Logistics in the transition to a circular economy

An analysis of the challenges and opportiunities in the capital-intensive manufacturing industry

Topsector Logistiek

Copper8

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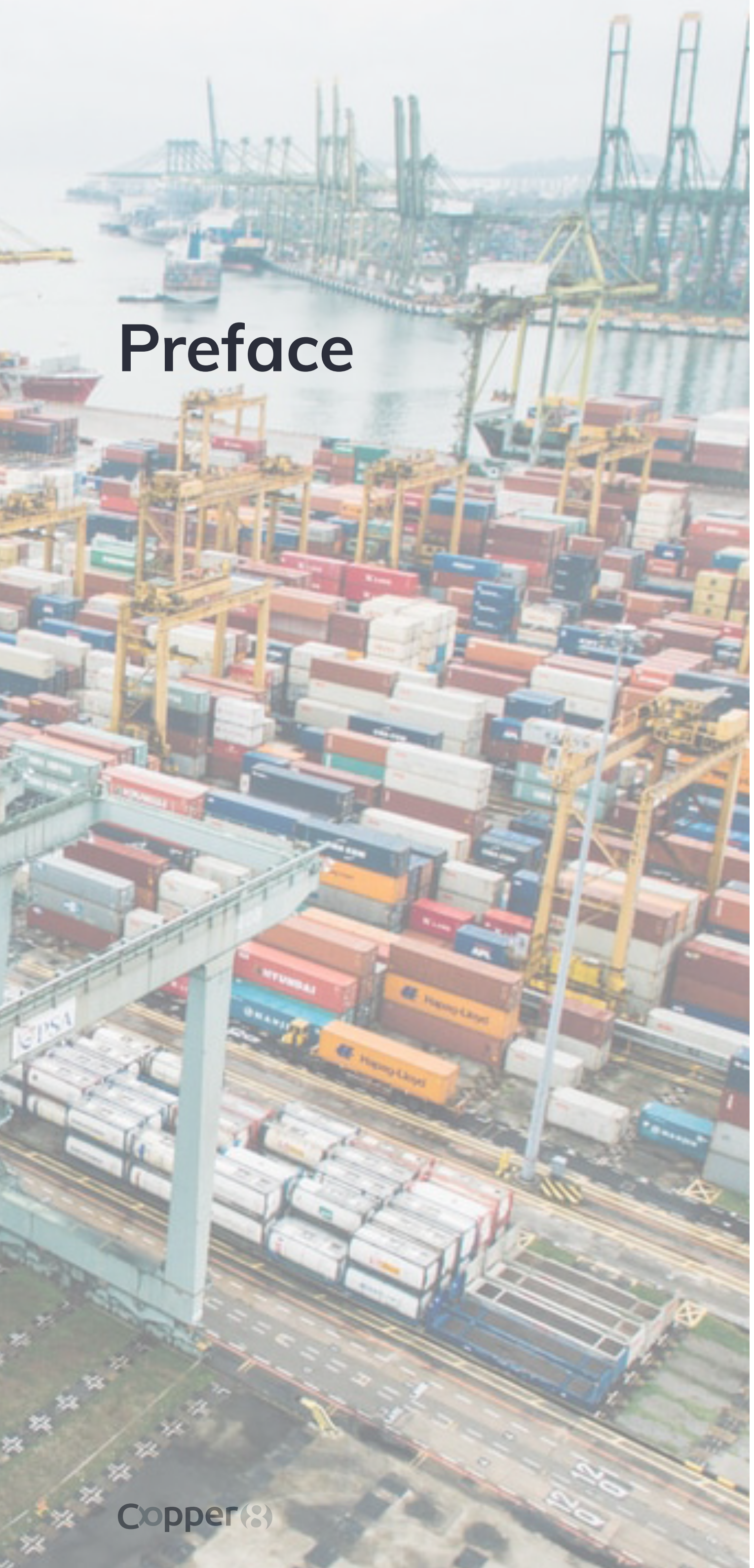

Preface

The transition to a circular economy is expected to change the role of logistics significantly. The Topsector Logistics (Dutch: "Topsector Logistiek" [i]) commissioned Copper8 to research this topic with key frontrunners active in the capital-intensive manufacturing industry. More specifically, this whitepaper is about the logistical challenges related to supplying, maintaining and returning high-value, capital-intensive products that tend to maintain their value over multiple years.

The insights from this research show the issues encountered by organisations at different stages in their transition to a circular capital-intensive manufacturing industry. This whitepaper can be a starting point for businesses providing or using capital-intensive products, organisations supplying the logistics for these products and organisations trying to get a better grip on the logistical issues of a transition to a circular economy. Topsector Logistics will use this research as a starting point for follow-up research.

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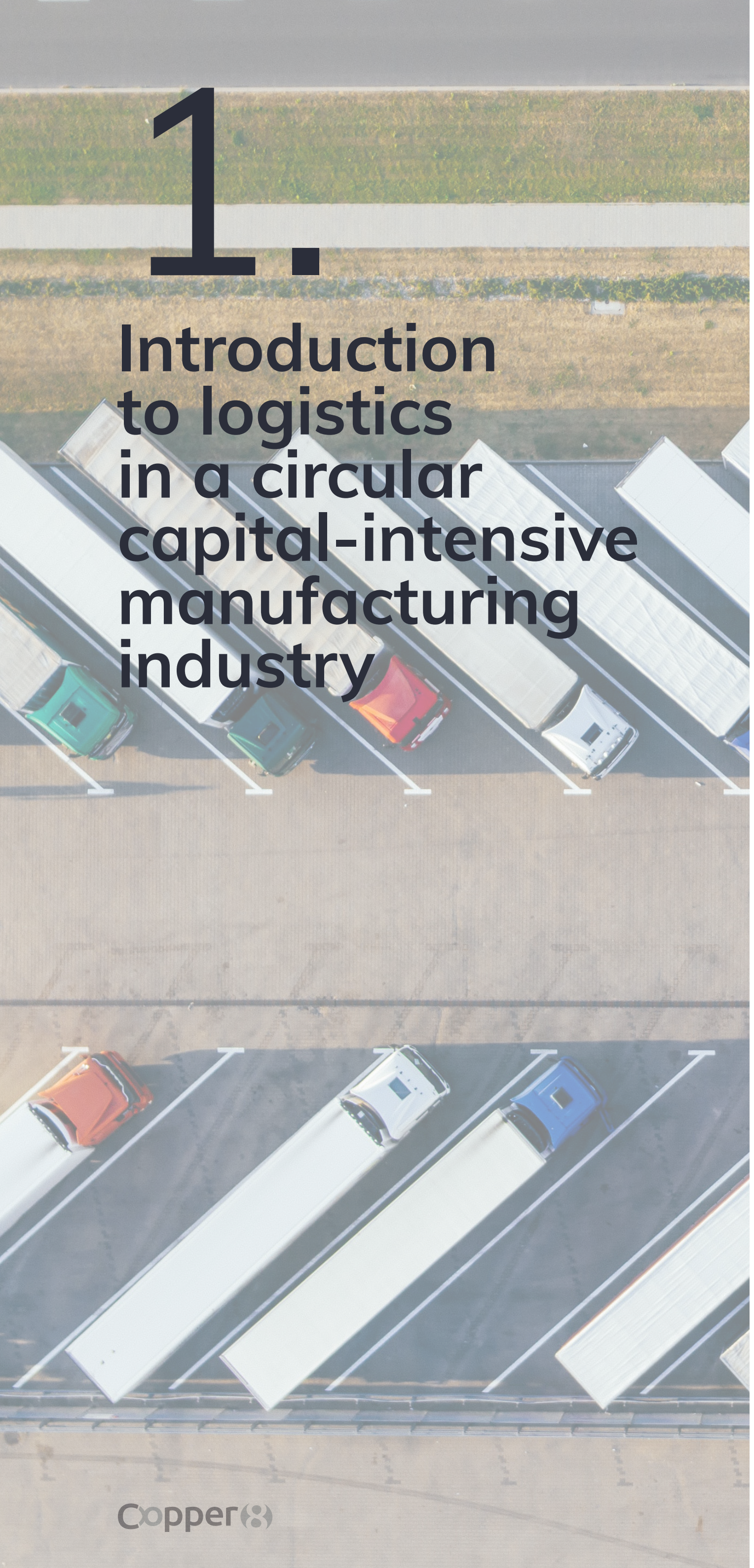
i The logistical sector is one out of nine "top" sectors that receive extra attention (knowledge and investments) from the Dutch government.



1. Introduction to logistics in a circular capital-intensive manufacturing industry

Our current take-make-waste economy is designed for high volume throughput of materials and products that lead to enormous landfills. Combined with a growing world population and ever-growing consumption patterns, this take-make-waste model has led to severe degradation of natural systems and anthropogenic climate change.

To help overcome these challenges, the transition to a circular economy has been set in motion. A circular economy (CE) is "an industrial system that is restorative or regenerative by intention and design" [1]. Business models in a circular economy are designed to derive value from reusing products and components.

The European Commission aims for a climate-neutral Europe by 2050 [2]. The Netherlands aims to achieve a fully operational Circular Economy by 2050, meaning that all resources in the Dutch economy will be reused [3], as well as achieving 95% CO_2-emissions reduction in 2050 compared to 1990 [4]. This requires an enormous effort on part of all sectors, including logistics. The logistics sector accounts for more than 20% of global greenhouse gas emissions [5] and is therefore a significant contributor.

Logistics for a circular economy

As the economy transitions from linear to circular, logistics will change as well. One obvious change is the growing importance of reverse logistics (as opposed to forward logistics of bringing a product to the customer), which concerns the activities related to products, components and materials returning into the value chain [6]. Reverse logistics are not a new phenomenon, as organisations have recognised the competitive advantage it can give for a long time [7] [8].

Reverse logistics have distinct characteristics compared to forward logistics [9]:

- Uncertainty in quantity supplied;
- Uncertainty in timing of goods;
- Uncertainty in product quality.

This makes reverse logistics more complex to manage, as intensive planning and organizational changes are required. The development and integration of innovative information and communication technologies will generate better insight in value chain processes, which will result in better matching of supply and demand [10].

On the flip side, reverse logistics offers several benefits [8]:

- Cost savings;
- Increased revenues;
- Reduced transaction risks for customers in selecting suppliers;
- Increased agility due to a decreasing need of inventory;
- Resilience to expected material scarcity in the near future [11].

If organisations are able to cover actual demand with circulating used components or remanufactured products, retrieved by reverse logistics, virgin resource need will be significantly reduced [12].

> *"The transition to a circular economy has been set in motion. A circular economy is "an industrial system that is restorative or regenerative by intention and design". Business models in a circular economy are designed to derive value from reusing products and components."*

Characterisation capital-intensive manufacturing industry

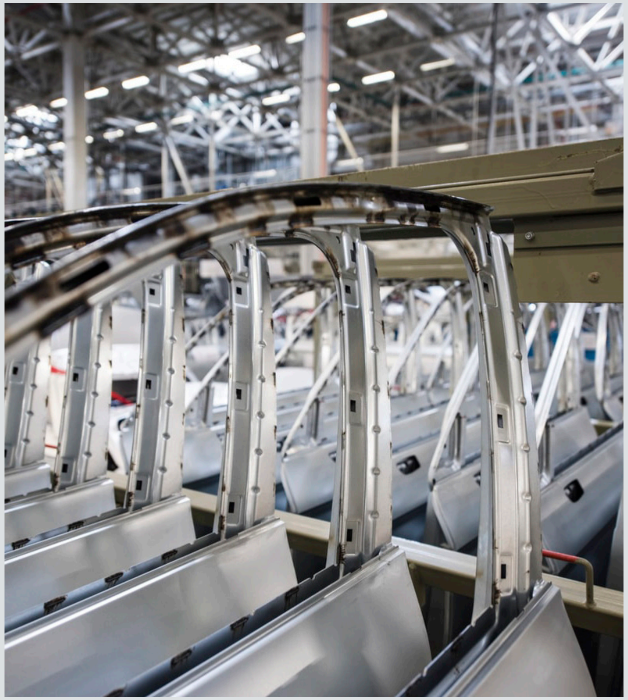
In this whitepaper, light is shed on the questions that relate to changes in logistics of the capital-intensive manufacturing industry as a result of the transition towards a circular economy.

A capital-intensive organisation is one that:

- Manufactures capital-intensive goods;
- Uses capital-intensive goods for manufacturing a product or delivering a service.

A capital-intensive good [15] is a good that:

- Has a technical lifetime of over 5 years;
- Consists of multiple and moving components (a 'complex product');
- Has a new value of more than €5000[iii] (based on the distinction between low-value and high-value assets by the International Financial Reporting Standards (IFRS)) [16].



Logistics in the capital-intensive manufacturing industry

Within this whitepaper the focus will be on the logistics of the capital-intensive industry and how this is expected to change in the transition towards a circular economy. The capital-intensive manufacturing industry makes use of capital equipment. This is characterised by a large amount of capital involved over a relatively long product lifespan, e.g. medical scanners, industrial printers and elevators. From a sustainability point of view, this capital equipment consumes more than half of metal ores globally and is responsible for 6.5% of worldwide emissions [13]. The integration of circular economy principles in this sector – by reducing the volume of equipment manufactured and lengthening the functional lifecycle of existing equipment – does not only have a huge potential in decreasing the amount of raw materials used but can also contribute substantially to decreasing emissions [14].

When discussing logistics in the capital-intensive manufacturing industry, this relates to the logistics of both manufacturers and users of capital-intensive goods (if these are used to produce products and/or deliver services), including maintenance and repair activities and end-of-life practices. This means that logistics providers are important actors as well as suppliers to manufacturers of capital-intensive goods.

Logistics play a vital role in the integration of circular economy principles in the capital-intensive industry as they facilitate the flow of materials between all actors in the value chain. For upstream activities – activities needed for the manufacture of a specific good – the role of logistics can be found in the transportation of components, spare parts and materials to capital-intensive good manufacturers, which enables them to manufacture the product and perform service activities.

> *"Logistics play a vital role in the integration of circular economy principles in the capital-intensive industry as they facilitate the flow of materials between all actors in the value chain."*

For downstream activities – which relate to activities after distribution of a good – service and reverse logistics are important for extending product life, maintaining product quality and reintegrating used components and materials into the value chain. Not all companies can execute and handle reverse logistics in-house as this requires substantial capabilities and resources, e.g. large warehouses and advanced IT management systems, to manage complex networks. They therefore can decide to outsource this activity to third party logistics providers, specialised in the required infrastructure and repair and remanufacturing activities [9].

Scope of this whitepaper

In this whitepaper we will provide insight into the most important questions related to the changes in logistics as a result of the transition towards a circular capital-intensive manufacturing industry. More than ten businesses have supported us in our research by sharing their own experience with implementing circular business models. Topsector Logistics will use these questions to develop follow-up research.

ii Scientific and business literature do not provide an unambiguous definition. Capital-intensive refers to "business processes or industries that require large amounts of investment to produce a good or service and thus have a high percentage of fixed assets, such as property, plant, and equipment" [19]. The high ratio of fixed to variable costs (operating leverage) makes capital-intensive businesses vulnerable to economic slowdowns. There is no precise distinction between capital-intensive and labour-intensive businesses, only the notion that a higher operating leverage makes a business more capital-intensive.

iii IFRS puts the threshold at $5000. For simplicity we have converted this to €5000.

2. Analysis of logistics in a circular capital-intensive manufacturing industry

Based on interviews a picture of the logistical flows in a circular capital-intensive manufacturing industry was developed (see Figure 2 on the next page). As can be seen, logistical flows in the circular economy can be subdivided into three major flows:

Distribution logistics is about the activities (warehousing, inventory management and transport) needed to get a product from the manufacturer to the end-user.

Service logistics is about maintenance and repair activities to ensure proper functioning of the capital good [17] and crucial for maintaining quality and extending product lifetime. Moreover, for the purpose of this whitepaper, this definition is enriched with aspects that are traditionally part of reverse logistics [6]. This includes end-of-life component returns, refurbishing and remanufacturing. Refurbishment is understood to be "major components that are faulty or close to failure", whilst remanufacturing relates to reusing functioning components to build new products [1].

Reverse logistics take place at the end-of-use phase [6], which, in this research, occur only once, i.e. the moment at which the product as a whole is discarded. Reverse logistics as such concern complete product returns, product transfers to third parties and integration of discarded products in production planning.

Figure 1 visualises the relationships between the logistics types and a product's composition.

In case a component or product is not returned to the original equipment manufacturer (OEM) or its suppliers, we refer to 3rd party logistics. These service and reverse logistics activites are executed by organisations that are not part of the initial value chain.

"In a circular economy, we expect service and reverse logistics to increase as components and products are seen as valuable."

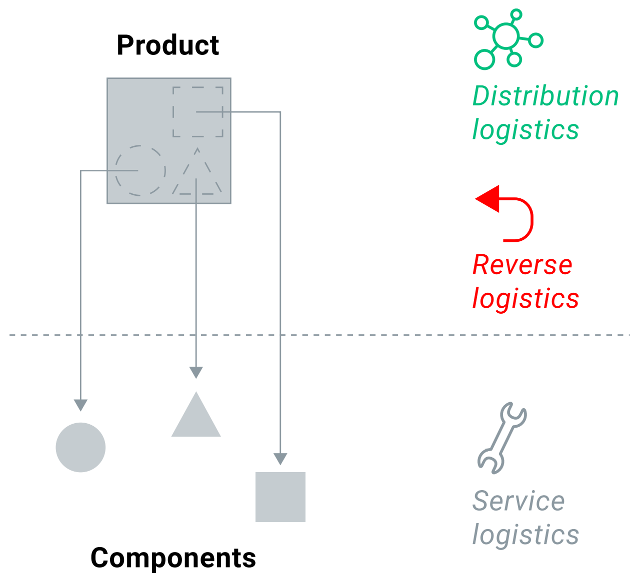
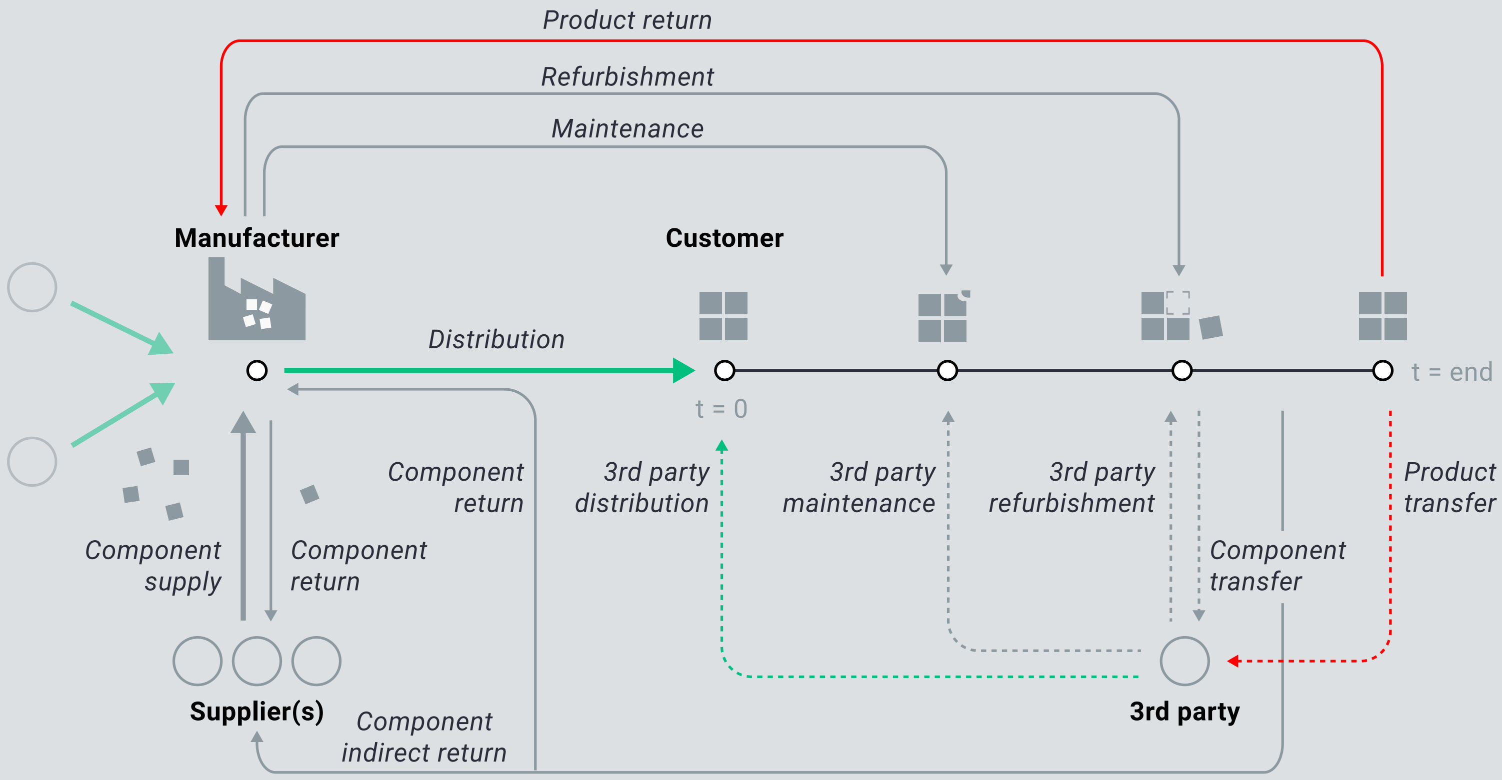


Figure 1 | The relationships between logistics types and a product's composition

In a circular economy, we expect service and reverse logistics to increase as components and products are seen as valuable. Reintegrating these into the value chain becomes increasingly important as a result. In the following paragraprhs, each of these logistical flows will be investigated in more detail to provide insight into the questions that arise as a result of the transition to a circular economy.



Logistics in a circular capital-intensive manufacturing industry can be subdivided in distribution, service and reverse logistics. Manufacturers distribute capital-intensive goods to customers, after which these goods will be used for a certain period of time. Maintenance and refurbishment activities are executed by either the manufacturer or a 3rd party, which results in components being repaired or substituted for new components.

When the product is at the end of its lifetime it is returned to the OEM or transferred to a 3rd party (which might be different than the 3rd party service provider). This party can then redistribute the product again to customers.

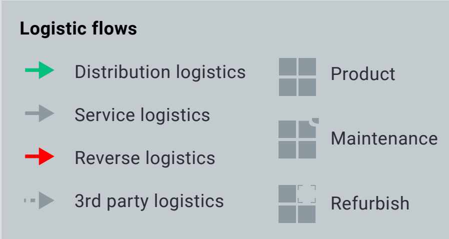


Figure 2 | Logistical flows in a circular capital-intensive industry.

Analysis of distribution logistics (products)

Distribution logistics concerns those activities (warehousing, inventory management and transportation) that are needed to get a product from the manufacturer to the end-user.

To understand the first question, a clear definition of a circular business model is needed. For this purpose the business model canvas [18] is used (Figure 3).

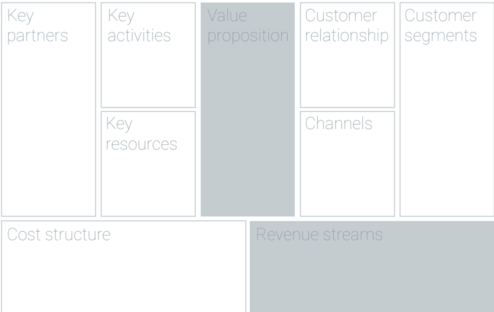


Figure 3 | Business model canvas by [18].

Osterwalder and Pigneur divide the business model into nine sections, each of which influence one another. Two of these have a determining effect for distribution logistics: The Value Proposition is the value an organisation delivers to its customers. Adopting a circular product design to deliver better quality or flexible functionality can change distribution logistics. A more flexible product could be oversized, thereby increasing distribution logistics.

Revenue Streams is the means by which money is earned. Part of applying a circular business model can lead to introducing a circular revenue model. Examples of this are rent and pay-per-use (e.g. customers paying for an amount of transport or light), each of which have a different Revenue Streams structure. Introducing a circular revenue model alters the Revenue Streams and can decrease distribution logistics.

QUESTION 1

In what way is distribution logistics changed by a circular business model?

Company: Spanbeton
Topic: Circular bridge

Spanbeton is specialised in manufacturing prefab concrete solutions for a wide range of infrastructure projects such as flyovers, bridges and ecoducts. Together with the Department of Waterways and Public Works (Dutch: "Rijkswaterstaat") and contractor Van Hattum en Blankevoort, Spanbeton developed the first circular bridge in the Netherlands. Modular concrete beams were designed, consisting of several interlocking concrete blocks which are linked by a steel cable. The bridge consists of five beams, each consisting of eight modular blocks. These can be easily deconstructed, transported and rebuilt.

Conventional beams are solid pieces of concrete, sometimes with a length of up to 60 meters, requiring special transport. Spanbeton's design allows for transport on regular trucks. A disadvantage of the new design is that the blocks are oversized for bridges shorter than 25 meters (increasing thickness from 70 to 100 centimeters) to be fit for multiple applications, thereby increasing logistical movements.

Company: UniCarriers
Topic: Pay-per-use forklifts

UniCarriers (part of Mitsubishi Heavy Industry Group) manufactures material handling equipment which includes a wide variety of forklifts. UniCarriers offers a pay-per-use solution in which customers pay for the horizontal (driving forklifts) and vertical movements (lifting cargo) of the forklifts. Sensors are used to gather data on utilisation and performance of individual forklifts. This provides insight in capacity utilisation per forklift.

In a traditional sales model, UniCarriers would deploy an overcapacity of forklifts to be able to always fulfil the customers' capacity needs. In this revenue model, UniCarriers remains owner of the forklifts and receives revenues based upon use. This gives the company an incentive to optimise individual forklifts' utilisation. This results in deploying less forklifts per customer, whilst guaranteeing uptime through predictive maintenance. The result is a decrease in distribution logistics.

Insights

The way in which distribution logistics is changed by a circular business model, is influenced by product design and the revenue model. A circular product can ease (de)construction, but might increase distribution logistics due to an oversized product design. A circular revenue model, on the other hand, can result in distribution logistics being organised more efficiently.

Analysis of service logistics (components)

Service logistics refer to the maintenance, repair, refurbishment and remanufacturing activities applied to product components, necessary to ensure proper functioning of the capital-intensive product. Service logistics are expected to increase in the transition towards a circular economy.

This increase will result in more complex logistics and extra costs. The environmental impact of these extra logistics and extra financial costs need to be compensated for in other parts of the business model (e.g. by lower virgin material demand) to make it a feasible choice.

Insights

The cases of ASML and Technische Unie show that only through intensive collaboration across the value chain service logistics can become successful. In order for organisations to eliminate inefficiencies in assessing and redistributing returned components, continuous information exchange is needed.

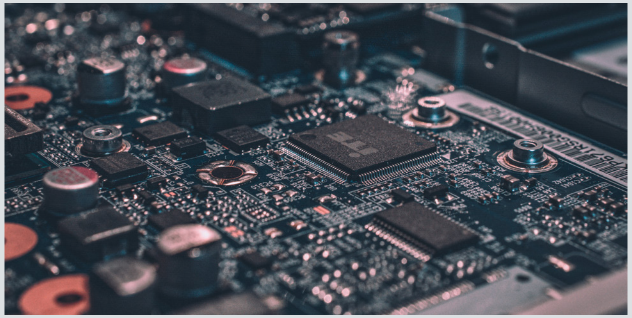
QUESTION 2

In what part of the value chain should quality control of faulty components be organised to ensure maximum efficiency of service logistics movements?

Company: ASML
Topic: Component return quality control

ASML offers integrated lithography solutions for chip manufacturers. A modular design enables ASML to upgrade machines according to customers' evolving requirements. Due to the product's complexity, maintenance and repair services are continuously provided by ASML service engineers on-site. These are revised and refurbished by ASML's suppliers before being stocked again as spare parts.

ASML struggles with documentation of component failure modes at customers' operations. Although service engineers are aware of failure modes, these are typically not documented as such that OEMs can use this documentation efficiently. This is also partially due to customers' security policies. Components are therefore sent to further upstream actors that necessary and these need to perform more thorough analysis than strictly necessary (e.g. checking all functionalities instead of some). Better sharing of failure modes between downstream and upstream parties could prevent unnecessary logistical movements and quality control activities.



QUESTION 3

What location is best (from a logistics and knowledge perspective) for collection, storage, registration and management of returned components?

Company: Technische Unie
Topic: Logistic hubs

Technische Unie (TU) is a wholesale organisation offering a wide range of products[iv] and components for the construction sector, delivering components on-site. TU is an experienced logistics provider, having built an intricate and delicate distribution infrastructure. TU leverages this infrastructure to transport components back to manufacturers, developing itself as a hub for used components.

The volume of returned components is relatively small and can be handled with TU's current warehouse capacity. The transition to a circular economy is expected to lead to an increased volume of returned components, for which TU expects a challenge related to warehousing and revising activities. From a logistics perspective, TU could be leading in developing and managing warehouses for returned components as TU is a pivotal actor between many organisations. However, TU does not have the necessary technical knowledge required to revise components. Therefore cooperating with organisations possessing technical knowledge for operating warehouses would be the best choice.

iv Which are excluded from analysis in this paragraph.

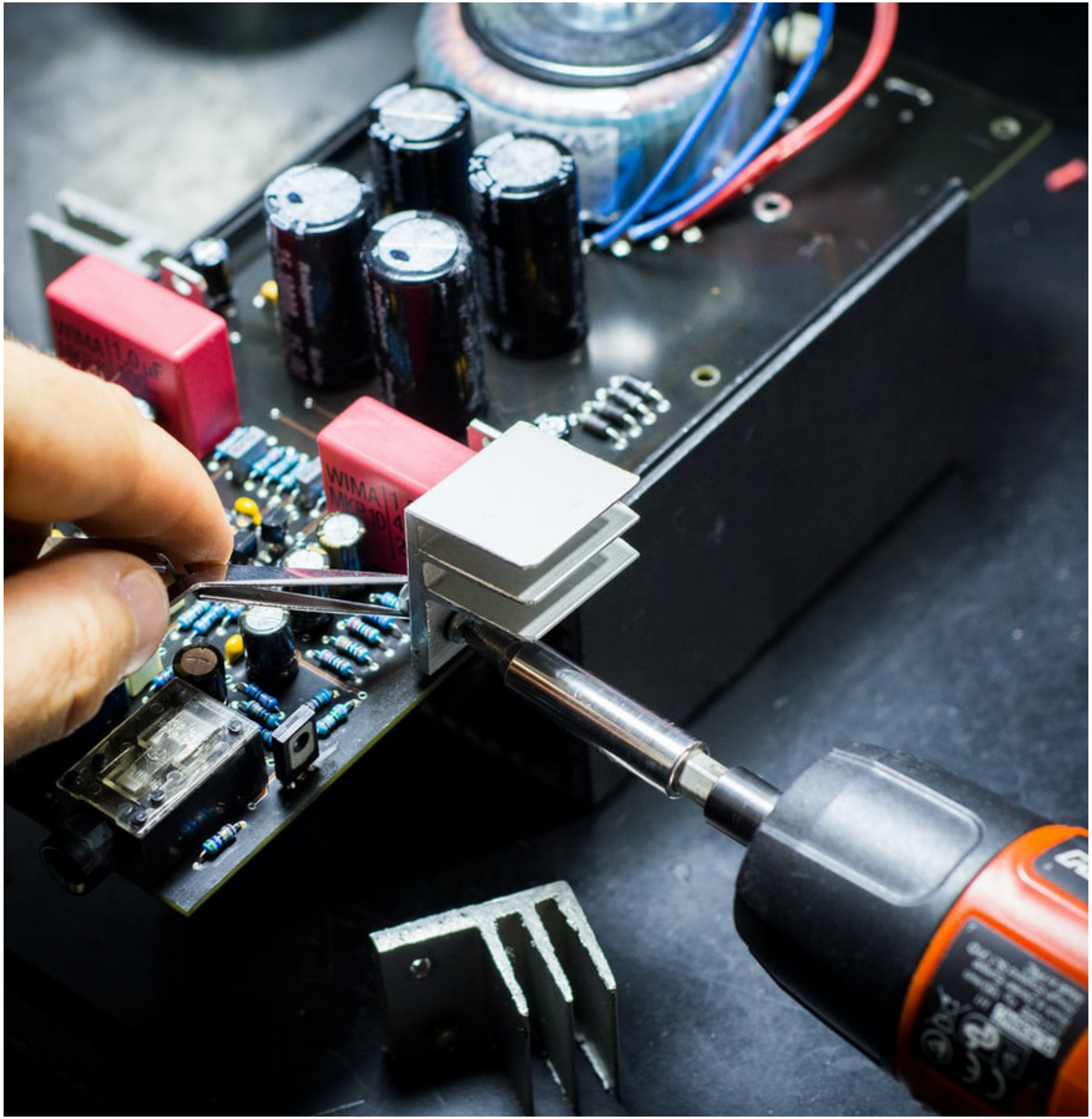
QUESTION 4

How to make a feasible business case for products for which reverse logistics represent a substantial part of the products' total value?

Company: ASSA ABLOY Entrance Systems
Topic: Industrial door and docking solutions

ASSA ABLOY Entrance Systems designs, manufactures and maintains entrance systems. Their products can be categorized into pedestrian door and industrial door solutions. The company is at the start of its journey, experimenting with circularity in various respects. Degree of circularity in products is improved continuously (in line with building regulations), whilst all doors already have a modular design enabling component replacement and upgrading.

As the company is transitioning towards a circular model, (preventive) maintenance is becoming increasingly important. This means that products' lifetimes are extended and that the flow of returning components increases. ASSA ABLOY already has a logistical infrastructure in place to transport components back and forth. Whether these components are actually being returned to the company depends on their economic value. In case this value represents a substantial part of total product value, creating a profitable business case becomes a challenge.



Analysis of reverse logistics (products)

Whereas service logistics relate to maintenance activities and refurbishing or remanufacturing components, reverse logistics are concerned with end-of-life handling of complete products. In a circular economy, products will be reused in order to minimise the need for virgin resources. This means that used products should be returned to the OEM in order to be reintegrated in manufacturing of new products. Reverse logistics are essential to make sure products are kept in the loop.

Insights

Reverse logistics are indispensable in the transition to a circular economy, but the cases show that establishing these logistics comes with serious challenges. In order for organisations to successfully deploy reverse logistics, they should be able to create a positive business case, as well as deal with locating reverse logistics and the uncertainty and complexity related to reintegrating returned products into the manufacturing process.

QUESTION 5

On what geographical scale should quality control and refurbishment centers for used products be organised?

Company: Vanderlande FLEET
Topic: Modular baggage handling systems

Vanderlande manufactures baggage handling systems for airports. Conventionally, baggage handling systems possess overcapacity in order to cover for rising demand in the future. Vanderlande developed FLEET as a capacity adaptive baggage handling system to adjust more smoothly to changes in capacity demand. FLEET consists of autonomous vehicles (runners) that can handle single bags, transport batches of bags and deliver bags to and from aircraft stands. The FLEET system does not suffer from downtime as the runners' algorithm enables them to move around broken runners.

FLEET has been operational at several locations across the world and is preparing for scale-up. This raises the question of determining at what geographical scale end-of-use and end-of-life runners should be returned. The challenge is to find a financially feasible business case that fits within current legal frameworks. Vanderlande is a globally operating company, making its reverse logistics flows widespread. Current (inter)national laws and regulations regarding presence, transport and handling of used products can complicate the organisation of reverse logistics to refurbishment locations.

Company: Philips Healthcare
Topic: Healthcare equipment

Philips Healthcare delivers magnetic resonance imaging (MRI) systems and other medical healthcare products with a modular design to customers around the globe in more than one hundred countries. Philips Healthcare has already been applying reverse logistics for decades; the flow of returned products is still growing as well as the refurbishment and parts recovery activities.

As Philips Healthcare is a globally operating company, its return flows have a global character too. The increase in returned products raises the question at which geographical scale new refurbishment centers should be established: global, regional or local? This decision will depend on distance between customers, financial considerations and the extent to which (inter)national regulations limit used products transfer.

3rd party service & reverse logistics (components & products)

In a circular economy, products' and materials' value is maximised by extending their lifetime as much as possible. The theory states that the shorter the cycle, the more value is retained [1]. The cycles from shortest to longest are: maintenance, reuse, refurbish/remanufacture and recycle (Figure 4).

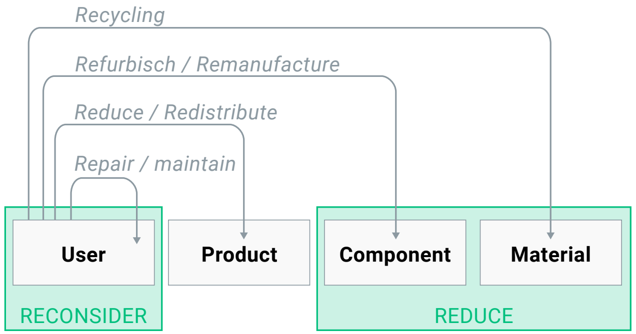


Figure 4 | Butterfly figure of the circular economy - adapted from [1].

The shortest cycle is reuse and therefore theoretical best for value retention. However, one should consider the value chain in which the product is being reused. If this value chain is exterior to the OEM's value chain, reuse might not be the best value maximisation strategy. The resources are drawn out of the sphere of influence of the organisation with the best product knowledge. Maximising products' value is therefore not as straightforward and requires strategic thinking over multiple cycles.

When a product exits the initial value chain, we consider it becoming part of 3rd party logistics. Indeed, the development of such 3rd party relationships is increasing rapidly. Examples of this are Insert and the Excess Materials Exchange (EME), each of which are marketplaces where companies can exchange new and used materials, components and products. Connecting supply and demand creates a key position for logistics to maximise product value.

QUESTION 6

How can existing capital-intensive products' value be maximised for the purpose of a circular economy?

Company: Drentea
Topic: Furniture manufacturing machinery

Drentea has been manufacturing office furniture for 75 years. This furniture is manufactured in the province of Drenthe in the Netherlands with the use of two production lines (i.e. factories) consisting of multiple capital-intensive machines supplied by an Italian supplier. Over time (sometimes as much as forty years) readjusting the machines to new technical developments becomes more difficult.

When it becomes too expensive to adjust the manufacturing line to new furniture manufacturing processes, it has reached its end-of-life at Drentea. The machinery could be returned to Italy and, as such, stay in the loop, but such an agreement does not exist. The manufacturing line itself can still function for more dated furniture manufacturing processes and has a significant resale value, for which it is being resold at a second-hand market.

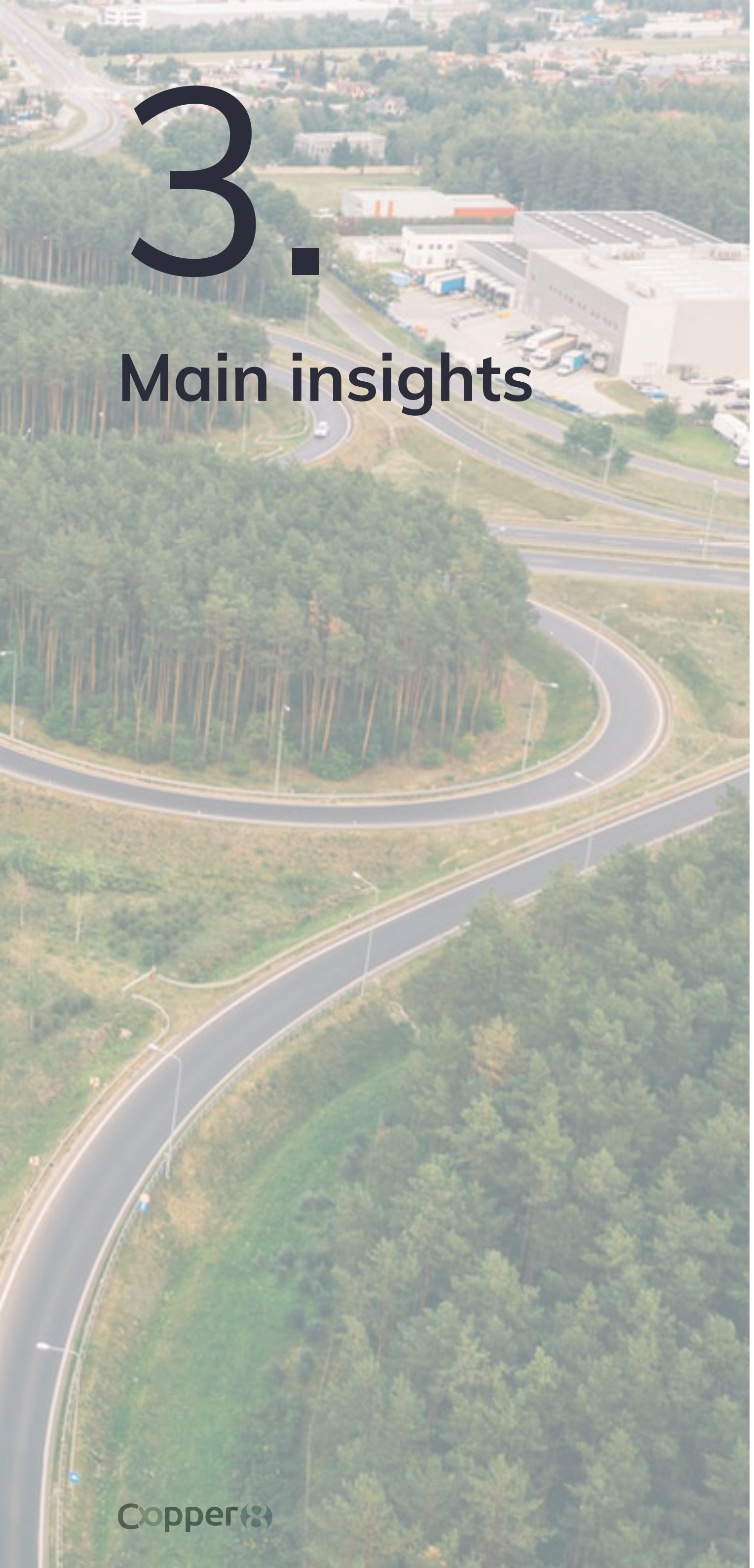
Company: Amphitec
Topic: Industrial vacuum pressure vehicles

Amphitec manufactures vacuum pressure vehicles, which are often used in industrial cleaning, suction excavation and vertical transportation of dry and web substances of all sorts. The vehicles consist of a chassis and a body. The chassis is similar to the one of normal trucks but supported by a subframe. The chassis is completed by a body consisting of an Amphitec vacuum tank with pump and blower.

The main components of these vehicles have a different lifespan: the chassis lasts for about 8 years, the pump for about 14 years and the vacuum tank up to 20 years. The body can be refurbished and mounted on a new chassis, delivering the same high-quality performance for the second half of its lifecycle. Because of this performance a considerable second-hand market for vacuum trucks exists, which indeed is an important part of the overall value chain.

Insights

The cases of Drentea and Amphitec show that capital-intensive goods can still have a significant value after a certain use period. Reselling them for direct reuse is very circular, but can be questioned taking into account the complete lifetime of materials. It might be better to keep the machinery in the original value chain, although this might result in a lower level of circularity, e.g. refurbishment or remanufacturing.



3. Main insights

The cases in this research give insight into the challenges in the transition to a circular capital-intensive manufacturing industry for each of the logistics' flows:

- Distribution logistics (products);
- Service logistics (components);
- Reverse logistics (products);
- 3rd party service & reverse logistics (components & products).

As organisations transition from a linear to a circular business model, the number of logistics types increase as well as the logistics' complexity. With this increase, more challenges (and therefore questions) related to location, scale and processes of service and reverse logistics will be encountered.

These challenges can be accounted for by 3rd parties becoming responsible for service and reverse logistics. The benefit from a circular perspective is that this can promote direct product reuse (as can be seen in the cases of Drentea and Amphitec), but this excludes products from the original value chain. This can decrease circularity in the longer term as parties outside the original value chain might lack product knowledge. Figure 5 shows the relationship between the transition to a circular business model and logistical developments in more detail.

As previously mentioned, developing other logistic types is paired with challenges. For each logistics type, one or more questions have been formulated. An overview of the nine described cases and their position with regards to logistical flows is given in Figure 6 on the next page.

Final remarks

Although the capital-intensive manufacturing industry consists of many and varying organisations, and the number of participating parties in this research is quite small, it provides interesting starting points for further research. Moreover, this research can be a starting point for (cross-sector) collaborations between organisations that face the same challenges in their transition towards a circular business model.

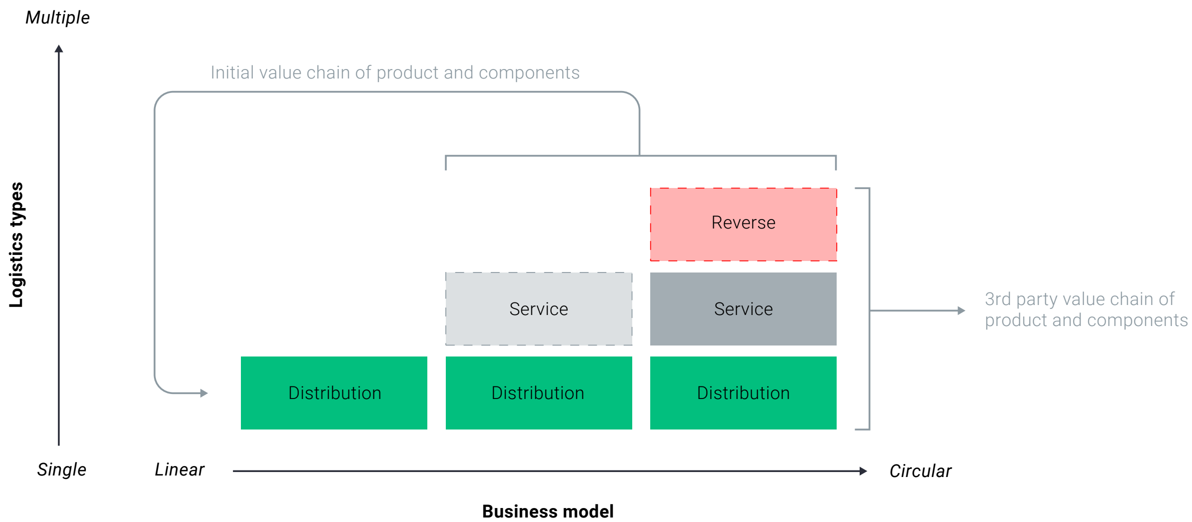
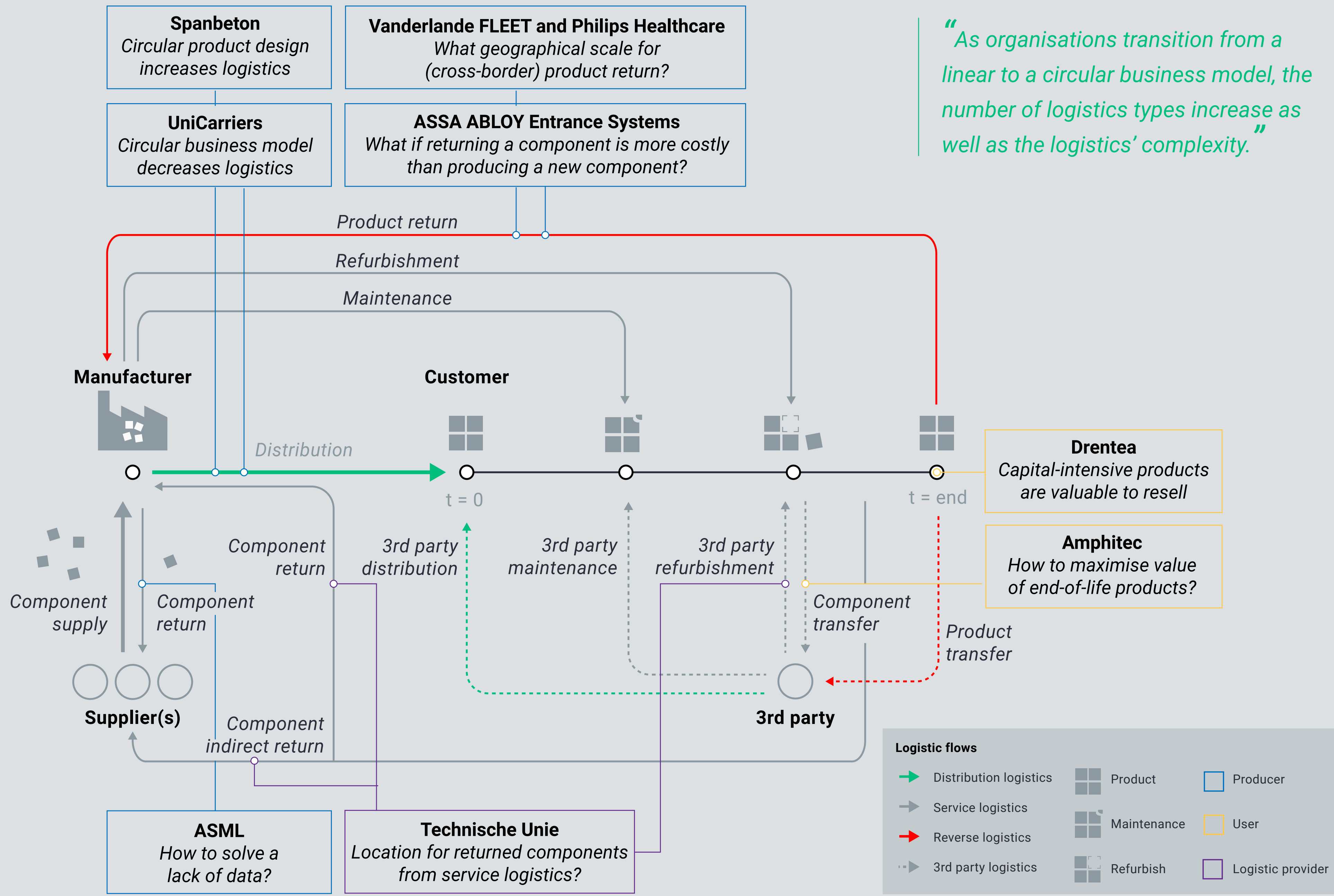


Figure 5 | Relationship between business model and logistics.



"As organisations transition from a linear to a circular business model, the number of logistics types increase as well as the logistics' complexity."

Figure 6 | Logistical challenges in a circular capital-intensive manufacturing industry.

4.

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