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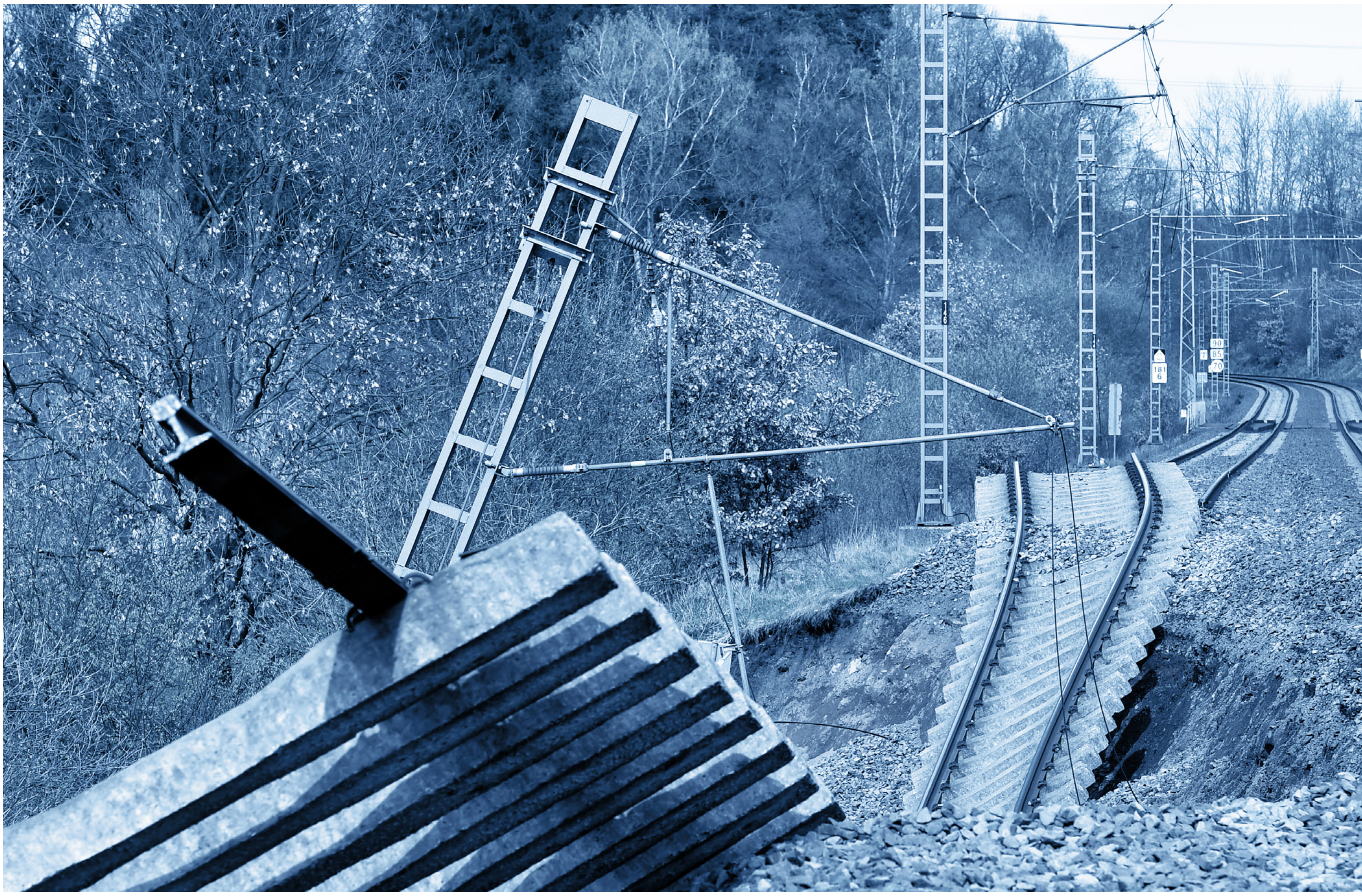

Efficiency and Sustainability in Multimodal Supply Chains

Discussion Paper

171

Roundtable

Jean-Paul Rodrigue

Hofstra University,

Hempstead

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The International Transport Forum

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International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org

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Table of contents

Global supply chains and multimodal transportation

Efficiency improvements are inherent to the sustainability of global supply chains. Supply chains are highly dependent on a diversity of material flows handled by numerous actors (suppliers, carriers, manufacturers, distributors, etc.) and the efficiency of these flows impacts the environmental performance of the supply chain. Yet, there is no particularly clear strategy about improving the efficiency of supply chains, notably from an environmental perspective. The debate about whether environmental efficiency is better achieved through innovation and market competition as opposed to environmental standards imposed by regulations is ongoing in sustainable transportation. Irrespective, further levels of integration along supply chains, supported by multimodalism, are expected to derive direct (less emissions) and indirect (better use of resources) benefits.

From intermodalism to multimodalism

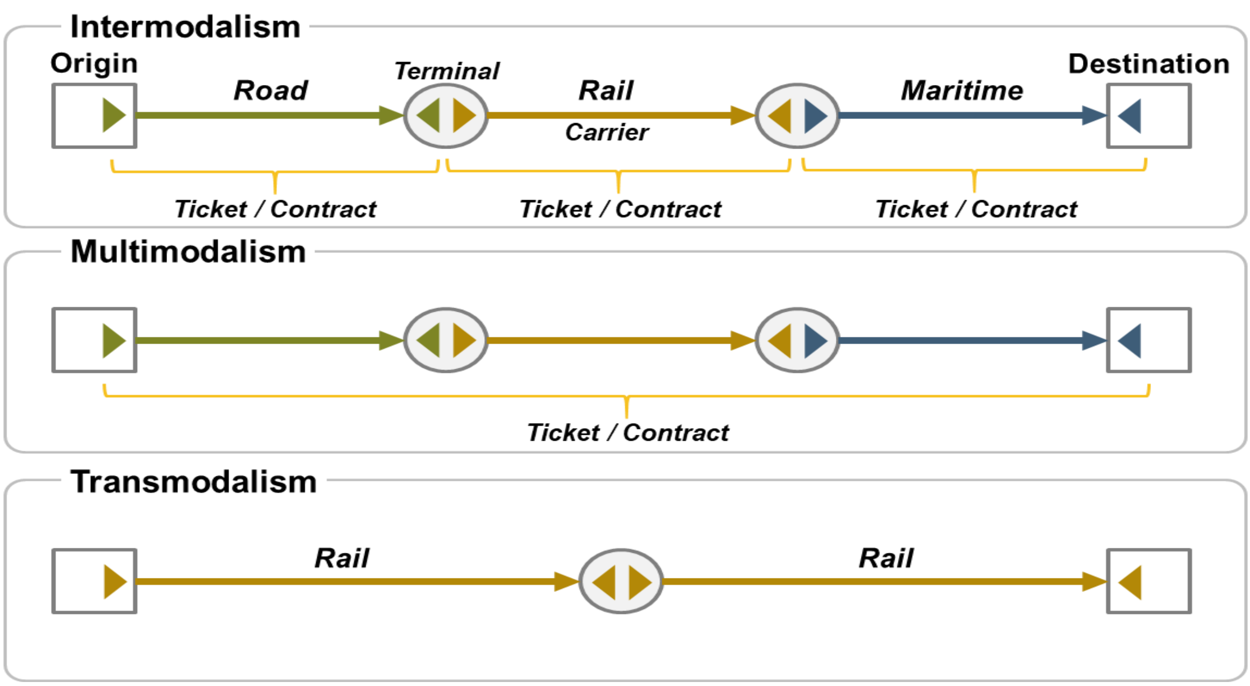
Intermodalism involves the organisation of a sequence of modes between an origin and destination, including the transfer between the modes (Figure 1). The main goal is to connect transportation systems that could not be connected otherwise because they are not servicing the same market areas due to their technical characteristics. The most fundamental technical difference is between maritime and land transport systems. However, each transport segment is subject to a separate contract that must be negotiated. The term intermodal transportation has also been specifically employed in reference to container rail transportation in North America.

Multimodal is defined as the movement of cargo from origin to destination by several modes of transport where each of these modes have a different transport carrier responsible under a single contract or bill of lading. Mutimodalism is reflective of:

- Integrated transport segments where frequency and services are better synchronised to favour continuity along the transport chain.
- Consolidation and strategic alliances between different carriers and terminal operators enabling them to issue a common contract.
- Improved information and communication technologies enabling actors to interact more efficiently.

The differences between intermodalism and multimodalism appear to be subtle, but they are fundamental. Although multimodalism may at first glance look more efficient since less transactional costs are involved for the user (dealing with a single provider), it is not necessarily the most efficient and sustainable from a supply chain perspective. A multimodal transport service provider will be inclined to use its routes and facilities during the transport process, since the main purpose of a third party logistics (3PL) service provider is to maximise the use of its assets and its profitability. For some supply chains, the routing, scheduling and use of storage facilities could be at odd with the benefits of their users. Why would a 3PL having significant trucking assets in a market be inclined to use an alternative mode of transportation for the freight it carries on behalf of its customers? In the same vein, why would a 3PL owning a distribution centre be inclined to use another distribution centre closer to the market of a specific customer? This underlines the power of stakeholders to route freight in a way that maximises the utilisation of their assets; even if it is not necessarily the most efficient process from a multimodal perspective.

Figure 1. **Intermodalism, multimodalism and transmodalism**



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Transmodalism

Transmodalism involves connecting different segments of the same mode between an origin and a destination. It tries to reconcile different modal services on the same network since they may be undertaken by different carriers. There is no specific term if transmodalism takes place as a single or separate ticket or contract.

Transmodalism is common for air transportation since a passenger can easily book a ticket between two locations, even if it involves transiting through an intermediary airport and using separate carriers. The strategies of air carriers particularly relied on transmodalism with the setting of major hubs that maximise the number of city-pairs serviced and code share services with complementary carriers. For freight transportation, transmodalism is more challenging since it was conventionally complex to switch load units within the same mode because of the large amount of handling required. Paradoxically, it is the development of intermodalism that has favoured the setting of transmodalism since it incited the development of long distance transportation services and an increase of container volumes to be handled across the same mode.

For maritime shipping, transmodalism took shape in the setting of intermediate hubs such as Singapore, Dubai and Panama, connecting deep sea and feeder services. For rail, the North American rail system and its land bridge is interconnected at major transmodal hubs such as Chicago. Transmodalism is emerging on the Eurasian land bridge as well, particularly for gauge changes.

The setting of intermodal transport systems

Moving cargo from one mode to the other has always been a challenge since the size of conveyances such as ships has commonly exceeded the ability to load and unload them in a timely fashion. Time spent at terminals such as ports and railyards was substantial. Through history, various systems were used to handle break bulk cargo, such as crates, barrels and even amphorae (antiquity), but hoisting loads was a labour intensive activity even when cranes or other devices were available. Loads larger than those handled by a crew of three to four people could not be conveniently used for the purpose of commercial transportation.

It was not until the 20th century that intermodalism could be achieved in its true form. The emergence of intermodal transportation systems is the outcome of several phases involving the application of key technologies, operational improvements and regulatory changes (See Figure 2).

Inventing intermodalism

The first significant intermodal innovation was pallets handled by forklifts. Even if the pallet is a simple device, it could not be implemented until there was a mechanical means to conveniently lift and move it. Paradoxically to its use today, palletisation benefited trucking more than rail since large truckloads could be effectively handled at any location, enabling truck transportation to gain market share. With the growth of trucking, trailer on flatcar services (TOFC) were adopted in the 1950s, permitting a preliminary intermodal integration of rail and truck services.

Setting intermodal standards

There were several attempts to establish container-like services in the 1920s and 1930s, particularly by railways, but those services were punctual and short lived. By the late 1950s, containerisation triggered a series of innovations related to more effective handling of containerised cargo, initially at port terminals and for maritime shipping, but later on over intermodal rail services. An important step was the standardisation of container sizes and latching systems in the late 1960s, which incited the construction of cellular containerships and the setting of container on flatcar services (COFC), mostly for domestic containers.

Operationalising intermodalism

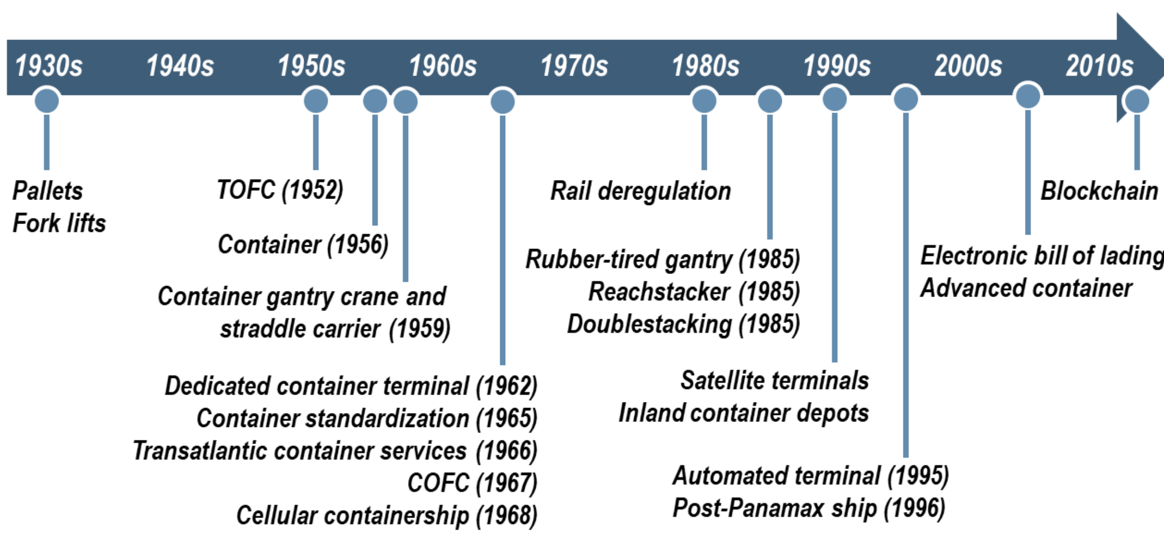
The 1980s marked significant changes for intermodal transportation, particularly with the onset of rail deregulation (in the 1990s for Europe), enabling railways to reorganise their services to more commercially driven imperatives. Long distance double stack rail services were established across North America, enabling maritime containers to reach inland destinations. More efficient intermodal equipment such as reachstackers and rubber-tyred gantries were developed. As the scale of the operations and the volumes rapidly increased, new intermodal facilities emerged, such as satellite terminals, inland container depots and inland ports, each fulfilling a specialised role in the continuity of intermodal transport chains.

Massification and automation of intermodalism

By the late 1990s, ships larger than the standard Panamax design arrived, pushing for economies of scale both on the maritime and inland sides. Automation, as opposed to the mechanisation that had until then been the driving force of intermodalism, began to be implemented at a few large intermodal terminals, but comprehensive automation would not begin until the 2010s. Information technologies also became one of the driving forces of intermodal integration, a process of many dimensions.

By the 2000s, electronic bill of lading systems (after some unsuccessful attempts in the 1990s) enabled a more effective handling of the crucial documentation related to intermodalism, which permitted intermodal transportation to become increasingly multimodal. The container itself was improved with Radio-frequency identification sensors (RFID) and positioning systems, enabling to track its location and conditions (particularly important if a refrigerated container). Along with the ongoing and potential automation of the modes and terminals involved with intermodalism, the implementation of blockchain technologies shows the potential to substantially improve the transactional effectiveness of intermodal transportation.

Figure 2. Main steps in intermodal integration



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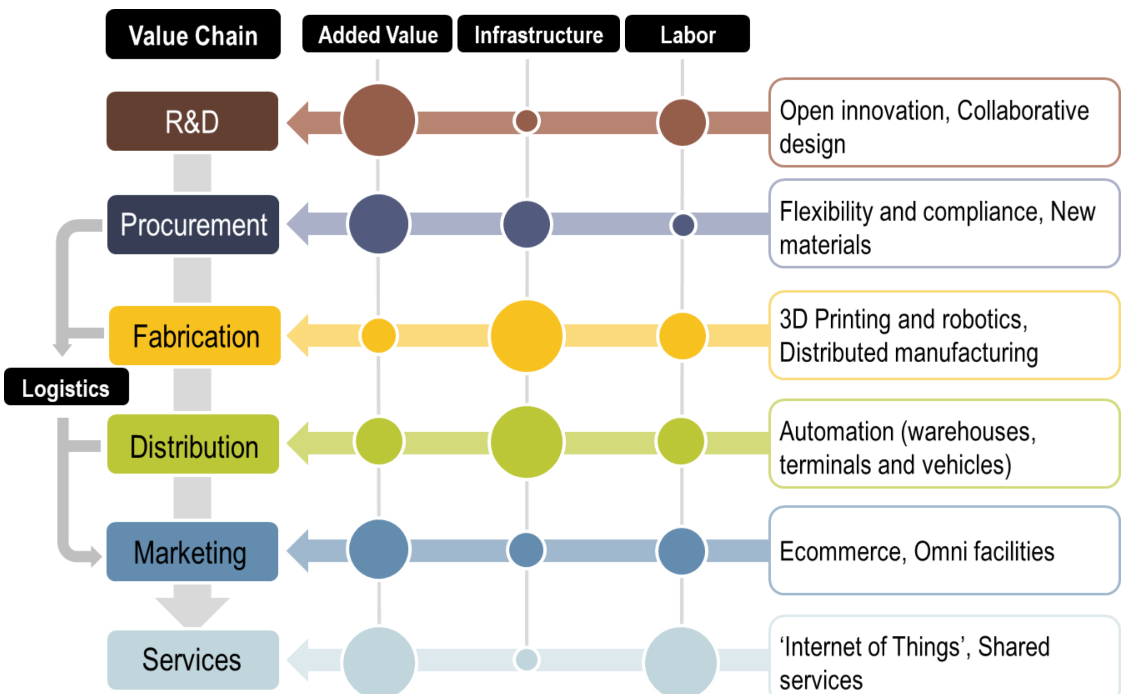
Intermodal transportation has therefore experienced an ongoing integration by technical means, but managerial and information technologies are playing an increasing role.

The fourth industrial revolution and the convergence of logistics

The current global manufacturing landscape is the outcome of successive waves of innovation and economic development and their geographical accumulation. What has been labelled as a ‘fourth industrial revolution’ is unfolding. It is mostly based on robotisation (with supporting IT structures forming cyber-physical systems), which confers a higher level of flexibility in terms of the locations, the manufacturing processes, the scale and scope of the output, and the customisation of the products. Robotisation goes beyond mechanisation by enabling machines to perform more complex tasks and being able to adapt to a redefinition of these tasks. Machines are therefore getting similar to the flexibility of human labour. They can perform not only simple and repetitive tasks, but average skilled and routine tasks as well. In such of context, the importance of input costs, particularly labour, are rebalanced as labour can be considered close to ubiquitous for manufacturing reliance on robotisation.

The focus therefore shifts to global value chains, which are a circular process to gather resources, transform them into parts and products, distribute finished goods to markets and finally make these resources available again through various recycling and reuse strategies. Manufacturing and supply chain management become closely embedded. Each functional component provides a specific level of added value and is supported by a level of physical infrastructure. They are each impacted differently by a series of drivers (Figure 3).

Figure 3. **Value chain drivers of the fourth industrial revolution**



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Research and development

Even if innovation has been a key driver in prior stages of industrial development, technological development and competition have underlined the high value of innovation as innovative products are linked with high profit margins. This is further underlined by intellectual property protection schemes such as patents, licenses and proprietary designs. Even if the science, technology and design behind innovation can be complex, a large share of it remains collaborative and accessible. Open innovation platforms are emerging where corporations can share Research and Development (R&D) requirements for innovators to provide solutions in exchange for compensation. Therefore, new products are designed using an existing digital information base (including schematics), which adds a high level of value in part because it can be replicated and customised.

Procurement, fabrication and distribution

In the current setting of global supply chains, procurement has become a complex endeavour considering the wide variety of options, quality standards and financing strategies of getting resources and parts for the expected output. Materials as well are subject to innovation when new materials can substitute for conventional materials. Access and connectivity to diversified procurement sources are expanded by the fourth industrial revolution. Additionally, more advanced information and communication technologies enable further predictability, flexibility and adaptability to procurement. Environmental considerations, such as certification schemes, are impacting procurement as well, with the recycling and reuse of materials.

The infrastructure intensiveness of fabrication has been enduring. The potential changes generated by what is defined as 3D printing as well as robotics has the potential to transform manufacturing, which is becoming less labour intensive, more scalable and adaptable and open to using new materials. These technologies can shorten production cycle times, improve productivity and decrease the footprint of manufacturing. This changes the locational requirements of several manufacturing sectors as well as the scale of production with the potential for smaller production units servicing local markets under just-in-time demand fulfilment. This new paradigm has been labelled as distributed manufacturing.

Automation has been an important driver for distribution as well, with a push towards the automation of warehouses and distribution centres to increase their throughput and responsiveness. The same applies with containerisation where terminals are being automated to improve gate, yard and transloading operations (see previous section). The potential for automated vehicles, particularly for road, is also a driver that could substantially impact the dynamics of freight distribution in the coming decades, including last mile and urban logistics.

Marketing and services

The conventional retail landscape has been characterised by a strong real estate footprint since direct accessibility to consumers has become a key factor. E-commerce has been an important driving force competing with and complementing standard retail systems. From a distribution perspective, this has favoured the growth of home deliveries, often through new specialised online retailers. From a fabrication perspective, this has enabled new actors an option to access markets for niche goods of their own innovations. The retail landscape is adapting be reducing its footprint (e.g. store closures) and moving towards Omni Facilities where the store is at the same time a showroom, a distribution centre, a pickup point and even a recreational area.

The service components of products particularly electronics, vehicles and appliances, has increased through internet connectivity using the Internet of Things (IoT) and their ability to use sensors and geolocation. For devices such as smartphones, the service components in terms of software, communication and media is often more valuable than the device itself. Due to the growing importance of environmental considerations, service activities related to upgrade, maintenance and repair are bound to gain importance as well. Online platforms have enabled the possibility to make expanded forms of services available such as ride sharing services, port community systems and possibly blockchains.

Since most of these drivers were recently introduced, their full impacts are not entirely known and can only be speculated. Some could be far more reaching than expected while others could turn out to be simple hype. Expectations are for a more efficient use of materials, a lower material intensity of goods (including packaging), and a lower environmental footprint for manufacturing and transportation. The full transformational consequences of the fourth industrial revolution on value chains remains to be seen.

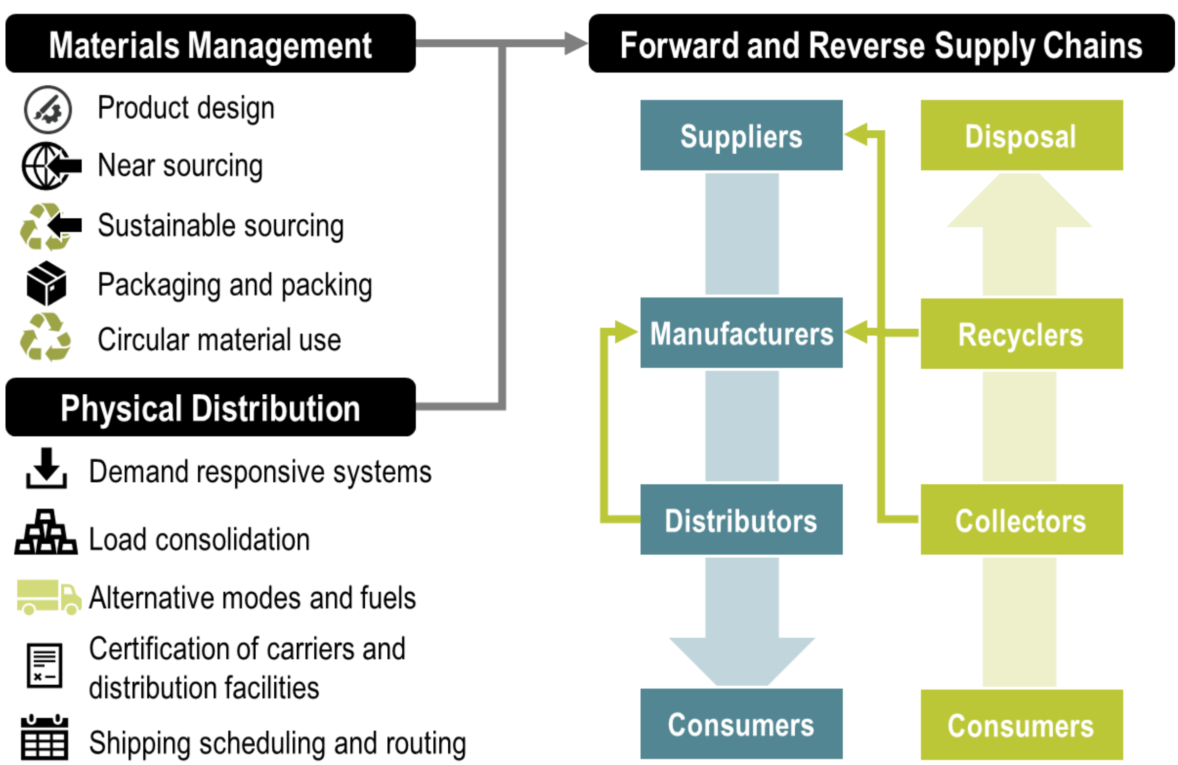
The greening of supply chains: An elusive goal

Since corporations are competing over their supply chains, their environmental efficiency must be assessed at that level instead of individual segments such as the manufacturing plant or a transport route. The greening of supply chains has been an ongoing issue for more than 20 years but has proven complex and expensive to implement. Environmental regulations can have unintended consequences, so the regulatory environment has shifted towards the setting of environmental certification schemes and incentives for compliance to available standards.

Green logistics strategies

While costs have always been an important driver of supply chain management strategies, the negative energy and environmental footprint of many supply chains has been a strong incentive to improve what is known as green supply chain management. Since logistics are related to all the activities involved in making goods available to the final consumers, including all the stages related to procurement and distribution, the green applications of logistics are numerous and covering two main conventional dimensions; materials management and physical distribution (Figure 4).

Figure 4. **Logistic activities and their green dimensions**



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Green materials management

Materials management focuses on developing products that have a lower environmental footprint, including their manufacturing, sourcing, re-use and recycling. The main possible strategies include:

- Product design. Since the product and its distribution is the whole purpose of a supply chain, its design perspective plays a crucial role in its greenness. This includes the types of materials used for its manufacturing with a greater focus on the environmental footprint of the components as well as the durability of the product.
- Near sourcing. Reassessing sourcing both at the global and domestic levels. This is best done if a comprehensive array of logistics costs is considered, particularly in light of energy and environmental constraints. While a supplier may appear to offer the lowest cost, if factors such as higher transport costs, more inventories in transit, longer response (lead) times and a higher level of unreliability are considered, alternative, but closer, suppliers could be more advantageous.
- Sustainable sourcing. A change in focus for sourcing based upon environmental standards and certification, which become the main factors in the selection and retention of a supplier. This has notably been the case in the food industry where quality and certification (e.g. organic) have an important marketing value. However, this strategy risks offering goods and services that are less competitive since consumers remain highly sensitive to costs in spite of stated environmental awareness.
- Efficient packaging and packing. Reduce the shipment volume of the same load by using less packaging or by changing how goods are packaged. How the goods are packed for shipments is also of relevance since it can reduce packing wastes and use transportation carrying capacity more efficiently. Higher transport densities are an important consideration for shipping since many goods tend to cube out their load units before they weight them out.
- Circular material use. Moving towards more efficient forms of use and sourcing for materials, including packaging and recycling so that what used to be an output can become an input. Optimally, a much higher level of re-use and recycling should be part of the inputs of the manufacturing sector (an overview of the circular economy is provided later).

Green physical distribution

Physical distribution ensures that the mobility of freight related to logistics operations is performed in a sustainable and environmentally friendly manner. The main possible strategies include:

- Demand responsive systems. The setting of demand responsive systems where supply chains are tightly integrated so that the goods being delivered are the outcome of an expressed demand. A better level of order fulfilment tends to reduce returns. This is in line with the setting of pull-logistics systems that have replaced many conventional push logistics systems.
- Load consolidation. This can involve a wide array of strategies such as a better consolidation of loads to avoid sub-optimal use of transportation (from Less Than Truckload (LTL) to Full Truckload (FTL). Strategies to pool the LTL cargo of small shippers are also an option so that loads and vehicles are better used. The risk is that load consolidation can lead to additional delivery delays.

- Alternative modes and fuels. Use a mode that is more energy and environmentally efficient. Rail is the logical alternative to trucking over longer distances, but short sea shipping can be suitable for coastal regions. For urban freight distribution electric and natural gas powered vehicles have been introduced as well as adapted vehicles such as small vans and even cargo bicycles.
- Certification of carriers and distribution facilities. Certification provides standards for vehicles and facilities in terms of their expected environmental performance such as emission and energy use at the risk of being less competitive with carriers that do not. However, a growing number of procurement strategies are now contingent to the provider of logistics services having a certification covering its vehicles and facilities. This gives carriers abiding to certification a competitive advantage.
- Shipping scheduling and routing. Adapt the scheduling of flows to insure a greater level of utilisation of existing transportation and warehousing assets. By allowing greater shipping time and outside congested periods the same assets can be used more rationally, which conveys energy and environmental benefits. Longer, but less congested routes can be selected as well as a sequence of delivery stops supporting FTL.

All these strategies can be individually or jointly applied. Since they involve different actors, concerted efforts are uncommon as each element of the supply chain pursues strategies that are judged to be the most effective along their respective channels, which leads to a duality between forward and reverse logistics.

Forward and reverse logistics

The conventional forward (linear) channel in freight distribution is well understood with raw materials, parts and finished goods flowing from suppliers to manufacturers, distributors and, finally, to consumers. A reverse channel is also emerging, where wastes, packages, and defective/obsolete products are "climbing back" the supply chain. In some instances, such as for a defective product, distributors will take back the merchandises, but in other instances, a specialised segment of the distribution industry aims at collecting and then recycling goods and parts. Thus, reverse logistics (or reverse distribution) is concerned about the movements of previously shipped goods from customers back to manufacturers or distribution centres due to repairs, recycling or returns. It incites new forms of collaboration between forward and reverse supply chains, which can take several variants:

- An important segment is customer-driven, where domestic waste is set aside by home-dwellers for recycling. This has achieved wide popularity in many communities, notably because the public became involved in the process and local regulations are enforcing it.
- A second type is where non-recyclable waste, including hazardous materials, is transported for disposal to designated sites. As landfills close to urban areas become scarce, waste must be transported over greater distances to disposal centres, a process that has become transnational (and controversial) towards developing economies.
- A different approach is where reverse distribution is a continuous embedded process in which the organisation (manufacturer or distributor) takes responsibility for the delivery of new products as well as their take-back. This means environmental considerations for the whole life-cycle of a product (production, distribution, consumption and recycling/disposal), an approach which is at the core of the concept of the circular economy applied to supply chains.

The circular economy: An emerging paradigm

From linear to circular supply chains

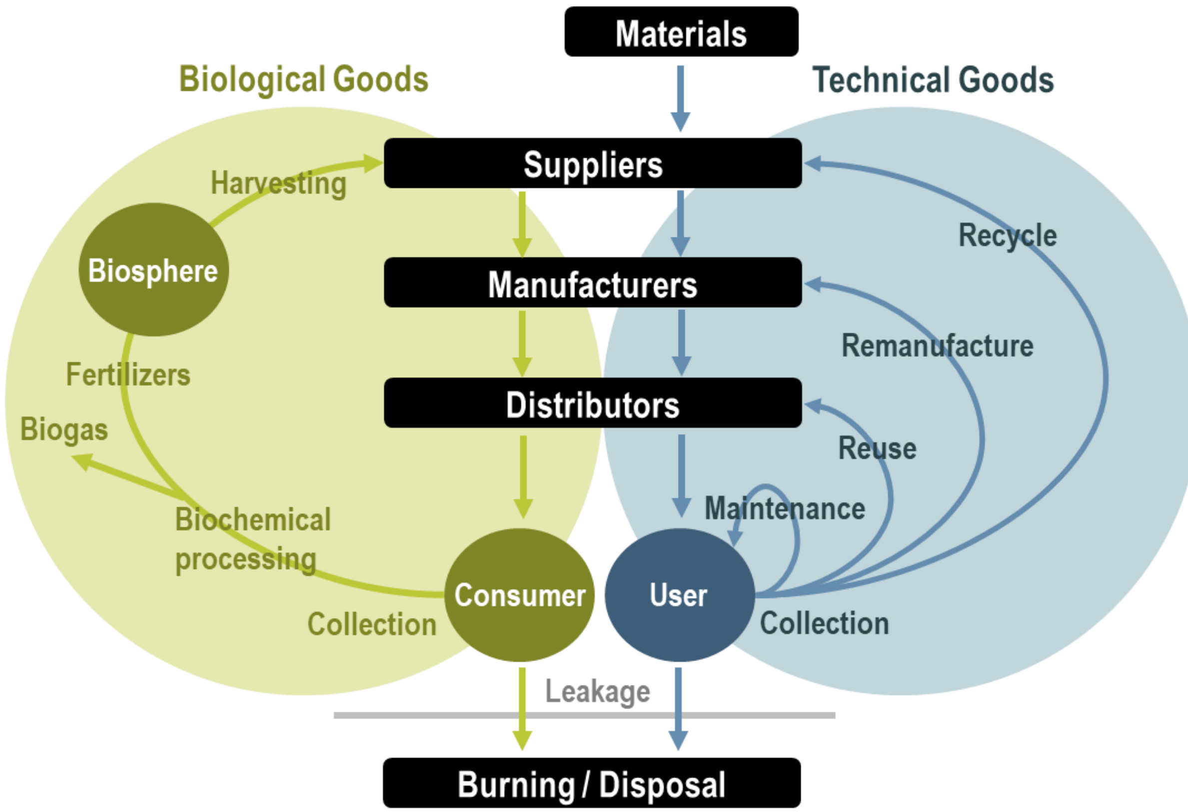
In spite of the perceived efficiency of manufacturing and freight distribution, the consumption and use of material goods in advanced economies is associated with high waste levels. Depending on the supply chain, more than half of the materials used will be burned or discarded while a smaller fraction will be reused or recycled. The reasons behind this reality are numerous but often linked with the comparative costs of sourcing from new materials as opposed to sourcing from recycled materials. Supply chain strategies can therefore be an important factor enhancing sustainability since they can make available new sourcing strategies.

The circular economy is a feedback system that tries to minimise the inputs of resources (biological and technical) as well as the generation of wastes leaking into the environment. It is an expansion of reverse logistics principles into a more comprehensive framework which includes two subsystems; one related to biological goods (e.g. food) and the other to technical goods (e.g. products) (Figure 5).

Although supply chains in a circular economy appear similar to conventional supply chains (a linear sequence from suppliers, manufactures and distributors to the user), there are two fundamental differences as the circular economy is actively based on forms of supply chain collaboration:

- The first concerns product design and the socioeconomic context of consumption. In a circular economy, products are designed to last longer and to be reprocessed in some manner once their life cycle is complete. It is also assumed that most goods are shared (particularly capital goods), which increase their utilisation level; less goods are required to provide the same service level.
- The second concerns the collection of used or consumed biological and technical goods for various forms of reprocessing, where the conventional linear structure of supply chains becomes a feedback loop.

Figure 5. The circular economy and supply chains



Source: Adapted from the Ellen MacArthur Foundation.

Layers of reverse logistics

The circular perspective about supply chains underlines four collaborative layers to the reverse logistics of technical goods:

- Maintenance. Ensuring the ongoing serviceability of a product, including its upgrade, at or near its place of use. Depending on the product, this can involve on-site maintenance.
- Reuse. The transfer of a product from one user (or user group) to another through its collection, maintenance, storage at the distributor and delivery. This is at the base of the 'sharing economy' where ownership is less prevalent.
- Remanufacture. The manufacturing of a new product from similar products once it has ceased to function because of damage or wear and tear. The manufacturer refurbishes major parts and if necessary adds new components for the parts that cannot be repaired. Then, the product is reintroduced into the supply chain.
- Recycle. Collecting various materials so that they can be used in the (re)manufacturing of new products.

Each of the above reverse logistics loops can have substantial impacts on the conventional linear components of supply chains but reduces their intensity since demand and flow patterns are modified. This, coupled with the potential impacts of the fourth industrial revolution on the location of manufacturing would further reduce the intensity of supply chains in terms of inventory levels and distance carried.

A controversial issue is that the circular economy is at odds with several manufacturing and marketing principles based on the principle of planned obsolescence and individual ownership / use. Still, circular economy principles are becoming increasingly integrated in manufacturing and distribution strategies. Firms that have reached a market saturation of their product lines are therefore more likely to implement circular supply chains as a strategy to gain or retain market share. Benefits are mainly derived from resource and energy efficiency gains, which are indirectly the outcome of reverse supply chains improvements.

Environmental Management Systems for supply chains

Regulation, innovation and certification

Environmental pressures in many economic sectors are already manifest, including for the logistics industry. The question is how these pressures are going to take shape and which actors are going to be the most proactive. For the later, three non-mutually exclusive scenarios are possible:

- A top-down approach where environmental standards are imposed upon the logistics industry by government policies through regulations.
- A bottom-up approach where environmental improvements are coming from the industry itself through the adoption of best practices through innovative firms seeking to compete.
- A compromise between the government and industry, notably through certification schemes leading to accreditation to desirable environmental standards.

Although the forces of regulation and innovation are always at play, the certification compromise appears to be the most desirable option with the industry following through with the implementation of environmental management systems.

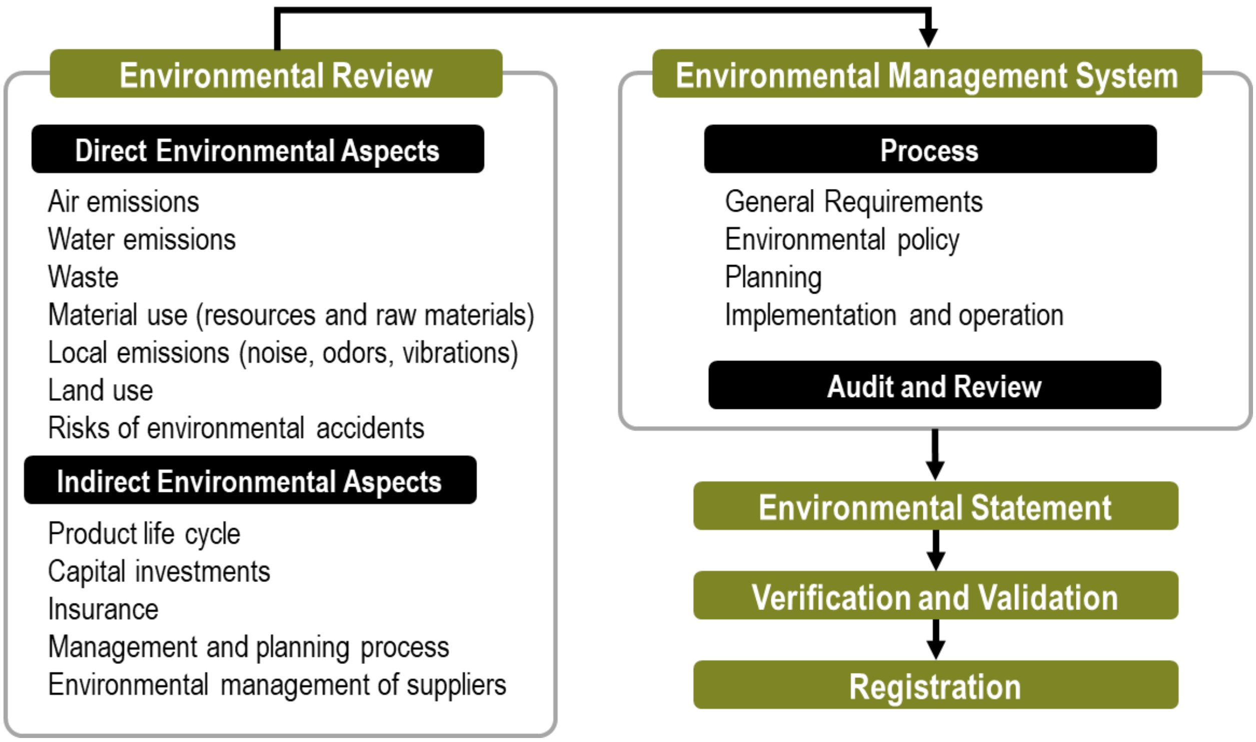
Environmental Management System procedures

An environmental management system (EMS) is a set of procedures and techniques enabling an organisation to reduce the environmental impacts of its activities and increase its operating efficiency. Obviously, transport and logistics firms can only manage environmental issues on which they can exert a controlling influence, which restricts their impact. The best environmental practices include procedures that:

- Match activities (transport facilities, operations or projects) with environmental components.
- Link environmental components with regulatory requirements.
- Assess risks, impacts and responsibilities.
- Identify environmental issues to be addressed.
- Develop commercial strategies and operations of private and public sector organisation.
- Introduce best practices.
- Undertake continuous monitoring and auditing.

These issues must be clearly understood before designing and implementing a particular framework of environmental management for a transport or logistics services provider (Figure 6).

Figure 6. **The Implementation of an Environmental Management System**



Source: Adapted from European Union, EMAS III Standard.

The implementation of an EMS within a transportation or logistics service provider requires several steps:

- Environmental review. In this phase, the corporation comprehensively reviews the direct (what it can control) and indirect (what it does not control but can influence) environmental aspects of its operations. This can include the generation of air and water pollution as well as wastes resulting from its operations. The total material use in terms of resources, energy and raw materials must be calculated since they are at the core of the environmental impacts.
- Environmental management system. The information gathered in the environmental review serves as input to articulate the environmental requirements to adhere to as part of an environmental policy. With these objectives, the planning and implementation of such policy can be formulated and environmental goals set. This is undertaken to ensure adherence to the guidelines established by environmental standards, such as EMAS or ISO 14001. An internal audit will be performed to validate the environmental review and the proposed EMS. At this point, the EMS has been endorsed by the corporation.
- Environmental statement. A comprehensive report underlining the environmental review and the proposed EMS is issued by the corporation to the certifying authority. Part of the environmental statement can also be issued to the public for promotional and relation purposes since it states goals and intended actions.

- Verification and validation. The certifying agency undertakes a review of the environmental statement, which can include site visits and specific queries. Its main goal is to ensure that the environmental statement meets the certification standards.
- Registration. Compliance is officially recognised, the corporation is issued a certificate, which is valid for all the authorities recognising the certification (e.g. customs, environmental agencies). Based upon a pre-determined schedule, the corporation will be audited to ensure ongoing compliance and a potential review of its EMS.

Eco-Management and Audit Scheme and International Standards Organization 14001

Numerous environmental management systems specific to each transport firm exist in relation to the problem, risks, impacts and responsibilities identified and the geographical environment in which it must operate. The most often mentioned environmental management systems are Eco-Management and Audit Scheme (EMAS) and International Standards Organization (ISO) 14001.

In 1993, the European Union created the norm EMAS, conceived to provide European firms with a framework and operational tools that would permit to better protect the environment. This approach rests on the need to identify environmental factors and their impacts by the operations and activities of any type of organisations, including transport enterprises. The impacts are evaluated according to a step by step procedure that examines each activity of a firm. Each impact is then assessed in relation to criteria developed by the firm. These criteria must evaluate the potential damage to the environment, the size and frequency of the activity, the importance of that activity for the firm, its employees and the local community, and the legal obligations emanating from environmental legislation. The EMAS was revised several times (I, II and III) to favour its integration with the ISO 14001 standard. This means that an organisation complying with ISO 14001 can comply with EMAS III through a simpler audit.

The ISO has developed a set of norms that represent the main industrial reference in terms of environmental management systems and sustainability. Introduced in 1996, ISO 14001 offers three categories of indicators to measure the environmental performance that could be applicable to the transport industry. The indicators of environmental conditions (IEC) present the information on the environmental conditions permitting a better understanding of the impacts or the potential impacts of transport operations. The indicators of management performance (IMP) present information on the management efforts that are being made to influence the environmental performance of transport operations. The indicators of operational performance (IOP) present information on the environmental performance of transport operations. These indicators permit to identify the most significant environmental impacts that are associated with transport operations, to evaluate, review and increase the environmental performance of transport firms, to identify new practices and opportunities for a better management of transport operations, and to have constant, credible and measurable information and data on the relationship between the environmental performance of a firm and its environmental objectives, targets and policies.

The main differences between EMAS and ISO 14001 can be summarised by the following:

- EMAS is a certification scheme that applies to the European Union while ISO 14001 is recognised internationally.
- EMAS is a site-specific certification, which means it applies to only specific parts of the activities of a firm and its supply chain. So, each site must undergo a specific certification process. ISO 14001 applies to all the activities and the sites of a firm to be part of the certification.

- EMAS requires an environmental review to take place before certification, while ISO 14001 does not.
- EMAS requires organisations to make an environmental statement publicly available, including an environmental policy and EMS, while ISO 14001 only requires an environmental policy.
- ISO 14001 is subject the less audits, while EMAS has a higher frequency and rigor of its audits.

Benefits and challenges for supply chains

The main drivers of EMS certification (either EMAS or ISO 14001) remain the perceived benefits a transportation and logistics service provider may gain from the process. The emerging perspective is that it is supply chains that are competing and as such their combined environmental performance is the frame of reference. The most common perceived benefits of EMS for multimodal supply chains include:

- Improved environmental performance and management methods of the transport or supply chain.
- Improved company image and stakeholder satisfaction.
- Competitive advantage in regulated markets.
- Mitigation of non-tariff trade barriers and the associated inspections and fines.
- Reducing capital and insurance costs for investments and operations.

Firms receive certification on the basis of establishing an environmental quality control and the setting up of environmental monitoring and accounting procedures. Obtaining certification is seen as evidence of the firm's commitment to the environment, and is frequently used in public relations, marketing, and government relations. This represents a fundamental commitment of the corporation to engage in environmental assessments and audits that represent a significant modification of traditional practices, in which efficiency, quality and cost evaluations prevail.

However, literature and evidence about the benefits of certification schemes over supply chains is scarce and the benefits remain circumstantial. The challenges of certification schemes include:

- Certification can be biased to represent or protect the interests of specific stakeholders and markets.
- Attaining compliance can be a costly endeavour in terms of time and resources with regard to the uncertainty of the benefits. This can be a negative factor for smaller firms or firms in developing economies. Thus, certification can create barriers to entry, effectively protecting the market advantage of the compliant firms. The latter will also have incentives to increase certifications requirements to further protect their market share.
- Once certification has been achieved, auditing and review can continue to be time and resource intensive as they can take place every three years. They can also relapse, implying that the certified firm may not consistently adhere to the standards they have been certified for. It remains challenging for a logistics firm to have a long term commitment to certification.

As such, there has been an observed decline in the number of EMAS certifications, particularly among smaller firms who find the cost of certifications difficult to assume and the benefits unclear, particularly on the long term. Still, EMAS is being expanded to include circular economy concepts and it's therefore increasingly synchronised with supply chain management practices.

Integrating multimodal supply chains

Irrespective of the expected environmental benefits, the improvement of multimodal supply chains relies on their integration and collaboration level. This integration relies on a series of well-defined strategies that can be individually or collectively addressed. An emphasis will be placed on the potential of blockchain as an information technology strategy to integration supply and intermodal transport chains.

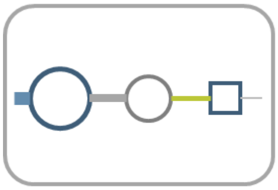
Elements of Supply chain connectivity and integration

Supply chain integration is the alignment of supply chain goals and policies along with related information and physical connectivity:

- Alignment. Shared goals among the components of the supply chain, often leaning towards reducing their costs and improving their environmental performance. This ensures consistency in the collaborative strategy pursued by the different actors involved.
- Connectivity. This concerns the information and physical flows between the elements of the supply chains, such as orders and tracking as well as the modes and terminals involved.

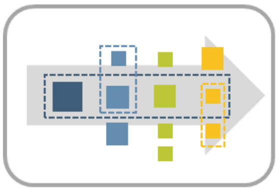
Connectivity usually relates to physical flows while integration usually relates to processes. It is possible to articulate supply chain connectivity and integration in seven general strategies (Figure 7).

Figure 7. Main Elements in Supply Chain Integration and Connectivity



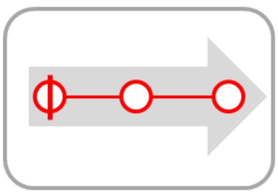
Transport Connectivity

Improving connectivity and interoperability of modes and terminals (intermodalism).
Infrastructure and superstructure improvements (capacity and throughput).
Synchronizing terminals and hinterland flows to increase throughput and reliability.



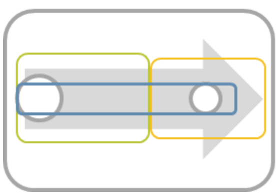
Commercial Integration

Trade and commercial agreements. Mergers and acquisitions along the supply chain.
Cost, time and reliability of transport and distribution services.
Vertical and horizontal integration of actors and processes (e.g. bill of lading).



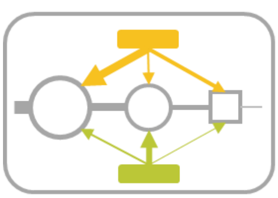
Customs and Security Integration

Moving cargo more efficiently across borders through prescreening and inspections.
Harmonization of customs and security procedures.
Assessments of cargo contents, cargo integrity, route integrity and information integrity.



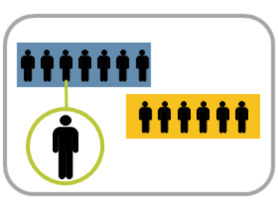
Regulatory Integration

Promote modal choice and avoid subsidized modal preference.
Harmonization of regulations across jurisdictions such as for vehicles, goods handling and transport, land use, labor and finance. Promotion of standards and certification.



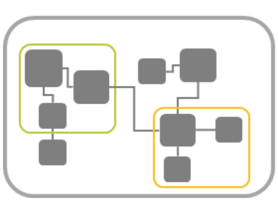
Planning and Funding Integration

Planning and funding of infrastructure provision from an integrated multi-modal and logistics chain perspective.
Respective roles and competencies of the public and private actors.



Work Practices Integration

Organizational (managing labor as a group) and skills (managing individual workers) competencies to move cargo efficiently.
Operational window (working hours), minimal service levels and essential services.



Information Systems Integration

Interconnectivity of information systems with blockchains.
Asset tracking, status monitoring, customs facilitation, freight status information and transport network status information.

Source: Author

Transport connectivity

The physical connectivity and interoperability of transport infrastructure, such as the ability to move containers efficiently along an intermodal transport chain (e.g. from ship to truck to rail). The transport terminal is the key infrastructure where physical flows are reconciled with the requirements of supply chain management. This is the purpose of intermodalism.

Commercial integration

The development of commercial arrangements, including service-level agreements and performance targets and penalties as well as the management process, such as between railways and ports (or terminal operators). It includes the elements of cost, time, and reliability as commercial goals that are benchmarked and included in commercial supply chain decisions. Because of the numerous actors in the freight distribution, each controlling different assets, the potential scale and scope of collaborative efforts becomes a complex matrix. This is the purpose of multimodalism.

Customs and security integration

Customs integration aims at moving goods more efficiently across borders from one country to another, including pre-screening and inspections. Security integration is the interconnectedness or harmonisation of security procedures that protect cargo from theft, tempering or damage and protect the public from risks posed by dangerous cargo or threats posed by illicit cargo.

Regulatory integration

The structuring of regulations to promote a better integrated freight distribution system. Regulations should promote effective modal choice, avoid subsidised modal preferences, and favour the harmonisation of regulation across jurisdictions. The promotion of standards and certification can also improve the productivity and environmental performance of supply chains.

Planning and funding integration

Freight transportation bottlenecks are potentially a significant hindrance to the integration of transport chains and to economic growth. It also recognises the concerns of government and industry that established institutional and finance arrangements have not adequately responded to the demands imposed by growing volumes of freight and passenger traffic and to fundamental shifts in regional and global patterns of trade.

Work practices integration

This involves organisational (managing labour as a group) and supervisory (managing individual workers) competencies. Since supply chain management relies on the timely processing of physical flows, labour issues play an important role in this process.

Information systems integration

The interconnectedness of information systems, including electronic data interchange, to improve management of supply chains. The setting of single window portals or port community systems is an example. These systems are being complemented by the emergence of distributed electronic ledger systems, colloquially known as blockchain.

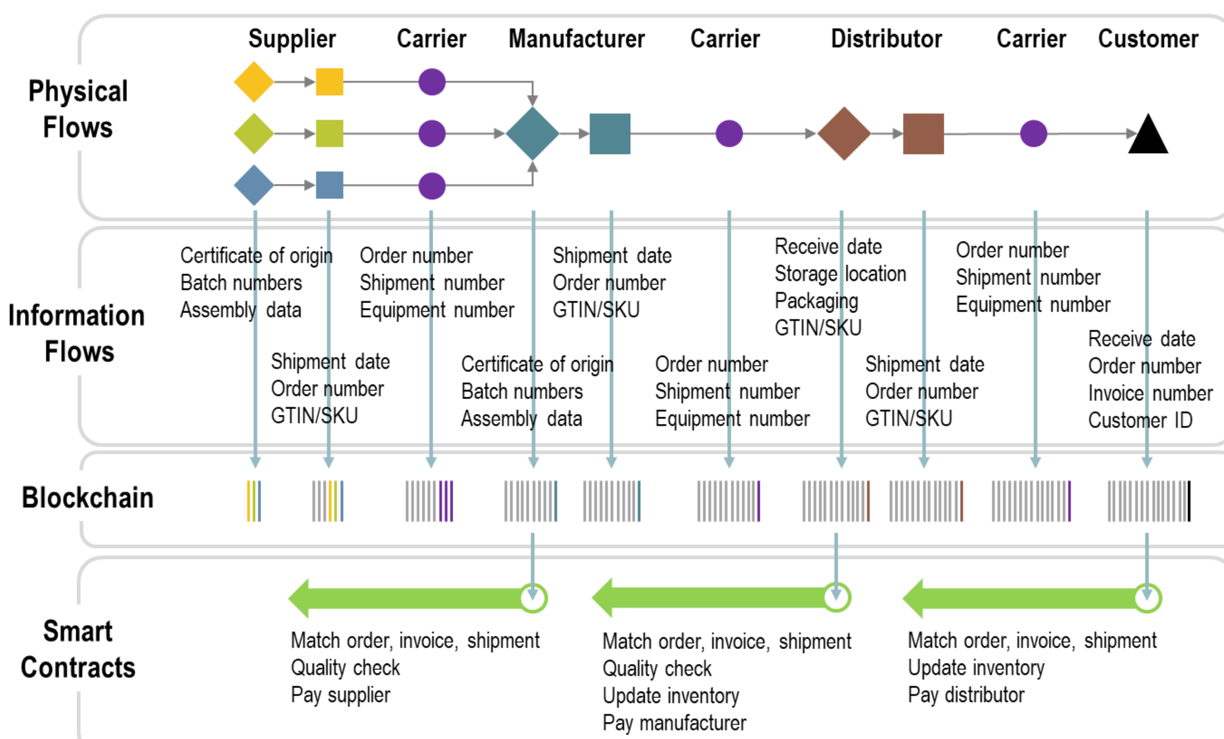
Supply chains and blockchains

A blockchain is a distributed electronic ledger that records transactions in units that are called blocks. Each block is stored on multiple servers (nodes) in a peer-to-peer network, implying the near impossibility of tampering the information once it has been inputted. Each time there is a new transaction a new block is created and appended to the existing blocks, thus the name 'blockchain'. All the blocks are updated on the network at the same time and contain the full history of the involved transactions, thus maintaining a chain of integrity. The novelty of the blockchain approach is that it does not require a central clearing house (e.g. a bank) to approve and record the transactions. Thus, intermediaries can be removed from the transactional system without in theory compromising its integrity.

Relevance to supply chains

Blockchains are particularly relevant to supply chains since they share many similarities. Supply chains are transaction intensive entities where multiple actors and stakeholders are interacting where each physical flow is related to supporting information flows. They are organized as sequences where the integrity of the orders must be maintained, enabling supply chains to fulfil their function (right product, quantity, condition, location and time).

Figure 8. **Supply Chains and Blockchains**



Source: Author

Figure 8 represents how blockchains can be used to support a simple supply chain. Four main elements are to be considered:

- Physical flows. The sequence of processes and movements from suppliers, manufacturers, distributors and the final customers (e.g. a retail store or an individual for -commerce). It requires facilities (e.g. distribution centres), modes and terminals.
- Information flows. Each supply chain task generates information flows. For instance, a manufacturer ordering parts from a supplier will generate an order number for a Global Trade Item Number (GTIN) or Stock Keeping Unit (SKU) () that it provides. This information is associated with production information such as batch numbers. Then, the carrier will generate an associated order and shipment number on a load unit being carried on specific equipment (a truckload, a container, etc.).
- Blockchain. Conventionally, the information flows stated above were processed through various information systems, at times in paper form, a process which is time and labour intensive. With a blockchain, each information flow creates a digital block which is attached to a previous block. As we progress through the supply chain, each actor uses previously created information stored in the blockchain to perform its role and at the same time adds its own blocks to the blockchain. At the end of the supply chain, the blockchain would contain all the associated tasks and processes that have led to the procurement of a specific good to a customer.
- Smart contracts. They refer to programs using the information contained in a blockchain to automatically fulfil an agreed upon contract. Since the contract is stored in the blockchain, it cannot be tampered with without the agreement of the concerned parties. Specific events in the blockchain will trigger the resolution of the smart contract. For instance, once a delivery has taken place and has met all the contractual requirements (e.g. quantity, quality, timeliness, etc.), then a payment can automatically take place.

Expected benefits

Blockchains are therefore an information substitute and improvement to the conventional processing of information associated with supply chains. Their expected benefits include:

- Velocity of supply chains. This is particularly the outcome of faster transactions, such as payments, which are a common cause of delay. There is less latency in the system, benefiting the cash flow and reducing inventory carrying costs. This is a form of digital multimodalism.
- Supply chain visibility (tracking). Because of its distributed structure, a blockchain is extremely difficult to tamper with and each transaction needs the validation of the involved actors. It is therefore possible to use the blockchain to track shipments along an intermodal transport chain and identify issues causing delays. Because of its potential visibility, a blockchain can be used to create a market where transport and logistics service providers could bid to carry or handle the cargo associated with specific blocks.
- Supply chain security (tracing). Since all the events of supply chain are stored in the blockchain as they took place, it is possible to see where, when and how a specific event took place. This is particularly relevant for cold chain logistics trying to monitor the integrity of a shipment across the chain. Counterfeiting and the use of sub-par materials would be easier to detect and trace since product information such as origin or batch number can be included.

- Standards and certification compliance. Blockchains are an effective tool to ensure compliance with agreed upon standards and certification guidelines. Blockchain events offer a proof that cargo was handled by specific modes, carriers and distribution centres. The sequence can even be used to accurately calculate energy use and environmental impacts (e.g. CO_2 emissions).

By improving the above elements, the level of supply chain integration increases substantially.

Blockchains and intermodal transportation

In spite of the costs of fluidity benefits of intermodal transport systems, processing and managing international trade documents can account for 20% of the transportation costs. Therefore, an important component in improving the efficiency of intermodal transportation resides on its transactional dimensions. The blockchain technology, as a distributed electronic ledger, can improve the transactional effectiveness of intermodal transportation both from managerial, tracking and settlement dimensions.

Multimodalism through blockchain bills of lading

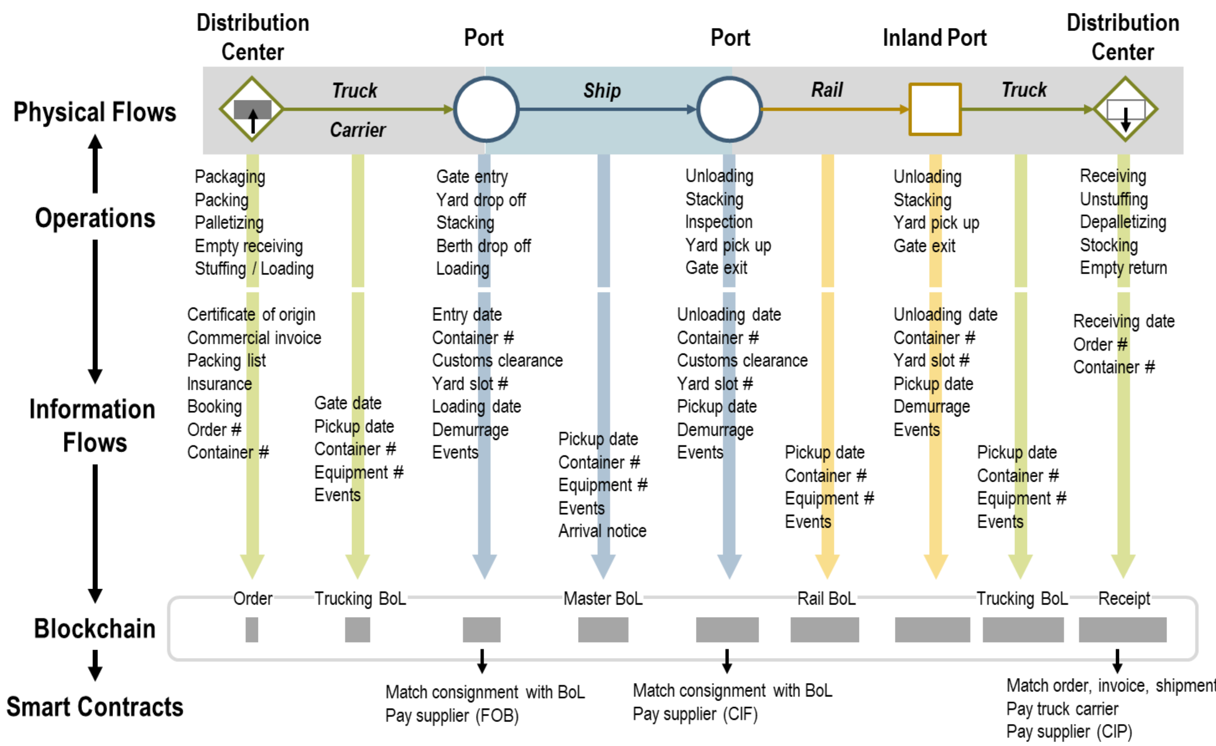
The bill of lading is a fundamental element to intermodal transportation since it involves the booking of carriers along a sequence of modes to carry freight (containers) on behalf of their customers. It is a key component of the integrity of an intermodal transport chain as it sets the responsibilities and liabilities of carriers and terminal operators (and other actors such as warehouses) for the cargoes under their care. Conventionally, bills of lading were transferred to different actors in paper format, a process subject to costs, delays, errors and potential tampering. Electronic bills of lading have been introduced since the late 1980s to improve the situation, but required a central repository managed by a trusted third party. Parties who wished to be involved in these transactions must be registered members. When a non-member is involved, an electronic bill of lading needs to be replaced by a paper bill of lading. The management of bill of ladings thus remained a cumbersome endeavour.

Blockchain technology involves the integration of the bill of lading as well as the letter of credit into a continuous electronic chain of verifiable information and transactions. For the bill of lading, it enables a consistent document that cannot be effectively tampered with and can thus perform more effectively its legal function (a document of title, a contract of carriage and a receipt for goods). For the letter of credit, blockchain enables the automatic settlement of contracts once stated terms have been met (right time, quantity, location and condition) and depending on the international commercial terms (Incoterms) of the transaction. This is particularly relevant since many firms pay additional demurrage costs because containers exceed free dwell time at terminals as a consequence of delays in the issuance of documentation or proof of payment. A similar occurrence applies to insurance where a blockchain could contain cargo insurance validation and the liabilities related to the cargo type and the intermodal transport chain.

Conceptualising a multimodal blockchain

Figure 9 illustrates a simple intermodal chain involving an exporter, an importer as well as the different carriers and terminals in between. It assumes one full dry container load (reefers or hazardous materials trade would generate more transactions and information). For an intermodal transportation chain to take place, a series of operations and their related information flows are required. Although the blockchain technology has little to do with the operations, it does substantially change the manner how the related information flows are stored and shared among the involved parties.

Figure 9. **A multimodal blockchain sequence**



Source: Author

The preparation of an order may require tasks such as packaging and stuffing the consignment into a container. This order generates information flows such as a certificate of origin, a commercial invoice, a packing list, an insurance certificate as well as the booking of a carrier (or a 3PL) to move the container consignment to a specified destination. This information can be stored in a blockchain and made available to the carriers and other concerned actors along the intermodal transport chain to use for their own purpose. One particular use is the construction of blockchain bills of lading.

The truck carrier uses the information in the blockchain to issue its bill of lading, which is appended to the blockchain and comes into force once the container has been picked up. This blockchain is populated with additional blocks as the carrier performs his transportation service, such as the equipment used (truck and chassis), the date the container was picked up, the container identification number as well as any notable events during transportation. An event can be passing at a specific location (e.g. a toll), the duration of a stop (for rest) or a change of driver and/or truck. Through the use of sensors it is possible to automatically input event information in the blockchain such as location.

At the container port terminal, various operations will continue to populate the blockchain. The time the container entered the terminal gate, its yard storage location as well as the customs export clearance are among the most important. A series of events can also be inputted into the blockchain, such as the equipment used to handle the container or if it was re-stacked (for yard management purposes). Once the container has been brought quayside and loaded into a containership, a smart contract can automatically be executed if the Incoterms involved Free On Board (FOB), which would pay the supplier when the terms of the contract have been met (under this contract, the supplier would also pay the truck carrier and the terminal operator). There is also the possibility to use cryptocurrencies to settle blockchain smart contracts as well as acting as booking deposits in case of no-shows from the shipper or over-booking from the carrier.

The shipping line issues a master bill of lading, which it is obliged to carry with the container from the stated port of origin to the port of destination. A series of events can also be recorded such as daily location or the use of a transshipment hub involving terminal operations and a change of ship (and even of shipping line). A few days before the arrival, the shipping line can issue an arrival notice (with ETA) on the blockchain to the consignee, so that land transportation can be arranged.

At the port of destination, similar intermodal operations are performed and appended to the blockchain. If the Incoterms are Cost Insurance Freight (CIF), then a smart contract can automatically pay the supplier (including the shipping line, the terminal operator and the truck carrier). Once the container received customs clearance (duties paid and appended on the blockchain) it is ready to be picked up by the land carrier. In this case, we assume a rail link performed from an on-dock rail facility with its own bill of lading to be appended to the blockchain. Then, the sequence is repeated for the last mile truck haulage with all the appended information to the blockchain.

At the destination, the final operations are performed on the container, such a destuffing and stocking the items at the distribution centre. Upon inspection, if the shipment matches the order, then the commercial invoice can be cleared, the blockchain updated and the supplier paid if the Incoterms were Carriage and Insurance Paid (CIP). This marks the end of this blockchain, which now contains the complete transport, intermodal and transactional sequence of this intermodal chain and its underlying supply chains.

Conclusion: Efficiency or sustainability?

In spite of decades of environmental initiatives, including regulations, the sustainability discourse within supply chains remains contingent upon efficiency improvements of production and distribution, as well as consumer preferences. Efficiency improvements tend to be ad hoc since they are implemented by a multitude of actors having different interests, goals and strategies. The environmental benefits are usually derived, not necessarily the other way around. An overview of the main drivers of the efficiency of multimodal supply chains indicate that sustainability is unlikely to be achieved if not supported by certification schemes, which builds upon standard setting behaviour in intermodal and logistics management. Accreditation becomes a process inciting a firm to closely examine its supply chains and their environmental dimensions and most importantly factors that could be improved upon within their environmental management systems (EMS). Under such circumstances, emerging paradigms such as the circular economy offer approaches towards greener logistics by combining forward and reverse supply chain principles. The current wave of multimodal supply chain integration through information technologies is finally providing tools that result in indirect environmental benefits through efficiency improvements. It is expected that certification and compliance could eventually become an analysis of the blockchains of supply chains (digital multimodalism), a process that can be much more reliable than existing certification procedures and therefore available to a larger number of suppliers.

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Efficiency and Sustainability in Multimodal Supply Chains

This paper describes approaches in intermodal supply chain management that aim to balance efficiency with sustainability requirements set by firms' corporate social responsibility commitments and society more generally. It explores how accreditation systems can help support green logistics efforts and outlines the competitive advantages and disadvantages of adopting these approaches.

International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
+33 (0)1 45 24 97 10
contact@itf-oecd.org
www.itf-oecd.org

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