# Logistics and Supply Chain Management: Developments and Trends

**Henk Zijm and Matthias Klumpp**

**Abstract** The demand for sustainable logistic and supply chain processes poses enormous challenges in terms of technology integration, the development of new business models, cultural change and job qualification, and as such requires a real paradigm shift. In this paper, we start with a brief sketch of how modern logistics and supply chains emerged as a result of diversification and specialization of industrial production, globally scattered availability of resources and more demanding consumer markets. Jointly with advances in freight transport and communication technologies, these developments have led to the global economy we face today. The strong growth of trade and consumption however also revealed some essential weaknesses of the system that renders current practices in the long run unsustainable—in social, environmental and economic terms (people, planet, profit). Future supply chains should no longer deplete scarce natural resources or contribute to climate change, should avoid environmental pollution and withstand safety and security threats, while at the same time remaining competitive and satisfying high labor quality standards. This requires not only the application of advanced technologies to mitigate or even neutralize these negative effects, but also the development of smart business models, new job qualification standards and corresponding (lifelong) training and education programs at all levels, including artificial intelligence based learning.

**Keywords** Logistics · Global supply chains · Sustainability · Circular economy · Physical internet · Logistics education · Logistics trends · Artificial intelligence

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# 1 Supply Chains: Definition and a Short History

A supply chain concerns the entire production and distribution chain from raw materials to final customers and on top of that the return flow of products and possible re-use of materials or components (closed loop supply chain). Almost always, such a production and distribution chain is not executed by one industry but instead encompasses a number of companies and organizations jointly operating in a chain or network. This so-called end-to-end supply chain is represented in the Supply Chain Operations Reference (SCOR) model, see Fig. 1 (Poluha 2007; Simchi-Levi et al. 2008).

Current supply chains often span the entire globe and involve production, trade and logistics organisations around the world. For instance, in many European countries, most solid materials products and a significant percentage of food products are not produced in the region or country of use or consumption but elsewhere, not seldom even at other continents. In this paper, we investigate why worldwide production and—as a consequence—worldwide logistics flows have become so dominant, what their merits are but also why current practices in the long run are not sustainable, either in social, environmental or economical terms. To turn the tide, a fundamental rethinking of the way we organise production and logistics as well as logistics information management and education is needed. To understand this paradigm change, we first briefly review the way current production systems evolved, see also Hopp and Spearman (2008).

## *1.1 The First Industrial Revolution: The Principle of Labor Division*

In 1776, the English economist Adam Smith published his "*An inquiry into the nature and causes of the wealth of nations*", in which he explained in detail the merits of what has become known as the "principle of labor division" and clearly demonstrated the productivity gains that could be achieved by systematically exploiting the learning curve (Smith 1776). That publication marked the start of the dominant philosophy of efficiency through specialization, worked out towards a first theory on production organisations by Charles Babbage (who later became known as the father of the digital computer) in his "*On the Economy of Machinery and Manufactures*" (Babbage 1835). The first industrial revolution, initiated by the invention of the steam engine, or rather its application in industrial production as engineered by James Watt, meant the definitive change from the classical domestic system and the craft guilds to mass production and mechanization, which has dominated production ever since. Mass production requires physical concentration and so the massive factories were born that colored the industrial landscape in the 19th and large parts of the 20th century. Ideas of mass production were governing the development of the steel industry by Andrew Carnegie, the large food

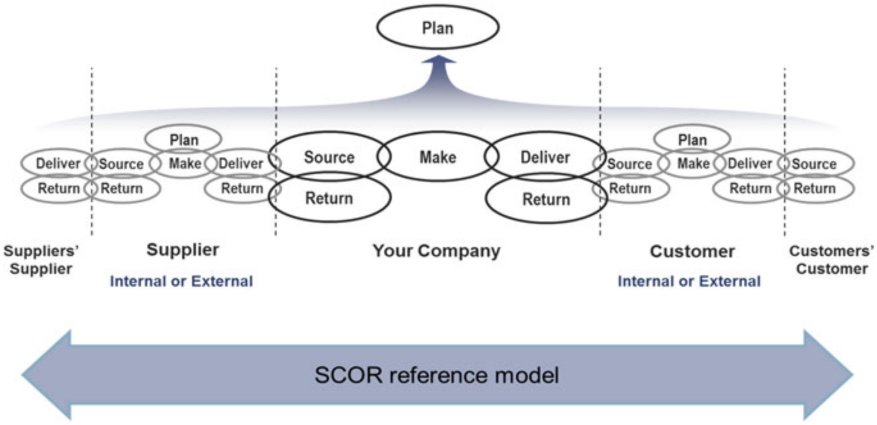


**Fig. 1** SCOR model of end-to-end supply chains (*Source* Supply chain council)

conglomerates, the automotive sector and so on: scale, not scope was the leading paradigm. Famous became the reply of Henry Ford to the question in what color the T-Ford was going to be produced and customers might choose from: "Any color, as long as it's black". It was also the time in which the first scientific management theories were developed, with Frederick Winslow Taylor, now often viewed as the first industrial engineer, as its most famous representative. His work on time and motion studies, best working practices and in particular the differential piece rate system, was followed by pioneers such as Frank and Lilian Gilbreth, and Henry Gantt, who introduced the Gantt Chart in project management, while a first attempt to systemize quality management was developed by Walter Shewhart through his work at Bell Labs on Statistical Quality Control methods.

Mass production and limited product diversity continued to be the name of the game, also during the first decades after the Second World War. There was a shortage of the most basic goods; everything that could be made could be sold. However, starting with the sixties, as prosperity grew, consumers began to demand larger variety, leading to more complex products. In response, manufacturing industries introduced more versatile machines that could produce a variety of products, albeit at the cost of large setup or changeover times. The result was still production in large batches: economy of scale remained the leading philosophy. Also, the transfer of production to low wage countries in the Far East and Southern America was an attempt to sustain mass production at affordable costs. Efficiency also marked modern logistics: the introduction of the container and modern materials handling systems meant a big step forward in processing the ever growing logistics and material flows. Functional specialization, concentration of mass production in large factories, the shift of routine production to low wage countries, and as a result supply chains that tend to grow longer and longer, marked the industrial landscape still in the seventies and eighties of the preceding century.

## 1.2 From Mass Production to Flexible Manufacturing and Logistics

The two oil crises of 1973 and 1979 for the first time revealed also the weaknesses of the prevalent production philosophy. Raw material prices and interest rates raised sharply and industrial companies started to realize that long supply chains represented large amounts of stock and hence capital invested; besides, long supply chains make it hard to quickly adapt to changing market demand. Companies were inert, and not prepared for the flexibility that a changing society required. In addition, publications such as “Limits to Growth” from the Club of Rome (1972) stressed the depletion of natural resources and the pollution of our natural environment at an exponentially increasing rate (Meadows et al. 1972). For the first time industry and the public started to realize that current supply chains were to become economically prohibitive, and socially unacceptable.

And so, large scale batch production once applauded as the most efficient production philosophy now became the cause of all evil. Fortunately, new technologies proved to be at least a partial remedy. The introduction of flexible manufacturing systems, often based on computerized (CNC) machining and robotized assembly, helped to balance efficiency and flexibility, not only in production but also in the nodes of logistics networks, i.e. the material handling and distribution centers. In addition, attempts were made to synchronize and integrate supply chains by means of administrative information systems such as MRP and ERP, or by introducing new production philosophies such as Just-in-Time, or lean and agile manufacturing that focus on rigidly removing any buffer stocks as these were primarily seen as indications of waste or slack that characterize non-synchronized production. These were the heydays of the Toyota Production System and the SMED (Single Minute Exchange of Die) system, an engineering philosophy advocated by Shigeo Shingo, who systematically sought to reduce machine setup or changeover times, thereby again aiming at flexible, synchronized manufacturing and logistics (Shingo 1985).

Hence, although factories became more flexible, long and expensive supply chains due to functional specialization and dispersed production of parts and components continued to be the overarching story. At the same time, these supply chains contribute significantly to the BNP of those countries for which logistics is a strong economic sector, including Germany and The Netherlands (which ranked positions 1 and 2 on the World Logistics Performance Indicator 2014, published by the World Bank). The unprecedented growth of production and logistics and its far reaching rationalization as a result of modern manufacturing methods, the introduction of the container and above all the penetration of automation and computing technologies is definitely one of the sources of prosperity in most developed countries.

But this growth comes with a price and more and more it is realized that current supply chains are fundamentally unsustainable. This will be outlined in the next section.

## 2 Unsustainability of Today's Supply Chains

Current production and logistics systems cause serious and in the long run unacceptable environmental damage, due to for instance the emission of hazardous materials ($CO_2$, $NO_x$, particulate matter), congestion, stench, noise and more general the high price that has to be paid in terms of infrastructural load. While the European Committee has set clear targets to reduce Greenhouse Gas Emissions (GGE) in 2015 to 60 % as compared to 1990, the percentage of transport related GGE has increased from 25 % in 1990 to 36 % today (ALICE 2014). Besides, the pressure of the infrastructure needed on land use gives rise to additional social and environmental problems which hit urban areas in particular. Below, we first describe various phenomena which sometimes represent threats but in all cases pose at least important challenges to future supply chain management. In Sect. 3, we list ways and developments that may help to address these challenges.

### *2.1 Scarcity and Sustainability*

Natural resources are scarce and not evenly distributed in terms of type and geographical location in the world. Logistic chains enable the distribution of materials, food and products from the locations where they are extracted, harvested or produced to people's homes and nearby stores. Current supply chains and logistics systems are global, partly due to natural conditions but certainly also because of labor rate differences between emerging and mature economies. First indications of reshoring production however become visible, not only because wage rates are moving upwards also in a number of Far-Eastern countries, but also since the amount of manual labor needed in high tech products continues to diminish, while logistic costs are increasing. As a result, future supply chains are believed to be "*glocal*"*: global when needed, local when possible*. On the other hand, global supply chains will remain inevitable in cases where conditions for growing food ingredients are only satisfied in some regions in the world, or when minerals are only locally available. They will also continue to exist in cases where material processing consumes such an immense amount of energy that this is only sustainable at places where energy is abundantly and sustainably available, such as locations with geothermic energy, locations with water-powered energy generation, and locations with long periods of sunshine.

### *2.2 Demographic Trends*

The current world population of 7.2 billion is projected to increase by 1 billion over the next 12 years and reach 9.6 billion by 2050, according to a recent United

Nations report (LOG2020 2013). Within Europe, population size is predicted to be stable—but a severe shift in population movements is expected from Eastern to Western Europe. Ageing continues, meaning that people in general will work longer in order to maintain a reasonable standard of living. Europe-based companies should be prepared for scarcity of human resources and should be able to provide working conditions that extend the working life of employees. The need to further increase productivity while at the same time diminishing the ecological and social footprint, requires a quality upgrade of the human resource pool, e.g. by better education and training, including lifelong learning programs. In parallel productivity can be improved by better support tools, easier access to relevant information, and finally further automation of both technical processes (i.e. robotics) and decision making (i.e. artificial intelligence).

## *2.3 Urbanization*

As urbanization continues[1] it becomes an unprecedented challenge to keep cities livable, which includes a sustainable logistics planning and execution. The development of wealth in Asia and Latin America has resulted in a huge shift from agricultural and nomadic forms of living to urban life. More and more cities with over 10 million inhabitants will emerge requiring different modes of transport and logistics systems than available today. There is an increasing interdependency between supply chain design or management and urban planning or land-use management. It is not yet clear whether mega cities are sustainable when wealth increases to the levels currently accessible for the population in developed countries. Innovative sustainable, safe and secure logistics might inspire agencies and institutions towards new patterns of sustainable urbanization.

## *2.4 Supply Chain Safety and Security*

Border-crossing supply chains and logistics systems often concern high-value goods, and therefore are vulnerable to crime and illicit acts. Within the European research programs, various projects have developed roadmaps to enhance supply chain safety and security. Regarding safety, extensive attention has been paid to safe working conditions (and for instance driving hour regulations) but the fight for supply chain security, abandoning crimes and illegal activities, appears to be a harder one. Economic crimes for example include: theft (robbery, larceny,

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[1]In 2007 the world passed the point in which more than half of its population is living in urbanized areas, in some developed countries the urban population percentage is well above 70 %, and continues to rise.

hijacking, looting, etc.), organized immigration crime (human trafficking, illegal immigration), IPR violations and counterfeiting and customs law violations (tax fraud, prohibited goods). Alternatively, ideologically or politically motivated crimes occur, next to obvious vandalism (Hintsa 2011). A legislative framework may in principle safeguard society against these unwanted practices and provide a mandate for government authorities to act. However, the challenge often is to find a balance between required inspections and interventions, and the economic interests of shippers and logistic service providers who wish to minimize delays, inefficiencies and additional costs.

Another aspect of supply chain security is supply chain resilience, which can be defined as the ability to maintain, resume, and restore operations after a major disruption (Gaonkar and Viswanadham 2007). This is a critical aspect of supply chain risk management and is generally seen as one of the major future challenges. Disruptions to supply chains can prove costly, as highlighted by a variety of natural disasters. According to research conducted by Accenture, significant supply chain disruptions have been found to cut the share price of impacted companies by 7 % on average (WEF/Accenture 2013).

## 2.5 *Changing Consumer Markets*

Commercial product life cycles tend to become still shorter. At the same time we observe an increased re-use of products, components and materials, both via (electronic) second markets and in so-called closed-loop supply chains (cradle-to-cradle, circular economy). Mass customization is an important aspect of current consumer markets, enabled by fast technological developments (to be discussed below). The rapid advance of e-commerce is another characteristic of today's markets: on the one hand it reduces the number of links in the supply chain, but without adequate regulation of both forward and reverse flows of packages it often leads to a rapid additional increase of urban congestion and pollution. Finally, we note that in some sectors customers no longer buy an actual product but only the service the product represents (e.g. cloud computing, music streaming, car sharing). These phenomena will have a profound impact on the ecological footprint of mankind and as such also on the design and planning of future supply chains.

All phenomena sketched above pose important challenges to future supply chain design, planning and control. Fortunately, technological innovations are extremely helpful to at least partially address some of these challenges. But technological innovation alone is only a part of the story; at least equally important are the development of smart and fair business models based on joint responsibilities and fair allocation of revenues instead of on individual profit maximization, and the mind shift needed for all stakeholders concerned, which in turn requires high investments in (lifelong) training and education programs (cf. Sect. 4).

# 3 Chances and Opportunities for Future Supply Chains

The observations outlined in the preceding section call for a fundamental paradigm change when redesigning future-proof supply chains, i.e. supply chains that are able to efficiently deliver goods and services when and where needed, while respecting social and environmental constraints. Fortunately, both technological and social-economic innovations provide adequate tools that may help to address that challenge.

## *3.1 New Materials and Manufacturing Technologies, Design for Logistics*

The design of new and lightweight (bio-)materials and their application in a wide variety of products poses exciting new possibilities to diminish both the costs and ecological footprint of these products. Rapid advances in such fields as polymer technology, bio-engineering and nanotechnology already lead to products that could not have been imagined only 10 years ago. Technologies like 3D-printing and micro-machining are also a step forward towards mass-customization but in addition have a profound logistic impact, for instance in stimulating "local for local" production. In addition, 3D printing which is believed to have a future in particular in small batch and one-of-a-kind manufacturing, may lead to far shorter lead times and hence a reduction of so-called anticipation (safety) stocks, because it allows production at the place and time needed. Another manifestation of improvement through technology is the continuous development of cleaner engines and non-fossil fuel based engines (e.g. electric, hybrid or LNG-powered vehicles for city distribution and local passenger transport, but also for both inland and sea vessels as an attempt to diminish the environmental footprint. It is important to realize the importance of an integrated supply chain view when focusing on reducing their negative impacts. As an example, consider product design. Modular product design allows the transport of components instead of full products which not only results in a higher package density but in addition again allows customization closer to the end-user. Also note that that 3D-printing and additive manufacturing in general is based on material addition, instead of material removal as in classical machining, hence in principle has a waste avoidance potential. Smart packaging logistics also may help to reduce volumes and to avoid waste, in particular in the case of bio-degradable package materials.

## *3.2 Automation and Robotics, Internet of Things*

The impact of robotics has already been visible for a long time e.g. in automotive assembly lines but also in warehouses and distribution centers, in so-called ASRS

(Automatic Storage and Retrieval Systems), often consisting of high bay storage racks which are served by fully automated cranes, and equipped with automatic identification, i.e. RFID technology. Apart from the visible hardware, innovative warehouse management systems help to coordinate and synchronize activities, in close communication with information systems covering both suppliers and customers. Similar developments can be found at container terminal sites in both seaports and inland harbors. Without exception, all such systems rely heavily on smart sensor and actuator systems, recently evolving towards the so-called Internet of Things, where devices are equipped with sensors that automatically signal when actions such as ordering or replenishment have to be initiated. Additionally, materials and machinery themselves are able to communicate with each other and find solutions based on decentralized and autonomous decision making using state-of-the-art algorithms. In particular the world of both passenger and freight transport is currently innovating rapidly, as demonstrated for instance by various experiments with freight vehicle platooning, in which a convoy of freight trucks is controlled by a single driver. Vehicle transportation in 2050 is foreseen to be largely unmanned transportation.

## *3.3 Business Information Systems, New Business Models*

Although many scholars view business information systems and architectures as belonging to the field of technology development, it is essentially more than that. Complex modern supply chains are first and foremost characterized by the fact that many stakeholders are involved in shaping its ultimate manifestation. Direct stakeholders are of course suppliers of raw materials, product designers, manufacturing and trading companies, logistics service providers, forwarders and transport companies, and ultimately the customer. Indirect stakeholders are supply chain financiers, ICT consultants, local and regional governments in their role as infrastructure providers but also as representatives of societal interests, customs authorities and indeed the public at large. The multi-stakeholder and multi-decision maker environments we deal with require adequate mechanisms to respond to their requirements, including distributed architectures, cloud computing solutions, cognitive computing and agent-based decision support systems. Organizational innovations are indispensable to fully exploit the potential of advanced information and decision support architectures. The recent attention for data driven models (big data analytics) marks an important further step towards full-blown automated decision architectures.

The design and acceptance of decision models based on both horizontal and vertical cooperation in supply networks however proves to be one of the most difficult steps to make. Although many stakeholders quickly recognize the potential win-win situation arising from collaboration they find it in general extremely hard to give up their autonomy. Mathematically, game-theoretical approaches have proven to provide adequate tools to handle such multi-stakeholder games, for instance the Shapley value calculation defines a “fair” allocation of cooperation gains to individual actors. But the key idea—established in the Nash equilibrium theory—that players may give up their individual optimal solution in order to achieve an overall stable equilibrium solution is still hard to accept in particular for private companies that were used to concentrate on their individual profits. This is perhaps the biggest hurdle to be taken to arrive at sustainable logistics; it involves not only smart business solutions but more important a change of mindset and indeed trust in the value of collaboration.

## *3.4 Circular and Sharing Economy, Servitization*

The key idea behind servitization is the realization that both private consumers and industrial asset owners basically need the functionality of assets and products, rather than the products itself (Cohen et al. 2006; Neely 2008). Initially, this idea has led to the establishment of after sales service models that aim to deliver improved availability and system performance based on smart service level agreements. One step further is not to sell products anymore but to lease them, or to provide “power by the hour” support as some industrial equipment suppliers already do. Apart from the long-term relationship between supplier and customer and the emphasis on lifecycle support it also enables a planned take-back and renewal of systems at the end of their functional lifetime. The circular economy is based on the idea that products and systems that are disposed of can be either restored and reused or disassembled after which components and parts are given a second life in next generation equipment. Another option is to jointly use equipment in a predefined group of people. Those products or systems are either owned by individual group members or remain property of the supplier and can be leased or hired at moderate costs. It may be clear that such developments may have important consequences for supply chain design, planning and control in that the focus may at least partially switch from delivering products to delivering services. An example can be recognized in the trend towards car sharing, implying for logistics that cars may not have be to delivered to the individual end customer (via the usual dealers) but more centralized towards several car sharing operators, changing the setup of the distribution logistics concept entirely.

Other important developments concern e.g. the design of new supply chain finance models, such as reverse factoring, and developments in marketing and sales. Figure 2 displays a key summary of the main developments that may serve as drivers for innovation in supply chain management, regarding the physical, information and financial flows (Zijm and Douma 2012).

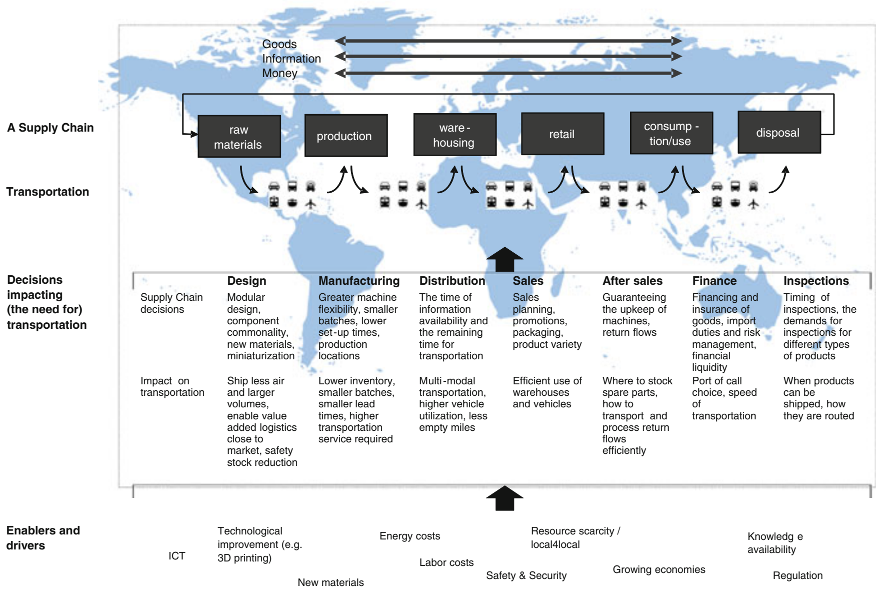


**Fig. 2** Decisions impacting supply chain sustainability (including transportation)

## 4 Roadmaps Towards Sustainable Logistics and Supply Chain Management

In this section we briefly sketch some developments at a European level, more precisely the foundation of the European Technology Platform (ETP) for Logistics ALICE (Alliance for Logistics Innovation and Cooperation in Europe). Within ALICE, five working groups have developed roadmaps that address the issues sketched in the preceding sections (ALICE 2014), converging to the Physical Internet paradigm. The five roadmap topics are listed below and visually integrated in Fig. 3):

- *Sustainable, safe and secure supply chains*: this roadmap aims at a thorough rethinking of the contents of the goods flow. How to design products and processes such that efficient logistics is enhanced at minimal social and environmental costs, and how to enhance safety and security (protection against theft and other illicit actions, but also supply chain resilience in case of natural disasters,
- *Global supply network coordination and collaboration*: to further enhance logistics efficiency, cooperation is needed, both along the supply chain and across various heterogeneous supply chains (i.e. horizontal and vertical synchronization). Combining flows and integrating forward and reverse flows may prove to provide adequate remedies against too low transport loads and empty vehicles drives.

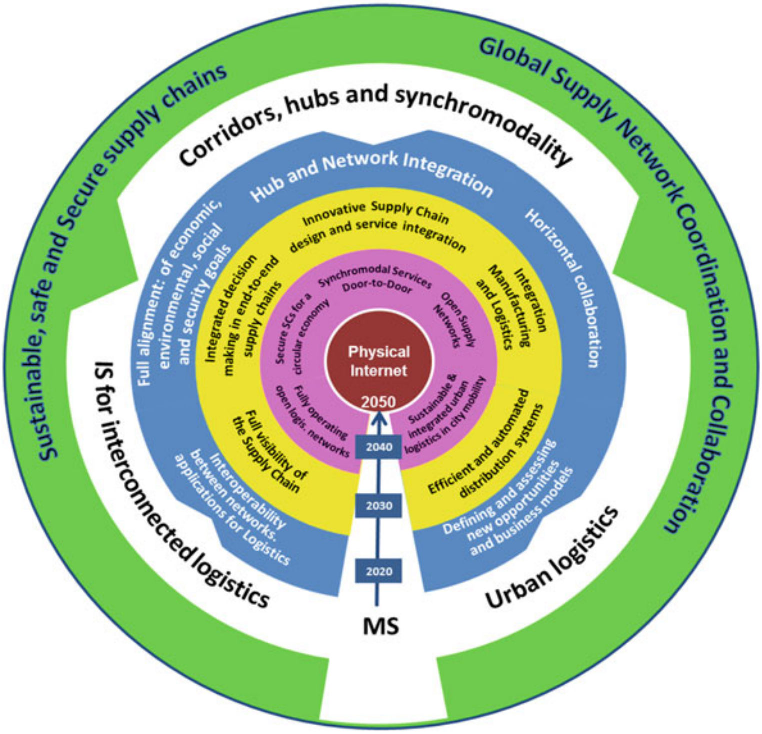


**Fig. 3** ALICE roadmaps and their interactions: towards the Physical Internet

- *Corridors, hubs and synchromodality*: hubs and corridors are key infrastructural elements to increase efficiency of transport. Synchromodality is the concept to exploit multiple modes in a flexible, dynamic way, and in this way to shift loads from road to e.g. rail or water, based on a reconciliation of economic and environmental goals (people, planet, profit).
- *Information Systems for interconnected logistics*: there is no doubt that a sound and, more important, uniform (single window) and transparent information infrastructure is essential to achieve a tight interplay between the many stakeholders involved, to really achieve economic and ecological sustainable solutions that integrate decision making along the supply chain.
- *Urban logistics*: the trend towards further urbanisation still continues which calls for drastic policies to preserve or enhance quality of life. The rapid advance of *e-commerce* causes a sharp growth of small load (forward and reverse) freight flows which further increases pollution, noise and congestion. Sound infrastructural policies are needed to address these problems in order to keep cities attractive as centres of economic activities.

The roadmaps and instruments outlined above all form important stepping stones towards more sustainable logistics and supply chains. In the long run, however, the concept of a "Physical Internet" as proposed by Montreuil (2011) may serve to integrate all these elements in a radical new logistics framework. The Physical Internet is defined as a logistics system in which modular packages are automatically routed from source to destination through a network of hubs and spokes. Major elements of such a network more or less exist for parcels, pallets, containers and "swap bodies". Carriers of these types of loading units do optimize between various alternative routes in their networks, e.g. by bypassing hubs, either in advance through offering more time definite services, or real time during the actual transport. A full-fledged physical internet may be built upon all these elements with the holistic integration of existing elements and concepts as the main challenge.

The Physical Internet should not be confused with the Internet of Things; the latter refers to the possibility of communicating devices, often followed by local actions initiated by software agents. Internet of Things technology may be an important building block of the Physical Internet, e.g. in determining alternative routes in case of congestion on the preferred route, or in signalling a potential quality loss in case of delays (e.g. in food and flower transport). But the Physical Internet is a full-fledged alternative to a classical, manually operated logistics network, with important consequences for all stakeholders involved but first and foremost transport companies and service providers.

Why is the Physical Internet a radical solution? Basically, because decentralized market economy mechanisms usually prevent holistic optimization as many providers of transport and logistics services are "locked-in" in their current ways of working and acting. This happens for instance by fixed or sunk costs in specific equipment, preventing the individual actor from agreeing to large-scale collaboration and optimization. To arrive at such enhanced cooperation levels, shippers, manufacturers, retailers, carriers and other providers of logistics services should take the broader sustainability goals into the economic equation. This requires new ways regarding decision making in the system on financial and market criteria but also on safety, security and environmental aspects. In particular, transnational governance and regulation is needed to achieve such a cultural shift, and to encourage collaboration, coordination and horizontal partnerships.

A major challenge is to design a multifaceted decision support system for the Physical Internet, with partly automated execution via intelligent agents. Radical new business models based on openness and sharing or resources are required, as opposed to the current local ownership and control of resources. Note that this notion of openness is almost in contrast with the core of e.g. supply chain security. Therefore, the adoption of a Physical Internet will require radical changes with respect to the roles and responsibilities of many stakeholders. Achieving such a combination of physical and electronic infrastructure is just one step, stimulating shippers and logistics operators to connect to it, is an even bigger challenge.

## 5 Logistics Training and Competence Management

So far, we only obliquely touched the topic of human skills and competences in logistics. However, it goes without saying that a fruitful contribution of technology innovation and smart information systems to sustainable supply chains critically depends on the presence of a competent workforce at all levels in both private organisations and government (LOG2020 2013). Training is needed to adopt and adequately apply new technologies while the design of smart business models requires academic skills to understand the increasing complexities of modern global supply networks. Figure 4 displays the essential three elements and their mutual relations that are essential in shaping future supply chains. Indeed, apart from natural resources and despite the growing world population, the quality and availability of human competencies appears to be the most important limiting factor (Wu 2007). That recognition was an important argument for several countries to invest not just in physical but above all in logistics competence clusters, of which the DINALOG cluster in the Netherlands and the Effizienzcluster LogistikRuhr in Germany are two notable examples. Such clusters not only govern applied research but moreover play an important role, together with the available knowledge infrastructure, in training and upgrading logistics operators and management alike. In this section, we take a closer look on logistics competence management.

The first scientific description of sustainability as a general concept is due to the 18th century German agriculture and forest academic *Hans Carl von Carlowitz*. In 1713 he defined sustainability in relation to wood cutting, as follows: “Wird derhalben die größte Wissenschaft und Einrichtung hiesiger Lande darinnen beruhen, wie eine sothane Conservation und Anbau des Holtzes anzustellen, daß es eine

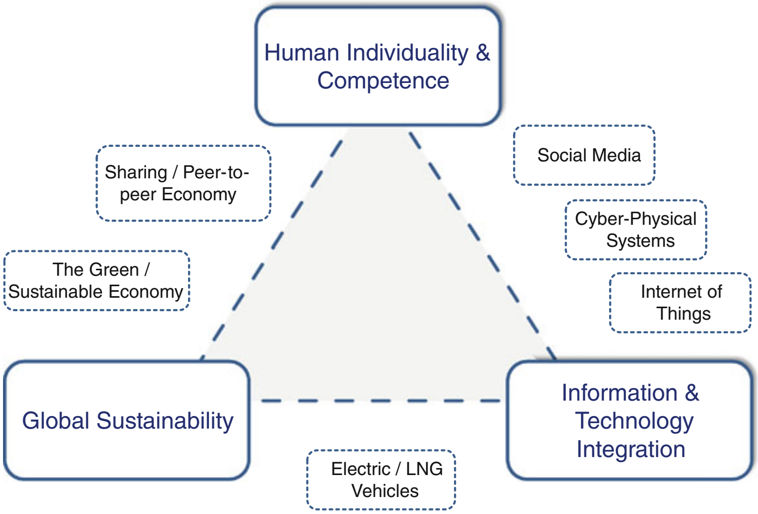


**Fig. 4** Essential elements in shaping future global supply chains

continuierliche beständige und *nachhaltende* ["sustainable"] Nutzung gebe, weil es eine unentberliche Sache ist ohne welche das Land in seinem Esse nicht bleiben mag"[2] (*Sylvicultura Oeconomica*, pp. 105–106).

If transferred to the question of available qualification and competencies of the human workforce, it is striking that the amount of research that has studied the development of human knowledge and competence in a general sense is fairly limited, in spite of the recognition that innovation essentially requires a close match between technology, policy and business support, and human skills development (i.e. Aghion et al. 2009). This is further outlined in Fig. 5, depicting an average competence level of the human workforce in a very simplified manner, inspired by an "application of knowledge paradigm".[3]

It can be stated that, starting from the industrial revolution ("A"), the necessary or expected competence level of the workforce has increased on average. For logistics processes especially it can be argued that this still ongoing process has a "double nature". First, existing activities such as truck driving, warehouse processes or production processes increasingly demand higher level competences—as demonstrated for example by the new vocational training for truck drivers in Germany or by EU regulations that request further training of drivers regarding safety regulations, sustainability and hazardous goods as well as technology usage. Whereas only thirty years ago truck driving was a typical "unskilled" profession without any necessary training to do the job properly (apart from a truck driver's licence), today no individual could just "start driving" a truck in complex transport processes as a multitude of systems (toll systems, routing systems, communication systems, auto ID systems etc.) have to be mastered. This development can be named "knowledge and competence *enrichment*" of existing processes. Second, new activities arise in logistics and global supply chains, typically with a very high knowledge and competence requirement, such as IT systems management, logistics consulting, logistics and supply chain finance, logistics tender management, logistics controlling and so on. This trend can be titled "knowledge and competence *extension*" as new processes increasingly demand new and higher knowledge and competence levels (see e.g. Klumpp 2013).

Between the ever-increasing expectations and requirements regarding human competence levels (the upper black line in the figure), a distinctive "gap" is opening up over time as the required training for humans has for each and every person to start "anew": learning cannot be "inherited" or automated. Longer schooling and training programs are needed in order to arrive at the required competence levels of a modern logistics and business environment. This can be termed a "*knowledge accumulation gap*" (grey field in the figure) that arises due to the fact that humans

[2]"The first and foremost objective of research and practical application shall therefore be a method securing the establishment and preservation of tree cultivation, enabling a continuous and sustainable use as this is an essential prerequisite for the well-being of the land."

[3]Competence is here understood as the *application* of knowledge and information for a given (exemplified) *real-world* problem, e.g. the transportation and placement of a container in a seaport terminal or the production of a car specified by a customer.

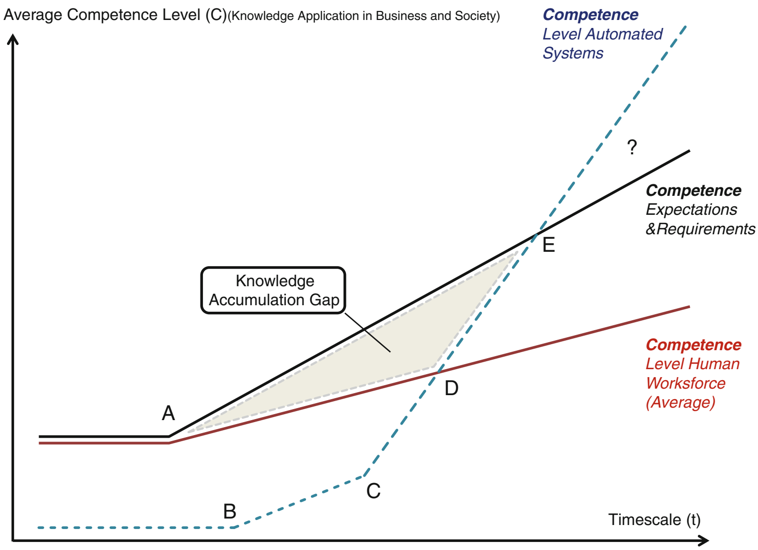


**Fig. 5** Competence development for humans and artificial intelligence

are not able to accumulate knowledge over generations, as opposed to machines and computers that are increasingly able to do exactly that. Artificial intelligence based machines may in the future mitigate or close this gap.

Besides human knowledge and competence levels, automated or artificial intelligence (non-human) competence levels (dotted line in the figure) are expected to impact technology and business development. Though artificial intelligence had a somewhat "slow start" during the sixties, seventies and eighties of the preceding century (Newell 1982), it has significantly accelerated in solution contribution width and depth recently. This is connected to the trend of "deep learning", allowing computers autonomously to acquire new knowledge and to find links as well as directions of further learning and meaning *themselves* (Erhan et al. 2010). As outlined in Fig. 5 (point "B"), automated systems were initially very slowly adopted;, examples in logistics include the *automated gearbox* in trucks, partly automated cranes and warehouse equipment as well as automated communication and transmission devices in logistics management (EDI systems, automated decision protocols). These "separate" and limited systems never really "matched" human competence levels, which is why the dotted line traverses significantly below average human competence levels between B and C. This was further demonstrated by introducing only slightly different context variables or *external changes* that proved to be too hard for these early automated systems, making human intervention necessary in every case.

In recent years however—symbolized by point "C" in Fig. 5—automated systems have undergone a drastic change, only partly described by a "merging" or an "integration point" as formerly separate systems now are increasingly coupled and are beginning to *interact*. This is on a rudimentary level the idea of the "Internet of Things" as outlined above. For example, current automated warehouses are integrated systems of software (warehouse management systems), hardware (moving goods) and even optimization (error analysis, automated storage optimization). This integration tremendously increases the capability of such systems and accelerates their "innovation speed" significantly.

In some cases artificial intelligence and automated systems are already "overtaking" human competence levels (point "D"). For truck driving for example, the "intelligent" combination of the "old" automated gearbox with GPS-based navigation systems allows a state-of-the-art truck to actually downshift before the steep slope of an oncoming mountain street is even visible to the human driver. This form of "foresight and decision as well as action" is a new capability of automated systems, which has recently passed new levels in freight platooning and automated passenger car driving experiments. The general prediction is that automatically driven vehicles are in the long run safer than those controlled by humans; the main obstacles to their further introduction are of a legal rather than a technical nature. More and more we see machines taking over increasingly complex tasks—not incidentally the year in which machines started to play continuously better chess than the best human being was in 2005.[4]

What comes after point "D" can only be speculated but it is not unlikely that in the future a point "E" is reached, where automated systems even *exceed* the expectations (set by humans) of society and business. This may sound risky, as "unintended and unforeseen behavior" of automated systems may rightly worry humans—not unintentionally artificial intelligence is listed as a risk by the "Centre for the Study of Existential Risk" in Cambridge. But as most technologies, it can easily be argued that risks and opportunities are usually embedded in any development, from the taming of fire to the atomic chain reaction and similar regarding artificial intelligence applications. Just for a short insight, some of an unknown multitude of applications and developments can be listed for the area beyond "E" signified with a question mark:

- Automated trucks may for example leave the motorway having information about a jam ahead or even a severe accident in order to make way for emergency operations.
- Automated production systems may increase output on specific workdays (Thursday say) due to an identified structure and repeating sequence for customer demand.
- Automated logistics systems may decide to switch to a different supplier in another country having analysed reports about imminent hostilities or fraud in the current supplier's country.

[4]The chess computer IBM "Deep Blue"; the first victory was already in 1997 against Garry Kasparov, but until 2005 human players still were able to score in some cases against computers. Today in chess ranking "ELO points" computers lead unchallenged with 3304 against the best human with 2.882 (Magnus Carlsen in 2014).

In any case, the future regarding logistics education and training (human as well a non-human) will be increasingly interesting and important to innovation processes in logistics.

In the light of the described qualification and training developments, the general model of innovation in a partnership of technological development and human qualification and training in implementation has to be scrutinized. In the past, the sequential model "A" in Fig. 6 was mostly implemented. This model of technology development, followed by implementation and finally training has a clear structure and also a very distinctive risk mechanism—workers were only trained for technologies already developed and implemented, "lost training" was therefore seldom. But in the modern world, this model is outdated as (i) the total time for change and innovation is shrinking, leaving no time for the "luxury" of sequential approaches and (ii) the volume and depth of training has severely increased, but is at the same time essential to complete a successful timely innovation.

The current model "B" is using a parallel approach for at least a part of the timeline, regarding implementation and training experiences as essential input for further technology development ("user involvement" in research and development). In some cases trainings even start before the actual implementation, i.e. before new machinery or software arrives at the manufacturing or office floor. A future outlook is suggested in model "C", where in an environment of largely automated blue and white collar work the innovation process may even be devoid of any large-scale human training. In such systems, human roles are limited to technology development as well as general oversight. Artificial intelligence and robot appliances may take over the innovation process completely by introducing new manufacturing as well as management decision concepts without necessary detailed human training.

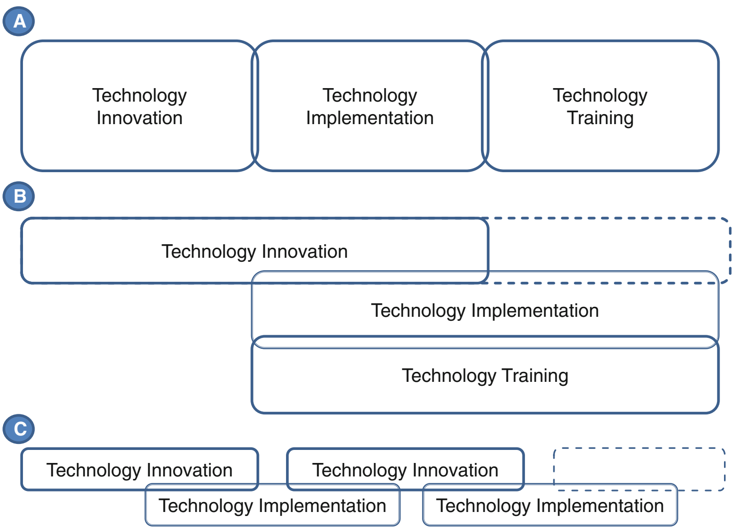


**Fig. 6** Innovation and training regimes in the past, present and future

This may also enable the phases of technology development and implementation to go largely "hand in hand" as innovation cycles grow shorter and shorter. Finally, such a foresight implies that technology development and implementation are two intertwined parallel infinite processes—as can be observed already in the smartphone app market today.

## 6 Outlook

As argued in this chapter we expect the landscape of modern logistics and supply chain management to change significantly in the next two decades, a shift unprecedented in its magnitude and impact. A comparative figure may be the development of the global *smartphone* market in the consumer arena: in 2007 there were only some "smart phones" as Apple introduced the iPhone on January 9. In 2015, only eight years later, there are more than 2 billion smartphone *users* on the planet, each on average with a computing power larger than the NASA Apollo 11 lunar module used in 1969 to put the first human being on the moon. In 2013, the annual sales volume exceeded one billion smartphones alone, bringing the average user lifetime per device to some one and a half years—a very fast and flexible market indeed. The smartphone device has already revolutionized private life, from buying to dating, communicating and learning to even selling goods and services, increasingly in a sharing economy—and all in less than a decade. An increasing number of applications and services—from travel booking to health analysis—are based on the smartphone device and are evolving faster every year. This comparative picture may indicate what the Internet of Things as well as the full use of automated systems and artificial intelligence may imply for the business context and global supply chains, as well as for its associated learning processes: nothing less than a revolution on how we do business and logistics lies ahead.

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