5P. A Model for Conceptualising Green Logistics and its use for exploring RFIDs in ‘Greening’ Supply Chains

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Abstract

Integrating environmental considerations into supply-chain management has become an increasingly important issue for industry, government and academic research. Supply chain managers are being required to respond to the challenges of new legislation, standards and regulations; changing customer demands; drivers for efficiency, cost effectiveness and return on investment; while simultaneously being ‘green’. Facing the central tension between business and environmental drivers is difficult, but critical to understanding how developments, such as RFID technologies can be incorporated to deliver holistic solutions.

This paper reviews contemporary discussions on the current state of supply-chain management and green logistics. It presents a model that combines a number of existing frameworks covering forward and reverse logistics as an approach to conceptualise green supply chains. The paper then illustrates how this combined model can be used to explore the potential of RFID technologies for ‘greening’ supply chains.

Keywords:
Supply chain models, Green supply chain management, green logistics conceptual model, RFID technology.

1. Introduction

The importance of Green Logistics is gaining increasing awareness among researchers and practitioners of operations and supply chain management and this issue is driven by the
escalating deterioration of the environment, e.g. diminishing raw materials and natural resources, overflowing waste sites, increasing levels of pollution and environmental awareness (Srivastava, 2007).

Industries are facing the challenge of how to respond to compliance with emerging climate policies such as the EU Emission Trading Scheme and the upcoming Australian Carbon Pollution Reduction Scheme [Emmissions Trading Schemes] (ETS) in 2010. At the same time changing consumer demands for carbon neutral products and/or environmentally friendly and sustainable production processes are directly impacting on supply chains. For example, logistics of perishable foods are facing increasing challenges related to quality and safety standards which require increased tracking and tracing to ensure compliance.

Even though from one perspective environmental policies can be seen to be socially rather than politically driven, there is an inherent irony between consumers becoming more concerned about the social impact of products and the continued growth in appetite and demand for products and the global growth of consumerism.

In order for organisations to minimise their impact on the environment, it has been argued that they need to evaluate and act from a total system perspective (Wu & Dunn, 1995). The supply chain represents such a holistic system and is a strong candidate for far-reaching greening initiatives. Supply chains link various types of organisations and extend across multiple borders before reaching the consumer. The volume of goods and produce being carried across the globe continues to grow. This is due in part to higher productivity, increased efficiency in primary industries, cheaper freight costs and the rapid expansion of the BRIC (Brazil, Russia, India, China) nations.

Conventional approaches to supply chain management continue to encounter the challenge of how to balance being effective and cost efficient on one hand, whilst becoming more environmentally friendly on the other (Rodrique et al, 2001). Technology has been presented as a means to resolve this tension between the need for cost efficiency in SCM and improved quality, safety, and environmental sustainability. However, the evidence of the return on investment (ROI) in terms of cost efficiencies or effectiveness of response towards carbon neutrality is lacking using current technologies (O’Connor, 2005). From a research perspective there is also a challenge in how to approach this tension and the generation of insights that can be used meaningfully by multiple stakeholders (industry, governments, community and consumers). Aside from the challenges of a lack of evidence of ROI, the use of technology such as RFIDs presents issues standardisation issues for global supply chains.

Integrating supply chains into sustainable systems that have no impact on the environment is a big challenge facing logistics. The importance of environmentalism and sustainability has led to a broadening of foci of logistics and this was recognised as early as the 1990s. An example is reverse logistics which is the reduction of waste and recycling of packaging. This was in contrast to the forward distribution focus of producer-to-consumer movement of goods. This was the first concept of ‘green logistics’ in the early 1990s (Byrne & Deeb, 1993).

The debate about carbon reduction, greenhouse gases, food miles/green miles and green logistics is what affect it will have on all industry sectors. Organisations will be responsible and will have to directly manage their carbon emissions which will then become another business risk factor (Department of Climate Change, 2009).

Different countries and regions are facing different problems and issues and they are exploring different solutions. Australia, with its highly deregulated logistics sector is now for the first time facing regulation from the highest level of government. The transport and
logistics sector is a major contributor to environmental issues such as greenhouse gases, global warming and pollution. With the Australian Federal government due to introduce its Carbon Pollution Reduction Scheme in 2010, logistics will be directly impacted by the new scheme. The scheme will set a cap on carbon emissions and also have a trade component. (Department of Climate Change, 2009, Geroliminis, 2005).

This paper reviews contemporary discussions on the current state of supply-chain management and green logistics. It presents a model that combines a number of existing frameworks covering forward and reverse logistics as an approach to conceptualise green supply chains (Srivastava, 2007, Easterby-Smith et al. 2002). The paper then illustrates how this combined model can be used to explore the potential of RFID technologies for ‘greening’ supply chains.

2. Supply Chains & Green Logistics

Although there are many definitions, the Council of Supply Chain Management Professionals (CSCMP) defines logistics as:

The part of the process of supply chain that plan, control and implement an effective and efficient flow for the purpose of storage of goods and services and other related information from the point of commencement to the point of final consumption with a aim to satisfy the requirements of its existing and prospective customers (CSCMP, 2009).

This definition includes inbound, outbound, internal, and external movements, both physical and importantly information flows. Significantly, this definition acknowledges the holistic nature of the logistics process. This implies control and organisation across supply chain management, manufacturing, warehousing, distribution and retailing.

In this context, many approaches to ‘green’ logistics have been more limited in scope and have tended to be restricted to concepts from the reverse logistics domain (i.e. wastage reduction from logistics activities). A review of current literature identifies at least three perspectives on ‘greening’ the supply chain that in various ways illustrate the ‘waste reduction’ approach to green logistics rather than a more holistic perspective that considers value-creation.

The first perspective relates to the scope of the supply chain. Previous research provided reviews of different problem contexts within the green supply chain area (Srivastava, 2007), as well as several functional models of environmentally friendly chains (Wu & Dunn, 1995, Sarkis, 2003). These models have contributed to the green supply chain theory by extending the focus of the greening initiatives from the end of the manufacturing processes. This can include, for example, filtering of waste products, recycling of products and to the whole supply chain perspective including the design of products. These models offer a number of aspects that different actors in the supply chain need to consider to decrease the total environmental footprint. What remains challenging in these models is how to establish the cross-functional and cross-company approach in order to achieve the synergetic effect on the environmental issues.

The second perspective of the greening initiatives in the supply chain is that of reverse logistics. Many frameworks for reverse logistics have been developed and these include the Reverse Logistics Hierarchy and identification of four environmental forces (Carter & Ellram, 1998), which was based on the work of Stock (1992), and Kopicky, et al, (1993), and others. Gungor and Gupta (1999) outlined a framework and also discussed environmental design and product recovery. Gogin and Browne (2000) suggested a resource recovery
taxonomy specifically for electronics and electrical equipment. Brito and Dekker, (2003) proposed a content framework based upon driving forces and return reasons and their relationships. Wadhwa and Madaam (2008) developed these frameworks further. Carter & Ellram (1998) hierarchy of strategies model (figure 1) proposes generic activities that need to be considered by each actor in the supply chain. At first, actors focus on resource reduction, referring to minimisation of materials used in a product, waste and energy spent in the process of handling the product. In this way the focus is placed at the source and throughout the process, and not only at the end-of-pipeline. Once the resource reduction option has been exhausted, the organisation should attempt to maximise reuse, followed by recycling. Disposal should be the last and least desirable option.

The third perspective includes the performance measures of the green initiatives through the supply chain (Table 1). The main presumption is that the supply chain footprint needs to be evaluated against specific indicators – performance measures, which are listed in the last row of Table 1. These are just a few ‘green’ performance indicators, and a more complete list needs to be developed in the future.

![Figure 1: Hierarchy of strategies (Carter & Ellram, 1998)](image)

<table>
<thead>
<tr>
<th>Players</th>
<th>Upstream</th>
<th>Midstream</th>
<th>Downstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw materials suppliers</td>
<td>Main suppliers</td>
<td>Wholesalers</td>
<td></td>
</tr>
<tr>
<td>Parts suppliers</td>
<td>Manufacturers</td>
<td>Importers/distributors</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Retailers</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Green activities</th>
<th>Upstream</th>
<th>Midstream</th>
<th>Downstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material selection</td>
<td>(Design for) disassembly</td>
<td>Packaging</td>
<td></td>
</tr>
<tr>
<td>Re-use of materials</td>
<td>Scrap, shred</td>
<td>Returns handling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transportation</td>
<td>Returns shipment</td>
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<tr>
<th>Relation performance measures</th>
<th>Upstream</th>
<th>Midstream</th>
<th>Downstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission rates and energy efficiency per material % of virgin material</td>
<td>Volume of goods disassembled per hour</td>
<td>Amount of “air” in package</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degree of utilisation transport equipment</td>
<td>Volume selected for recycling</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Players, activities and evaluation of greening efforts throughout the supply chain (van Hoek, 1999)

These three perspectives describe the environmental aspects (or ‘greening business process’) of a supply chain as they deal with who is involved through the supply chain, what activities are undertaken, and how the greening process performs. Noticeably however, these
perspectives on green logistics are missing a more holistic approach that considers the potential for value-creation.

Only more recently have these more holistic approaches to green logistics emerged. These value creation approaches view green logistics as involving processes that have the potential to be drivers for innovation, job creation, and energy conservation, as well as CO₂ reduction. It is evident that the emergence of new technologies such as RFIDs have the potential to support these more holistic approaches. Addressing the tension between business and environmental drivers remains difficult but is critical to understanding how developments, such as RFID technologies can be incorporated to deliver holistic solutions.

The next section of this paper presents a model that combines a number of existing frameworks covering forward and reverse logistics as an approach to conceptualise green supply chains from this more holistic value-creation perspective.

3. A Model for Conceptualising Green Logistics

Green supply-chain management has been defined as ‘integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life’ (Srivastava, 2007). However, such a definition does not explicitly address the need for information flows between all parties in the supply chain to effectively achieve ‘greening’.

A holistic perspective needs to look at the (direct and indirect) interconnections including information flows that an organisation has with other participants in the supply chain. This means that the environmental effect of an organisation is not only from its own actions and/or inactions, and the actions of its first tier suppliers (direct effect), but also a result from suppliers up the supply chain (indirect effect) (Darnall, et al, 2008), as well as customers and parties interacting with the end of lifecycle down the supply chain.

Cases from the automobile and computer industry provide examples of manufacturers who are considering the environmental aspects of their suppliers, and, thus evaluating the potential environmental problems that may be transmitted from suppliers. Such manufacturers are beginning to pay attention to designing green products and also demonstrate commitment to initiate recycling of products. In this way organisations are taking a more proactive approach, which should be differentiated from the reactive approach where a company’s activities focus mainly on “end of pipeline” initiatives to lower the environmental impact of production (Srivastava, 2007).

However, having an environmental friendly logistics process can also presuppose some economic detriment often at the cost of the logistics provider or the end customer or user. Being green from a logistics perspective is not that simple. Even collecting and analysing basic data can be difficult.

Some examples are provided here.

- A manufacturer could use plastics that decompose naturally within a reasonably short period. This could reduce recycling costs as well reverse logistics costs, but the initial raw material cost of the plastics could be more.

- A new factory can be more expensive to build and use more sophisticated material, but have almost no emissions. Production strategies might have to change.
More production, freight movement and warehouse despatch could take place at night when cooler conditions prevail; thus saving on fuel and electricity costs, but with higher salary and labour costs for night rates.

Environmentally friendly products and services could cost more, causing it to come into conflict with traditional logistics. Logistics has traditionally been focused on forward logistics rather than reverse logistics and this is where the efficiency gains are concentrated. Reverse logistics has traditionally been the actual ‘green’ logistics (Rodrigue, et al, 2001).

This has now taken on a new meaning and implies not just the recycling of waste but also the reduction of harmful by-products such as carbon dioxide and monoxide, minimisation of the use of fossil fuels and the use of technology to improve efficiencies; e.g. RFIDs.

The difficulty with green logistics is ensuring that each stage of the logistics process and the supply chain can deliver some environmental benefit – no matter how small. Trying to measure these benefits is often impossible or not cost-effective. If extracting a raw material increases the cost of a product (from an environmental perspective) more than the net logistics gain, then perhaps that particular logistics supply chain will have a negative environmental impact.

As Rodrigue et al. (2009) describes, there is a paradox regarding the application of green logistics, which suggests that the application of green logistics could be more difficult than might be expected.

Rodrigue lists these paradoxes and they are briefly summarised here:

**Costs.** The purpose of logistics is efficiency gains and thus reducing costs.

**Time/Speed.** Distribution and delivery time reduction, especially for high value products as well as JIT manufacturing is a strategic goal for logistics providers.

**Service Reliability.** In a competitive market, customer service is important. Together with speed, service reliability is one of the main desirability of customers. Speed and reliability often use the least environmentally friendly modes of transport such as air and road.

**Warehousing systems** are based on the reduction of inventories as the speed and reliability of deliveries removes the need to have large inventories. But this reduction in inventories relies more on efficient transport systems. The most efficient transport systems are air and road; the most environmentally unfriendly modes of transportation.

**E-Commerce.** Electronic commerce is a burgeoning market sector. This is due to integrated systems between manufacturers, suppliers, distributors, transporters, etc. The number of small parcels and cartons being shipped is staggering. However, once again the most efficient transport systems are air and road; the most environmentally unfriendly modes of transportation.

In this context, this paper combines a number of frameworks to examine these green logistic issues and challenges from this holistic perspective. In particular, this paper overlays a modified view of Porter’s (Porter, 1985) Value Chain model consisting of primary and support activities, with three other considerations: Reverse Logistics, Substitution & Re-Design, and Information Logistics. Some aspects of Zou’s (2009) green logistics model is also included.
Figure 2 shows a Green Supply Chain System conceptual model that incorporates the four dimensions of logistics – namely:

1. Forward Logistics
2. Reverse Logistics
3. Re-Design & Substitution
4. Information Logistics

Note that in 2. Reverse Logistics, the acronym GSCM, is used for Green Supply Chain Logistics in this particular context.

4. Green Logistics Reference Models

While it is acknowledged that the Supply Chain Operations Reference (SCOR) Model can be applied to green logistics as it describes measures and evaluates supply chain configurations, it does not directly measure green logistics and green supply chains (Rodrigues, 2006). The SCOR toolkit is designed to evaluate performance between companies, competitiveness and process requirements. It is important to align the Key Performance Indicators (KPIs) with green logistics and if required, to develop a new set to assess the performance of transport from a holistic green supply chain perspective (Rodrigues, 2006, Reichard & Nichols, 2003).

Zhou (2009) developed a system diagram to show a green supply chain system for textiles. In this diagram Zhou explicitly tried to include a holistic approach to green supply chains: “In the green textile supply chain management, the management objects become into the strategic partners among enterprises through many basic flows such as green plan, green stock, green manufacturing, green distribution, green logistics, green consumption and green reclaim” (Zhou, 2009).

Although, this diagram was developed for the textile industry by being explicit about this holistic perspective, it provides a useful basis for adaption and combination with other models such as Porter’s (1985) that need to be included in a more holistic conceptualisation of green logistics that aims to adopt a value-creation perspective. Figure 2 combines elements from both Porter’s Value Chain model and Zhou’s model to facilitate consideration of three other elements: Reverse Logistics; Re-Design & Substitution, and Information Logistics.

These four dimensions all need to be considered to effectively conceptualise green logistics. These are briefly listed below:

1. Forward Logistics which includes manufacturing, assembly, distribution and warehousing, retailing and end user.
2. Reverse Logistics which includes recycling, returned good and damaged goods, legislative requirements and disposal.
3. Re-Design & Substitution which includes product and rare material substitution, redesign and the use of the four natural capitalism principles.
4. Information Logistics which includes an environmental scorecard and benchmarks to evaluate and assess supply chains. Criteria could include
Figure 2: Green Supply Chain System conceptual model (adopted from Porter, 1985, and Zou, 2009)
- Carbon footprint
- Product miles or food miles
- Fuel consumption, cost and efficiency
- Waste disposal costs
- Reuse and recycle costs
- Renewable energy

The model above identifies four dimensions for holistically conceptualising green logistics. The next section uses this model to explore the potential of RFID technologies to provide support for value-creation in each of these dimensions.

### 4.1. Radio Frequency Identification Technology (RFID) & Green Logistics

From a technological perspective, the ability to monitor environmental factors including time, temperature and shock as well as product location and compliance verification across the whole supply chain is now possible through the deployment of active RFIDs.

Numerous projects involving pilot tests have illustrated how active RFIDs can offer opportunities for supply chain participants to acquire benefits; but adoption of active RFIDs remains slow. A review of the research literature indicates that most of the pilot tests continue to be conducted in the retail and manufacturing sectors (Saran & Mohamed, 2005, O'Connor, 2005).

Unlike static technology, active RFID technology and systems can identify, communicate, update and process data and characteristics (such as time, temperature, shock, product location, weight, etc) on tags on remote products. Another advantage of RFID is the potential for information visibility and automation of information processing to all the participants throughout the supply chain.

RFID clearly outperforms barcode systems but has, however, not yet become the primary approach to collect data from the supply chain activities. This is partly due to the (relative) high cost, partly due to the fact that not all of the expectations of this new technology have been met, especially the ability to identify single items in a batch. As well systems integration in and across supply chains remains an issue.

Despite considerable recognition within the research literature of the need to develop a substantial theory on the economic impact of active RFID technology for quality assurance and for clear business models that identify ROI/pay back, these have not been fully developed to date. Decisions on whether and how to implement RFID are confronted with large up-front investments, with payoffs that look small in the short term and uncertain in out years (Laubacher, et al, 2005).

Furthermore, the evidence of the return on investment of RFIDs in terms of cost efficiencies or effectiveness towards environmental issues (carbon neutrality) is lacking and under-researched. How these technologies can be used, and what benefits arise from their deployment to ‘green’ supply chains remains under-researched (Brennan, 2005, Collins, 2004/2006, Fontanella, 2004, Intermec, 2005, Kevan, 2004, Mason, 2005).

A number of researchers and practitioners have already considered the application of RFID in certain areas of green supply chain (for example in recovery processes, Lee, 2009, Payaro,
In reverse logistics, RFID has been adopted to increase the service level to the customers to complete the recovery service. In forward logistics, RFID helps replenish the goods in a timely manner to satisfy customer needs.

The most widespread area where RFID is implemented is inventory management (including warehousing). Furthermore, RFID has frequently aided improvements of production processes, of workers performance, as well as optimisations of logistic systems. Most of these improvements have been based on the potential of RFID to liberate human labour from certain workflows (offer “process freedom”, Angeles, 2005), as well as to decrease the possibilities of human errors in repetitive activities.

4.2. RFIDs across the Four Dimensions of Green Logistics

New technologies for supporting supply-chain management have the potential to assist organisations in achieving cost efficiency, value advantage (Rundh, 2008) and environmental sustainability. RFID technology is considered as one of the potential enablers for greening of the supply chain. Therefore, some of the previous implementations of this technology in (green) supply-chain management are presented.

Four business processes, which are part of a supply chain and have benefited from advantages of RFID, are briefly presented here.

a. RFID and Green Forward Logistics

RFID used to automatically update inventory as items enter a distribution centre, enabling discrepancies between purchased orders and incoming items to be identified. Putaway locations can be readily and replenishment operators can be freed from scanning products and verification procedures.

RFID can be used for order filling to direct pickers to the correct location and automatically verify that correct products in correct quantities have been removed, with inventory automatically updated. Alerts can be activated if inappropriate items or quantities are handled. Similar advantages can be obtained in shipping departments by speeding up the of conveyor system made possible due to the increased read speeds of RFIDs compared to barcode technology. In all the cases, the system can automatically generate error-free documents (Angeles, 2005).

The ability to track products and assets as they pass through critical points of the supply chain where reader portals have been installed is a big benefit. Retailers have the ability to track shipment movements from the time of release by the supplier until it arrives at their receiving dock. The time at each point can be recorded on the RFID tag and alerts can be generated if shipments take longer than expected and can prompt investigation. Lower safety stock inventory levels can employed as products can progress more swiftly. Furthermore, retailers can save as much as 80 percent of detention and demurrage charges for third-party-owned assets since they can track their products and different products handling assets (Angeles, 2005).

Besides product identity storage, RFID tags could be used for storing other product or process information that can increase the safety of products.
b. RFID and Green Reverse Logistics

RFID-based systems can be used for reverse logistics by placing a tag on each product at the manufacturer, and updating the data at the retailer and customer to determine if a certain service has been conducted on the product (Payaro, 2004). The data from the RFID tag is later used in reverse logistics to assist in deciding which components can be remanufactured, refurbished or send to landfill or destroyed.

The advantages include: increase of recovered products, tracking of returned products, simplification of the operations of collecting, sorting, and disassembly, as well as reduction of the quantities of toxic components in the environment.

RFID implementation requires a unique identification system, need shared systems of coding among all the manufacturers of a particular product (integration), requires organizational change, as well as a high level of modularity of products.

Overall, RFIDs enables minimisation of the complexities of the reverse logistics processes that comes mainly from irregular material flow as well as inventories that are in different conditions (repaired, defective, damaged, etc).

Intelligent systems can determine economical transportation and minimise holding time and depreciating value of returned products (Lee & Chan, 2009). Improved reverse information flow supported by RFID could reduce resource utilisation such as transportation, storage and obsoleteness and reduce the environmental impact of the product lifecycle.

c. RFID and Green Re-Design & Substitution

Natural capitalism presumes increased resource productivity, industry redesign producing zero waste and toxicity, leasing rather than selling products and using organisational profits to invest in natural capitalism. Examples include building redesign, hyper vehicles, and the use of natural materials for manufacture. Natural capitalism requires a whole new business model that harnesses environmental performance as a mechanism for competitive advantage.

d. RFID and Green Information Logistics

A measure of the emission rates and energy efficiency of virgin material could be a key performance measures. RFID technology can be utilised to enable screening of different processes through the supply chain over any period of time of time of days or weeks in order to identify the emission rates and energy efficiency of different components of the process.

The usual use of RFIDs in supply chains are mostly focused forward and reverse logistics and savings in resource consumption could occur at the re-planning and re-designing process.

RFIDs could also be used as a diagnostic mechanism to improve standards, benchmarks and to develop new sets of performance indicators.

From this representation of current applications of RFID use in the supply chain, a model (Figure 2) can be developed that can present the use of RFID in greening the supply chain.
From this model it can be determined that reverse logistics have explicit environmental performance effects such as waste reduction. The use of RFID in this context could increase the number of products returned and provide greater process efficiency.

The applications of RFID in transportation have implicit environmental performance advantages as well, enabling economical and thus environmentally friendly transportation. Implicit performance can for example include a trade-off between, cost, service and carbon footprint. It can be speculated that RFID can enable significant reductions in logistic-related costs by helping eliminating unnecessary transportation and finding the optimal mode of transportation for all shipping. This can provide significant carbon benefit and can be perceived as being ‘green’. The current case examples of RFID application in distribution and product safety do not have explicit environmental performance effects, but implicit effects can be speculated.

5. Conclusions

This paper has reviewed contemporary discussions on the current state of supply-chain management and green logistics including the cost efficiency of RFID systems.

The paper identified three existing perspectives that consider green supply-chain management and highlighted that these are tied to discourses on reverse logistics only. The paper proceeded to argue for a more holistic approach to green logistics that include value creation.

A Green Supply Chain System Conceptual model was presented that combines a number of existing frameworks covering forward and reverse logistics as an approach to conceptualise green supply chains. This combined model was then used to explore the potential of RFID technologies for ‘greening’ supply chains.

Based on this exploration it was found that supply chain efficiencies and green initiatives can complement each other and generate real value for logistics organisations. In the current highly competitive market for companies in the western world, green technologies are seen as a strong business option compared to traditional manufacturing operations covering both forward and reverse logistics and information systems.

6. References


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