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Sustainable logistics: in search of solutions for a challenging new problem

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Abstract In order to establish a sound basis for discussing the notion of 'sustainability', the article starts by proposing a clear and unambiguous definition that can serve as an anchor for further research as well as for discussions with and among scientists, managers and politicians, ideally across different disciplines. The basic assumption behind the developed approach is the conviction that in order to make logistics sustainable, we will have to reinvent larger parts of it. The author argues that this cannot be achieved if logistics remains in a position where it only has to ensue the presettings of other department's means (especially those of marketing) thus neglecting fundamental interdependencies. The interdependency highlighted here is the effect of an uncontrolled product proliferation on sustainability that can only be understood when looking at a formerly hidden multilevel chain of cause and effects crossing the borders between the functional departments of a company. As a consequence the author argues that within companies striving seriously for sustainability the status of logistics must (and consequently will) be enhanced. Among the drivers of change, a special attention is given to the future role of transportation costs.

Keywords Supply chain management · Systems thinking · Organisational structures · Flexibility · Transportation costs · Climate change · Greenhouse gas emissions · Lead time extension

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1 Sustainability research beyond 'greenwashing'

Three years ago the international consulting company BearingPoint conducted a survey study exploring actions taken by companies seeking to enhance the sustainability of their operations. They summed up their findings by stating: 'When companies take action, they are typically taking the easy route of reputation and brand protection on green messaging' (see [1]).

This may be one reason why quantum leaps towards the goal of sustainable logistics are not being observed in the business world. Unfortunately, science, in this respect, does not seem to have moved far ahead of business practice either. Harris et al. [2, p. 116] state that 'there has been little research on the impacts of supply chain practices on green logistics performance'. And after combing through the current literature, Halldorsson et al. [3, p. 89] evaluate the level of discussion as 'rather sobering'.

This article is meant as a contribution to fill this gap. It aims to address some of the deeper causes for the apparent lag of progress in the search of solutions to the sustainability challenge. For obvious reasons, it will have to start by clarifying what is and what should be meant when using the notion of 'sustainability'. This has to be done with sufficient accuracy, because a definition that helps the cause should be stable enough to serve as an anchor for further research, as well as for the discussions among scientists, managers and politicians. It should work across different disciplines.

The character of this paper is purely conceptual. The argument is based on the comparison of a new model of the processes and network architectures in the field of logistics with more traditional ones in order to

- detect previously neglected impacts of logistical processes and architectures on the environment and

- provide new directions to action avoiding these neglected impacts and to align logistics more with the requirements of sustainability.

This can neither be done with the help of quantitative models nor by collecting data and testing hypotheses or conducting survey studies, because pivotal lines of argument are not quantitative or quantifiable by nature. A strictly empirical approach can only generate ex-post-judgements about the viability of innovative concepts.

The major intention of this paper is to stimulate und support thinking about *alternative* measures and *alternative types of* models that will be needed in the future. Hopefully, it will contribute to move thinking ahead of still unsatisfactory current business practices. The basic assumption behind this approach is the conviction that in order to make logistics truly sustainable, significant parts of it we will have to be reinvented. Academics doing research in the field of logistics should not shy away from the challenge of restating and reinventing fundamental premises of their work by premature commitments to a rigid methodology. They should provide room for critical, out-of-the-box thinking about the content of established strategies, of the structure of their models and of potential secondary effects of strategy implementation.[1]

2 A proposal for a meaningful definition of sustainability

The current debate on ‘sustainability’ is based on many years of an intense examination of its meaning and implications. A major initial impulse was the report of the Club of Rome on ‘The Limits to Growth’ [6]. Meanwhile, the number of articles and books published on this subject matter can hardly be counted any more. Nevertheless, one still has to notice that there is no clear and generally accepted definition of ‘sustainability’. As a consequence, this important concept is used in an inflationary manner, thus giving too much room for hollow public ‘commitments’ and management activities not going beyond a mere ‘greenwashing’. A typical indicator for this conceptual aberration is the frequent talk about ‘green logistics’ (see, e.g., the titles of the books written and edited by Emmet and Sood [7] or by McKinnon et al. [8]). Whereas ‘sustainability’ must be understood as a definite condition of a system, green is just a colour. This is unsatisfying both for scientific research and for practitioners looking for a sound basis and a mental guideline of their respective work.

Several older definitions of ‘sustainability’ refer to the notion of ‘preserving a stock of natural resources’—like a stock wood or fish. One of the first authors presenting this idea was the German forest official von Carlowitz [9] with his claim that the clearing of trees in a forest should never exceed the rate of new planting. This definition seems to be simple and self-evident (although some 100 years ago on the Easter Islands, a whole population nearly got extinct due to extreme deforestation).

However, this early, narrow definition may lead to overlook an important aspect of sustainability. Trees are more than a basic physical material provided by nature to enable us to build ships, houses or tables and chairs. They also provide important additional services like photosynthesis, the prevention of soil erosion, the retaining of rainwater, the absorption of carbon dioxide or the conservation of the diversity of species. Even the fact that trees, by casting shadow, are supporting and pleasing joggers may be regarded as a an additional service.

One might argue that this insight does not yet establish the necessity to expand the definition of sustainability just mentioned. By preserving the number of trees in a forest physically, one automatically preserves all the secondary functions that these trees deliver to human beings. But once we start to calculate the external effects of cutting trees, we will immediately realise that in doing so we loose much more than building materials (for an early discussion of the important notion of ‘external effects’ see Scitovsky [10]). Moreover, an automatic connection between the preservation of certain physical stocks and related functions and services does not always hold because there are systems providing functions that are not based on physical stocks.

If we were asked, for instance, what we regard as the most important property of an economically sustainable transportation system, then we would presumably answer that it should allow to carry people or goods from a place of origin to a place of destination at an acceptable cost and within an acceptable time such that we can maintain our current level of economic wealth. Of course, there is some kind of capital stock involved in order to produce such a service, and we understand that this stock (like streets, tracks and trucks) should be maintained as a condition of ‘sustainability’. But as the capacity of this stock largely depends on our intelligence of using it, the idea of a stock preservation neither is the main issue nor does it lead to an unambiguous method of measuring sustainability. We may, for instance, get more goods carried with a significantly reduced stock of equipment and infrastructure if we would

[1] Insofar this author disagrees with Mentzer and Flint’s [4] recommendation that ‘scientific’ research should be confined to the testing of theories that are ‘derived from observations of the real word’. Within the philosophy of science especially Popper [5] has brought forward serious doubts concerning the idea that theories can be generated by generalising observations. Important inventions in the field of logistics, like the just-in-time-concept, would never have been found through empirical research, simply because before they did not exist prior to their conception.

increase the capacity utilisation of trucks. So, instead of linking the notion of 'sustainability' to the idea of the preservation of some kind of stock, it would make more sense to connect it to the idea of preserving a required level of services and functions that the system should provide (like enabling a level of mobility for the people and things)!

In this latter case, an adequate measure of economic sustainability could be the maximum number of vehicle-kilometres travelled per period of time on a given transportation network, which is required to maintain a given level of division of labour in the economy, respectively, a given level of economic wealth. If looked at from a purely environmental point of view, the sustainable number of tonne-kilometres per year might be defined by the system's maximum volume of emissions allowed to keep global warming within a tolerable range.

In the first case, the main function of a transportation system is the support of an economy based on given level of the division of labour. In the second case, an additional requirement is added, which rather shows the character of a restriction. Transportation will probably always be associated with greenhouse gas emissions, and it will therefore never be 'green'. But hopefully it can be organised in a way which keeps these emissions within an acceptable scale. It is one of the new functions of logistics—a function beyond the strictly economical one—to arrange for this and thus to contribute to a sustainable way of working and living.

As a conclusion from the argument developed so far we propose to regard systems as 'sustainable', which are adapted to a set of actual or foreseeable future conditions, restrictions and requirements in a way that they can reach and/or maintain their desired state and need no further adaptation as long as these conditions hold. Vice versa, systems may be called 'unsustainable' which have left important adjustments unsettled.

Admittedly this is a rather abstract definition that could be applied to any other systems than logistics as well (for instance, it can also be applied to social security systems facing an aging population). But this is rather an advantage than a shortcoming, because it supports discussions across different disciplines and fields of action on the basis of a common understanding of a basic issue concerning the future of mankind. One only has to link this definition to a concrete reference system in order to use it for the analysis of practical or theoretical problems.

This definition shows some analogy to the way biologists think when they look at the reason why some species survive in a changing environment while others do not. But the reference to a 'desired state' means that when talking about sustainability, we are not only concerned with survival 'by all means', but with reaching or maintaining a situation in which life is perceived as worth living by the majority of people. The majority of climate scientists agree about the proposition that beyond an increase in temperature of 2° (Celsius, compared to the average temperature of 1850) the living conditions for large parts of the world population will deteriorate dramatically. Following Elkington [11], many authors would add that sustainability by definition is only reached if the requirements of a 'Triple Bottom Line' containing environmental as well as economical and social aspects are fulfilled. This view can be supported with some strong arguments, but it makes the measurement of sustainability almost impossible, because it encompasses a large number of complicated goal conflicts and different fields of action including areas that are largely out of scope for many managers (especially those in the field of logistics). So a more flexible definition like the one proposed here, which allows the coupling with separate reference systems and specific breakdowns, can make 'sustainability' more tangible.

Connecting the notion of sustainability to the idea of a system that has adapted itself successfully to actual and expected future changes and thus has gained the capability of still continuously achieving its goals provokes the association of an equilibrium. Sustainable systems are in a stable balance with their environments, even under changing environmental conditions and uncertain future requirements—they are capable to maintain a dynamic equilibrium!

It is important to understand that the definition proposed above connects sustainability to '*foreseeable* future conditions and requirements', thus making judgements about the state of a system under inspection dependent on forecasts. This has two important implications:

1. sustainability requires the *permanency* of solutions for the foreseeable future (e.g. if the transportation sector is expected to show continuous growth rates, changing the modal split between road and rail can only generate a limited ease thus contributing to the achievement of sustainability without being sustainable in itself);
2. 'sustainability' must be regarded as a leading concept capable to enlighten our way into the future and to measure progress without enabling us ever to fix a date when we have finally done our job. Whenever we have reached a status where no more adaptation seems necessary an unforeseen further change in basic conditions and determining factors may appear forcing us readapt again.

The latter point marks a difference to the popular idea of connecting sustainability to some kind of stock preservation. Stock preservation can be a sustainable solution, but in some important cases, it will turn out to be insufficient. For instance, while depleting oil reserves the search for substitutes is unavoidable. Renewable energies are not derived from finite resources which we must maintain for future generations, but they can possibly solve a part of the problem. Thus, the definition proposed here encompasses the idea of stock preservation without restricting the notion of sustainability to it. This is also important because sustainability has to do with the limited capacities of sources *and* sinks.

Sources like raw material deposits usually are owned by someone (companies or the state), so we can leave the dealing with their scarceness to the market mechanism. Some sinks like garbage dumps are owned as well. But when we use nature as a sink (like we do when we store greenhouse gas in the atmosphere) there is no owner who attaches a price tag on this scarce capacity. This forces and legitimates politics to act as if they were owners of the sinks thus preventing market failure by internalising external costs (for instance, by creating a market for sink permits in a 'cap and trade' mode; a detailed explanation and discussion of the concept of emission trading which was first developed by Dales [12] have been delivered by Zwingmann [13]).

In order to conclude the debate on the notion of 'sustainability', we have to look at another popular definition that might be regarded as a competing alternative. According to the report of the World Commission on Environment and Development on 'Our Common Future' (also called 'Brundtland-Report') 'sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. [14, p. 43]. One might argue that the definition delivered above contains the requirement of attending to our children and grandchildren while demanding the maintenance of a 'desired state'. But this argument would overlook that caring about the well being of our descendants is the answer to a *moral* question. Most economists regard moral issues as a subject matter that cannot be treated within their theories (they analyse what they call 'moral hazard' as an empirical phenomenon within the 'principle-agent-theory' but shy away when asked to develop 'normative' recommendations by themselves. For a more detailed discussion of the theory mentioned see the reader of Brousseau and Glachant [15] on 'New Institutional Economics').

The moral implication of including the needs of future generations into our goal system becomes clear, if we look at our economy as 'an open subsystem of the larger earthsystem', and accept that this larger system is 'finite, nongrowing and materially closed' [16, p. 15]. In the 30-year-update of their famous book on 'Limits to Growth', Meadows et al. [17], in preface, state that around the year 2000, mankind has claimed 1, 2 times of the resources that the earth can provide under the condition of sustainability. If we regard our children as principles and ourselves as agents acting on behalf of them we have to admit that obviously some opportunistic behaviour creating moral hazards is already taking place.

3 Possible contributions of logistics to a sustainable economy

In the past years, the variables that have to be controlled in order to achieve 'sustainability' have been largely restricted to the level of greenhouse gas emissions. Although global warming is a very frightening threat to mankind, this has deprived other variables like the diversity of species or clean, drinkable water of some of the attention they deserve. On the other hand, the focus on emissions helps us to concentrate our energy and attention on a very important issue. Furthermore, within the field of logistics, this goal displacement is less harmful than in other areas of politics or management.

In the preceding section of this paper, 'sustainability' was defined as a property or a state of a system (this idea has first been published in [18]). In a narrow sense, logistics is not a system because it is not an entity that can fail to survive in its own environment. Nevertheless, as a subsystem of a company, logistics controls many resources and activities that have a large impact on the sustainability of the respective company's activities. The most important single one of these activities is transportation:

> The transport sector is a huge consumer of energy (accounting for 19% of global final energy consumption in 2007) and will account for 97% of the increase in world primary oil use between 2007 and 2030. The consequent implications of oil-dominated road transportation to future energy supplies and to greenhouse gas emission mean that reducing the amount of fuel used in this sector is one of the highest priorities for all countries [19, p. 11].

This remaining section of this article will not discuss all the options that are at the disposal of logistics in order to keep the transportation activities at a level that is compatible with the capability of the earth to supply energy and to absorb greenhouse gas.[2] It will focus on the question to what extent the containment of transportation activities at 'sustainable' levels can be achieved through the means and powers that logisticians typically command. The answer that will be arrived at will be sobering to transport and logistics decision makers, as Fig. 1 suggests:

[2] For a detailed discussion of other aspects see Bretzke and Barkawi [18]!

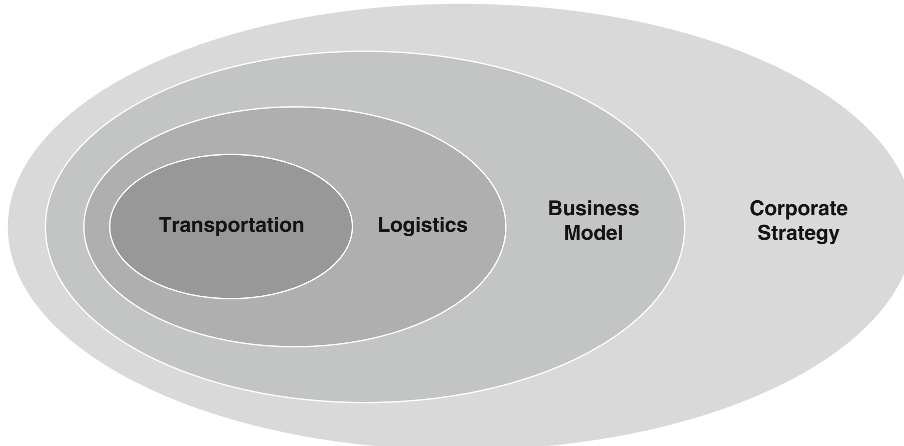


Fig. 1 Areas of management

The figure shows a hierarchy of managerial concerns in a typical business organisation. Transportation management is assigned to the lowest level and is therefore restricted to a rather limited scope of activities, such as vehicle routing. Logistics comprises transportation management and has more means at its disposal, e.g., the replenishment of inventory. A typical example for a responsibility at the level of logistical responsibilities and decision making is the configuration of a distribution network by which consolidation of cargo volumes and better transport capacity utilisation may be achieved. The effect of those higher-level logistical decisions is likely to be more powerful with respect to the system's sustainability than the actions at the transportation operation level. Tolerating longer lead times may be another example for the potential impact of higher-level logistical actions, because it may allow for levelling peaks and troughs in the utilisation of truck capacities on a high level.

After all it changes the service profile of a company, and the shaping of this profile often is regarded as a domain of marketing or, if service profiles are meant to give the company a competitive edge, even as part of the business model. (As an important intermediate result, we can record that service levels are constraints which restrict the options of logisticians in configuring process or network models and that therefore one can contribute to render a company more sustainable by untightening these constraints).

The differentiation between business models and the overall strategy of a company cannot be drawn without some amount of arbitrariness. But a simple example can show its meaning in the given context. A German retailing company is offering its customers a completely new assortment every week. This is rather a business model with the character of an instrument than an ultimate goal (the goal being the maximisation of profit). It is rather easy to show that this business model is not compatible with the requirement of sustainability as defined above. The shops have to be supplied in two waves with the second wave responding to concrete demand signals and therefore consisting of small consignments. Due to the inherent forecast risks of this model, a considerably large proportion of the products pushed into the shelves has to be withdrawn at the end of the week, and this causes another transportation unknown in conventional retail stores (where the greatest part of the products can remain at the point of sale until they have found a customer). To complete the story, it has to be mentioned that there will be one more transportation necessary bringing the unsold products to another retailer which is specialised in making use of leftovers. If sustainability requires the reduction of transportation to an acceptable minimum (ideally without damaging the growth rates of the economy) then this business model clearly is not sustainable. But changing it usually is not regarded as the business of logisticians.

This insight can be generalised. A lot of the work of logisticians while designing the architectures of processes and networks follows the requirements of other departments (especially marketing). The consequence is that making logistics more sustainable is a challenge for the top management. Logisticians have often claimed 'systems thinking' as the central concept that should guide their work: The underpinning philosophy mentioned most often in the SCM process literature is systems thinking [20, p. 21]. But systems thinking means taking all relevant interdependencies into account that have to be regarded when defining a problem in an adequate, holistic manner. Putting logistics into a position where it only has to ensue the presettings of other departments means neglecting interdependencies. But the only hierarchy level that enables managers not only to *think* but also to *act* in a systems dimension is the top of the leadership pyramid. This argument can also be transformed into a forecast. Within companies striving seriously for sustainability, the status of logistics must (and consequently will) be enhanced. What logisticians themselves can do before they gain more attention and power is to calculate and communicate the costs of complexity which are caused by other departments who are not made responsible for the side effects of their decisions.

Probably the best example for side effects of this kind is the proliferation of products and product variants which has—in combination with more and more shortened product life cycles—damaged our ability to generate stable demand forecasts. In more and more companies, the classical textbook assumption that forecast errors occur by accident and follow the pattern of an assumed probability distribution does no longer hold. New products (among them those invented by competitors) cannibalise the sales contribution of existing items and there are no time series available, which could be used to predict their own performance. The main consequences that logisticians have drawn from this self-made uncertainty is

1. the requirement of extremely short lead times and the highest possible flexibility on the supplier's side and
2. the replacement of plan-based activities by order-driven activities within postponement concepts, changing the process architecture from a push- to a pull mode.

The first consequence can at the same time be regarded as an answer or a solution and as a new problem that is represented in Fig. 2.

The complexity trap shown in Fig. 2 has exposed many supply chains to a great stress. As will be shown later, this complexity is the result of human actions, but not the result of a goal-oriented man-made design. The results in terms of efficiency can at most be rated as ambivalent. But doubtlessly in a complex world compressing time has a significant negative impact on the sustainability of logistics. The main negative consequences are the trend to smaller fluctuating transportation lot sizes, the lost ability to sink demand peaks for transportation capacities into days with a low demand, and the incapacity to change the

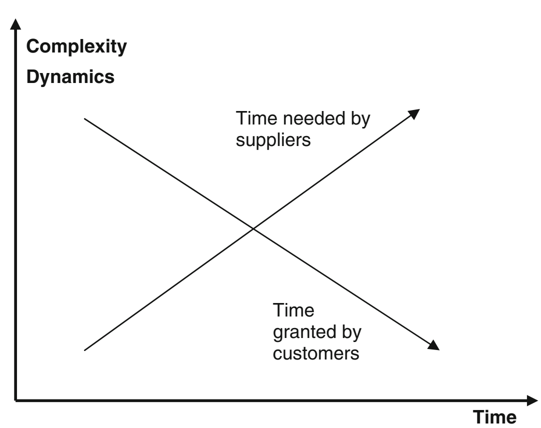


Fig. 2 The complexity trap

modal split in favour of ecologically beneficial means of transportation like railways or container vessels. Another side effect is rather hidden but can be highly relevant as well. 'In lean supply chain thinking, inventory is regarded as one of the seven wastes' [21, p. 65]. But depriving supply chains of any buffers and organisational slack in order to make them as 'lean' as possible has lead to logistical systems that are highly vulnerable. As the idea of detecting disruptions and delays immediately after their occurrence using a new tool called 'Supply Chain Event Management' turned out to be too weak to alleviate the impact of an increasing number of unforeseen disturbances, we had to accept increasing amounts of express freight shipments (a detailed discussion of the SCEM-Concept can be found in Bretzke and Klett [22]). Emergency shipments reflect the attempt to regain time that has been lost at other places before. They always indicate an unbundling of commodity streams and this undoubtedly harms the environment.

Once we have pointed out the necessity of embracing the top management of a company while looking for options to make logistics a part of the solution (instead of leaving it as part of the problem), the question remains why it is helpful or even necessary to make a distinction between business models and the strategy of a company. After all they are both part of same management domain. The reason for this distinction is simple. Only companies that embed 'sustainability' as an additional requirement into their overall strategy can be successful in pursuing this goal. 'Sustainability' can only gain the necessary attention and support on the basis of a clear and unambiguous commitment of the persons who are in charge of leading the company. And only they are able to solve goal conflicts between the requirements of profit maximisation and sustainability once they arise. It is an illusion to believe that sustainability can be reached absolutely 'free of charge'. (According to Stern [23], limiting global warming to a maximum of 2°C until 2050 would require investing an annual amount of 2% of the world's gross domestic product into measures capable of confining greenhouse gas accumulation in the atmosphere to a level of 450 parts per million).

There are mainly two reasons why the impact of marketing decisions on sustainability have not yet gained the attention they deserve. First of all the chain of cause and effect that is represented in Fig. 3 is rather complex, because it changes the direction of conventional analysis. Instead of stating that in the past, a high diversity of articles and product derivates has enforced short lead times, the message now is that in order to extend lead times one has to reduce variety. Since the basic distinctions made by Aristotle, this logic is also called 'causa finalis'. The second reason for the disregard of this chain is that it crosses the borders between the functional silos of traditional organisational structures. On the lower levels of the

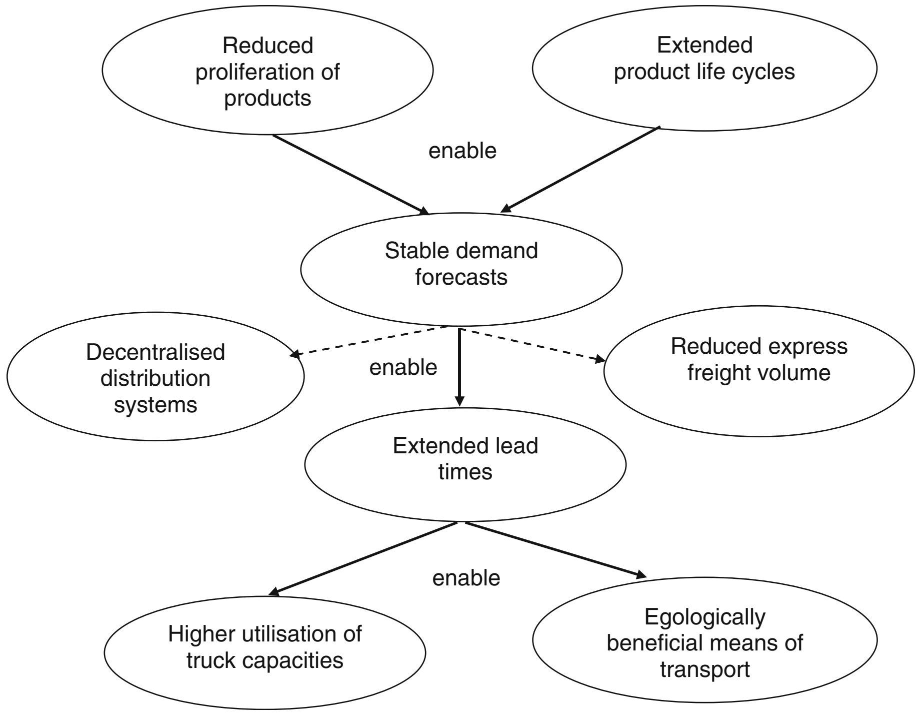


Fig. 3 A pivotal cause and effect chain

hierarchy, no one feels (and actually is) responsible for this chain as a whole, while on the top level, the necessary deeper insights into interdependencies between logistics and other subsystems of the company often are missing (that is why logisticians must gain an enhanced standing if an organisation strives to become truly sustainable). Current organisations too often restrain themselves from 'systems thinking' thus making this apparently self-evident approach a nontrivial claim.

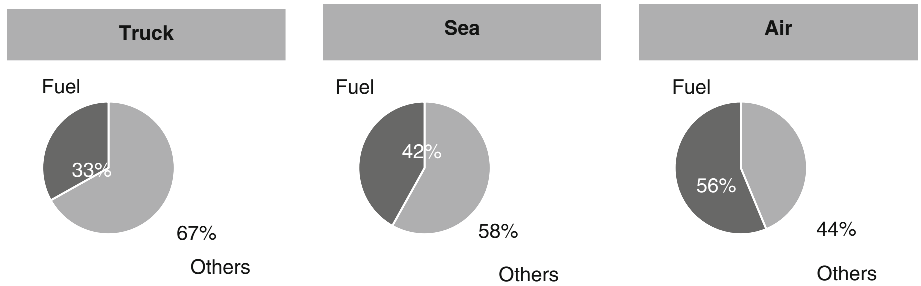
Basically, Fig. 3 shows the benefits of a decompression of time (including the enabling and furthering of decentralised distribution systems through the decoupling of stock replenishment from incoming orders). This is contrary to essential parts of modern thinking about the design of competitive supply chains, but it may turn out to be unavoidable in order take make bigger steps in pursuing the goal of sustainability. 'Competing against Time' was not only the title of a widely acknowledged book published in 1990 by Stalk and Hout [24], moreover this message has evolved as a kind of 'mantra' for a whole generation of managers, consultants and scientists working in the field of logistics. This gives the mind change that is necessary from the author's point of view the character of a paradigm shift. (According to Kuhn [25], the attributes of a 'paradigm' are the following: a shared world view (which is rather a perspective predefining our perception of reality than a theory about it), a number of standard problems (like the 'bullwhip-effect'), a number of solution statements (like calling for 'systems thinking' or the mantra of total integration combined with an utmost time compression) and a community of scientist who confirm each other in their self-absorbed way of thinking (this is not an entirely negative classification: according to Kuhn scientific research without a paradigm is impossible)).

Whether we call this current approach a paradigm or not: For comprehensible reasons, we will not achieve sustainability if we continue to create a confusing variety of products (with questionable benefits to the society), spread their segmented manufacturing across the whole globe and at the same time demand their immediate availability independent of our own location. In the past, logisticians have been praised for making the business models underlying such strategies feasible and finding ways out of the complexity trap represented in Fig. 2 time and again. In the future, they will have to work out the implications that these models have on the consumption of scarce energy sources and on the emissions of greenhouse gas. Furthermore, society will ask logisticians to develop ways to confine these effects to a sustainable level. Taking into account the effects an uncontrolled global warming would have on the living conditions of humans, this is an amount of responsibility logistics has never been confronted with (a detailed description of these effects can be found in [23]).

4 The pivotal role of transportation costs

While striving to achieve this, logisticians will gain support from an effect not discussed yet: rising transportation costs.

Fig. 4 Fuel costs depending on traffic mode



Most experts in this field expect rising oil prices in the near future. Figure 4 shows the fuel costs as a fraction of the total costs of a journey for different modes of transport (data collected recently from interviews with leading service providers in their segments). These fractions will rise further if (what has to be expected) the increase in oil prices exceeds the rise of other costs. Airfreight is the most vulnerable traffic mode. Seafreight, which is currently accountable for more than 90% of the global trade volume while only causing 2.7% of the world wide greenhouse gas emissions (according to the German agency for the protection of the environment), is the least vulnerable when calculating the cost per unit of transport (see [26, p. 11]). This is due to the large capacity of container vessels.

Oil prices are not the only cost drivers which cause rising transportation costs in the future. Bottlenecks in the infrastructure will have increasing negative impacts on the productivity of many means of transport, the costs of additional security requirements will have to be compensated, and governments are committed to internalise external effects with the help of the known instruments (tradable emission permits, charging companies with additional taxes, force the manufacturers of trucks to build lowemission vehicles and all the rest of it).

Increasing transportations costs will have only small effects on the amount of transportation per unit of gross national product for the short term (e.g. some companies will increase the reliability of their processes and those of their suppliers in a way that airfreight can be reduced to a minimum), but it can have strong effects in the long run because some important trade-offs are changed. Two effects in the area of network design deserve a special attention:

1. For companies distributing products with low or medium value/volume-rates, it will become more attractive to store these items in regional warehouses, because the decoupling of the stock replenishment from the actual customer demand allows for an optimal usage of transportation capacities. Goudz et al. (2009) confirm this while depicting the results of a simulation study in step with actual practice. Focussing on the effects of rising oil prices Simchi-Levy [27, p. 179 ff.] reports about similar effects: 'Regional distribution centres are more attractive'. Corresponding effects on the level of greenhouse gas emissions will amplify the attractiveness of decentralised distribution system. By adding two additional regional warehouses in China, the Health Care Division of the Bayer AG has been able to reduce CO_2-emissions by 75% (see [28, p. 288]). While discussing the cause and effect chain represented in Fig. 2 it was shown that reducing product variety would make the change to decentralised systems a lot easier because it lowers the requirement of largely increased safety stocks and/or sales lost due to stockouts.
2. If higher transportation costs encounter decreasing wage differences, the off-shoring of outsourced activities to low-cost countries will become less attractive. According to the paper 'The Economist' (May 14th 2011, p. 67) 'Pay for factory workers in China, for example, soared by 69% between 2005 and 2010', letting the gains from labour arbitrage shrink considerably. The only question referring to 'sustainability' is whether these effects will be strong enough and emerge in sufficient time. Managers striving for sustainability have to drive the change while at the same time they are driven by change. Waiting for the latter can be fatal.

From a short-term perspective rising, transportation costs may be perceived as an annoyance. But sustainability by definition requires a long planning perspective (which is one of the main reasons why progress in this field is disappointing so far). Within a long planning perspective, rising transportation costs will prove to be pivotal as a driver of change. In an article about the necessity to restructure the logistics systems and supply chains when striving for 'green logistics' Harris et al. [2, p. 119] notice: 'Traditional supply chain management focuses primarily on market and manufacturing issues, and transport has typically been considered as a rather marginal activity'. In order to approve this assessment, one only has to look at one of the core tools developed for the purpose of enhancing supply chain planning. Modern 'Advanced Planning Systems' are build upon the theory of constraints and represent all kinds of restrictions except one: transportation capacities in most cases have been neglected because it was assumed without saying that the market will provide them on a sufficient scale (for a comprehensive introduction into the functionality of 'Advanced Planning Systems' see the reader published by Stadtler and Kilger [29]). This will have to change. As mentioned above, the dependency of the transportation sector on fossil fuel currently equals about 98% (see also [30], p. iii). Because of the specific difficulties to decarbonise this sector experts like the general director of the EU for Energy and Transportation expect that by 2050, the transportation sector will come up for 50% of the global CO_2 emissions (statement in a speech delivered at the Logistics Forum Duisburg on March 17, 2011; the current rate regarding the freight transportation sector is around 15%). Once we acknowledge that the capability of the atmosphere to store greenhouse gas emissions is restricted and that abatement costs in this sector range significantly above average, we will learn to treat transportation as a scarce and valuable resource.

Rising transportation prices will help us to change our attitude and act accordingly. The definition of sustainability as the result of a successful and enduring adaptation to a set of foreseeable future conditions shifts our attention to the conditions in question. Some of them are rather abstract because they are derived from complex computer models used by climate scientists to simulate 'business-as-usual-scenarios'. This makes the required adaptation somewhat delicate. In contrast, rising transportation costs will appear as undeniable facts. Ignoring them is not only a missed chance to facilitate sustainability. Furthermore, it will have negative impacts on the earning power of all companies unwilling to adapt.

5 Conclusions

In a recent article, Halldorsson et al. [3] asked themselves whether confronting supply chain management with the new requirement of sustainability is 'a blessing or a curse'. From the author's point of view, it simply is a necessity. In this article, I have tried to point out that larger parts of the concepts that are propagated under this headline have to be scrutinised and adapted. This means: in order to leave the current status as part of the problem and become part of the solution supply chain management must not only be extended, but changed. Those who accept this challenge may also think of it as a blessing (personally I would prefer to speak of an opportunity) because, as mentioned above, the status and standing of logistics and supply chain management will be enhanced. A simple evidence underlining this is the growing demand for 'carbon footprints' that can only be generated via gathering information about specific emission levels from every stage in the value chain (from 'sheep to shop'). But of course the larger challenge is waiting for us beyond the task of measuring (although for several reasons not discussed here, this can be regarded as a challenge of its own).

The main proposition presented in this article is the statement that logistics cannot be transformed into a subsystem delivering sufficient contributions to the sustainability of the company they belong to if this challenge is left to logisticians alone (at least if they are operating within the framework of a traditional functional organisation). Many of the decisions that must be regarded as root causes for making logistics unsustainable in the past are marketing-driven and/or have been taken on higher levels of the respective management hierarchy. This has a major impact on the way companies should organise themselves. In order to detect formerly hidden, cross-functional causal chains with negative effects on sustainability and in order to gain the necessary room for manoeuvre to mitigate these effects, a reassessment of the role of logistics is indispensable.

Some authors have recommended that 'all of the traditional business functions should be included in the process of SCM' [31, p. 16]. At least when looking at the organisation structures implemented in well-known German companies independent of the respective industries one has to notice that so far they did not follow this advice. Those who have established SCM as a top management function generally confined the extension of responsibility to the consolidation of logistics and procurement, thus enabling purchasing processes following the 'total-cost-of-ownership'-rule. On the other hand one can still find numerous companies in which logistics is not yet represented on the top management level. Although from an academic point of view 'systems thinking' almost appears as self explanatory, this claim has been widely ignored in practice. Nonetheless, the requirements of sustainability can only be met if companies start reorganising themselves in a way which gives 'systems thing' a greater chance.

Readjustments in the field of logistics will have to be based on scrutinising all concepts developed so far, including concepts that are currently regarded as state of the art (like the centralisation of inventory or a just-in-time-replenishment) and which, following the pull principle in a rigid manner, aim at 'one-piece-flow-models'. Many of these concepts 'carry a significant environmental penalty' [32, p. 15]. If companies redesign their organisational structure in a way that causal chains crossing the interfaces within the organisation appear in their range of sight, they can get access to more powerful options for achieving sustainability. Among other insights, it will then become clear that there is a multistage chain of causation between an abundant proliferation of products and product variants on the one side and the requirement of extremely short lead times leading to a needlessly low usage of truck capacities and an overstrained transport infrastructure at the other end.

According to Halldorsson et al. [3, p. 86], 'an ecologically sustainable company can be characterised as a company that has incorporated ecological considerations in its daily operations as well as its strategic planning'. From the author's point of view, this is not more than a basic prerequisite of sustainability. Sustainability cannot be assessed on the level of goals or 'considerations'. Instead it must be measured on the level of results. Referring to the definition proposed above, this implies that like all other segments and subsystems logistics has to contribute to transform our economy into a system that is able to produce a desired level of prosperity getting by with 20 per cent of the greenhouse gas emissions discarded in 1990. According to an agreement reached by the G8-states in L'Aquila in 2009 (the meetings held in Copenhagen and Cancun thereafter have failed to reach a global agreement on this although it is a recommendation of the United Nations International Panel on Climate Change) this goal has to be achieved by the developed countries until 2050 in order to prevent global temperatures to rise above a critical level.

If the findings of the Stern-Report on 'The Economics of Climate Change' [33] are correct temperatures rising above the critical level of 2° will change our living conditions into a previously undesired state. By definition, this would indicate our failure to reach sustainability. Technological innovations may help us getting closer to reach this goal, but reducing and/or replacing fossil fuel in the field of transportation will turn out to be more difficult than in other areas, and in a world with strong economic growth rates and an expanding global population many positive effects of an increased energy efficiency will be offset by a growing number of energy consuming products used by a growing number of people (for a more optimistic assessment of the capability of technological innovations see von Weizsäcker et al. [34]). This will leave a considerable amount of the burden on the shoulders of logisticians who have to find ways to decouple transport volume from economic growth by changing their networks and processes. 'Sustainability' therefore is a more challenging requirement than many affected managers and some experts in the field of science currently envisage, probably because 'the literature discusses the topics from a micro-point of view, but not from a macro-point of view' [3, p. 92]. In order to fully understand the meaning and the implications of 'sustainability' one has to see the whole picture.

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