White Paper

# Supply Chain Collaboration through Advanced Manufacturing Technologies

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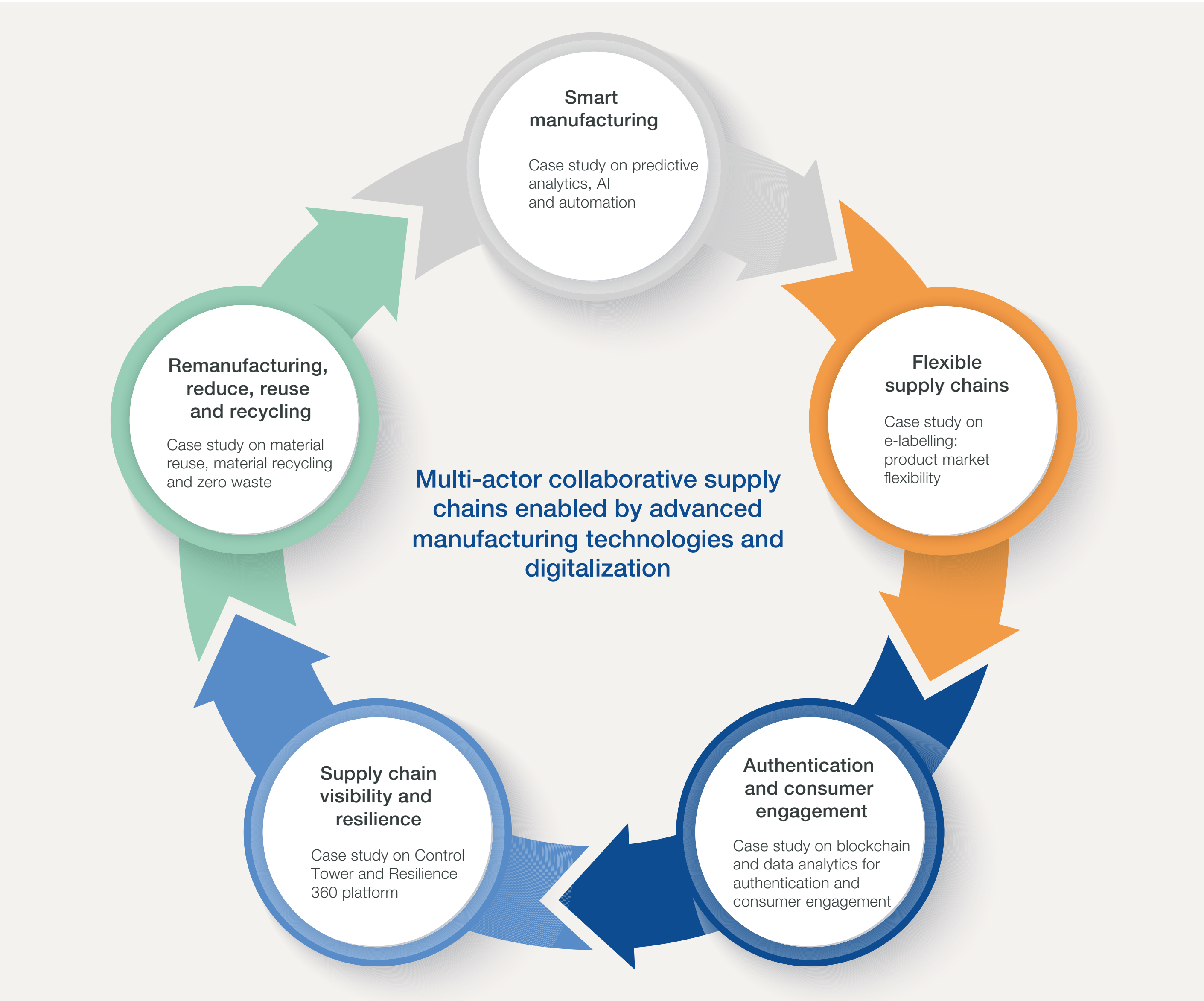
# Contents

# Introduction

This report is the result of a collaboration between members of the World Economic Forum Council on Advanced Manufacturing and Production. It summarizes the main findings of work conducted on the application of advanced manufacturing and digital technologies on future production and supply-chain models. The applications set out in this paper highlight the importance of collaborations across supply-chain partners as crucial to technology adoption and exploitation.

As summarized in Figure 1 below, five advanced manufacturing transformations are presented that offer real-world examples of how advanced manufacturing and digital technologies are driving new supply-chain capabilities achieved through supplier-producer-user collaboration. These five transformations, while not aiming to be exhaustive, demonstrate 1) smart manufacturing, 2) flexible supply chains, 3) authentication and consumer engagement, 4) supply chain visibility and resilience, 5) remanufacturing, reduce, reuse and recycling. These example transformations are described below.

**Figure 1:** Collaborative supply chains through advanced manufacturing technologies



# 1. Smart manufacturing for improved performance through AI and predictive analytics

**Background:** Improving productivity and resource efficiency through AI and predictive analytics is becoming a reality for many manufacturing organizations. Companies in both the process and assembly industries are now demonstrating increased levels of right-first-time production with consequent benefits in cost reduction and material efficiency. This is particularly critical in firms where machine up-time and scarce materials require high levels of quality and production efficiency.

**Opportunity:** Material consumption can be reduced by running factories more efficiently and effectively, using data available on machines. Predictive analytics and machine learning open up a new world of opportunities to reduce material consumption. In this case, we explore some of these approaches to improving resource efficiency, with concrete examples from the information and communication technology (ICT) supply chain. In the example below from Foxconn, close collaboration between the AI technology provider, manufacturer Foxconn, and the production management systems developer is leading to a step change in factory productivity, machine up-time and material efficiency.

## Case study – AI-enabled smart manufacturing in Foxconn

The integrated circuit (IC) mounter in the Surface-Mount Technology (SMT) process moves electronic parts by nozzles using vacuum suction. However, the lifetime and usage of nozzles will affect product yield, requiring timely nozzle maintenance. Predicting the health of the nozzle can improve process efficiency and reduce component rejection rates. This case looks at how AI can be applied to the IC mounter in order to better manage nozzle lifetimes, improve production efficiency and reduce material consumption.

First, the main factors affecting the lifetime of the nozzle were determined. Through the collection of 57 hours of production data, nozzle lifetime and vacuum values were identified as significantly related, with the most important factor affecting vacuum value being the cleanliness of the nozzle filter. Improving the cleanliness of the nozzle filter can greatly extend its lifetime.

Second, in the data-collection process, each nozzle has a QR code and, through internet-of-things (IoT) technology, nozzle life-cycle data was captured in terms of component rejection rate, allowing the correlation of failure intervals using field-data distribution profiles.

Third, machine learning models are applied so that production control systems can automatically identify the status of nozzle filters and predict the remaining life of nozzles. This function has also been integrated within nozzle health-management production systems as shown in Figure 2, with alarms for abnormal nozzle breakages, prediction of remaining nozzle functionality, inventory management and maintenance management.

By predicting the nozzle's health condition, replacement intervals have been extended from 24 hours to 25 days, resulting in significant inventory reductions (64%) and decreased maintenance and component rejection costs (66%).

**Figure 2:** Nozzle intelligent health management, monitor nozzle health condition real time through APP

# 2. Flexible supply chains through electronic labelling

**Background:** Supply chains can benefit greatly from the ability to provide their products and services across organizations and borders with no or minimal barriers, potentially avoiding time- and resource-consuming physical checks and unnecessary labelling. This is now an emerging possibility through the selective use of digital technologies, which can underpin product and supply-chain integrity while paying due regard to required regulatory, customs and other documentation requirements.

**Opportunity:** The seamless movement of products across different markets presents a significant opportunity. Current constraints may be due to country-specific labelling requirements, lack of common standards and protocols, and the multi-actor custodianship of many manufactured goods as they progress through the supply chain. The primary requisite is, of course, to ensure adherence to product and trade regulations, but also to prevent fraudulent practices, undesirable parallel trade and illegal importation across borders.

Advanced manufacturing technologies such as track-and-trace recognition systems and e-labelling mechanisms are now emerging as potential solutions. While these can address the regulatory and governance controls required in international trade, they can also support resource efficiency by building late customization into digital formats, providing greater authenticity and product provenance for consumers.

The removal of non-value-add activities at borders and the unnecessary physical labelling on products can also speed up supply chains, where digital alternatives can make product supply chains more adaptable and responsive to changing market or information requirements, with enhanced visibility and assurance.

However, a vital condition for success is collaboration between multiple agencies that span traditional inspection points, using digital data to ensure product quality and provenance right through to the consumer. Cloud-based digital platforms for business, and smartphone apps for consumers, provide mechanisms for stakeholders to interrogate aspects of the extended supply chain.

**Enabling technologies:** The main technology developments have been the ability to digitally capture data throughout the supply chain, at the point of generation, enabling pre-registration at multiple points of production, and codified containerization with secure systems in between transit points. Within the sphere of smart product e-labelling, as in the Apple iPhone case, these technologies enable late customization and localized decoding.

From a logistics perspective, manual processes can be replaced using AI-informed random inspections at ports and the use of automated and autonomous transport.

Digital platforms have become mechanisms for multiple actors to collaborate effectively, building trust mechanisms through usage data between suppliers and customers – whether in the case of customer-intensive operations such as platforms run by Airbnb or Uber, or retailer giants such as Amazon, each driving new e-commerce-based business models.

A critical requirement in the seamless exchange of goods is collaboration on governance protocols, with effective audit regimes and legal sanctions when supply-chain integrity is compromised. Where there is international trade, regulatory equivalence or harmonization on standards becomes an essential prerequisite. Within the digital-trade context, new initiatives by institutional bodies, such as the World Trade Organization (WTO) have sought to address the gap within the policy landscape.

## Case study – electronic labelling

Compliance markings inform consumers and regulators that a product adheres to health, safety and environmental regulations and standards. While regulators have traditionally required a physical mark, an electronic label is also an effective technical solution to convey this information, either via an integrated electronic display or a machine-readable code that links to a webpage (e.g. a QR code). Moreover, electronic labels enable supply-chain efficiencies, greater design flexibility, environmental benefits and improved regulatory outcomes, including effective consumer awareness and education.

Industry bears significant costs every year associated with the physical labelling of products, including the administrative burden of tracking and monitoring region-specific labels throughout the manufacturing process. The cost of indicating compliance in the EU, for example, is estimated at €797 million ($873 million) per year. If the EU were to adopt electronic labelling, it could reduce those costs by 15%.[1] Regulatory agencies also incur significant costs associated with the archiving and handling of compliance documents, and assessing and collecting the information, which would be reduced if compliance information were hosted online by the manufacturer, with links via a QR code or URL on the device.[2]

Electronic labelling can shorten the launch schedule of new products by simplifying the otherwise disparate physical labelling requirements that create complexity in manufacturing processes and product-distribution chains. E-labels can also eliminate supply-chain waste created by extra machinery, yield loss from the etching of physical marks and the scrapping of labelled products when labels need to be modified to reflect changes in regulations and compliance information or changes in demand.

E-labelling can also help to reduce $CO_2$ emissions created by processing and shipping multiple models. Finally, electronic labelling can enhance supply-chain security and reduce fraud, because there are no on-device marks to be counterfeited and the integrity of the compliance information is maintained by the manufacturer on both the device itself and online.

As electronic products get smaller, physical labels are becoming more difficult to create and harder to read. Electronic labelling can better achieve the policy goal of consumer awareness and education by ensuring that the relevant information is in a format that is accessible, comprehensible and continually updated, whether on a device screen or on a separately maintained website. Electronic labelling also removes constraints that physical labels may place on product design as technological innovation allows for new materials and smaller products.[3]

All governments should allow electronic labelling in order to generate the maximum benefits for industry, regulators and consumers. Moreover, governments should exploit the flexible, voluntary global standards-setting process in order to avoid divergent electronic labelling approaches that would undermine some of the efficiency-related benefits it is intended to generate. Country-specific requirements could become a barrier to entry as manufacturers prioritize various markets that require less time and money to ensure compliance.[4]

What may seem like a divergence in a mandatory labelling requirement can have significant implications for manufacturers looking to enter different markets. Industry is currently developing a standard ISO/IEC 22603 in ISO/IEC JTC 1/SC31/WG8 to help guide the implementation of electronic labelling in a manner that avoids such divergences. The objective is to set out general guidelines, while leaving enough implementation flexibility to take account of the diverse range of materials, products and supply-chain structures across industry.

Finally, governments that have already adopted electronic labelling have found it to be effective, but the allowance is still limited to certain types of products: e.g. the allowance in many countries for electronic products with integrated screens and the allowance in the EU for certain medical devices.[5] Governments should now take that experience and expand the allowance for electronic labelling to all products, whether through an e-label displayed on an integrated or paired screen, or on a website accessed through a machine-readable code (e.g. a QR code) or human-readable code (e.g. a URL), in order to enable e-labelling benefits.

**Figure 3:** Example of QR code implementation

# 3. Product authentication and consumer engagement

**Background:** As manufacturing supply chains become more complex, often involving multiple organizations in material and component supply, final product assembly and distribution, it is vital for consumers to have confidence in the authenticity and provenance of the product. Emerging digital technologies can provide the necessary assurance, on authenticity and safety, enable supply-chain transparency and also enable consumer engagement for additional value-adding services.

**Opportunity:** Digital technologies can provide information and compliance to provide product assurance, demonstrating the provenance of goods in terms of materials used and how the product has been manufactured, stored and transported, thereby ensuring product integrity. Advanced manufacturing technologies can also address the risk of counterfeit products, as well as facilitating improved financial control in terms of tax avoidance and money laundering.

Anti-counterfeit measures can be built into the production process. This is particularly relevant for high-value branded goods and those that require assurance in the production process (e.g. the use of biomarkers in organic food supply chains).

The use of digital twin digital identity technology in the cloud that dynamically updates a product's evolution and pathway, as described in the case of Ralph Lauren, is a solution that has been pioneered to address the challenge of counterfeiting faced by luxury goods manufacturers.

## Case study – Ralph Lauren product authentication

The Ralph Lauren Corporation (RLC) designs, markets and distributes premium lifestyle products in five categories: apparel, footwear and accessories, home, fragrances and hospitality. RLC manufactures apparel around the world with an annual volume of just under 200 million product items. RLC is working with EVRYTHNG, a consumer product IoT platform, to create a unique digital identity for its products. This new digital platform ensures the authenticity of its products from manufacture through to purchase. The solution provides innovation and efficiency opportunities for its third-party manufacturing partners, RLC corporate functions and retail stores, and the end consumers.

RLC has a necessarily diverse supply chain, with hundreds of trusted manufacturing contributors, systems and processes. However, in its complex supply chain, the company did not have precise visibility into the status of each unique item created by its factory partners. The company wanted to develop a way to provide real-time visibility into hundreds of third-party manufacturing providers to track production of each item – to support its brand integrity, operational efficiency and consumer engagement.

A solution platform has been built to provide data that delivers intelligence and perspective on each product's journey. The benefits include visibility into the supply chain and manufacturing process to drive operational efficiency, the ability to uniquely authenticate each product and the opportunity to enhance the overall product and brand experience with end consumers.

At its core, RLC's solution involved mass-scale product digitization – led by EVRYTHNG with supply-chain partner Avery Dennison. The solution involves each product item:

- Being assigned a unique Active Digital Identity™ (ADI) in the cloud to manage the data from and about that item through the supply chain from manufacturing to purchase
- Having a label and QR code unique to that item, linking the item to its ADI in the cloud
- Being produced in a third-party manufacturing facility with its unique label scanned and authenticated with its digital identity in the cloud, providing the company with real-time visibility and capturing critical manufacturing data. RLC can aggregate additional orders, supply and retail data and transactions associated with each item's unique digital identity in the cloud, thereby assembling the data on the item's full supply-chain journey

End consumers can interact with the QR code on the item label, accessing dynamic digital applications linked to that specific item and generating consensual data for RLC after the point of purchase. From an RLC perspective, the company uses the EVRYTHNG platform to manage each item's ADI to provide visibility and apply data intelligence as each item moves between different organizations in the supply chain (manufacturing, enterprise, retail) and ultimately into the hands of the end consumer. The platform provides the collaboration mechanism to deliver:

- Real-time visibility for RLC into third-party factory production and intelligence to detect and respond to issues as they arise, with the ability to provide product item status and authentication
- Tracking of each individual product's journey, from the point of manufacture in a factory through the supply chain
- An ability for the end consumer to engage directly with products using their smartphone

**An investigation into the technology**

The technology behind RLC's advanced manufacturing solution is underpinned by:

– Digitally serialized labels provided by Avery Dennison's Janela solution in each third-party factory, with item-level Active Digital Identities™ in the cloud capturing data through each item's life cycle, enabling real-time authentication and trackability

– Enterprise integration with RLC planning systems that connect product items and order information via the EVRYTHNG platform

– Dynamic experiences for end consumers enabled through unique QR codes on the product label and software rules in the cloud

– Analytics dashboards and workflow tools provided by the EVRYTHNG platform for real-time factory visibility, item traceability, alerts and notifications, and the control and configuration of dynamic end-consumer digital experiences

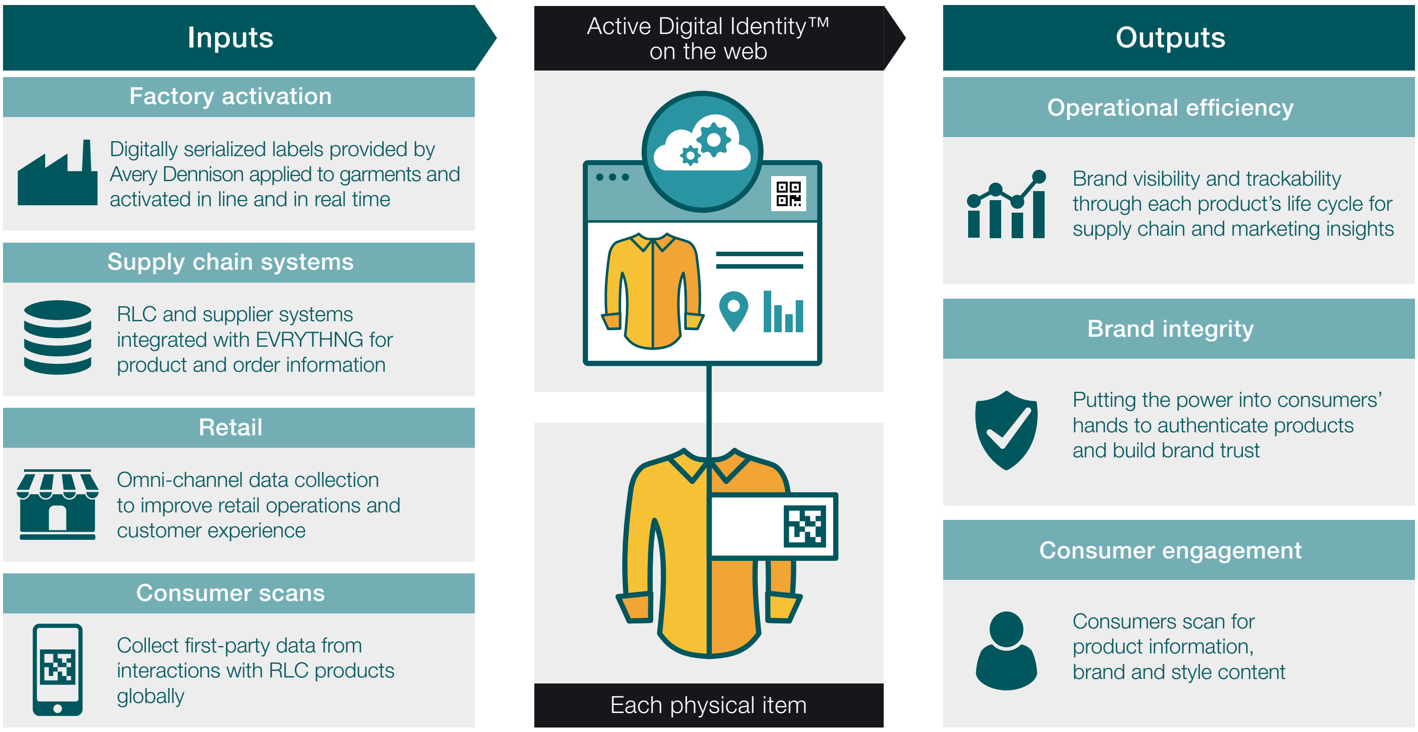
**The outcome:** The digitalization of the production process, item and product labelling within a highly fragmented third-party producer-distributor network provides a common collaborative platform that supports operational efficiency, brand integrity and consumer engagement. Specifically, the collaboration provides:

– The company with real-time visibility into factory/vendor performance, enabling it to adjust as needed to support on-time deliveries

– Consumers with the ability to authenticate the products they purchase, providing assurance and clarity and thus protecting brand integrity, as well as the ability to connect directly to RLC to receive product information and related recommendations. RLC in turn can offer experiential product stories and related style information

– RLC with the ability to track each item from point of manufacture to ensure product integrity, enabling it to monitor and control parallel trade, back-door and counterfeit activity

**Figure 4:** Consumer engagement and product authentication through digital platforms at Ralph Lauren Corporation (RLC)



# 4. Supply chain visibility and resilience

**Background:** Disruptions to supply chains, whether natural or trade-related, can have a major impact on production systems. Visibility across the extended supply chain through digital tools can provide early alert and response systems, but this requires collaboration from supply-chain partners on data provision, systems integration and risk mitigation.

Recent cases include the imposition of trade restrictions on major multinational corporations that have been extended to their component suppliers. Supply-chain resilience is the ability to resist and/or recover from any costly disruptions such as equipment failures, quality and delivery issues, natural disasters, political or social instability etc., so that production systems can quickly resume normal activity.

OEM supply networks are typically distributed across different continents and their design and operation need to address a number of resilience challenges, such as;

– Low-probability, high-impact events (e.g. natural disaster, political and trade issues, cyberattacks, breakdown of systems and equipment). The risk posed by these low-probability events was exemplified by the disruptive impact of the Fukushima tsunami and Thailand floods on the global automotive sector.

– Building redundancy in critical-supply sourcing vs. the costs of doing so. The trade-offs between building redundancy and a lean supply base requires risk mitigation to be built into supply-network design, with contingency measures secured through pre-agreements and collaboration, as has been observed by Huawei's recent response to restrictions on US critical-component suppliers.

– Data transparency vs. data security/sovereignty. Data transparency is essential in terms of conformity and assurance, but many suppliers are generally reluctant to share their production data with their OEM customers unless contractually obligated to do so. Collaboration therefore becomes a critical element in achieving supply-chain transparency and visibility

**Opportunity:** The Fourth Industrial Revolution brings many enabling technologies that can help address the above challenges, enabling visibility and boosting supply-chain resilience. These Fourth Industrial Revolution technologies include:

– **Data mining:** Data-mining tools allow firms to process vast amounts of seemingly uncorrelated information (such as geopolitical instability, climate data, energy/fuel prices and consumption, social media traffic, macroeconomic and trade data, consumer behaviour etc.) so that they can better understand, discover and predict potential risks as well as their disruptive impact on production systems. Data-mining tools provide firms with an unprecedented capability to anticipate disruptive events.

– **Predictive analytics:** Predictive analytics can give firms valuable early-warning windows so that they can take preventive measures for disruptive events, allowing for better demand forecasting and an ability to build contingency for any interruptions.

– **Blockchain:** Blockchain technology will be increasingly adopted in improving supply-chain integrity and resilience. It can help firms to greatly simplify the traceability and authentication of supplied goods, thus greatly reducing the costs in the supply network transactions.

– **IIoT:** The wide adoption of the industrial internet of things (IIoT) will greatly improve the transparency of operations both within and across important suppliers' and OEM factories. This also allows collaboration across the manufacturing supply network to collectively address underlying causes of production and quality issues.

– **Edge computing:** Edge computing technologies allow manufacturers to process complex data on site, which greatly improves the forecasting of system degradation, potential interruption and dynamic changes in production as well as transportation systems.

– **AI and decision support:** The rapid development in AI (artificial or augmented intelligence) has greatly enhanced the decision-making process in global supply networks. Previously human experience-based, decision-making in supply-chain design has now been revolutionized by the adoption of AI tools and intelligent-decision support systems. This has greatly expanded the horizon of decision-making scenarios as well as the ability to deal with stochastic uncertainties.

## Case study – Control Tower applications

General Motors (GM) has invested in its capability to monitor its supply network to minimize disruptions and facilitate rapid recovery when disruptive events occur. As a result, during the Thailand floods in 2011, GM experienced limited disruptions despite having a significant supply base in the region, while other competitors suffered major setbacks due to the disruption of material flow.

DHL launched a supply-chain risk-management platform, DHL Resilience 360, to assist businesses to predict, assess and mitigate the risk of supply-chain disruptions. This tool provides supply-chain visualization, trade compliance and near real-time monitoring of incidents.

In order to improve future resilience, companies move to build up their capabilities, including:

- **Increased visibility** – enables early warnings through the development of data visibility across the entire supply network
- **Real-time collaboration** – allows corporations to switch among alternative suppliers in the event of disruptive shutdowns or inventory losses
- **Flexible response plan** – prepares companies to predict, simulate and evaluate what-if scenarios so that teams can design back-up alternatives

# 5. Remanufacturing, reduce, reuse and recycling

**Background:** Remanufacturing, reduce, reuse and recycling are different approaches taken to achieve greater resource efficiency. Integration of design for remanufacturing, new consumer perceptions and behaviours, business model transformations, and policy and regulations are all important enablers of these approaches. They all need strengthened cross-company collaboration and new forms of partnerships across the supply chain.

Remanufactured goods are products rebuilt to meet the performance specifications of the original manufactured product using a combination of reused, repaired and new parts, including replacing obsolete components or modules.

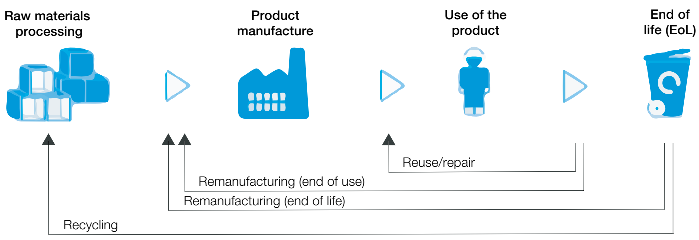
**Opportunity:** Products from mobile phones to heavy construction equipment can be processed in this way, with as much as 90% reduction in use of resources, processing energy, environmental impact and cost of producing the product. Guaranteed performance, warranties and trust in the brand provide consumer confidence. Product life cycles can, in the first instance, be extended by designing for longevity, durability and reliability. The market for **reused** products can be significant. For example, the global used smartphone market was estimated at $17 billion in 2016. Product lifespan can then be further extended, and the greatest efficiencies gained, where a product is refurbished or completely **remanufactured** to meet the specifications of the original manufactured product using a combination of reused, repaired and new parts, often replacing obsolete components and modules. For lower-value products where remanufacturing isn't economically viable, the next best resource efficiency is gained by reuse. For example, older high-tech products can be reused where cutting-edge performance is not needed, particularly where software updates continue to be provided. Both remanufactured and newly manufactured products can use **recycled** material. Recycling can also recover embedded value by recovering select components such as aluminium, plated gold and rare-earth materials.

## Case study - Apple initiatives on reuse, recycling and zero waste

**Material reuse:** Apple demonstrated that most of the aluminium recovered from iPhones can be part of the 100% recycled aluminium enclosure of a MacBook Air. Reaching deeper into its supply chain, Apple partnered with battery and final-assembly suppliers to also send Apple's battery scrap to its recycler upstream. Now, recycled cobalt from both scrap sources is being recycled into the batteries of new Apple products – a truly circular supply chain.

The circular use of resources enabled by remanufacturing has several benefits for the company, customers and the environment. However, there are challenges to implementing the infrastructure that enables remanufacturing. Mainly, there is a significant uncertainty in the variation of quantity, timing, quality and demand of incoming returned products or their parts (cores). To improve quantity and timing, manufacturers need to focus on reverse logistics, a series of processes used to acquire and transport components. To address the variability of quality, new manufacturing process are created that are typically costly and complex because incoming cores have longer inspection times, and restoring cores to their original condition can require cleaning, repairing and surface finishing.[6] Designing products for easier disassembly can decrease the complexity and cost of remanufacturing processes. Lastly, marketing strategies can help ensure stable demand of the remanufactured goods by highlighting to customers that the reproduced product meets the specifications and warranties provided by the manufacturer.

**Figure 5:** Instruments of a circular economy[7]




In addition to reducing the amount of materials needed in manufacturing, companies should prioritize the use of recyclable/renewable materials over non-renewables. By building products from recycled and renewable materials, the usage and sourcing of limited resources and waste from non-recyclable material is decreased. Where the substitution for recyclable/renewable material is not available, companies should work with their suppliers to develop substitutable recyclable material. Developments such as these are crucial to ultimately making all manufactured material recyclable, and the success of these developments is entirely dependent on collaboration between multiple nodes in a supply chain. When new recyclable resources are developed, they should be made available to all manufacturers/buyers of the material, enabling more companies to reduce their non-renewable material consumption and waste production and to drive down the costs of the newly developed material.

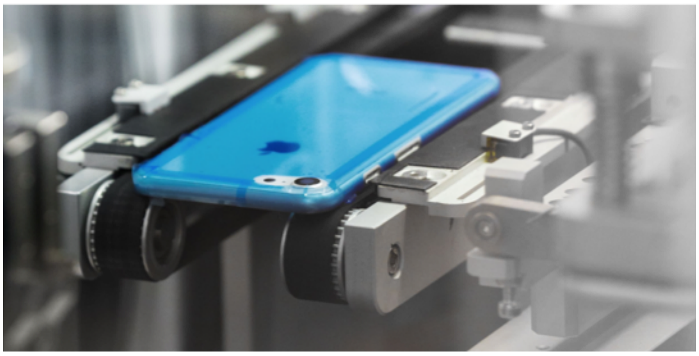
Waste reduction is also becoming an imperative for firms, as treatment and disposal processes generate about 5% of global carbon emissions. Waste levels are rapidly growing, expected to increase by 70% by 2050. Moreover, in low-income countries, 90% of waste management is not yet controlled.[8] Zero waste to landfill helps keep materials out of landfills by prioritizing reuse, recycling, composting and conversion to energy. By driving zero-waste initiatives, using international standards such as those established by Underwriters Laboratories (UL), companies can help mitigate harm to the environment.

In order to achieve zero waste, manufacturers need to redesign their processes and products such that all waste can be captured and is recyclable. Moreover, they need to develop new methods to track the waste they do produce. The success of zero waste depends largely on collaboration between manufacturers, suppliers, recycling facilities and all other stakeholders involved in the supply chain.

**Material recycle:** It takes multiple pieces of protective film to cover an Apple product during its journey along the assembly line. Film is placed and removed to help keep products pristine. Each piece is small, but it adds up to a significant portion of the non-recyclable waste generated during the product-assembly process. Apple set out to find a solution – finding a new protective film that could be diverted from incineration and, instead, recycled.

After conducting research, it became clear that no recyclable protective film was available on the market. This introduced an opportunity for Apple's engineering teams to partner closely with a protective film supplier. The turning point for the project came with the creation of a combination of adhesive and film that could be recycled.

**Figure 6:** Film application, iPhone production



The result was cost-neutral, recyclable protective film that, in its first year of adoption, diverted 895 metric tons of waste from incineration and avoided 1,880 metric tons in carbon emissions from the manufacturing of Apple products. Better yet, the film has also been made available by the supplier for other companies to adopt as part of their manufacturing processes.

**Zero waste:** Apple's Zero Waste Program was created in 2015. Through this programme, suppliers must identify waste-elimination opportunities. To help suppliers achieve this objective, Apple provides tools and guidance, including the services of experts in sustainable waste-management solutions. Apple provides support and education that enables its suppliers to reduce the amount of waste sent to landfills while manufacturing Apple products. Suppliers dedicate months to identifying ways to reuse or recycle materials and divert waste from landfills. This can result in suppliers not only improving their environmental management systems, but also benefiting from the sustained conservation of resources. Suppliers must demonstrate that they meet Zero Waste to Landfill certification through UL (UL 2799 Standard); this is a rigorous and comprehensive standard measuring waste streams from manufacturing environments.

In 2018, Apple's efforts to achieve a zero waste supply chain reached a significant goal. All final assembly facilities for iPhone, iPad, Mac, Apple Watch, AirPods and HomePods in Apple's supply chain are UL Zero Waste certified. A million metric tons of waste have been diverted from landfill through this programme. Apple continues to work with suppliers in its supply chain to implement zero-waste practices and eliminate landfill waste.[9]

# Collaborative supply chains – a call for action

In this paper we have identified the opportunities for a collaborative approach to the adoption of advanced manufacturing technologies across supply chains, namely the development of:

- Smart manufacturing solutions through AI and predictive analytics
- Flexible supply chains through electronic labelling
- Digital twin digital identity technology in the cloud in support of product authentication and consumer engagement
- Supply-chain visibility for improved monitoring and resilience
- Remanufacturing, reuse and recycling initiatives for resource efficiency

While there are exciting advanced manufacturing technologies emerging, many organizations have been challenged with making the right decisions on technology adoption[10] and wary of the pilot purgatory of experimentation without scale-up. In this paper we introduce some real-world applications that have had significant impact and the actions required to exploit them more fully.

The use of AI and predictive analytics for **smart manufacturing** is now being rolled out across both assembly and process industries, redefining the benchmarks for robust controlled production. These developments are leading to more operational cyber-physical digital twins, with new possibilities for an increase in distributed and replicated production. Further development will require collaboration across partners on standards and the sharing of successful use-case experiences.

The development of e-labelling across multiple industries is creating more **flexible product supply chains**. This will enable changes in information on product specification, guidance or use to be more dynamic, efficient and flexible to changing market and technical requirements, while also providing much-needed mechanisms for supply-chain integrity and compliance. Beyond the examples in this paper, these concepts are also being trialled in other sectors, for example:

- Product labelling and patient information leaflets in medicine manufacturing
- Intelligent shipment tagging with custodianship control in cross-border supply
- E-commerce delivery models involving crowdsourcing of third-party logistics

In the case of e-labelling, the next steps should include;

- *Global implementation of e-labels for products with integrated and paired screens:* There are still major markets that have not adopted e-labelling devices with integrated screens. For example, while the EU has allowed e-labels for medical devices since 2012, industry and users of consumer electronic devices will better realize the full benefits of e-labelling if extended to these products, and companies will not have to maintain separate EU supply chains.

- *Development and adoption by governments of flexible, voluntary global standard for electronic labelling:* Divergent approaches to e-labelling will undermine some of the efficiency-related benefits it is intended to generate. Country-specific requirements could become a barrier for trade as manufacturers prioritize various markets that require less time and money to ensure compliance. Small mandatory requirements can have significant implications for manufacturers entering different markets.[11]

Beyond the digital industry, an increasing number of sectors can benefit from e-labelling as more and more devices become connected. The mechanical engineering association in Europe, representing the EU's largest manufacturing sector, advocates for e-labelling as a modern solution to indicating compliance. Other industries such as toy manufacturers and the white goods industry are increasingly likely to benefit from the flexibility provided by e-labelling. The benefits of e-labelling are being recognized and reflected in the provisions of modern trade agreements. If done correctly, electronic compliance labelling on devices with and without digital displays can significantly reduce the environmental, organizational and monetary costs of physical labels, while achieving the policy's goal of ensuring that the relevant information is accessible, comprehensive, comprehensible and continuously updated.

In order to improve ***supply-chain resilience and visibility***, companies need to exploit data from supply-chain partners, including appropriate data structures and sharing protocols. This will support supply resilience involving:

- **Real-time collaboration** – allowing corporations to switch among alternative suppliers in the event of disruptive shutdowns or inventory losses
- **Flexible response planning** – enabling companies to predict, simulate and evaluate what-if scenarios, so that teams can design redundancy and back-up alternatives

And finally, perhaps most importantly, is the need for a collaborative approach on **resource efficiency**. It is vital that manufacturing companies redesign production processes, products and supply chains to decouple future growth from the increased consumption of natural resources – using renewable materials and enabling ease of component and product reuse, recycling and remanufacturing.

# Acknowledgements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# Endnotes


1. Valdani Vicari and Associati, *Study for the Introduction of an E-labelling Scheme in Europe*, 2018: www.digitaleurope.org. Industries covered by the research include NACE 26.20 manufacturer of computers and peripheral equipment, NACE 26.30 manufacturer of communication equipment, NACE. 26.40 manufacturer of consumer electronics. The impact is estimated for the European market.
2. Valdani Vicari & Associati, *Study for the Introduction of an e-Labelling Scheme in Europe*, 2018, pp. 1–66.
3. Cory, Nigel. *How E-Labels Can Support Trade and Innovation in ICT*. ITIF, 2017: www2.itif.org/2017-e-label-support-ict.pdf?_ga=2.83504854.1507184721.1552429978-381021246.1552429978.
4. Ibid.
5. Barroso, Jose Manuel, *Commission Regulation (EU) No 207/2012. Official Journal of the European Union*, 2012, pp. 28–31: eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:072:0028:0031:en:PDF.
6. Andrew, Magdalene and Ibrahim, R.N., *Remanufacturing Process and Its Challenges. Journal of Mechanical Engineering and Sciences*. 2013, 4, pp. 488–495. 10.15282/jmes.4.2013.13.0046.
7. ZDI ZRE, *Resource Efficiency through Remanufacturing*, 2017, p. 10: https://www.resource-germany.com/fileadmin/user_upload/downloads/kurzanalysen/VDI_ZRE_KA18_Remanufacturing_en_bf.pdf.
8. World Economic Forum, *Global Waste Could Increase by 70% by 2050, According to the World Bank*, 2018: https://www.weforum.org/agenda/2018/09/world-waste-could-grow-70-percent-as-cities-boom-warns-world-bank/
9. To reach platinum certification, a factory must divert 100% of its waste from landfill, with a maximum of 10% sent to a waste-to-energy facility. To reach gold certification, a factory must divert 95% from landfill. In two cases, Apple suppliers have achieved gold certification because the carbon impacts of shipping recyclable materials long distances outweighed the environmental benefits of landfill diversion.
10. Standard ISO/IEC 22603 in ISO/IEC JTC 1/SC31/WG8 is currently being developed to help guide implementation of electronic labelling in a manner that avoids such divergences. The objective is to set out general guidelines, while leaving su cient implementation flexibility to take account of the diverse range of materials, products and supply-chain structures across industries, learning from existing regulatory and industry practices. Electronic labelling technologies and codes are already in place and can provide demonstration cases for regulators in other fields. For example, QR codes have become the industry standard for food manufacturers in the US in response to the rule by the Agricultural Marketing Service, USDA (United States Department of Agriculture) that implements new national mandatory bioengineered food disclosure standards (NBFDS). Similarly, the US FDA has established a unique device identification (UDI) system for medical devices that will include various pieces of regulatory and compliance information in machine-readable form.
11. Srai J.S., Christodoulou P. and Settanni E., *Next Generation Supply Chains: Making the Right Decisions about Digitalisation*, University of Cambridge Institute for Manufacturing, Cambridge: https://www.ifm.eng.cam.ac.uk/insights/global-supply-chains/nextgensc/; *The Digital Supply Chain Revolution: A Mountain Worth Climbing?*, World Economic Forum blog article.

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