Green Logistics Consortium Working Paper

Title:

Supply Chain Management, Transport and the Environment- A Review

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Abstract

Purpose: The aims of this paper are:

- To determine the gaps in the literature regarding the impact of Supply Chain strategies on Green Logistics performance
- To evaluate potential existent solutions to the trade-offs between the overall supply chain economic performance and Green Logistics performance

Design/Methodology/Approach: This paper presents a literature review in Supply Chain Management, Transport and Green Logistics. The literature review covers supply chain management, supply chain strategies-lean thinking, Just-in-Time, Agility and Postponement, supply chain integration, supply chain practices-VMI and FGP, and green supply chain practices. The methods of generalisation such as clustering, categorisation and cross-comparison have been applied.

Findings: Firstly, the project should determine the forms of logistics uncertainty that impact on supply chain performance. After that, intensive research should be carried out in establish the impact of supply chain strategies and principles on green logistics performance. Moreover, the project should also clarify the impact of horizontal integration on green logistics performance. However, the impact of green logistics intervention on supply chain strategies should be one of the main focuses of this project as well.

Originality/value: Little research has been undertaken in the dynamic relationship between supply chains and transport and its impact on Green Logistics performance. This literature review is a starting point for research in the topic area. It integrates all the body of knowledge in supply chain management and transport with the ecological literature in supply chain management.

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Supply Chain Management is a subject that involved many areas, from the hard to soft topics. Supply Chain Management as an independent field was originated from Marketing and Strategic Management. In this review, the most relevant and current topics of Supply Chain Management will be discussed, taking as a primary focus the impact of supply chain issues on transport and green logistics performance. The topics that will be discussed in the rest of the paper are supply management from a top-view perspective, uncertainty in the supply chains and transport, supply chain strategies and transport, current supply chain practices and transport, and supply chain integration and collaboration.

1. Supply Chain Management

The Council of Logistics Management (CLM) defines Supply Chain Management as the strategic coordination of the core functions and tactics across these functions within a specific organization and across its partners within the supply chain for the purposes of improving the long-term performance of the individual organizations and the supply chain as a whole. 'Supply Chain Management has been defined to explicitly recognise the strategic nature of coordination between trading partners and to explain the dual purpose of Supply Chain Management: to improve the performance of an individual organization and to improve the performance of the whole supply chain' (Li et al, 2006). On the other hand, SC constituent by two pipelines, information and materials flow. These require operational strategies, which can integrate and complement the individual characteristics of both pipelines (Mason-Jones and Towill, 1999). However, Stock et al (2000) define the most significant performance factors, Channel Governance, Geographic Dispersion and Logistics Integration.

Regarding to green logistics, these three factors affect the performance of transport providers that are directly and indirectly linked to supply chains. Channel governance affects the strategic focus within the whole supply chain, and as a consequence, the way that transport is planned throughout the supply chain. Geographical dispersion has a direct impact on the economic and environmental performance of the supply chain, since the more geographical dispersed is the supply chain, likely the highest will be the external and internal costs of transport. However, there should be ways of mitigating that negative impact of geographical dispersion on the sustainable performance of supply chain and transport, such as the horizontal and vertical integration of transport flows, so logistics integration is the third but not least important factor, which according to Stock et al (2000), have a considerable impact on supply-chain performance. However, it is important to determine the impact of integration on green logistics performance.

In the rest of this section, the main topics related to supply chain management will be discussed, which are Supply-Chain Key Performance Indicators, Supply Chain Management and Transport, and Supply Chain Practices.

1.1 Supply Chain Key Performance Indicators (KPIs)

It is essential to assess the supply chain in a numerical manner, since the individual companies involved and the supply chain as a whole can benchmark themselves against their competitors, so they can continuously improve, and dynamically adjust their KPIs. As Inger et al (1995) say, the most strategic supply chain KPIs are delivery performance, schedule adherence, lead time and product logistics costs.

Meanwhile, Reichard and Nichols (2003) used the SCOR model KPIs to assess the performance of a significant number of organisations. They categorised three external and one internal attributes and they selected specific KPIs to measure the performance of organisation. These attributes were supply chain delivery reliability, supply chain responsiveness, supply chain flexibility and supply chain asset management efficiency. The KPIs that they used to measure organisations were delivery performance to commit date, fill rate, perfect order fulfilment, order fulfilment lead time, SC response time, production flexibility, cash-to-cash cycle time, inventory days of supply, net asset turns. However, it is important to align these KPIs to green logistics, it is vital to determine whether or not these KPIs can be aligned to sustainable distribution, and if not, it will be necessary to develop a new set of KPIs to assess the performance of transport from a holistic green supply chain perspective.

1.2 Supply Chain Management Practices

Several authors have researched about supply chain management practices, but most recently, Li et al (2005) developed a list of sub-constructs for supply chain management practices to link them to performance. These constructs are Strategic Supplier Partnership, Customer Relationship, Information Sharing, Information Quality, Internal Lean Practices and Postponement. Li et al (2005) define these sub-constructs as:

- Strategic Supplier Partnership: long-term relationship between companies and their suppliers. It is designed to align the strategies of the companies with their suppliers. However, when they say suppliers they mean materials suppliers or they are including third logistics providers under this sub-construct. Therefore, it is necessary to determine the impact of strategic third logistic provider partnership on green logistics performance, since it represents a different dimension of integration, the horizontal dimension. Moreover, regarding to reverse and forward flows in the supply chain, it is also important to determine the impact of vertical integration on green logistics performance.
- Customer Relationship: practices that have the purpose to define how companies can manage customer complaints and develop a long-term relationship with them. Third logistics providers need to define who their main strategic customers are and how they can develop a win-win relationship with them, positioning them on strategic segments, so they can satisfy their specific needs. But, it is vital to determine the impact of the customer-third logistic provider relationship on green logistic performance.
- Information Sharing: the extent to which strategic information is shared with suppliers. However, this concept leaves a question opened, to what extent information sharing is vital between third logistics providers and their customers, and also the impact of information sharing on green logistics performance should be determined.
- Information Quality: this concept is to how accurate, credible, current and adequate the information exchanged is.

- Internal Lean Practices: the extent to which there are practices of waste elimination and value creation within the supply chain. This specific area will be discussed more in-depth later on in the paper.
- Postponement: represent the practices of delay some activities within the supply chain. It has the goal of making the supply network more responsive. Due to the relevance of this area and its impact on green logistics performance, a more in-depth discussion will be developed later.

Towill (1999) also developed other framework to guide supply chains to reach an effective operation. He stated a number of pre-conditions that companies need to apply in order to simplify material flow. These rules are: ‘unbiased and noise-free information flows; time compression of all work processes; achievement of consistent lead times; choice of smallest possible planning period; adherence to the schedule i.e. elimination of pockets of ‘Just-in-Case’ materials, selection by simulation of the ‘best’ supply chain controls; and finally, matching the simulation model to the real work process via process flow and information analyses’.

However, there has been little research on the impact of supply chain practices on green logistics performance; this gap in the green logistics literature needs to be filled.

Research Question 1*: How do fundamental supply-chain principles impact on Green Logistics?*

1.3 Supply Chain Management and Transport

Supply chain management is a field that is usually been studied more from a market and product perspective rather than from a transport point of view. However, some authors have recently worked in the development of the supply chain and transport relationship. Firstly, Stank and Goldsby (2000) developed a decision-making framework that positions transport in an integrated supply chain (Figure 1). Regarding to transport decision-making, decisions are made from strategic to operational level and from macro to micro level, they categorised these decision as total network and lane decisions, lane decisions, mode/carrier assignment decisions, service negotiation and dock level decisions. However, they do not determine the impact of each of these decisions on Green Logistics performance, and most importantly, the decisions made at macro and strategic levels possibly have a more significant impact on Green Logistics performance, so it is vital to fill this gap on the literature.

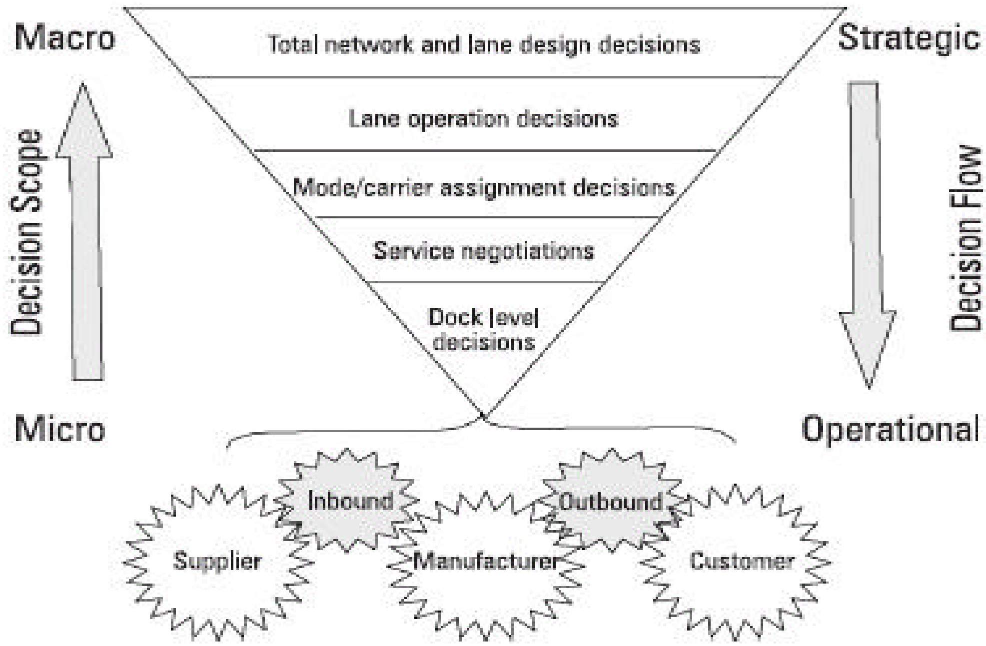

Figure 1 Transportation decision making in an integrated supply chain (Source Stank and Goldsby 2000)

Meanwhile, Potter and Lalwani (2005) stated that there has been little degree of change of transport management techniques, although there is evidence of demand variability, and subsequently, demand amplification on transport operations. In terms of demand amplification and transport, there has qualitatively been suggested a negative relationship between these two variable. However, according to Potter and Lalwani (2005) that negative relationship has not been proven.

In addition, Potter and Lalwani (2005) developed a framework that integrate five main strategic themes, namely coordinated distribution network management, transport cost visibility, exploitation of ICT, collaborative relationships and information feedback. However, these authors left an unfilled gap in the body of knowledge of supply chain and transport, since there has not been determined the impact of transport demand amplification on green logistics performance, and also the impact of their five main strategic themes on green logistics performance.

Supply chain management and transport are areas that should be discussed more in-depth, in order to do so it is necessary to develop a framework that allow a holistic analysis from a system perspective. Therefore, before discussing about supply chain strategies and practices, it is important to discuss more deeply about sources of uncertainty between supply chain companies and third logistics providers. Therefore, a detailed analysis on sources of uncertainty will be developed in the next section of the paper.

2 Uncertainty from a Supply Chain and Transport Perspective

Supply chain uncertainty is a concept that has been widely discussed on the literature. According to Van der Vorst and Beulens (2002), 'SC uncertainty refers to decision making situations in the SC in which the decision maker does not know definitely what to decide as he is indistinct about the objectives; lacks of information about its environment or the supply chain; lacks information processing capacity; is unable to accurately predict the impact of possible control actions on SC behaviour; or, lacks effective control actions'. Therefore, uncertainty is produce mainly because of insufficient information within the supply chain and lack of effective control decision tools.

On the other hand, at a strategic level, uncertainty can be divided in two main categories, external vulnerability and supply chain agility (Prater et al 2001). External Vulnerability is related to demand and forecasting uncertainty, and complexity. Supply chain agility is related to sourcing flexibility and speed, manufacturing flexibility and speed, and delivery flexibility and speed. Therefore, it is important to determine the impact of external vulnerability and supply chain agility on green logistics performance.

Prater (2005) developed an uncertainty framework that can be used to determine the causes of supply chain and transport uncertainty. This framework classified uncertainty from a macro to micro level (See Figure 2). At a macro level, uncertainty is typified as general variation, foreseen uncertainty, unforeseen uncertainty and chaotic uncertainty. General variation consists of variable, multi-goal and constraint uncertainties. Foreseen uncertainty is caused by amplification and parallel interactions. Unforeseen uncertainty is the consequence of deterministic chaos and long-term planning. And, chaotic uncertainty is general non-deterministic chaos that cannot be predicted by a mathematically function.

Macro Level	Micro Level
General Variation	Variable, multi-goal and constraints
Foreseen Uncertainty	Amplification and parallel
Unforeseen Uncertainty	Deterministic chaos and long-term planning
Chaotic Uncertainty	General non-deterministic chaos

Figure 2 Micro-level Types of Uncertainty in Supply Chains (Source Prater 2005)

Regarding to supply chain systems, Wilding (1998) emphasised ‘the importance of treating the supply chain as a complete system. The whole is not the sum of the parts’. He developed the ‘supply chain complexity triangle’, which highlights that SC uncertainty is created by amplification, parallel interactions and deterministic chaos. Therefore, taking a supply chain and transport perspective, the impact of parallel transport providers interactions and parallel customer-transport providers interactions should be established, since it could represent a very significant source of transport uncertainty, and as a consequence, have a considerable impact on green logistics performance.

Mason-Jones and Towill (1999) developed the uncertainty circles framework, determining the main uncertainty sources, which are supply side, demand side, process, and control systems. However, this model was developed from a manufacturing perspective, so we need to adapt it to transport operations, taking a logistics perspective. In doing so, we will start developing the uncertainty logistics triad model (Figure 4), extending the logistics triad model developed by Bask (2001) (Figure 3). That model highlights the importance of the tripartite existent between shipper, customer and 3PL for the effectiveness of the supply chain as a whole.

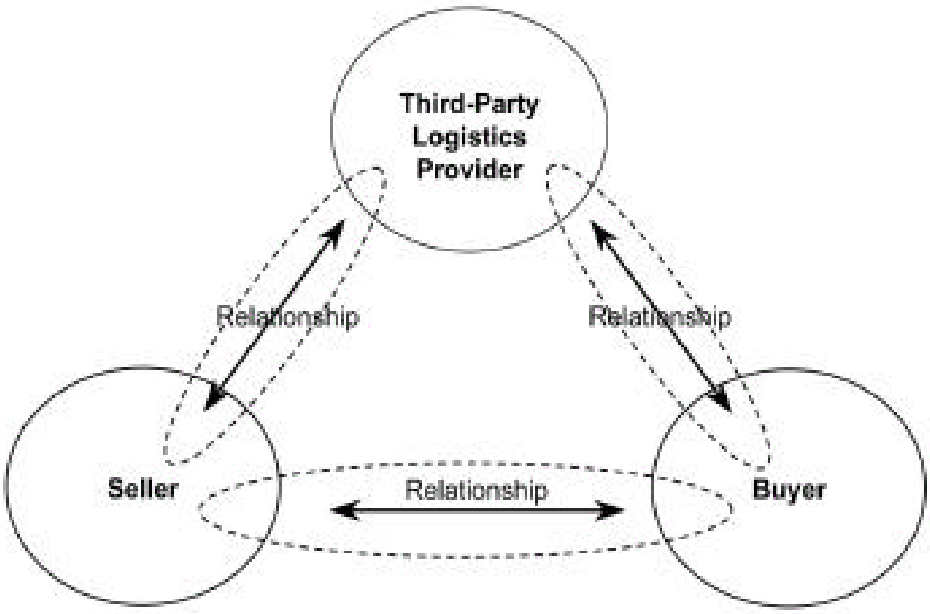

Figure 3 Three dyadic relationships among seller, buyer and third logistics provider- Logistics Triad Model (Beier 1989, Bask 2001)

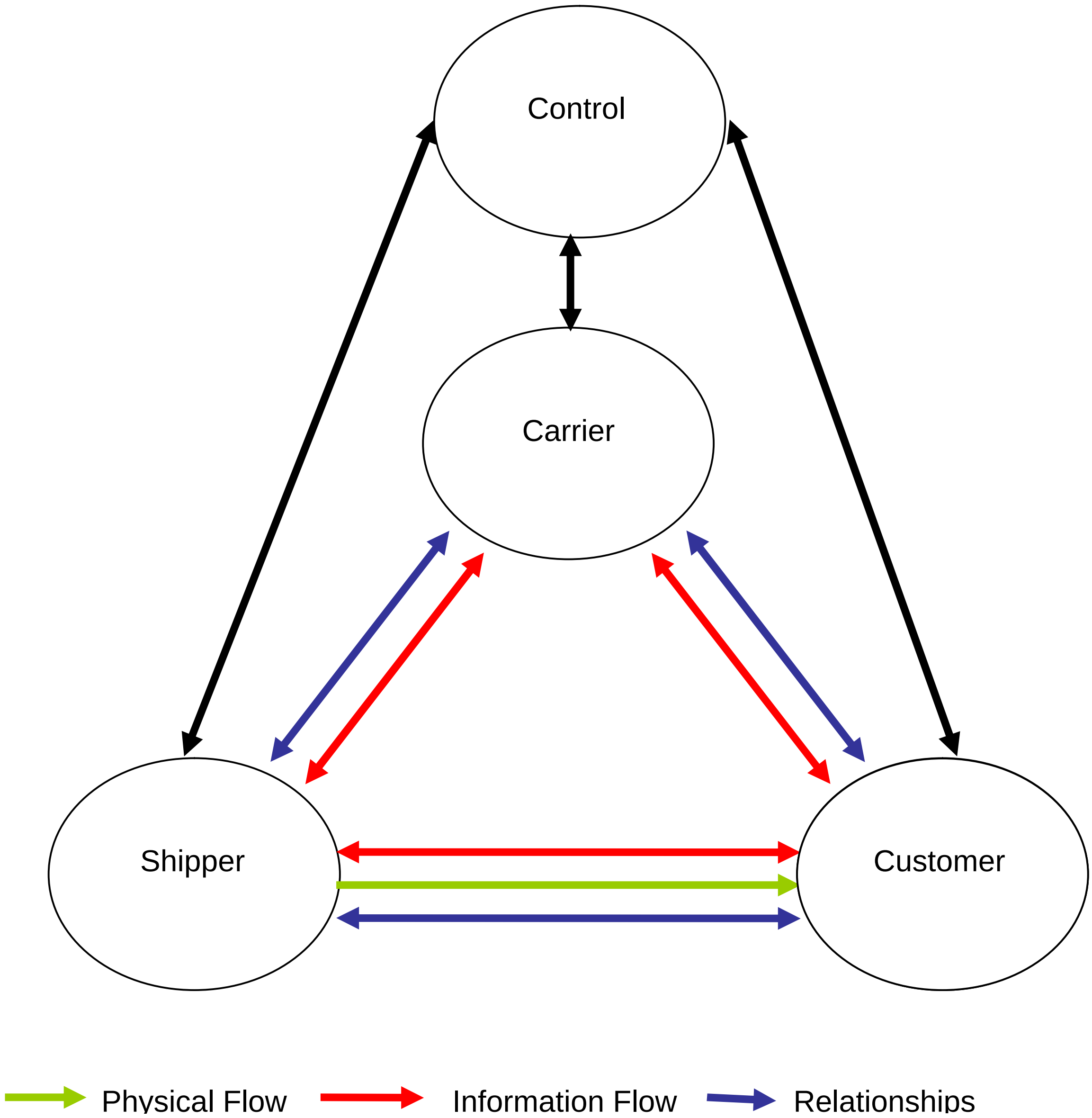

Figure 4 Logistics Triad Uncertainty Model

In developing the Logistics Triad Uncertainty Model, we will integrate to the model other frameworks that have been developed to exemplify uncertainty depending on the type of sources. Van der Vorst and Beulens (2002) extended that Mason-Jones and Towill's Uncertainty Circle Model, adding three dimensions to the original model. These dimensions are quantity, quality and time. However, it is necessary to determine in each source of uncertainty the impact of each of these dimensions on green logistics performance (See Figure 5), so we will include the these three dimensions in the new model (Figure 4).

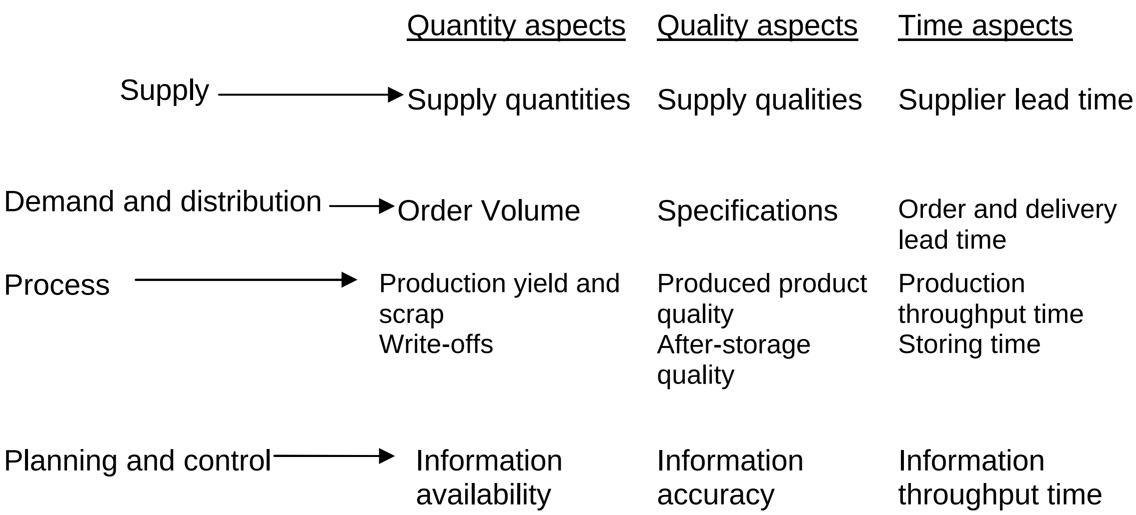

Figure 5 Typology of sources of supply chain uncertainty and aspects they concern (Source, Van de Vorst and Beulens 2002)

Geary et al (2002) also extended the Uncertainty Circles Model, giving examples of bad practices that can potentially cause uncertainty (See Figure 6). This framework will also give us some lights in the development of the Logistics Triad Uncertainty Model.

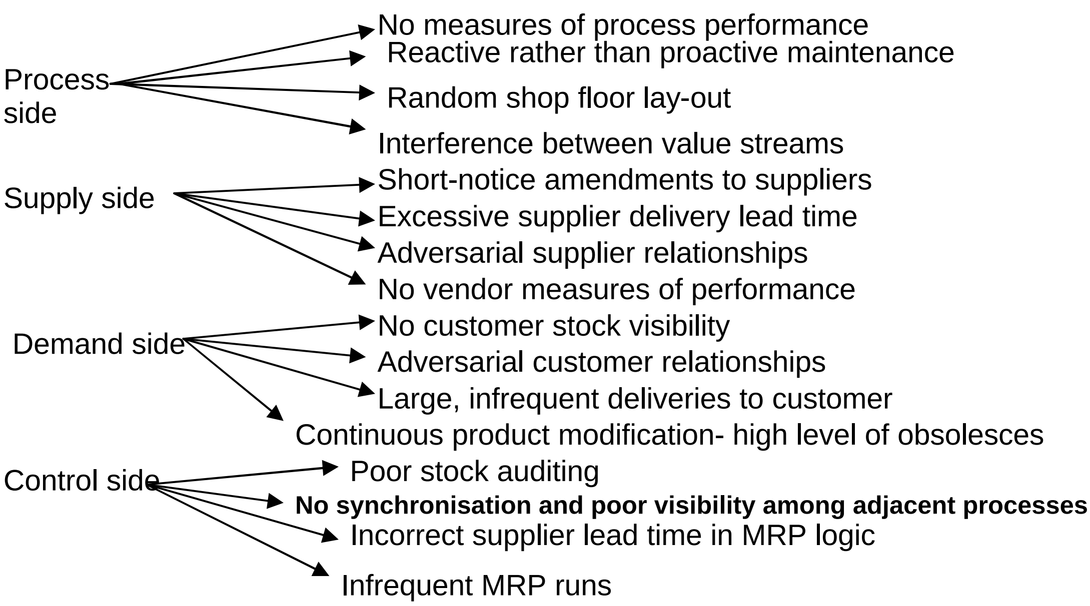

Figure 6 Examples of bad practices from the four sources of supply chain uncertainty (Source, Geary et al 2002)

Regarding green logistics, it is important to establish the impact of these bad practices on the environmental performance of transport taking a holistic supply chain view. Therefore, there should be a considerable degree of clarity about what aspects of uncertainty are relevant to green logistics. In order to determine this we should consider:

- All the sources of uncertainty that affect the supply chain and transport.
- Consider the causes and effects of each type of uncertainty
- Determine where each type of uncertainty is originated, in transport operations or supply chain?
- Link the causes and effects of uncertainty taking account of the whole supply chain, with transport as an strategic activity
- Determine the impact of the causes of uncertainty on green logistics performance
- Prioritise within that causes of uncertainty and develop solutions to mitigate their implications

Supply chain and transport uncertainty is a field that is directly related to other supply chain themes. Therefore, different supply chain strategies and practices which have direct impact on transport performance will be discussed in the following sections of the paper. From this section, it can be concluded that uncertainty needs more research in logistics and transport, and we need to determine the forms of supply chain uncertainty that exist within transport operations and how do they impact on Green measures.

Research Question 2*: What forms of supply chain uncertainty exist within transport operations and how do they impact on Green measures*

3 Supply Chain Strategies

Supply Chain as a field has been developed in two main schools of thought, Lean Thinking and Agility. In this section, these two different strategies are discussed from a conceptual level to a more tactical and operational level. The potential impact of these two strategies on transport are addressed when is necessary.

3.1 Lean Supply Chain

The theory of Lean Thinking has evolved with time. The term lean production was first used to describe the process of minimisation of waste in the automotive industry (Womack et al., 1990). Jones et al (1997) say Lean thinking has a natural starting point with value for the customer looking at the whole rather than the individual processes. However, Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule (Naylor et al, 1999).

More recently, Hines et al (2004) stated that Lean exists at two levels: strategic and operational. The customer value-creation strategic thinking applies everywhere, the shop-floor techniques do not, but value creation is only equal to quality, cost and delivery. However, Lean Thinking is not a supply chain strategy that can be adapted to all sorts of products. Developing a supply chain strategy consists of matching market characteristics (products attributes and demand variability) with supply, and there are two sorts of products, fashionable and commodities (Fisher 1997). Therefore, the commodities can be adapted to the lean environment since there is high predictability of demand, and in consequence, the process can be control be the lean-thinking level schedule requirements (Suzaki 1987). However, all this discussion leave questions opened about the characteristics and attributes of this supply chain strategy and it is also necessary to deduce the potential implication of lean thinking to green logistics performance. This will be discussed in the following sections of the paper.

3.1.1. Lean Supply Chain Characteristics

From the Toyota's tool box, Jones et al (1997) stated the characteristics of truly lean-thinking strategy, value creation, value stream, level schedule (level demand and supply), organisation of work (preventive maintenance), pull system through Kanban inventory control system (minimisation of safety stock), standardisation of work (Total Quality Management), visual control devices and production errors detection. From these characteristics, it can be noticed that waste minimisation and level schedule play a strategic role in any Lean Thinking programme. However, it is important to thinking in the feasibility of this strategy, how this strategy can be adapted to volatile market. Also, it is necessary to determine the impact of a typical lean thinking supply chain, where minimisation of inventory is achieved through level schedule and pull systems, on green logistics and transport performance.

Furthermore, Naylor et al (1999) define the Leanness characteristics as use of market knowledge, value stream and integrated supply chain, lead-time compression, elimination of waste and level schedule. It is necessary to discuss these characteristics separately, in order to compare and integrate the contribution of other authors.

- **Use of Market Knowledge**: Naylor et al (1999) said that if market knowledge is not exploited, a mismatch can be produced, where demand is not synchronised with supply. Lean thinking is value creation for customers (Jones et al 1997, Hines et al 2004). But, what is actually value creation; it is effective market research and R&D, or what. It is essential to determine the impact of effective use of market knowledge on Green Logistics and transport performance.

- **Value Stream and Integrated Supply Chain**: 'with the integrated supply chain both the information and material flows will be simplified, streamlined and optimised reducing waste and lead times' (Naylor et al 1999). Likewise, several authors have included integrated supply chain as one of the most strategic requirements of lean thinking (Ohno 1988, Jones et al 1997, Mason-Jones et al 2000, Abernathy 2000, Bruce et al 2004, Hines et al 2004). However, the impact of vertical integration on Green Logistics and transport performance should be determined. Also, it essential to establish whether or not vertical integration is enough to achieve economic supply chain effectiveness, and at the same time, mitigate the negative impact of transport on the environment.

- **Lead-time Compression**: lean is elimination of all types of wastes, including waste time, so time compression is essential for lean manufacturing (Naylor et al 1999). Other authors emphasise this position (Aitken et al 2003, Hines et al 2004). However, looking at the waste minimisation thinking only in terms of total lead time can have secondary effects on supply chain performance. Moreover, lead time can be compressed by increasing the speed of delivery, but this could have a negative effect on green logistics performance. More importantly, in a very stable market where most of products are commodities, time compression could be balanced with accurate demand forecast.

- **Elimination of waste and pull system**: as Naylor et al (1999) stated, 'in a "pure" lean supply chain there would be no slack and zero inventory'. Several authors include elimination of waste and pull system as a strategic lean-thinking characteristic (Ohno 1988, Jones et al 1997, Abernathy 2000, Mason-Jones et al 2000, Bruce et al 2004, Hines et al 2004). This represent a similar issue as time compression presents, since there can be multi-goal problems between inventory reduction and transport optimisation. Therefore, it is important to establish how an inventory reduction strategy under a pull system can achieve its main goal, and at the same time, mitigate its negative effect on Green Logistics and transport performance.

- **Level Schedule**: 'Boeing pursued a lean manufacturing strategy without taking into account the variability of demand in the aerospace industry, level scheduling the market demand' (Naylor et al 1999). Many authors also emphasise that level schedule is one of the key of a lean-thinking initiative (Jones et al 1997, Mason-Jones et al 2000, Aitken et al 2003, Bruce et al 2004, Hines et al 2004). This could represent a weakness if a company apply this without being flexible to change in market demand, so under transition periods level schedule could potentially lead to obsolesces, and in consequence, to unnecessary transport movements (forward and reverse). However, it is important to determine under which situations level schedule works and add value to green logistics performance, and under which situations not.

This set of characteristics are taken from a process perspective, they do not consider the market characteristics, or specifically, the particular attributes that originate a lean thinking strategy. This will be discussed in the next section.

3.1.2. Lean Supply Chain Attributes

The word “attribute” has been used in the field of supply chain management to describe the market features of supply chain strategies (lean and agile). As it is shown in Figure 7, the lean supply chain is applied when the attributes of the market place are stable and predictable in the long-term (Mason-Jones et al 2000a). More specifically, lean supply chains satisfy needs in traditional market segments that do not typical change dramatically, so they offer commodities and a low variable product range under a very predictable demand. Therefore, the focus of this sort of supply chain is costs and their profit margins are low.

Distinguishing Attributes	Lean Supply Chain
Typical products	Commodities
Marketplace demand	Predictable
Product variety	Low
Product life cycle	Long
Customer drivers	Cost
Profit margins	Low
Dominant costs	Physical costs

Figure 7 The distinguishing attributes of lean (Source Mason-Jones et al 2000a)

On the other hand, as Bruce et al (2004) have emphasised, there are particular sectors such as textile and apparel sector, where companies needs to be able to respond quickly to change in market demand and to continuously replenish end customer inventories, but at the same time, they cannot afford to store large quantities since products have a very short life cycle and fashion markets are seasonal. Therefore, it is difficult to categorise an industry or even a single company of being lean or agile, so supply chains satisfy different segments and products, which require different degrees of leanness depending on particular distribution channels. However, regarding to Green Logistics and transport, this leaves an unfilled gap in the literature which is how transport providers can satisfy at the same time agile and lean customers, and how they integrate them under the same distribution strategy.

Now, it is important to discuss the research of the ecological body of knowledge and how lean thinking can contribute to improvements on sustainable supply chain performance, and when needs to be adapted to the current situations and complement with other green supply chain practices. This will be addressed in the next section.

3.1.3. Potential Implications of Lean Supply Chain to Green Logistics Performance

It can be argue that lean manufacturing has a positive impact on the environment, since its primary focus is on waste minimisation. However, there are certain constraints that need to be taken into account to determine whether or not lean-thinking has a positive impact on the overall green supply chain performance. ‘Design, modelling, and analysis of the traditional supply chain has primarily focused on optimising the procurement of raw materials from suppliers to the distribution of products to customers’ (Beamon 1998).

This has included production/distribution scheduling, inventory control and locations, number of echelons, distribution centres (DC), plant - product assignment, buyer - supplier relationships: Determining and developing critical aspects of the buyer-supplier relationship and product differentiation step specification. However, this does not consider the total product life cycle, including reverse supply chain processes. ‘No longer is it acceptable or cost-effective to consider only the local and immediate effects of products and processes; it is now imperative to analyze the entire life cycle effects of all products and processes. Therefore, the traditional structure of the supply chain must be extended to include mechanisms for product recovery' (Beamon 1998). Hence, in order to mitigate the negative impact of transport on the environment, the integration of forward and reverse flows in the lean supply chain should be consider, so it should be determine how supply chain companies and transport providers can integrates that flows to holistically optimise transport movements.

Lean supply chains based their strategy on pull systems that aim to minimise the inventory within the chain. In order to achieve waste minimisation, these sorts of systems require Just-in-Time (JIT) delivery. McKinnon (1996) has suggested that JIT delivery can not be considered a green solution; despite that it has not greatly increased road volume. Zhua & Sarkis (2004) have stated that 'company to company relationships aspects of JIT and its focus on movement of materials may cause more detriment in terms of a moderating effect on the relationships between practices where an existence of such programmes may supersede finding environmental efficiencies for the sake of improved operational performance'. 'The more JIT strategies are applied, the further the negative environmental consequences of the traffic it creates' (Rodrigue et al 2001). Moreover, 'the least polluting modes are generally regarded as being the least reliable in terms of on-time delivery, lack of breakage and safety. Ships and railways have inherited a reputation for poor customer satisfaction' (Rodrigue et al 2001). Lean plants have started to increase painting batch sizes- similar colour, although it conflicts with JIT philosophy (Rothenberg et al 2001). However, this does not consider the level of predictability of demand and the demand forecast accuracy, if the demand is more predictable and its forecast is more accurate, inventories can be held on strategic locations of the supply chain. Therefore, the least fast and polluting modes could be used.

On the other hand, 'the trade-offs evaluated in most inventory management models are primarily inventory carrying costs and transport costs' (Wu and Dunn 1995). Moreover, 'with a reduced number of logistical nodes in operation, logistics managers are able to run a more efficient operation at lower levels of inventories while maintaining the same, if not better, level of customer service'

(Wu and Dunn 1995). One example of this is that ‘Procter & Gamble has successfully consolidated its warehouses and increased its customer service and revenue levels at the same time’ (Henkoff 1994). Other case of minimising the trade-offs between inventory and transport is that ‘Federal Express’s Parts Bank service where a single warehouse of parts serves the entire country with high level of service’ (Aron 1994).

In addition, Mason et al (2002) have developed a taxonomy to position green-lean different situations and they have concluded ‘the synergy of ‘time and CO2’ and the ‘Lean and Green’ argument depends on ‘End to End’ supply chain improvements locating in the ‘Win-Win’ box’ (Figure 8). There is a high potential for reciprocal benefits between firm environmental practices and lean manufacturing, since success of the lean manufacturing system relies heavily on the supply chain integration (Simpson & Power 2005). However, these potential solutions to the transport-inventory constraints need more testing, since they have been applied in practice, but a valid and reliable research study has not been undertaken to corroborate them.

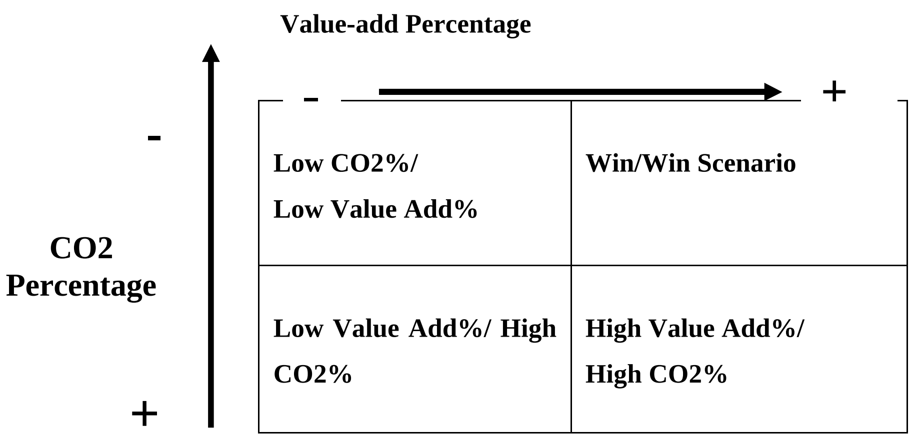

Figure 8 Green and Lean Decision Box (Source Mason et al 200X)

JIT is one of the main strategic features of Lean Thinking and is by far the one that represents the greatest challenge for Green Logistics. Therefore, in order to achieve a high level of green logistics performance, under JIT system, supply chain companies and their third logistics providers need to look for alternative means of achieving both at the same time. This will be discussed more in-depth in the next section.

3.1.4. Just-in-Time (JIT) and Green Logistics

There appears to be a problem of contradicting objectives between JIT and transport, and in consequences, between JIT and Green Logistics. In this section, a number of points related to this issue will be discussed. In a comparative study undertaken in 1995, Ramarapu et al concluded that reduction in waste, reduce lead-time, reduced set-up times, stable production, continuous improvement and cross-training/education are the most significant critical factors in a JIT implementation. Moreover, they also come to the conclusion that 'elimination of waste and production strategy are the most specific critical factors of JIT implementation. On the one hand, reduction of waste and lead-time can potentially mean for transport more deliveries and lower delivery performance in terms of full loads. On the other hand, continuous improvement and a more stable production can also have a positive impact on obsolesces. Therefore, in other to determine the impact of JIT delivery on Green Logistics performance, it is necessary to take account of the whole value stream, including forward and reverse logistics in the supply chain.

Swenseth & Buffa (1991) stated 'advocates of JIT argue that variation in lead time is also eliminated by establishing relationships with vendors and transport carriers that assure delivery at scheduled times, with little or no lead time variation'. If there is better information transparency and visibility between the vendor and carriers, a JIT strategy can be synchronised between production and delivery. Moreover, as a consequence of level schedule, lead-times and safety stocks can decrease (Swenseth & Buffa 1991). However, they also emphasised that 'decision related to the appropriate JIT order cycle time must be based on realistic estimates of unit freight rates, average transit time, and transit time variability' (Swenseth & Buffa 1991). Thus, this confirm that under a JIT production and delivery system transport should be carefully analysed as an strategic issue, since it can bring collateral effects to the overall supply chain performance.

According to Minanham (1997), Toyota is under a continuous improvement process of its JIT system, 'location of the suppliers' base helps to achieve a close-loop distribution network, known as "milkrun" that can deliver parts from its suppliers to assembly base in a JIT principles'. Therefore, from a transport and supply chain perspective, sourcing and location of suppliers are critical factors to achieve an effective JIT system, since optimisation of transport flows can be achieved in conjunction with minimisation of inventory. Furthermore, Millighan (2000) stated that 'overnight delivery carriers, fewer high-quality carriers and improvements in order traceability (investments in IT capabilities)' are also essential under a JIT system. In Japan, 'Nissan with its factories more dispersed than Toyota, soon found the addition of buffer stock, well above that of those levels maintained by Toyota, to be a useful tool to offset traffic congestions in urban areas ' (Polito and Watson 2006). Therefore, from a transport and supply chain perspective, it is important to determine the main strategic factors that allow high level of Green Logistics performance under a JIT system.

Some authors have emphasised the benefits of JIT. Stank and Crum (1997) concluded that firms that successfully implemented a JIT system have high level of performance in inbound replenishment and customer order cycle-time reductions, and on the Green Logistics side, are in a better position to achieve routing and scheduling consolidation for both inbound and outbound shipments. However, that depends on how integrated they are with their suppliers and how well they integrate their key party logistics providers in the JIT process. Waters-Fuller (1995) emphasised that lack of support of suppliers and carriers are two of the mayor causes of failure of a JIT implementation.

There are alternative ways to achieve high level of Green Logistics performance under a JIT delivery system. Information sharing within the supply chain including transport providers is essential to achieve JIT delivery and keep a high level of delivery performance. In United State, Union Pacific Railroad and R.H. Macy's offer joint together to 'provide seamless transport to meet the retailer's demand'

(Bowersox 1990). Modal-shift can also potentially have a strategic role to play in the improvement of Green Logistics performance under a JIT system. ‘Rails companies initially have problems to compete under JIT, since their railroads are design to carrier large bulk of shipments and have a lack of what the trucking industry offers’, but one way of improving the efficiency of Rail as a transportation mode under JIT systems is ‘buying or using trucks to deliver goods from the Rail Depot to manufacturer, on the exact day and specific time that the material is needed’ (Helms and Dileepan 2005).

As manufacturers improve their forecasting accuracy, water modes become more feasible under a JIT system (Helms and Dileepan, 2005). In Japan, ‘DHL has endeavoured to reduce the number of vehicles they use and shorten the distance they travel by optimising transport routes based on forecasts of cargo volume and transport time, for example, to improve collection/delivery efficiency’ (DHL Report 2005). However, it is necessary to test these hypotheses in a more robust manner to determine the feasibility of using alternative transport modes to road under a JIT system, and determine how that can improve green logistics performance.

Lean thinking and JIT are strategies that are widely applied in many sectors. However, Agility is a new supply chain paradigm that has come as an alternative in the beginning of the 21st century, since the markets are getting more volatile and customers more fashion. Therefore, this new paradigm and its potential impact on Green Logistics will be discussed in the next section.

3.2 Agile Supply Chain and its Implications on Green Logistics Performance

Agility has come as a new paradigm under the current market conditions in several sectors. Naylor et al (1999) define Agility as ‘using market knowledge and a virtual corporation to exploit profitable opportunities in a *volatile* market place’. Christopher and Towill (2000) stated that ‘Agility is a business-wide capability that embraces organisational structures, information systems, logistics processes and, in particular, mindsets’. ‘A key characteristic of an agile organisation is flexibility, and indeed the origins of agility as a business concept lie in flexible manufacturing systems' (Christopher and Towill 2000). However, definitions of Agility leave questions opened about the characteristics and attributes of this supply chain strategy and it is also essential to determine the potential implication of Agility to Green Logistics performance. This will be addressed in the following sections of the paper.

3.2.1. Agile Supply Chain Characteristics

In the last seven years, several authors have defined Agility with slightly different perspective, but they have started from the same definition developed by Naylor et al (1999). Therefore, it is important to determine how the concept of Agility has developed since 1999, comparing and cross-checking how other relevant authors have defined this supply chain paradigm. Naylor et al (1999) define the Agility characteristics as the use of market knowledge, integrated supply chain value stream/virtual corporation, lead-time compression, rapid configuration and robustness. It is important to discuss these characteristics, in order to integrate contribution of other authors.

- **Use of Market Knowledge**: 'the nature of the end-user or market sector as a whole will have a direct impact upon which paradigm will be the most apt for any supply chain or part of a supply chain' (Naylor et al 1999). Stalk and Hout (1990) stated that if market knowledge if not exploited, 'the supply chain run the risk of producing a wide variety of products at short notice when there is not demand for them'. 'The Agile supply chain is market sensitive, so it is capable of reading and responding to real demand' (Christopher and Towill 2000). Other authors have stated that information transparency (Narasimham and Das 1999, Christopher and Towill 2000) and market as a coordinated mechanism (White et al 2005, Van Hoek et al 2001) are important characteristics of supply chain Agility, and they are directly related to use of market knowledge. For Green Logistics purpose, it is important to determine the impact of effective use of market knowledge on transport performance, linking use of market knowledge to obsolesce levels within the supply chain. Obsolesces can potentially increase the requirements for reverse logistics, but this need to be verify with a robust methodology.

- **Integrated supply chain/virtual corporation**: Naylor et al (1999) said that ‘the goal of an integrated supply chain is to remove all boundaries to ease the flow of materials, cash, resources and information’. Stream lined material flow and virtual integration are strategic aspects of an Agile supply chain (Mason-Jones et al 2000, Christopher and Towill 2000, White et al 2005, Van Hoek 2001), since all the supply chain members need to be electronically linked to be prepared to respond to sudden changes in the market place. However, the level of complexity that supply chain integration caused should be taken into account, and the impact that integration has on Green Logistics performance needs to be determined.

- **Lead-time compression**: according to Naylor et al (1999), lead-time compression is one of the three foundation characteristics of Lean-thinking and Agility. Lead-time compression can be achieved by applying ‘inventory and transport consolidation’ (Childerhouse et al 2002, Naim and Barlow 2003). In this sense, one example of best practice is ‘Honda improves its transportation efficiency by promoting a modal shift to transportation by ship and rail as well as joint transportation with other companies’ (Honda Annual Report 2005). However, the effects of inventory and transport consolidation on Green Logistics performance should be tested more, so it could be determined what means inventory and transport consolidation in terms of CO_2 emissions.

- **Rapid reconfiguration**: in an agile supply chain, ‘the ability of “rapidly reconfigure” the production process is essential’ (Naylor et al 1999). Postponement and Modularity are basic aspects of effective supply chain reconfiguration. Manufacturing and Logistics Postponement are the result of increase in product variation, and the supply chain needs to absorb their potential increase in costs (Childerhouse et al 2002). Other authors have emphasised that Product Modularisation is key to achieve Agility in the supply chain (Narasimham and Das 1999, Barlow et al 2003).

However, in order to determine its impact on Green Logistics performance, it is important to investigate this characteristic in a more in-depth way.

- **Robustness**: ‘An agile manufacturer must be able to withstand variations and disturbances and indeed must be in a position to take advantage of these fluctuations to maximise their profits’ (Naylor et al 1999). According to Christopher and Towill (2002), ‘agile supply means reserving capacity to cope with volatile demand. Whereas information transparency is desirable in a lean regime, it is obligatory for agility’. This means that the Agile supply chain needs spare capacity to respond to rapid changes in the market demand, where this changes are usually unpredictable. Therefore, in order to have a robust agile supply chain, there should be spare capacity in key processes within the supply chain; this is more evident in supply chain members that are closer to the end customer. However, from a transport perspective, spare capacity can potentially mean poor delivery performance in terms of in-full loads. This can also have some negative impact on the environment. However, there are alternative ways to mitigate this negative effect of having spare capacity, ‘freight consolidation improves vehicle efficiency and allow logistics providers to achieve robustness without having a negative impact on transport costs and the environment’ (Wu & Dunn 1995). Therefore, the impact of Robustness on Green Logistics performance under Agility should holistically be assessed.

- **Customer focus**: according to Childerhouse et al (2002), ‘focus is required to ensure demand chains are engineered to match customer requirements. Such focus is enabled via segmentation on the basis of each product’s characteristics’. According to Christopher and Towill (2000), ‘a customer can order from Dell on-line 24 hours a day or by phone from early morning until late in the evening. A Dell representative is available to make suggestions and help customers determine what systems will best meet their needs. Through the Web site, customers can access product information and receive price estimates instantaneously. Dell then confirms the order and verifies the financial credit charge’. The UK house building industry is becoming more agile, ‘to capture customer requirements and more responsive production systems to provide a more customized product’ (Naim and Barlow 2003). From a Green Logistics perspective, it is necessary to undertake a holistic analysis of the effects of such a system. One of the potential effects of this strategy is that the manufacturer needs to postpone activities and have excess capacity to respond to change in demand, so that can potentially increase the total transport costs. However, if the supply network is re-engineered, inventory and transport consolidation can mitigate this effect. ‘Environmentally responsible practices tend to favour fewer shipments, less handling, shorter movements, more direct routes, and better space utilization’ (Wu & Dunn 1995). While, other effect of this strategy can be a potential reduction of obsolesce levels, so this can represent reductions in reverse logistics costs.

3.2.2. Agile Supply Chain Attributes

As it is depicted in Figure 9, Agility is applied when the attributes of the market place are fashion and volatile in the short-term (Mason-Jones et al 2000a). More specifically, agile supply chains satisfy needs in customised market segments that change rapidly, so they offer customised products and wide product range under a very unpredictable demand. Therefore, the focus of this sort of supply chain is availability and their profit margins are high.

Distinguishing Attributes	Agile Supply Chain
Typical products	Fashion
Marketplace demand	Volatile
Product variety	High
Product life cycle	Short
Customer drivers	Availability
Profit margins	High
Dominant costs	Marketability Costs

Figure 9 The distinguishing attributes of agility (Source Mason-Jones et al 2000a)

Christopher (2000) emphasised that agility in individual companies can be considerably hindered by the degree of complexity in terms of brands, products, structures and management processes. Therefore, in order to achieve supply chain agility, companies must change dynamically alongside with the market changes, and should reduce as possible the unnecessary complexity of their systems. It is important to determine the impact of complexity and rigidity, under an agile environment, on Green Logistics performance.

3.2.3. Potential Implications of Supply Chain Agility on Green Logistics Performance

After discussing the potential implications of an agile supply chain strategy, it is important to conclude that supply chain Agility could have positive and negative implications on Green Logistics performance. However, the negative impact of supply chain Agility could possibly be mitigated by implementing alternative transport strategies, such as modal-shift, 3PL horizontal integration, and inventory and transport consolidation (See Figure 10).

Postponement constitutes a corner stone of any supply chain Agility strategy. Therefore, it is important to look more in detail the potential effects that Postponement can have on Green Logistics performance. This will be discussed in the next section of the paper.

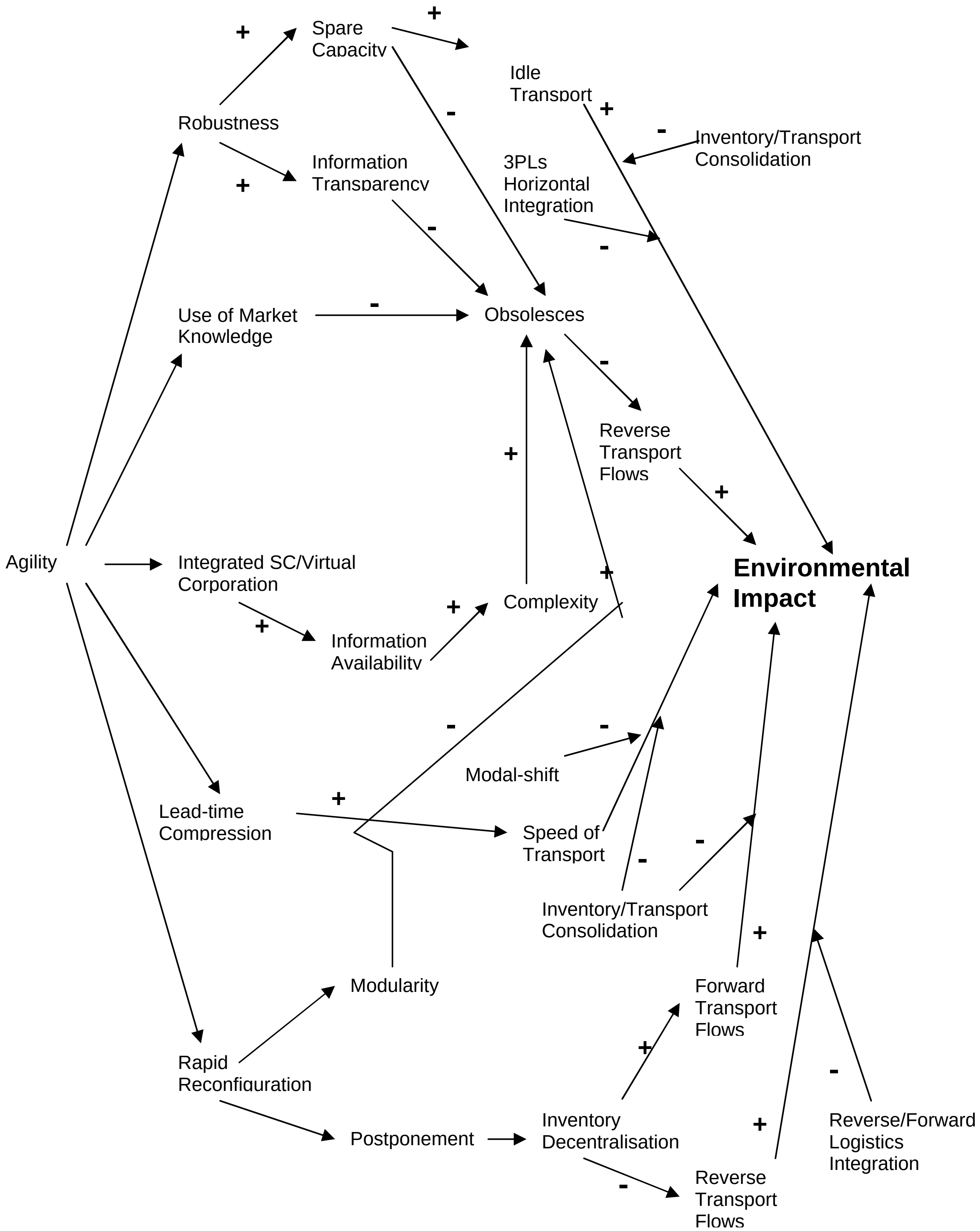

Figure 10 Agile supply chain characteristics, its potential implication to Green Logistics and its possible alternative means of mitigation

3.2.4. Postponement and its Implication to Green Logistics

Postponement as a principle has been discussed in the academic spheres since 1950; it has its origins from Marketing. ‘The most general method which can be applied in promoting the efficiency of a marketing system is the postponement of differentiation…postpone changes in form and identify to the latest possible point in the marketing flow; postpone changes in inventory location to the latest possible point in time’ (Alderson 1950). From the point of view of the distribution channel as a whole, Postponement might be considered a method for individual companies to transfer the risk of owning goods to another (Bucklin 1965). The principle of Postponement represents the interaction between the risk of product ownership and the physical activities executed to deliver the product through time (Bucklin 1965).

’Postponement may relocate final configuration from manufacturer plants closer to the end customer, allowing for rapid delivery of customised products and quick responsiveness to changes in display mixes’ (Yang et al 2004). Therefore, from a Green Logistics perspective, Postponement as a supply chain strategy can potentially have pitfalls and advantages. That depends on the main external factors that encourage supply chain companies to implement postponement. Also, Postponement can vary accordingly to specific market realities. Therefore, all this aspects of Postponement will be discussed in the following sections of the paper.

3.2.4.1. **Determined Factors of Postponement**

In order to analyse the factors that influence on a Postponement strategy, the product value and time need to be considered as the most important variables. There are three major determinants that impact on the supply chain strategy, product (life cycle, feature and value), market demand (frequency and time of delivery, and demand uncertainty) and manufacturing and logistics (economies of scales and special capabilities) (Pagh and Cooper, 1998). Uncertainty of demand is the most significant factor of time postponement (Zinn and Bowersox 1988).

The total product cost is the most relevant variable that justified postponement in product customisation (Zinn and Bowersox 1988).

Regarding to market demand, 'the increase in fashion rise the risk of obsolesces in particular in point closest to the customer' (Bucklin 1965). This increases the degree of uncertainty in market demand. The main benefit of postponement is its capability of lessen uncertainties caused by the dynamic and changeable characteristics of the marketplace, which companies might have to adapt in their supply chain strategies (Yang et al., 2003). Therefore, taking a Green Logistics perspective, it is important to consider the resultant variables of a Postponement strategy. Potentially, delaying activities until marketplace demand becomes more certain can have a positive impact on levels of obsolesces in the end-customer side, so this can reduce the reverse logistics requirements, hence the reverse logistics costs. On the other hand, this strategy potentially requires decentralisation of inventories within the supply chain, increasing the costs of inbound forward logistics. However, this needs to be addressed more carefully later in the paper.

Other factor that determines a Postponement strategy is the different dimensions of the product. The total product cost is the most relevant variable that justified postponement in product customisation (Zinn and Bowersox 1988). According to Fisher (1997), when the supply chain produces innovative products, it should respond quickly to the unpredictable demand to minimise loss in sales and obsolesces. If product innovation increases, the product value usually increases. Therefore, an innovative environment can potentially encourage companies to delay product customisation until orders from the marketplace are received. This also potentially have negative and positive effects on Green Logistics performance, but this should be tested with a robust methodology.

Other important factor is manufacturing and logistics costs. 'A relationship may exist between level of customisation versus standardisation and level of globalisation versus localisation in the supply chain' (Van Hoek 1999). According to Van Hoek (1999), 'part of postponement is the allocation of the appropriate assets or resources to the specific locations to perform the value adding activities at the prescribed cost and customization'. Proximity to local markets is relevant to achieving local responsiveness capabilities (Van Hoek 1998). The delay of inventory locations can potentially have a mitigation effect on the gains in economies of scale in transport and warehousing. However, 'product's cube and/or weight increases through customization/final manufacturing- Reduced transportation and inventory carrying costs' (Van Hoek 2001). But, the steady growth in transport haulage has been driven by the centralisation of activities in logistics postponement environments, wider geographical area of supply and distribution, and hub-spoke networking (McKinnon 2003). Therefore, before determine the impact of Postponement on Green Logistics performance, it is important to consider all the variables involved (warehouse location, product dimensions, obsolesces, transport mode, etc.).

All these factors have a significant impact on the choice and degree of Postponement that a supply chain should implement. Therefore, it is important to discuss in more detail the most relevant taxonomies that have been developed in the last two decades.

3.2.4.2. **Types of Postponement**

Postponement has been studied from different perspective by different authors. In this section of the paper, several frameworks will be presented, and the potential implications of the different types of Postponement will be addressed.

Zinn and Bowersox (1988) classified Postponement depending on the logistics activity involved. They developed a taxonomy that gives a detailed classification of the postponement of five types of logistics, labelling, packing, assembly, manufacturing and time postponement (See Figure 11). All these types of postponement have a direct impact on transport and warehousing costs. However, this needs to be tested with more robust methodologies to ensure reliability and validity.

POSTPONEMENT TAXONOMY

POSTPONEMENT TYPE	PHYSICAL DISTRIBUTION COSTS
Labeling	Inventory carrying costs Warehousing Processing (labeling)
Packaging	Transportation Inventory carrying costs Warehousing Processing (packaging)
Assembly	Transportation Inventory carrying costs Warehousing Processing (assembly) Cost of lost sales
Manufacturing	Transportation Inventory carrying costs Warehousing Processing (manufacturing) Cost of lost sales
Time	Transportation Inventory carrying costs Warehousing Cost of lost sales

Figure 11 Type of Postponement depending on the activity postponed (Zinn and Bowersox 1988)

Meanwhile, Pagh and Cooper (1998) have developed a matrix that classifies supply chain strategies according to manufacturing and logistics activities (See Figure 12). They position supply chain strategies from full speculation strategy, to the logistics postponement strategy, to the manufacturing postponement strategy, and to the full postponement strategy. These different strategies can have different implications on Green Logistics performance. A full speculation strategy can have a negative impact on the level of obsolesces within the supply chain, so it can potentially increase the reverse logistics costs. As it has been discussed, manufacturing postponement can have positive and negative implications on the CO2 emissions of transport flows, it can reduce the space required for transport, and hence the forward transport costs, but it can produce losses in economies of scale in inbound areas of the supply chain.

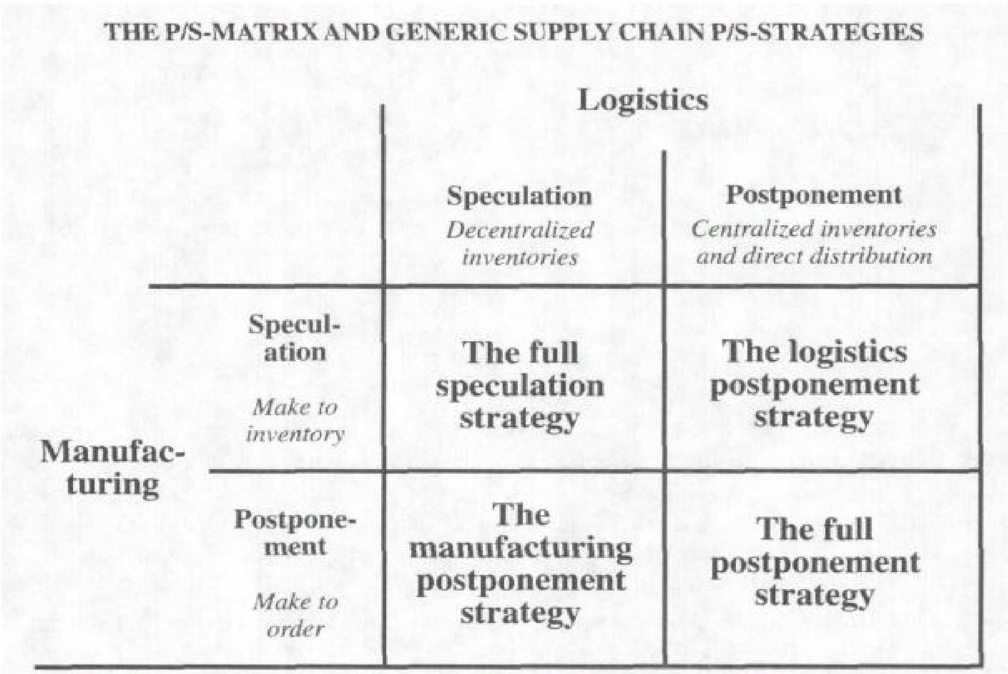

Figure 12 P/S Matrix an Generic Supply Chain P/S Strategies

Van Hoek (1998) developed a framework to guide business in the different stages of the implementation of Postponement (See Figure 13). These stages are direct export, national warehouses, logistics postponement and postponed manufacturing. Direct exports as a strategy imply that raw materials are sourced from several countries and all manufacturing activities are executed in home-countries around the world. The products are moved from the country that manufactured them to retail companies in different countries. This can have negative implications on global transport costs and level of obsolesces, because activities are performed globally without taking into account possible logistics economies of scale and customisation.

After that, the inventory is decentralised by the implementation of national warehouses in each country where the products are sold. This can decrease the transport costs of inbound areas of the supply chain, due to economies of scales of central distribution in those warehouses. Therefore, this has a positive impact on the environmental costs of transport. Following that, in order to postpone the distribution of goods to different countries in a specific region of the world, supply chain companies implement regional Distribution Centres (DCs). This has a positive effect on inventory and warehouse costs, but unfortunately, increase the distances from DCs to final point of sales. Therefore, this strategy can potentially have a negative impact on the overall transport costs in global regions, so the CO2 emission can increase as well.

At the fourth stage, supply chain companies implemented manufacturing postponement, establishing more national factories in outbound areas of the supply chain, sourcing different modules of the products from different countries. Furthermore, they execute final manufacturing activities at regional levels. This can have a positive impact on product dimensions and on responsiveness levels of the supply chain. Therefore, the transport costs of the supply chain outbound areas can be reduced. However, due to an increase in transport distances, there can be a rise in the transport costs of supply chain inbound areas, since postponed manufacturing needs to be complemented by JIT delivery systems, which ‘ (Nieuwenhuis 1994).

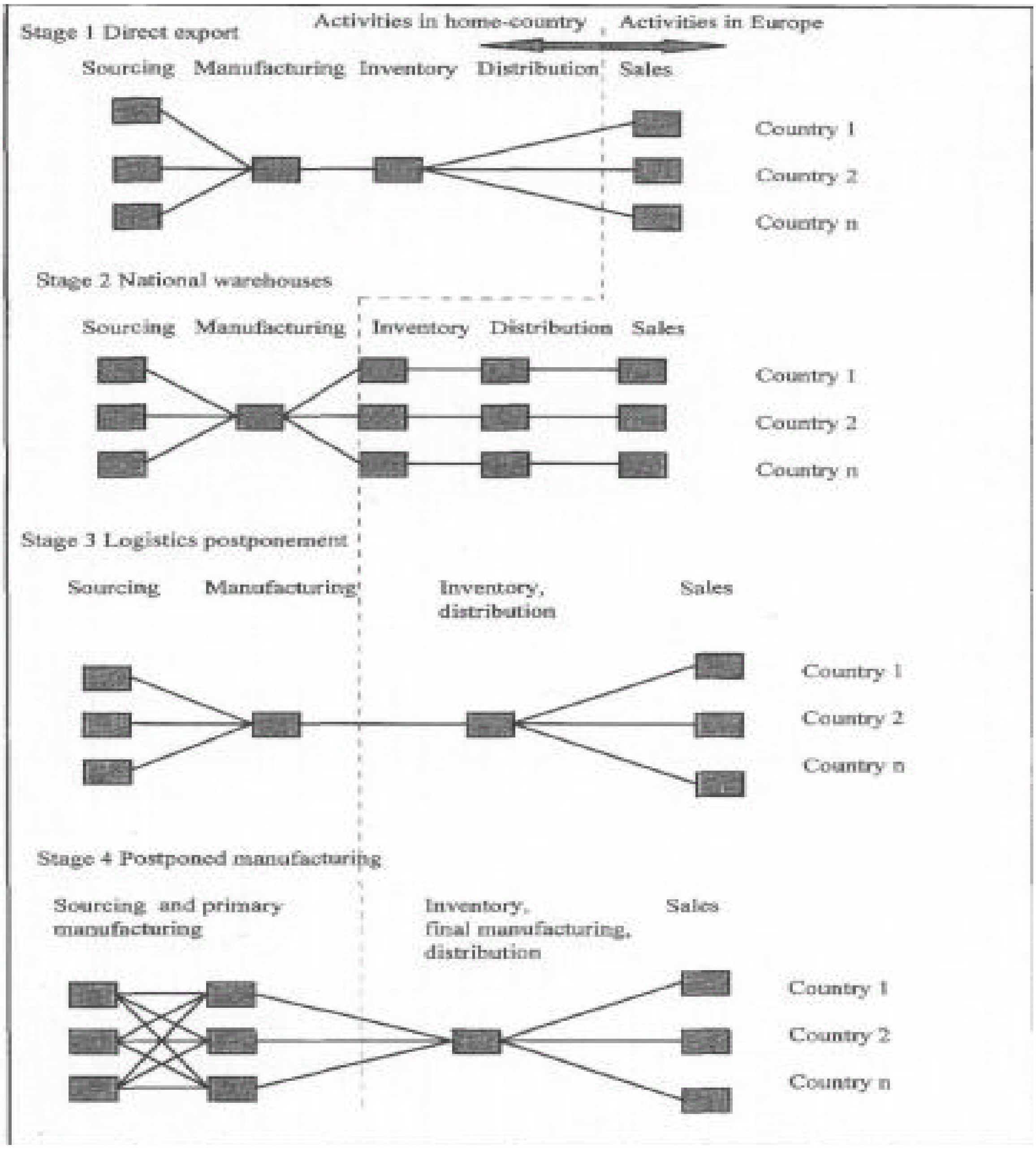

Figure 13 the Stages of Postponement

From a Green Logistics and transport perspective, it is important to evaluate the benefits and disadvantages of Postponement, taking account of the effects that Postponement can potentially have on reverse logistics costs. This will be discussed in the next section of the paper.

3.2.4.3. **Benefits and Disadvantages of Postponement**

Postponement has several practical implications on the economic performance of the supply chain. However, it is important to determine the impact of these economic implications on Green Logistics performance. To do so, the different strategic implications of Postponement will be discussed separately.

Postponement can lead to lower buffer inventories (Lee and Tang 1997). This can have a positive impact on the level of obsolesces in supply chain inbound areas (Towill et al 2002). Meanwhile, a Postponement strategy can reduce the lead times, making the delivery process more reliable (Towill et al 2002). Therefore, this can significantly improve the service levels of the supply chain (Lee and Tang 1997). To shorten the lead times and make the delivery process more reliable can potentially mean an increase on transport speed, and in consequence, it can produce a negative effect on the CO2 emissions generated by transport. However, this can potentially also cause a reduction in the product dimensions (Van Hoek 1998), so this can reduce the space required to transport products in outbound areas of the supply chain. Hence, transport flows in outbound areas can be reduced, and subsequently, the environmental impact of transport may be mitigated.

On the other hand, 'the relocation of final customisation activities often leads to localised production, which may require an increase in local sourcing of materials and thus decreases the volume of international transport flows' (Yang et al 2005). Therefore, this can potentially have a positive effect on the total CO2 emissions produced globally. When HP implemented a form postponement strategy in their DeskJet printers, they realised that there was a great reduction in transport costs due to a decrease in product volume (Twede *et al,* 2000). In order to meet all the specific needs of local markets, 'Gillette created a new European packaging and DC to delay the final customisation of their products' (Yang et al 2005). By delivering bulk furniture components in the smallest forms (through postponement) to a local DIY shop, a furniture company saves on transport, as well as handling and loading/unloading expenses (Yang et al 2005). This form of postponement strategy could also lower transport costs since products can be shipped in bulk to the regional DC (Yang et al 2005).

From the sections 3.1 and 3.2, we can realise that there is an unfilled gap in the literature regarding the impact of supply chain strategies on green logistics. This project will intend to answer this question.

Research Question 3*: How do supply chain strategies impact on Green Logistics performance?*

Postponement is a strategy that develops Agility throughout the supply chain, but can have implications to Green Logistics and transport performance. These potential effects of Postponement and other supply chain strategies discussed before can possibly be mitigated by horizontal and vertical coordination of materials and information flows between transport providers, supply chain companies and suppliers. Therefore, it is necessary to address the different strategic aspects of supply chain integration in the next section of the paper.

3.3 Supply Chain Integration

Integration is a concept that has been studied widely in the field of Supply Chain Management. ‘Integration can be characterized by cooperation, collaboration, information sharing, trust, partnerships, shared technology, and a fundamental shift away from managing individual functional processes, to managing integrated chains of processes’ (Akkermans et al 1999). ‘The effectiveness of an organization’s response to rapidly changing market conditions will be largely determined by the capabilities of trading partners. A manufacturer with key suppliers that have poor quality and delivery records will find it very difficult to provide high levels of customer service, even in stable environments’ (Power 2005).

Wood (1997) emphasised the significance of KPIs alignment across departments through cooperation and collaboration, and stated that traditionally manufacturing and sales have had poor alignment of targets. ‘Consistent with the short-term, piece-meal orientation implied in the traditional approach, the selling and buying organizations typically consider only their own cost structures and profitability' (Zinn and Parasuraman 1997). The main aim of strategic alliances is to manage and optimise costs jointly, while simultaneously consolidating the partners' market positions (Zinn and Parasuraman 1997). Logistics has emerged as a key building block of many seller-buyer agreements (Bowersox et al 1995).

Supply Chain Integration has been researched from different perspective and focus. Academics have investigated themes like type of external relationships that a company can have, activities and responsibilities that can be shared, scope and intensity of integration, factors that determine integration programmes and KPIs alignment. All these topics need to be understood before addressing specific literature on transport and logistics-related integration and their implications to Green Logistics. They will be discussed in the following sections of the paper.

3.3.1 Types of Business Relationships

Riffer et al (2004) discussed the different types of business relationships where integration can be feasible. A business can have integrated functions with suppliers, complementors, customers and/or competitors. He addressed the possible purpose of integration in each of these cases.

- **Relationships with customers**: Satisfy customers' needs and co develops new products and services. In the case of transport, this can be seen in the relationship between a 3PL and its supply chain customer. The level and intensity of this integration depends on the size of the distribution channel that the 3 PL is covering; the complexity involved in the delivery process and the economies of scale the 3PL is capable to achieve.
- **Relationships with suppliers**: 'Relationships with suppliers of strategically valuable products and services can be an important and durable source of competitive advantage and one that is hard for others to imitate'. In this way a retailer, for instance, can decrease the order and

materials flow lead times, and can considerably reduce the need for demand forecast.

- **Relationships with complementors**: ‘Firms develop relationships with many other types of firms whose outputs or functions increase the value of their own outputs, such as Lego teaming with Hewlett Packard to serve the children’s toy market and Procter and Gamble teaming up with complementary product suppliers (Coca Cola or Pizza Hut) in promotion campaigns’. Transport providers can potentially decide to integrate their operations, when they are not directly competing in the same sector, but they have opportunities to consolidate their deliveries, since the products distributed by them can have commonalities on certain strategic characterics (size, weight, delivery temperature required, and so on).
- **Relationships with competitors**: Collusion is not the only reason why competitors may integrate their activities. For example, ‘competitors collaborate to develop product and technology standards, such as the 3G mobile telephone’ (Grundstrom & Wilkinson 2003). The integration of competitors located in different global regions to enter to new international markets (Welch et al 1996). Hauliers can potentially also integrate their operations to satisfy a wider range of customers, to improve their bargaining power in their sector, to be more responsive to emergency deliveries of volatile markets like clothing.

However, it is important to define the scope and intensity of integration programmes and the reasons why companies take different path in this sense. This will briefly be discussed in the next section.

3.3.2 Scope and Intensity of Integration

Depending on the purpose of an integration programme there are different types of strategic alliances, they differ in scope and intensity. Zinn and Parasuraman (1997) have developed a classification of strategic alliances, limited, extensive, focus and integrated alliances (Figure 14).

	Intensity	
	High	Low
Scope		
Broad	Integrated	Extensive
Narrow	Focused	Limited

Figure 14 Typology of Logistics-Based Strategic Alliances (Zinn and Parasuraman 1997)

- **Limited alliances**: 'Limited alliances offer a low-cost and low-risk opportunity for firms to experiment with alliance formats and partners'. This sort of alliance has the risk of not taking account of the whole cost reduction opportunities.
- **Extensive Alliances**: 'An extensive logistics-based strategic alliance incorporates a broad range of services, but lacks the intensity of an integrated alliance'. From a Green Logistics perspective, this can be a problem since certain activities can not be core part of the core capabilities of the service company, so the customer company can lose opportunities to find a specific company that can develop better performance in some logistics activities.
- **Integrated Alliances**: 'An integrated logistics-based strategic alliance is both broad in scope and high in intensity. Such alliances typically evolve over an extended period of time'. This is developed in the long-term, and usually integrated alliances are formed since there are a broad range of logistics capabilities that can be developed better by a 3PL or even a 4PL. The size, geographical coverage and market power of the two companies are very important, since that determine the achievable benefits in terms of costs reduction and market growth.
- **Focus Alliances**: 'A focused alliance is an attractive alternative for customer companies that want to benefit from the cost efficiencies of intense relationships with their logistics partners but, for strategic or

competitive reasons, wish to keep confidential certain types of information'. Regarding to core competences, companies need time to build trust in their relationship, because of the danger that imitation represent, so they develop very focussed and specific alliances to allow a long-term process of integration.

Under a strategic alliance, one of the main strategic issues is the extent to which companies can align their KPIs. According to Barrat (2004), if companies get the fit wrong between their KPIs, conflictive behaviour between them can potentially be created. Therefore, when supply chain companies and logistics providers integrate a set of activities, they need to redefine a set of KPIs and develop integrated control system, so the benefits of their alliance can be fully achieved. However, logistics integration in supply chains can occur in two dimensions, vertical and horizontal. These two dimensions of integration represents different but similarly feasible solutions for the tradeoffs problems between transport, inventory and green performance. Therefore, they will be addressed in the following section of the paper.

3.3.3 Logistics and Transport Integration

Companies can integrate their logistics systems in two possible ways, vertically and horizontally. Caputo and Minimo (1996) developed a framework to improve understanding of different types and features of vertical and horizontal logistics integration. They included five logistics functions, order management, inventory management, warehousing, handling, packaging and unitization, and transport. This will be discussed in the next section.

3.3.3.1 Vertical Logistics Integration

Caputo and Minino (1996) develop a framework that defines different vertical-integration interventions of logistics functions (See Figure 15).

- **EDI**: Electronic Data Interchange (EDI) is a solution that manages the order process within the supply chain (Caputo and Minino 1996). This IT system eases the information flow and improves the transparency and visibility within the chain. This can have a positive impact on transport and Green Logistics performance. Since, it reduces the demand amplification in all the supply chain members, so it can potentially reduce the transport amplification and optimise transport. However, this needs to be proved by a robust method, such as simulation or survey.

- **Continuous replenishment**: ‘Continuous replenishment is an inventory managing system in which producers always send full loads to distribution centres, but the mix of each load is fixed a short time before departure, according to the principle of replenishment of a prearranged level of stock’ (Caputo and Minino 1996). Through this system inventory can be minimised throughout the chain, but transport performance can suffer, and most importantly, the number of vehicles needed within the chain increases dramatically. Therefore, it is important to determine how supply chain companies and transport providers can operate under a continuous replenishment system, and at the same time, keep the Green Logistics performance on an exemplar level.

Functions	Type of intervention	Implications Branded product implications	Large-scale trade business
		Information flow	
Order management	EDI	Reduction of errors of transmission Reduction of delivery time	Reduction of errors of transmission Reduction of order cycle
Inventory management	Continuous replenishment	Stock reduction Out-of-stock reduction Improvement of production planning	Reduction of costs of inventory management
		Physical flow	
Warehousing	Cross-docking	Elimination of local warehouses	Reduction of stock Elimination of centres of distribution
Handling	Cross-docking		
Packaging and unitization	Pallet standardization Definition of sub-pallet size Definition of the number of consumer units per carton	Elimination of re-palletization Assigned stands in PoS Less time for packaging Possibility of ordering the economic quantity	Elimination of re-palletization Less time for order setting Reduction of packaging costs
Transport	Multi-drop and multi-pick Rationalization of the use of couriers	Reduction of costs of transport Reduction of delivery time Reduction of costs of transport	Reduction of costs of transport Reduction of delivery lead time Elimination of lines of vehicles for unloading to centres of distribution

Figure 15 Vertical Integration of Logistics Systems (Caputo and Minino 1996)

- **Cross-docking**: this technique is based on a large marshalling area on which a number of manufacturers' and retailers' vehicles converge and in which pallets are marshalled between different points of delivery (distribution centres and stores) (La Londe and Masters 1994). According to Caputo and Minino (1996), 'the solution with picking on the marshalling area does not create stock because goods are immediately de-palletized and re-palletized'. However, they emphasised that the main constraints in this method are: (1) balance ingoings and outgoings in order to have full loads, (2) reduce suppliers delivery time, and (3) synchronise arrivals and departures. Furthermore, cross-docking between retailers is a bit more complex because horizontal coordination between them is needed. Therefore, it is necessary to determine when cross-docking is the right solution and what are the critical success factors of this logistics method.
- **Multi-drop, multi-pick and rationalisation of couriers**: 'Transport can be more economical with the adoption of multi-drop, multi-pick and the rationalization of the use of couriers' (Caputo and Minino 1996). Multi-drop involves one producer distributing to different point of delivery, and multi-pick involves the combination of deliveries of several producers to one point of delivery. However, this depends on the level of volume in the producers' and retailers' sides, or more explicitly the position of each player regarding realising economies of scales and scope. Therefore, it is important to define the factors that encourage multi-drop and multi-pick systems, and which is the impact of these two systems on Green Logistics performance.

3.3.3.2 Horizontal Logistics Integration

Caputo and Minino (1996) also develop a framework that defines different horizontal-integration interventions of logistics functions (See Figure 16). From the framework, only the intervention methods that have a direct relation with supply chain and transport will discussed.

Functions	Intervention of horizontal logistic integration Branded product industry	Large-scale trade businesses
	Information flow	
Order management	Standardization of computerized document content Standardization of application system interface	Standardization of computerized document content Standardization of application system interface
Inventory management	Standard code choice for consumer units, cartons and pallets	Definition of economic order quantity and frequency Improvement of the automatic reordering system
	Physical flow	
Warehousing	Multi-supplier warehouse	Multi-distributor centre
Handling	Multi-supplier warehouse	Multi-distributor centre
Packaging and unitization	Pallet height standardization	Definition of the number of consumer units per carton Definition of pallet sub-multiples Standardization of carton arrangement on pallets
Transport	Co-ordinated multi-pick	Co-ordinated multi-drop
	Proposal regarding the aggregation of suppliers to a courier and the choice of a common courier	

Figure 16 Horizontal Integration of Logistics Systems (Caputo and Minino 1996)

- **Electronic Standardisation**: this consists of the standardisation of the IT system such as EDI and all the codification of SKUs (Caputo and Minino 1996). All producers and retailers involve in the intervention needs to standardise their systems, otherwise the information can be highly distorted.
- **Multi-supplier warehouse**: this method is more feasible for suppliers with medium-low delivery volumes and minimise inventory from the suppliers' side. Moreover, transport flows can decrease since the aggregation of suppliers' stocks facilitates full vehicle loads (Caputo and Minino 1996). However, it is important to link this technique to Green Logistics performance, determining the factors involved on it, its advantages and disadvantages and its impact on Green Logistics performance.

- **Multi-distributor centres**: ‘Distributors can choose to share the same warehouse when sales volume is not high enough to justify the opening of a regional distribution centre. In fact costs incurred in utilizing a multi-distributor centre can be lower than transport costs to points of sale from the nearest centre’ (Caputo and Minino 1996). Therefore, from a green logistics perspective, it is important to determine when a multi-distributor centre has a positive impact on transport performance, and the critical success factors of this method.

- **Co-ordinated multi-pick**: ‘in order to exploit advantages from frequent and shared deliveries, producers make agreements to realize the so called co-ordinated multi-pick, that is subsequent pickings at fixed dates and coordinated hours so that loads are synchronized’ (Caputo and Minino 1996). The main problem of this sort of system is that information flows, transport inflows and outflows need to be tightly co-ordinated and synchronised. These systems, if implemented effectively, can have a positive impact on transport and Green Logistics performance, since transport can be optimised in a holistic manner. However, this needs to be tested by a robust method, such as simulation and survey.

- **Co-ordinated multi-drop**: this represents the integration of flows of suppliers led by a common distributor (Caputo and Minino 1996). Consolidation of deliveries is necessary to make the system simpler to manage (Caputo and Minino 1996). This system can potentially reduce the transport costs, since the vehicle distance and number of vehicles can decrease. However, the factors that determine this sort of arrangement needs to be defined, and its impact on Green Logistics performance also.

Therefore, horizontal integration is a vital part of the quest to solve the trade-offs between rapid transportation and Green Logistics, so we need to determine the impact of horizontal integration on green logistics performance. After discussing all the different supply chain strategies and integration as a significant enabler of them, other supply chain management practices will be introduced in the following section.

Research Questions 4*: How do horizontal integration of transport providers and supply-chain companies impact on green logistics performance?*

3.4 <u>Other Supply Chain Practices</u>

A number of authors have researched in specific supply chain practices and their impact on transport performance. Vendor Management Inventory (VMI) and Factory Gate Pricing (FGP) have been system solutions developed around the concept of horizontal integration or aggregation of supplier inventories and transport outbound flows.

3.4.1 Vendor Management Inventory (VMI) and Transport

Vendor Managed Inventory (VMI) is a system that connects suppliers and customers inventory information that enables faster, aggregate all the transactions of suppliers for a particular customer. 'The VMI supply chain enables a smoother dynamic response than that associated with the traditional supply chain, enabling a reduction in manufacturing on-costs. 'VMI circumnavigates the trade off between improved dynamic properties (reducing manufacturing costs), and the minimisation of transport demand' (Disney and Towill 2003).

Several authors have emphasised the benefits of VMI from a supply chain and transport perspectives. Better sign and hence understanding of both information flow and material flow and Elimination of bullwhip (Disney and Towill 2003). VMI can reduce the batching of transport dispatches that have a significant distortion effect on dynamic response of an internal integration scenario (Disney et al 2003). Reduction of manufacturing costs and minimisation of transport demand (Disney et al 2003). Regarding Green Logistics, VMI is based on the consolidation of inventory and transport flows of several suppliers. As McKinnon (1996) said, external and internal consolidation of transport flows is one of the most feasible solutions to solve the trade off between inventory minimisation and transport optimisation. However, it is important to determine the impact of VMI on Green Logistics performance, and how transport provider can be integrated under a similar conceptual system to VMI, but with transport idle capacity as a unit rather than inventory (See Figure 17).

3.4.2 Factory Gate Pricing (FGP) and Transport

FGP is other supply chain practice that has had a significant impact on transport performance. Taking the Tesco's supply network, Potter et al (2003) developed a model of FGP, proposing a number of consolidation centres in outbound areas of their supply chain. They calculated a potential reduction of 'around 28% in the mileage accumulated in transporting less than truckload consignments to DCs, equating to over 400,000 miles per week, as a result of the increased use of consolidation centres'. Le Blanc et al (2004) determined FGP could potentially encourage a reduction of 22 per cent of the total supply chain costs of the Dutch retail distribution. FGP can be one of the solutions to the trade off between transport and inventory. However, it is essential to define in what situations FGP applied, and as well as the case of VMI, how this sort of systems can be applied in a more horizontal manner, maybe changing the unit from stock to idle transport capacity.

3.5 Green Supply Chain Practices

According to Klassen and Johnson (2002), there are five possible green supply chain management practices, environmental certification, pollution prevention, reverse logistics, life-cycle assessment and design for the environment. Moreover, it is very important to take a holistic approach in the analysis of environmental programmes. Reverse logistics should be one of the most important themes in Green Logistics. However, if supply chain systems are effective the need for reverse flows can potentially be mitigated. In the project, the main focus should be the prevention of supply chain from a transport perspective, but life-cycle assessment should be to include external variable such as international sourcing or green manufacturing. In order to include potential government green logistics interventions on the equation, we should determine how that potential interventions impact on supply chain strategies.

***Research Question 5**: How do Green Logistics policy interventions impact on supply chain strategies and infrastructure?*

3.6 Concluding Remarks

The most relevant literature on supply chain management, transport and green logistics has been integrated in this paper. Firstly, the project should determine the forms of logistics uncertainty that impact on supply chain performance. After that, intensive research should be carried out in establishing the impact of supply chain strategies and principles on green logistics performance. Moreover, the project should also clarify the impact of horizontal integration on green logistics performance. However, the impact of green logistics intervention on supply chain strategies should be one of the main focuses of this project as well.

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3.8 Appendix

Uncertainty/Variance

- Information uncertainty
- Supply uncertainty
- Manufacturing process uncertainty
- Demand uncertainty.

According to Van der Vorst and Beulens (2002), ‘SC uncertainty refers to decision making situations in the SC in which the decision maker does not know definitely what to decide as he is indistinct about the objectives; lacks of information about its environment or the supply chain; lacks information processing capacity; is unable to accurately predict the impact of possible control actions on SC behaviour; or, lacks effective control actions’

Trends

- Supply chain integration
- Postponement
- Agility
- Transport/inventory consolidation
- Transport providers integration

Measures

- delivery performance to commit date
- fill rate
- perfect order fulfilment
- order fulfilment lead time
- SC response time, production flexibility
- cash-to-cash cycle time
- inventory days of supply

- net asset turns

Methods/Techniques/Tools

- Survey
- Modelling/Simulation
- Case Study
- Literature review
- Theoretical papers

Sectors

- Transport
- Retail
- Food
- Electronics
- Computers
- Some of the papers are wider (Survey)

Geography

- Europe
- UK
- USA
- Australia
- The Netherlands