adopting a lean approach to environmental impacts. This works because lean and green thinking have a great deal in common, both challenging the way resources are currently used and promoting initiatives designed to "do more with less".

Lean achieved a step change in economic improvement in the supply chain by focusing on the product flowing through the supply chain instead of optimising individual silos in the supply chain. It can also deliver similar benefits to the environment.

To achieve this, however, we need a more accurate understanding of how the procurement and distribution of products impacts on sustainability issues such as emission rates. What has been lacking so far is a simple do-it-yourself method for establishing the facts. Research is now demonstrating that one of the tools developed to operationalise lean thinking –value stream mapping – can be adapted to operationalise green thinking too. The result, "sustainable value stream mapping", is a tool that helps companies evaluate supply chain decisions in terms of sustainability as well as quality, cost and delivery.

Lean has shown that time compression is a leading indicator of quality, cost and

Exhibit 2: Value-adding logistics and the environment interface (adapted from Wu et al, 1995)



delivery. The economic equivalent of time compression – the leading indicator of environmental energy – is carbon dioxide emissions. From an input perspective, carbon dioxide emissions closely relate to transport, industry and domestic energy usage and mode. From an output perspective, other emissions are related to carbon dioxide and can be quantified as carbon dioxide equivalent[3]. Hence, the environment objective proposed is to "minimise the CO^2 emissions in relation to the market weight of the product".

Clearly the value stream interfaces with the environment at every stage and throughout there is potential for both value adding activity and pollutant output (Exhibit 2).

It therefore follows that the evaluation of emissions should be a process-centred technique as well, not a functionally focused analysis addressing one element of the supply chain, such as transport, in isolation. The technique again takes the view that opportunities and choices are best seen and learnt by following the whole value stream for representative products of a product group, from the farm to the home (and maybe beyond, to complete the recycling cycle or complete life-cycle analysis). We can extrapolate the knowledge across the rest of the group and identify different solutions for different types of products.

To begin the mapping process the boundaries of analysis have to be drawn. Value chain mapping has been extended to an end-to-end scope, such as in the illustration of tracking a coke can from mine to home[4]. This found, for example, that there were 12 processes and 14 storage steps, which in total took a fairly horrific 416 days to complete. With the environmental significance of the recycling process, the scope of sustainable mapping potentially extends further than value stream mapping to a full life-cycle.

Once the boundaries are drawn the intermediate processes are then identified. From farm to home, these processes might include processing on the farm after picking, transport to a storage site, storage, packing, transport again to a consolidation centre, more storage, transport to a regional distribution centre, more storage, transport to a store, more storage backstage and on the shop-floor and finally transport to the consumer's home and more storage, possibly in a fridge or freezer, before cooking and consumption.

For each of these processes, CO^2 emissions attributable to a single product should be established. This can be calculated relatively simply once certain data inputs are known. So for a storage step, where the emissions for the total warehouse over a period and the proportion of total pallet area taken up

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Exhibit 3a & 3b: **Based on United Kingdom government (DEFRA, 2003 and DfT, 1999) figures for CO^2 emission rates for electricity, gas and road transport**

	CO^2 Kg per kWh
Electricity	kWh x 0.43 = $KgCO^2$
Gas	kWh x 0.19 = $KgCO^2$

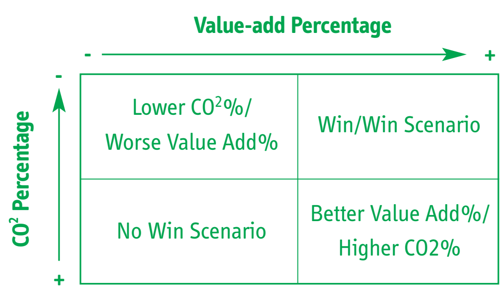
	g/CO^2/Km
Car	200g
Light Goods Vehicle	230g
Heavy Goods Vehicle	970g

Exhibit 4: **Sustainable value stream mapping – the top key performance indicators**

$$\text{Maximise “Value Add \%”} = \frac{\text{Supply Chain Value Adding Time x 100}}{\text{Total Supply Chain Time}}$$

$$\text{Minimise “}CO^2\text{\%”} = \frac{\text{Supply Chain }CO^2\text{ x 100}}{\text{Market Weight of Product}}$$

Exhibit 5: **Decision Box**



by a pallet are confirmed, the emission per pallet per hour can be established by using government (for the UK, DEFRA) guidelines for CO^2 production from electricity and gas utilisation (Exhibit 3a). Similarly for transportation, taking the distance and the two-way load factor together with the number of units carried, the emission per unit can be established using government (for the UK, DfT) CO^2 emissions factors for different modes of transport (Exhibit 3b). Other process legs such as manufacturing operations can be similarly evaluated.

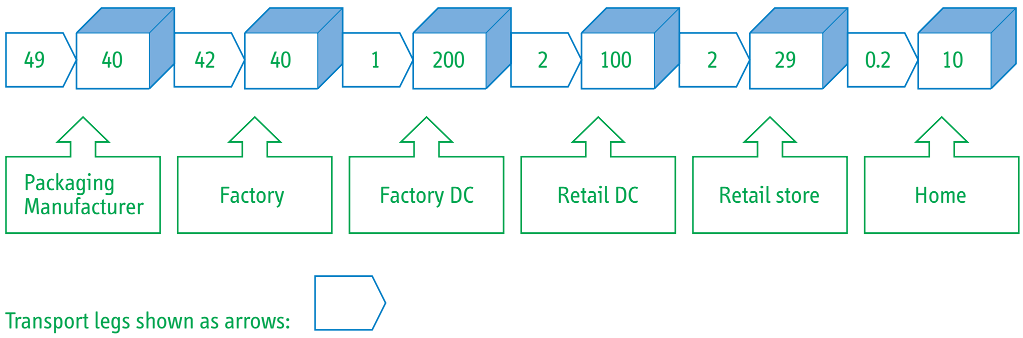
Once each of the legs are established the results can be combined to produce the total CO^2 output for the supply of the product to consumption. To enable different products to be benchmarked and for relative progress to be monitored, the CO^2 output is then divided by the market weight of the product to produce a percentage. This gives the overall sustainability metric of the total CO^2 generated per unit weight.

The mapping technique can, when combined with the value-added percentage derived for the same processes, be applied to evaluate the current state, or used as a planning tool to aid the scoping and assessment of future scenarios. In future state plans the results produced by the map will fall into one of four categories dependent on whether they are beneficial to increasing the value adding percentage and/or decreasing the CO^2 proportion.

There are obviously many strategic choices where the changed CO^2 emission rate combined with the value added percentage could be critical in informing decision makers. The following examples show how this method might be used and the choices it may inform. One is an ambient processed product, long-life orange juice, which is increasingly made in large centralised factories and distributed through several layers of distribution centres. The other is a fresh seasonal product, apples, that can be picked locally and stored to supply demand throughout the year or brought from distant locations in the appropriate seasons.

For each of these examples a summary sustainable value stream map shows where emissions occur, with a summary

Exhibit 6: Time (hours – colour code blue) per unit of orange juice



CO^2/weight measure for the whole value stream, and highlights some key strategic sourcing and logistics choices such as:

- for ambient processed products, the choice between distant, focused factory and distributed processing close to a distribution centre for a region
- for fresh, seasonal product, the choice between sourcing locally and using refrigerated storage to extend the selling season with domestically grown product, in contrast to transporting the product from where it is in season around the world
- for the home leg the emerging tendency for grocers to pick and deliver against the traditional method of the consumers picking, carrying and delivering to the home themselves.

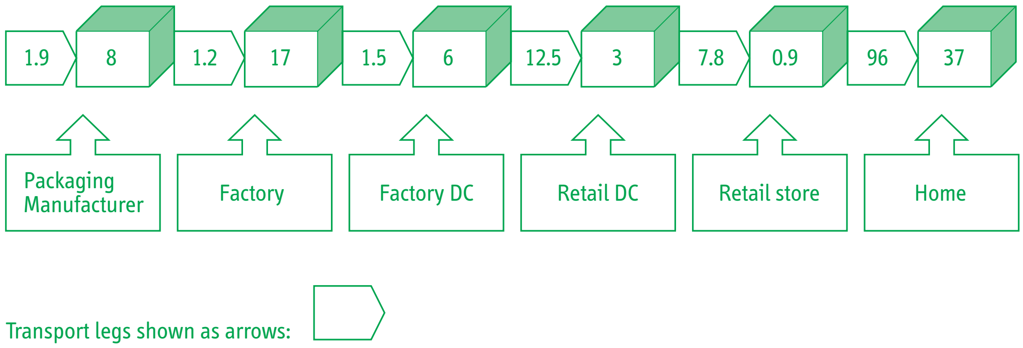
For a single long-life orange juice carton value stream, mapping work indicates that in a conventional supply chain for a large supermarket it takes 522 hours from receipt of the packaging material at a British port through all the production, storage and transport steps to consumption at home. The hours resulting from each process step are illustrated in the blue boxes in Exhibit 6.

Of that 522 hours, only 7.2 hours is categorised as value adding – the creation of value that is appreciated by the consumer-equivalent to 1.3 per cent of time.

This mapping is then enhanced to calculate the CO^2 emission per item, shown in the green boxes in Exhibit 7 (all further examples will just focus on the CO^2 enhancement of the mapping), which in total is 193g per unit: 19.3 per cent when compared with the selling unit weight of 1000g. Interestingly, the CO^2 produced by storing the product for just four days once opened in the fridge, at 37g per unit, is equivalent to 19.2 per cent of its total end-to-end emissions. In addition, the home transport leg, which will be discussed in the last scenario, accounts for 96g, equivalent to 49.7 per cent of the total. The processes of production, storage and transport for an orange juice carton accounts for a total of 31 per cent of the total emissions.

Nevertheless, as discussed in the introduction, companies and enterprises are increasingly expected to be driving through measures to reduce emissions under their direct control. An illustration of this is "distributed manufacture" proposed by Jones and Simons (2000) in the food industry, which involves the relocation of production to a more local alternative of a purpose-built factory adjacent to the distribution centre. Using the mapping tool the total time per unit to make, transport and store a carton of orange juice collapses to only 265 hours under this method. Value added time is now 6.6 hours or 4.8 per cent, while CO^2 output falls to 166g per item (16.6 per cent), largely as emissions attributable to

Exhibit 7: CO^2 emissions (g) per unit – colour code green



the transport of the heavy finished product have been greatly reduced.

On a variable cost as well as a sustainable basis, there is a strong argument to adopt more local production-based solutions for this case study product. The key to making such a system work would be to minimise overhead costs through lean administration of the distributed manufacturing units. Theory on where to locate production facilities distinguishes between weight-adding products (for example, water is added to orange juice concentrate) close to the market and weight-losing products (for instance, meat is trimmed and cut to final product) close to raw materials. The second case study product (apples) is weight neutral. Would local production be suitable for such seasonal crops that could be stored for consumption out of season?

Over the past 20-30 years the domestically consumed apple crop in the UK has fallen considerably as apples from across Europe and from all round the world have taken a bigger proportion of the British market. The alleged increase in emissions from this increase in international sourcing, it is argued, make this unsustainable. Research carried out for the Transport 2000 Wise Moves Project[5], used the mapping technique to analyse this issue. Transport figures from that study are used with secondary sources to industry estimates for process, refrigeration and storage.

If production and storage of British apples is compared with the production and shipping of apples from overseas, in this case New Zealand, the results that emerge are interesting. Firstly, Exhibit 9 summarises the emissions of 1kg of apples from picking at the farm to arrival at the consumer's home. In total the emissions are 125g per kg.

Next, Exhibit 10 summarises the emissions from production in the UK when stored for home market consumption after four months. The total emissions per kg are 129g, virtually the same as for the apples produced in New Zealand. This intuitively surprising figure is due to the high emissions from storing the apple at the required temperature during the period between harvest and call off for selling. Thus it could be concluded that after around four months it makes questionable sense, on environmental grounds, to store British apples for the domestic market.

The final scenario chosen to illustrate the scope of the mapping method is to compare emissions for the home delivery leg. In the last three to four years a number of supermarkets have begun to offer consumers the opportunity to order their groceries over the Internet and have them delivered direct to the home. The business model most commonly used is for the supermarket to pick from the

Exhibit 8: **Change in value added percentage and CO^2 emitted percentage for oange juice distributed manufacture per single carton**

Product Weight -1000g	Current		Distributed Manufacture	
	Time	CO^2	Time	CO^2
Total	522 hrs	193g	265 hrs	166g
Value Added	7.2 hrs	-	6.6 hrs	-
Percentage	1.3%	19.3%*	4.8%	16.6%

* CO^2 emitted in whole chain as a percentage of market weight.

shelves of the local store rather than a distribution centre, so a comparison in emission rates can be made contrasting the delivery by supermarket van with the traditional method of customer self-selection and delivery in their own car.

To examine this, certain assumptions have been made using the data from the orange juice scenario presented above. The customer lives 8km from the store. The weight of the shopping is 40kg. The customer's car is effectively empty when travelling to the supermarket. For the home delivery van, there are 10 customers' orders on the van each averaging 40kg, and the circumference of the journey is (2 x 3.142 x 8 = 50 Km). Using the CO^2 per km emission factors (Exhibit 3b) the CO^2 emission rate for the customer collection method equates to 96kg, while the home delivery method equals 46kg.

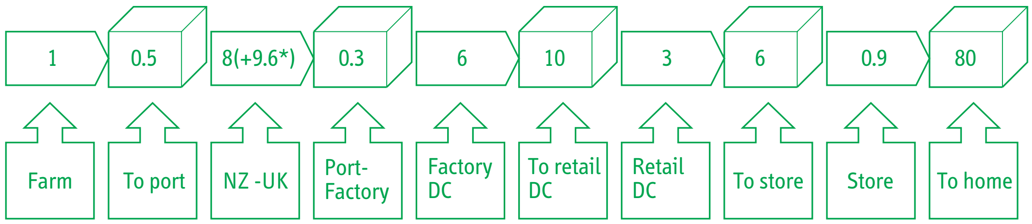
While there are a large number of assumptions incorporated in this example, the mapping analysis does indicate that if the delivery van method can be planned effectively, ensuring optimum route planning and achieving high service levels (small percentage of missed deliveries), there are perhaps environmental benefits from grocery home delivery.

We have worked for several years with retailers and suppliers implementing ECR and lean initiatives focusing mainly on attaining a simpler and faster flow of the product through the supply chain. The analysis shows that getting closer to the customer through distributed manufacture and consolidating transport through home delivery can be strongly argued economically. But it also has a positive environmental impact.

However, as the orange juice example shows, after the last journey from store to home, the refrigerator is by far the biggest environmental waste. Modification of the orange juice or its packaging to allow ambient storage could at a stroke provide greater environmental benefit than reconfiguration of any upstream supply chain step. Clearly, this may be difficult to achieve as consumers may not want ambient juice. However, the example does raise wider questions about the storage, preparation and cooking of meals: perhaps environmental benefits can be traded off further up the supply chain. In other words, when mapping environmental impacts, we need to take a broader interpretation of "end to end" than a lot of previous research, which focuses exclusively on financial and economic benefits.

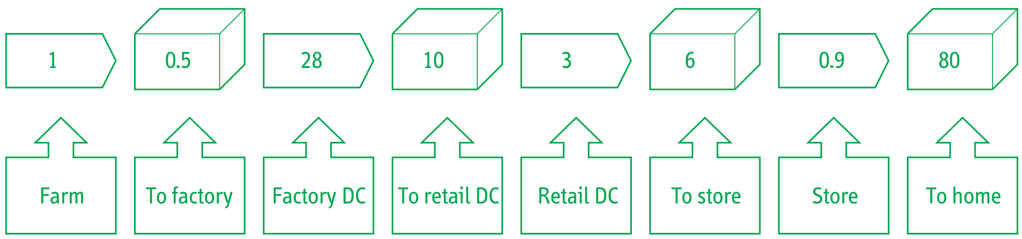
Quantifying the environmental wastes beyond the boundaries of the organisation has potential for companies and industry bodies to lobby legislators on regulation content and timing.

Exhibit 9: CO^2 emissions (g) per 1kg apples



* An extra 9.6g of CO^2 emissions occur from refrigerating the product on the ship

Exhibit 10: CO^2 emissions (g) per 1kg apples



Understanding the silo trade-offs (Exhibit 1) has potential for supply chains to predict where future legislation may be targeted and to shape discussions with regulators.

Over a number of years, lean has shown that value stream mapping and end-to-end time compression delivers economic benefit across sectors and cultures. With sustainable value stream mapping we may be able to achieve end-to-end CO^2 minimisation which could have similar benefits from an environmental standpoint. The synergy of the "time and CO^2" and the "lean and green" argument depends on end-to-end supply chain improvements locating in the "win-win" box in Exhibit 5. Indications from this paper are that generic improvements in producing closer and more responsively to the consumer gravitate towards this "win-win" situation. However, these are early days for sustainable value stream mapping, and as with the original mapping the real test will be a number of case studies providing consistent empirical evidence of analytical effectiveness of the approach and the lean green correlation.

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