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Sustainable distribution networks -challenges and opportunities

Introduction

During the last decades sustainable development has gained much attention from companies as well as policy makers (Seuring and Müller, 2007; de Brito et al., 2008). The sustainability concept encompasses "the development that meets the needs of the present without compromising the ability of future generations to meet their needs" (Brundtland, 1987:8). From an organizational point of view a sustainable organization is one that contributes to sustainability by simultaneously delivering *economic*, *social* and *environmental* benefits often identified as the 'triple bottom line' (Norman and MacDonald, 2004). The discussion concerning how these dimensions are related has been modified from a belief that the economy dimension is in contradiction to the efforts needed in the other two dimensions, to a view that the three dimensions can be simultaneously improved and thus not necessarily in conflict (Mulder, 2006; Sharma et al., 2008). However, accomplishing these improvements at the same time is no easy undertaking since the three aspects of sustainability are tightly interconnected (de Brito et al. 2008). This implies that so-called sustainable initiatives should be analyzed according to an integrated approach, which would consider the trade-off between the environmental, social, and economic axis. Hence, what "may appear as an environmental friendly initiative (e.g. the use of organic fibres) has to be read in the light of other strategic choices (e.g. relocation of production) which may counterbalance the positive effects." (ibid:549).

Since the mid 80's, governments and consumers are increasingly pressuring companies to reduce the negative impact of their operations and products concerning both environmental and social aspects (e.g. Vandermerwe and Oliff, 1990; Thierry et al., 1995; Seuring and Müller, 2007). Within the supply chain management area, these issues have been dealt with under the terms 'green supply chains' (Sarkis, 2003), 'sustainable supply chains' (Markley and Davis, 2007; Carter and Rogers, 2008), and 'integrated chain management' (Seuring and Müller, 2007). Environmental aspects refer to for example reduced CO2 emissions, development of environmentally friendly products, and reduced packaging (e.g. Walker et al., 2008). Social aspects involve dealing with improvements in issues related to work conditions such as safety and wages, labor and diversity, human rights etc (e.g. Markley and Davis, 2007).

Obviously, it is important for firms to somehow relate to these requirements for sustainability. However, in order to cope with these sustainability challenges "deep reorganisation is needed, both inside each company and between the different actors" (de Brito et al., 2008:550). Reorganising will bring various effects that will be perceived as both benefits and sacrifices for the actors involved. This is in accordance with Fritz and Schiefer (2008:443) arguing that any improvements in the supply chain activities "build on the perceived anticipation of improvements in the balance of benefits over costs; however, there are different perceptions and priorities for society (policy) and for enterprises". Furthermore, this view will not likely be identical to the various companies in the network. This is also in line with de Brito et al. (2008) when claiming that "there is not a unified

view on sustainable development and business" (p. 540) and "when companies launch new sustainability-oriented activities, conflict may arise among the different actors implied in the same supply chain" (ibid:549). Altogether, this means that each firm will have a certain view of the challenges and opportunities that comes with meeting these sustainability demands and on the action plans concerning how to handle the requirements.

With this in mind we agree with Fritz and Schiefer (2008:441) in their claim that the challenges related to creating sustainability "cannot be met by any individual enterprise but require concerted actions and coordination of initiatives", thus calling for a holistic perspective in the analysis of the potential benefits and sacrifices accompanying increasing levels of sustainability.

Aim and outline of the paper

The aim of the paper is to explore the challenges and opportunities associated with enhanced attention to sustainability. As explained above this analysis requires an understanding of the 'different perceptions and priorities' of companies that are affected, the 'conflicts that may arise among the different actors' and the 'concerted action and coordination' required. Our attempt to grasp this totality is based on the industrial network model (Håkansson and Snehota, 1995). Exploration of the potential impact of sustainability in the three network layers of activities, resources, and actors, should hopefully enhance the understanding of potential benefits and sacrifices related to increasing sustainability.

Our basic point of departure is that enhanced attention to sustainability will require changes in the distribution arrangements in the industrial network. These arrangements are simultaneously affected by other ongoing reorganizing ambitions within the network. Attempts to increase sustainability may either constrain or support these efforts. In order to explore the potential consequences in this respect we begin the paper by identifying some important recurrent modifications in the three network layers. We continue by analysing the interplay between three dimensions of sustainability and each of these ongoing changes. The paper is concluded by an analysis of the combined impact on sustainability of these other dynamics affecting distribution arrangements.

Current dynamics in distribution networks

Contemporary industrial networks are undergoing fundamental restructuring in several ways, of which the demand for sustainability is but one (e.g. Narus and Anderson, 1996; Walters, 2008). In this paper we are primarily interesting in how the distribution arrangements in these networks are impacted by the demand for sustainability. The basic function of distribution has been expressed as to "somehow bring together heterogeneous supply on the one hand and heterogeneous demand on the other" (Alderson, 1965:200). This task is still the same but the way this 'bringing together' can be accomplished is changing. Technical development in logistics, manufacturing, and information exchange makes new distribution solutions possible. Both suppliers and customers exploit these alternatives in their efforts to improve the efficiency and effectiveness of these arrangements. The ongoing reorganization impacts considerably on all three network layers. For our further analysis we will bring up a main development in each network layer and explore its potential interplay with efforts to increase sustainability.

One of the major modifications of distribution is a shift away from mass-distribution towards individualized solutions in relation to particular customers (Wilson and Daniel, 2007). This is primarily an outcome of evolvements in the resource layer where the importance of large-scale operations has been reduced. Flexible manufacturing systems have shortened production lead-times

in the same way as efficient logistics have made in distribution. Over time therefore it has become possible to design customer-tailored distribution solutions at reasonable costs and delivery times. These changes thus lead to an increasing customization of distribution arrangements which represents the dynamics in the resource layer that will be used in our analysis.

Increasing customization and less reliance on mass-distribution will have a direct impact on the activity layer. Just-in-time delivery is one example of enhanced customization. These arrangements build on tight synchronization and increase the interdependency among activities. Another effect of reduced lead-times and improvements in information exchange is an increasing attention to build-to-order production (Gunasekaran and Ngai, 2005). These arrangements also call for extensive coordination since buffers in terms of inventories will be reduced. Consequently, in the activity layer the major dynamics concern the increasing interdependency which is the issue we bring into our analysis.

Customization and activity interdependence influence the actor layer. Customization calls for variety of distribution solutions and for suppliers design of 'multi-channels' has become an important strategic issue (Weinberg et al., 2007). Actors involved in these arrangements tend to be specialized in various ways in order to play a particular role in bridging the distribution gap. Technical development has provided opportunities for various specialists, for example 'information brokers' in the flow of information and logistics service providers in the flow of goods. The third dynamic issue in distribution completing our framework for analysis is consequently the increasing specialization in the actor layer.

As a result of the changes hinted to above, distribution has become an increasingly complex issue. The bringing together of heterogeneous supply and demand is not only a matter of handling 'finished' products in a channel of intermediaries. Due to customization and built to order, there are no 'finished' products ready to be channeled out. Instead, the 'total' supply chain needs to be considered, often back to a component level. Hence, 'distribution' today is often hard to distinguish from 'production'. For example, final assembly is often performed at 'distributors' close to customers. Contemporary distribution networks, therefore, often include types of activities, for example production, not traditionally considered distribution activities.

The current dynamics in distribution are thus assumed to affect, and be affected by, efforts aiming at enhanced sustainability. As shown in the introduction sustainability has a broad interpretation and must therefore be decomposed into dimensions that can be analyzed in relation to the dynamics in distribution. In this paper we make a distinction between three sustainability dimensions: Material consumption, Transportation work and Facility exploitation. Material consumption concerns aspects relating to the use of natural resources. This includes use of raw material, handling of scrap and waste, and energy use. We also include issues regarding opportunities for recycling, reuse, disassembly and remanufacturing under this theme. Transportation work relates to how products are transported and especially this involves issues regarding use of fuel and rates of emissions of CO2. Facility exploitation is concerned with aspects relating to for example economies of scale, such as for example fill-rates in transportation facilities and the degree of utilization of distribution resources in terms of for example distribution centres.

Our framework for analysis of the potential interplay between sustainability and ongoing distribution dynamics is illustrated in Figure 1.

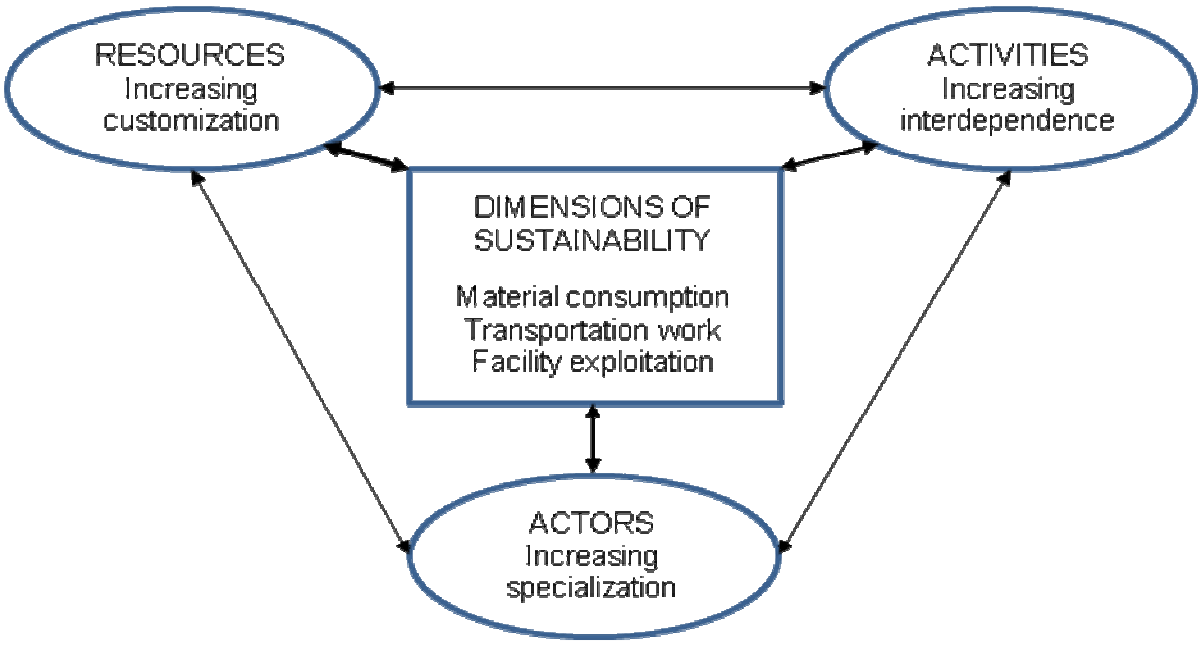

Figure 1 The interplay between sustainability and current distribution dynamics

The industrial network model seems to be a relevant framework for analysis of this complex interplay. Previous research on sustainability calls for holistic approaches. For example, Kovács (2008:1572) claims that "corporate responsibility has long been considered an issue lying within the boundaries of a company". Such perspectives imply a focus on local optimization of environmental issues within the borders of a firm (Linton et al., 2007). This view is increasingly challenged since it is argued that the tight connections to other companies should impact on the ways in which a firm is handling its sustainability efforts (Kovács, 2008). Therefore, a supply chain perspective on sustainability has been advocated (e.g. Linton et al., 2007; Kovács, 2008). With a supply chain perspective the focus is directed to the flow of goods from raw-material provision to end-customer. Another stream of research has been dealing with a reverse distribution approach emphasizing recycling of products after end-of- life (e.g. Murphy, 1988; Rogers and Tibben-Lemke, 1998; Flygansvaer, 2006). Recent research has recognized the need for an integrated perspective on forward and reverse arrangements. For example, Defee et al (2009) advocate a 'closed-loop supply chain' where the forward and the reverse supply chain need to be managed jointly. A problem with this extended approach is that this integration is limited to "the supply chains that the company operates" (ibid. p. 88). In reality, however, supply chains are interconnected. Therefore the functionality and efficiency of a particular chain is affected, and affects, the functionality and efficiency of other chains. On this basis advocates from various schools of thought have suggested a network perspective on supply chains and distribution channels (Christopher 1998; Gadde and Håkansson, 2001; Rindfleish and Heide, 1998). The same recommendation for a holistic approach can be found in the literature on sustainability. For example, de Brito et al. (2008) claim that the 'sphere and scope' of sustainability research needs to be broadened beyond the traditional supply chain boundary.

In the coming three sections we explore the interplay between ongoing distribution dynamics and sustainability. Each section begins with a description of the main characteristics of the respective change and is followed by an analysis of the potential impact on sustainability.

Increasing customization

In order to understand the impact of current dynamics we need to investigate not only where changes are directed but also from where they are derived. Going in the direction of customization means a drift away from standardization. Potential impact on sustainability thus must be considered in two dimensions: the impact of increasing customization and the impact of decreasing standardization.

As claimed in the introduction the increasing attention to customization was made possible through technical development that shortened lead-times in both production and distribution (see also Yang et al., 2005). Evolvements of production technologies made manufacturers less dependent on large scaled manufacturing (Schmenner and Tatikonda, 2005). These changes, in combination with logistics advancement, have improved delivery services considerably (Delfman et al., 2002). Moreover, developments in information technology have enhanced the conditions for exchange of information between firms, which impacts on both the efficiency of the information flow (e.g. Lichtenthal and Eliaz, 2003) and the reliability of material flows (e.g. Garcia-Dastugue and Lambert, 2003).These changes in the resource layer provided opportunities for design of cost-efficient customized solutions at reasonable delivery times. Therefore, during recent decades customization has been at the top of the management agenda in most businesses (Feitzinger and Lee, 1997; da Silveira et al., 2001).

Once technical development changed the basic distribution conditions suppliers were able to generate value to buyers in new ways. They no longer had to rely only on standardization and low cost but were able to make adjustments to the specifications from individual buyers. Suppliers now began to increasingly apply the 'logic of individualization', which made possible "a move to greater customization in a wide variety of industries" (Lampel and Mintzberg, 1996:23).

The attention to customization requires suppliers to differentiate their offerings, since customers have very diverse opinions on what is an appropriate distribution solution. This means that some end-users demand advanced solutions while others will require a very cost efficient solution (Ford et al., 2003). The actual differentiation is achieved through resource adaptations in relation to the resources of customers and other business partners. First, the physical product and the way it is packaged can be adapted. These adaptations make the product fit better in its 'use' context and the resource collection of the end-user. Second, offerings can be differentiated through extensions of the physical product in terms of various service elements, (e.g. Olivia and Kallenberg, 2003; Sawhney et al., 2004; Rothenberg, 2007). Third, customized offerings may involve adaptations of distribution arrangements (Lampel and Mintzberg, 1996). These adaptations may concern distribution facilities (e.g. vehicles, terminals etc) as well as transportation routes. Therefore, over time "channels have become dynamic webs, comprising many direct and indirect ways to reach and serve customers" (Anderson et al., 1997:59).

These direct and indirect ways to reach and serve customers have called for changes in the distribution arrangements of suppliers. Increasingly the resources required for these undertakings reside outside the ownership boundary of the company since 'multi-channel'- structures are evolving. These arrangements appear since a supplier no longer can rely only on its internal resources. Rather, they are required "to be able to combine these resources in new ways and to gain additional resources, and to do this repeatedly" (Wilson and Daniel, 2007:10). Multi-channel arrangements deal with two aspects of distribution variety. First, they contribute to handle the diversity between various customer groups. Second, these arrangements make it possible for a specific customer to select the distribution solution that is most appropriate in a particular situation (Weinberg et al., 2007).

There are obvious benefits related to the increasing customization. Resource adaptations and differentiation in relation to specific counterparts make more efficient and effective solutions available. Multi-channels and variety will increase the options for customers and therefore be value-generating. But adaptations and variety also affects value negatively since they are accompanied by

increasing costs. Adaptations and variety are always costly since they decrease standardization in turn leading to diminishing economies of scale. What is gained on the benefit side might thus be outweighed on the cost side. A supplier then must find a balance between the level of customization and the level of standardization.

One way to balance individualization and standardization is to rely on so called mass-customization strategies (e.g. Feitzinger and Lee, 1997). Mass-customization builds on the principle of modularity where pre-assembled modules are combined into end-products in accordance with customers' request. These arrangements make it possible to allow for customization at the same time as economies of scale can be secured as individualized operations downstream are decoupled from standardization upstream (Radder and Louw, 1999). In these efforts synchronized planning across company borders are required in turn calling for sophisticated systems for information exchange (Su et al., 2005).

Sustainability and the increasing degree of customization

We start by discussing how adaptations of the physical *product* impact on sustainability. With regard to material consumption, one important sustainability initiative concerns how products are designed with regard to reuse and disassembly (Carter and Rogers, 2008). This is an increasingly important area and many companies struggle with recycling, remanufacturing and refitting programs (Sharma et al., 2008). These activities are more easily accomplished when products have a modular design, which a majority of products don't. (ibid.) When producing purely customized products this modularity is harder to accomplish, which makes it more difficult to cope with these sustainability initiatives. When using so called mass-customization systems, the 'emphasis of product design will be on modular design that aids BTO processes, recycling, and remanufacturing.' (ibid.:10). Furthermore, when a product is adapted to a certain end-customer it will fit better into the 'user context' of this end-customer. This means that the product will be adapted to fit with regard to the existing resource collection in the end-customer's facility. In turn, this will lead to that the resource collection as a whole can work more efficiently with less waste. With regard to facility exploitation, a customized product might not fit into the ordinary distribution set-up in terms of facilities for material handling and transportation. This in turn might require adapted distribution solutions that do not make use of the existing resource collection efficiently.

Another issue relates to adaptations of the *product package*. Regarding material consumption, product package involves waste – package becomes waste when the product is being used and this waste needs to be taken care of. The amount of packages and what type of packages, for example if they are reusable, has great impact on sustainability through the amount of material consumption it generates. Product packages adapted to one specific customer will be hard to reuse in relation to other customers. Furthermore, if packages are designed from a pure end-customer perspective without considering aspects related to distribution this might hinder efficient facility exploitation. For example, fill-rates might be lower than would have been the case if packages were designed also from a distribution perspective.

Adaptations of *facilities* provide both opportunities and obstacles for sustainability initiatives. First, the use of uniquely designed material handling equipment can reduce environmental impact. For example, Markley and Davis (2007) report on how the automotive company Ford started to ship car parts in recyclable plastic containers that were especially designed for Ford. This reduced shipping cost by 25%. Furthermore it reduced the cost for handling packaging waste. This had a positive impact on sustainability since the total amount of transportation could also be reduced due to more efficient packing of goods. Second, by adapting distribution facilities, e.g. trucks and distribution

centres, they can be more efficiently utilized. For example, by using adapted trucks, fill rates can be improved and shipping costs as well as emissions and fuel consumption can be reduced. However, adapting towards certain products or customers makes it harder to use the facilities for other products and customers. All in all, material consumption in terms of waste can be reduced when distribution facilities are adapted to better fit a certain customer but at the same time it hinders the common use of facilities among customers which have a negative impact on facility exploitation.

As discussed earlier, increasing customization has led to *differentiated distribution solutions*. In general, transportation work will increase when working with unique deliveries to customers. However, in some rare cases, for example, if customers are situated very close to a supplier, it may be the other way around. In differentiated distribution it will be very costly and have high environmental impact if not facilities in terms of trucks, distribution centres etc, can be shared among these 'unique solutions'. Hence, share of resources becomes crucial in order to obtain resource efficiency through facility exploitation. For example, fill rates in transportations need to be considered. In order to accomplish this, each individual customized distribution solution needs to be combined with other distribution solutions in order to ensure cost efficiency as well as a sustainable solution. Cross-docking systems are used by many companies to handle this issue. If this is not accomplished purely customized deliveries can lead to highly increased emissions and energy use as well as high costs.

In order to meet requirements for sustainability, firms can help customers to consume less (Rothenberg, 2007). Increasing the share of *services* in offerings means a shift from selling products to providing services (ibid.). The main principle behind this is an effort to get more services out of fewer products. From a sustainability stand point this means less material consumption. By focusing more on services than products firms can help customers reduce costs at the same time as becoming more sustainable. For example, Xerox have aimed at improving the efficiency of their customers' handling of documents rather than selling more printers. By selling this service, customers can reduce the number of printers used, the use of related material, and by doing so they reduce cost in the same time as reducing environmental impact (ibid.). Obviously, material consumption is the main aspect here but less products produced also reduces transportation work.

Increasing activity interdependence

Increasing interdependence among activities owing to changing activity configurations are directly associated to modifications in the combining of resources. Evolving activity patterns are characterized by extensive serial interdependencies accompanying for example customer adapted just-in-time deliveries and build-to-order approaches. These patterns have replaced previous configuration relying heavily on inventories. Inventories were required to balance discrepancies between demand and supply, but also because efficient manufacturing required large-scale production and implied large set-up costs. In the efforts to serve customers within reasonable delivery times inventories played an important role and thus made warehousing a significant activity.

These inventories were not only critical resources for the effectiveness in distribution arrangements. They also served as buffers in the material flows and thus caused only limited dependence between activities. The changing conditions in the resource layer reduced the value of the inventory resources and the warehousing activities. Instead activities contributing to efficiency in material flows and information exchange gained in importance and so did the resources behind these activities. Previous activity configuration where inventories were crucial relied on standardisation and large scale and thus the logic of speculation, since supply qualities and quantities had to be decided before demand was known and thus based on plans and forecasts (Bucklin, 1965). Current changes indicate a shift from speculation to postponement, implying that operations are postponed as long as possible and

favourably until an actual customer order has been received. This approach is crucial in any customization effort since differentiation can be postponed "to the latest possible time in the marketing flow" (Alderson, 1950:1). Today, it is common to distinguish among three types of postponement; time, place, and form (Bowersox and Closs, 1996) and it is claimed for example that changes concerning inventory location should be postponed to the latest possible point in time. Ideally, the order from a customer should trigger the start of operations.

The ultimate form of postponement is build-to-order (Gunasekaran and Ngai, 2005). This approach allows "firms to effectively and efficiently customize their products" (Sharma and LaPlaca, 2005:476). Building to order reduces inventories related to raw material, work-in-progress, and finished goods as well as requirements for space (ibid.). It reduces demand uncertainty but call for enhanced synchronization owing to increasing interdependence.

Other signs of serial interdependence concern system for just-in-time delivery (JIT), efficient consumer response (ECR) and quick response (QR). In JIT-arrangements the activities of buyer, supplier, logistics providers and other significant actors in a supply chain are tightly synchronized (Claycomb et al., 1999). The main mission for the actors is to reduce, or even eliminate, work-in-progress inventories and finished inventories by ordering and delivering the exact quantity of components needed for quite a short time period. JIT-approaches are thus associated with frequent deliveries of small quantities. The outcome is thus that by "sourcing supplies on a JIT basis, companies trade off more transport for less inventory" (Yang et al., 2005:198). Quick Response (QR) was developed in the US in the mid-1980s when suppliers and fashion retailers where struggling to face the competition from off-shore manufacturers. Throughout the supply chain there were excess inventories and the long lead times from the state of raw fiber to garments resulted in fabrics that were never demanded as well as stock-outs when sales exceeded forecasts. Cooperative planning by supply chain partners and similar activity adaptations as in JIT, improved efficiency in operations but also caused increasing interdependencies (Birtwistle et al, 2003).

These evolving activity configurations can be traced back to the features of the Toyota production system established in the 1980s (Christopher, 2000; Bruce et al., 2004). The main characteristic of these configurations is the focus on reduction and elimination of waste – identified as lean manufacturing. Over time the increasing demand for customized products and distribution solutions have created a supplementary need for so called agile supply chains that can respond quickly to changes in customer needs (Christopher, 2000; Baker, 2004). These conditions induce yet other interdependences and make supply chains increasingly vulnerable.

Hence, recent developments in the network's activity layer have increased the connections among activities. Successful handling of this interdependence requires a change from efforts to optimize individual activities towards the effective integration and coordination of chains of activities (Lambert and Cooper, 2000). Issues related to integration between manufacturing and logistics processes has become a main concern for supply chain performance (Christopher and Towill, 2001; Garcia-Dastugue and Lambert, 2003). Successful efforts in this respect call for enhanced coordination between activities within a company, for example between marketing and supply chain management (Jüttner et al., 2006). However, since activity interdependences increasingly cross the boundaries of the single company coordinative action has to do the same which is a highly resource demanding effort.

Sustainability and activity interdependencies

One of the main effects of increased activity interdependencies is the reduction in *inventory*.

Reducing inventories means more transportation work and as argued by Yang et al. (2005), firms are trading off transport for less inventory. With regard to material consumption, reductions in inventory have a positive effect on sustainability. When firms use build-to-order production and just-in-time solutions they do not produce on speculation. Sharma et al. (2008) define this strategy 'reducing surplus supply', implying that firms do not produce more than needed, meaning a reduction in the use of raw material. This also means that fewer products are in need to be disposed, in turn reducing the need for recycling or remanufacturing (ibid.). Another positive effect of reduced inventory is that the risk of stored material being damaged, leading to waste, is reduced.

Another effect of increasing activity interdependencies is that JIT and BTO require more *frequent and smaller lot sizes* from suppliers. With regard to material consumption, small and frequent deliveries result in more wrappings and waste to be handled in the supply chain. Furthermore, more frequent and smaller lot sizes also increases transportation work. Hence, the efforts of reducing inventory levels in order to reach less capital costs stands against increasing costs for transportations as well as the environmental effects these transportations bring with them. In these situations the sharing of resources, e.g. co-loading and cross-docking, becomes important to obtain high fill-rates in transportation, impacting on the possibilities for facility exploitation.

Another characteristic of JIT and BTO strategies is that they rely on *postponement*. From a sustainability standpoint the postponement in form, time, and place is not unproblematic. For example, with regard to transportation work, firms may benefit from time postponement by using faster transport, e.g. air fright. However, this might often have negative impact on the environment in terms of increased emissions. Form postponement, implying that final assembly is located close to customers, might lead to more local sourcing, and thereby reduce the need for international transportation (Yang et al., 2005). However, this is not always the case since in some situations local customization is performed with components sourced globally which might even increase transportation. Hence, the transportation work is a main aspect here. Furthermore, form postponement means repacking of goods that might lead to increasing amounts of wrappings and handling of waste and hence impacts on material consumption.

The increasing degree of activity interdependencies among firms leads to *vulnerability* in the distribution networks. For example, relying on just-in-time deliveries from a limited number of suppliers might require urgent measures if there are delivery problems. This often means extra ordinary distribution solutions with for example fright transportations, extra and non standardised package and not fully utilized facilities. These actions are required by customers since the effects of delayed or cancelled deliveries will result in heavy disturbances in customers' production processes, and consequently high costs. Hence, these extraordinary solution increase transportation work, reduce the possibilities for efficient facility exploitation, and generates more waste.

Increasing specialization of actors

Customization and multi-channels on one hand and opportunities for improvements of activities through specialization have impacted considerably on the actor layer of distribution networks. In previous sections we identified that logistics service providers and information brokers may contribute to enhanced efficiency in the specialized activities in which they are involved. These forms of specialization improves efficiency primarily because it makes possible a reliance on a limited range of core capabilities and resources and providing opportunities for undertaking each function at its optimal scale. Specialization within one area, such as logistics, creates opportunities for other firms to specialize in other areas, like information exchange, according to theory on 'proliferation of opportunities' (Alderson, 1954). However, the outcome of specialized activities must in some way be integrated to form a total solution for the end-customer. Hence, specialization

in one part of an activity structure requires integration somewhere else (Piore, 1992). So the gains in efficiency that can be made if single activities need to be regarded in the light of the integration required in the larger activity structure.

Postponement might also contribute to structural changes in the actor layer. For example, form postponement "may lead to a downstream positioning of production activities from a manufacturer to a distributor" (Yang et al., 2005:198). Another example of changes in division of labour is that "postponed manufacturing activities are often included in the service offerings of logistics service providers as services supplementary to core-services of transportation and warehousing" (van Hoek and van Dierdonck, 2000:206). These types of relocation of activities have led to the emergence of new forms of 'intermediaries' in the production and distribution network. Systems integrators, configuration centres, third and fourth party logistics providers, contract manufacturers etc. have come to play a central part in these new arrangements.

The functioning of distribution networks is significantly affected by ongoing changes in resource combining and activity configuring among manufacturers. We claimed above that large scale is no longer a prerequisite for efficient operations in individual facilities. On the other hand companies specialise and focus on particular resources and activities in order to develop specific skills and capabilities which they then utilize in global operations. These large players then strive to exploit available resources in the best way and their basic approach has been described as "slicing the activities more finely and finding optimum locations for each closely defined activity" (Buckley and Ghauri, 2004:81). Through such arrangements single facilities can be operated in the most efficient way. On the other hand increasing resources are required for integration and transportation since customers are not always located in close proximity to these facilities. The enhanced attention to off-shoring to low-cost countries is a significant example of this since a huge number of studies show that off-shoring firms have underestimated the increases in logistics costs (Ackerman, 1996, Kennedy and Clark, 2006). These facilities are served by suppliers. Sometimes the facility is supplied by firms in the same low-cost country which then reduces transportation work for supply. In other situations, however, some components and systems may be shipped from a 'high-cost' country and after final assembly be transported back to customers in other parts of the world.

Finally, manufacturers with operations in 'high-cost' countries in general are increasingly relying on suppliers in low-cost countries (Byrne, 2005). The gains in manufacturing costs must be balanced against increasing transportations work. These examples of specialization and globalization make distribution and transportation intricate not only in terms of the resources and activities involved. Also the actor layer becomes multifaceted since when "a growing number of companies are getting involved in outsourcing and offshoring activities the complexity of globally distributed networks is increasing" (Slepniov and Waehrens, 2008:73-74)

Sustainability and specialization

The increasing specialization discussed above means larger and more global actors. One of the main reasons is that *capacity utilization* can be increased when activities are performed by specialized resources. When exploitation of facilities can be improved, economies of scale can be gained, which have a positive effect on sustainability.

One important issue related to sustainability and increased specialization is that a larger number of actors are involved in the production and distribution process when *activities are globally dispersed*. Furthermore, according to de Brito et al. (2008) this relocation of production and distribution means smaller sizes of deliveries which increase transportation work, and thus raise the environmental impact. Furthermore, increasing specialization means that a larger number of actors are involved in

the offering to one customer. When these suppliers are dispersed around the globe this means more transportation work with regard to serving one customer. When firms outsource activities to low-cost countries, transportation work increases even more. However, this might lead to the use of local suppliers, which limits the increase in transportation compared to if global suppliers are contracted. Form postponement is also a part of the increasing specialization and might lead to shorter distances to customers. Obviously, one important factor concerning the increasing specialization is the distance among the involved actors and how this distance is handled with regard to transportation. Different modes of transportation as well as resource sharing and cross docking have impact on the sustainability of these solutions. According to Yang et al. (2005) it is necessary to consider sustainability aspects as emission and use of fuel in decisions regarding the organisation of supply networks and subcontracting of production. In line with this we agree with Busi and McIvor (2008) that environmental requirements might act as a restriction when it comes to companies' abilities to outsource production to distant locations as China and India. However, Yang et al. (2005) point to the fact that it is not an easy decision to turn back to local production if production has already been out-sourced to a low cost country. This is mainly due to that the differences in production costs compared to transportation costs if global and local production is compared, are so large that most firms are not willing to take the increasing cost for turning back to local production. All in all, increased transportation work has a main impact on sustainability when activities are globally dispersed.

When firms specialize in certain activities it opens up for new types of actors engaging in the coordination of these globally 'dispersed activities'. Hence there is an *evolvement of specialized actors* taking part in the reintegration of these dispersed activities. Some of these firms might specialize in activities directly related to reducing environmental impacts. For example, some distributors have turned into service providers, providing waste handling services, taking care of all scrap and waste related to a delivery. Other firms specialize in 'green' transportations, focusing on using more environmentally friendly transportation facilities and using resources in a more efficient way. Hence, the evolvement of specialized actors can lead to efficient waste handling through specialized actors and thereby impact on positively on material consumption. In the same line other actors might specialize in a way that increases facility exploitation or reduces transportation work.

Discussion

So far we have discussed three different changes of importance in the contemporary industrial environment; the increasing degree of customization, the increasing degree of activity interdependencies and the increasing specialization. Furthermore, these 'changes' and their implications were viewed in the light of some aspects of sustainability; material consumption, transportation work, and facility exploitation. In the following section, we take our point of departure in the three sustainability dimensions and discuss how each of these is related to the ongoing dynamics.

Material consumption

This section brings up two important aspects of material consumption; waste and the use of raw material.

Concerning waste, the increasing activity interdependencies, point in two different directions. On the one hand, reduction in inventories and less surplus supply reduce the amount of waste. This has been one of the major positive aspects and driving forces for using JIT and BTO strategies. However, on the other hand, more frequent and smaller lot sizes, generate an increase in the need of wrappings in

need of disposal, leading to increased waste. Furthermore, form postponement means repacking and increased waste. The vulnerability created by activity interdependencies also result in more waste. The positive aspects of the decrease in waste resulting from the reduction in inventories and surplus supply is hence partly limited by the increased generation of waste from other aspects of activity interdependencies. However, this increased generation of waste can be reduced by customization of packages and wrappings as well as facilities for transportation. Furthermore, specialization of actors provides opportunities for firms to specialize in waste handling. Hence, the negative impacts on sustainability created by aspects of activity interdependencies can be handled by increased customization of packages and transportation facilities and specialized actors in waste handling.

Other aspects of customization also impact on waste. First, the increasing degree of services in product offering means a shift from selling products to creating opportunities for increased services that leads to less waste since less products are produced and handled. Second, better resource combinations from a user perspective can help to reduce for example wear of machineries, reduce scrap, and reduced energy consumption at the user's facilities. Third, in product design, the way products are constructed in terms of for example modularity, will decide the possibilities for remanufacturing, reuse, and disassembly. How products and offerings are customized is hence a crucial issue if waste is regarded. By considering customization early in the production development process and from different perspectives, e.g. use, transportation, material handling and production, the amount of waste can be heavily reduced.

When it comes to the use of raw material, increasing activity interdependencies resulting from a reduction in inventories lead to less use of raw material. In the same line customization of products means less use of material since less products are produced to stock. Furthermore, the increasing degree of services also points in this direction since it leads to less products produced. However, increased customization of products will also have an impact on the production processes. If products are only designed from a user perspective it might not be the best solution from a production perspective with regard to use of raw material. Hence, when it comes to use of raw material increasing activity interdependencies supports this. However, when it comes to customization this is not so obvious but if customizations of products are performed in a way that fits production processes this can result in less use of raw material.

Transportation work

Our discussion shows that in general increasing activity interdependencies, stemming from more frequent and smaller deliveries, reduction of inventories and postponement, lead to increased transportation work, and thereby increased emissions and use of fuel.

The specialization of actors also affects transportation work. Outsourcing and off-shoring and form postponement arrangements in general lead to increased transportation work. However, this is partly dependent on if global or local sourcing is used, which has consequences for the distances among involved actors. So in some rare cases, transportation work can be decreased. Consequently, the impact on transportation work is largely dependent on how these arrangements are organized.

The negative effects on sustainability created by increasing activity interdependencies and increasing specialization can be partly counterbalanced by the customization of facilities and distribution solutions. For example, adapted facilities for material handling and actors specializing in consolidating shipments can help to decrease transportation work. However, customized distribution solutions can also increase transportation work. Especially in cases where there is a necessity to take urgent measures in order to fulfill a delivery, this can lead to increased transportation work.

All in all, a general conclusion concerning transportation work is that the activity interdependencies have a negative impact on sustainability due to the increased emissions and fuel consumption generated by increased transportation. This can to some degree be handled by specialized actors, focusing on consolidating shipments and customized material handling facilities that might reduce the need for transportation.

Facility exploitation

One important factor for sustainability is that facilities are exploited in a way that enables resources to be used efficiently. The increasing activity interdependencies stemming from more frequent and smaller deliveries make it harder to exploit transportation facilities in an efficient way, for example fill-rates in trucks. Another potential problem is the purely customized distribution solutions, which can be the result of an ordinary customer requirement or an extra ordinary situation. In these situations facility exploitations might be very low if not efforts are made to prevent this. Specialization may counterbalance these issues since it creates opportunities for firms to specialize in the coordination of such physical flows and thereby increasing the exploitation of facilities by different types of cross-docking and co-loading arrangements.

Another important factor is how customization is handled. If customization is done purely from the perspective of the end-user and its context, this might lead to that production and distribution facilities can be less exploited since they are possibly harder to combine with other products. However, if customization is done so that the design of packages and facilities supports high fill-rates this can increase facility exploitation.

Conclusions

The aim of this paper is ”to explore the challenges and opportunities associated with enhanced attention to sustainability” in distribution. The basic point of departure is that these challenges and opportunities have to be considered in relation to other dynamics in current distribution arrangements. For this exploration we selected one major development in each of the three network layers - customization and its impact on the resource utilization, increasing dependence among activities and specialization among actors. Our analysis shows a complex interplay both among these three changes and the potential impact on sustainability in terms of material consumption, transportation work and facility exploitation. Customization supports some of the aspects of sustainability at the same time as other aspects are constrained. The same conditions are valid for the potential impact of interdependence and specialization.

Our main conclusion is that the analytical framework has shown to be useful for analysis of the multifaceted relationship between sustainability and the functioning and dynamics of distribution arrangements. First, investigations of these patterns require the identification of relevant aspects of the broad spectrum of sustainability. Second, analysis of the relationship between these aspects and the three network layers provides insights regarding the challenges and opportunities that can be expected from enhanced attention to sustainability.

A second conclusion is that the framework needs further refinement. Our analysis shows that the dynamics in each of the network layers may have both positive and negative consequences for sustainability. The aspects of sustainability therefore need reconsideration. Some of the three aspects may have to be further refined and other aspects may have to be added. The conclusion in this respect is that the framework cannot be further refined in general terms. What are relevant aspects of sustainability will differ depending on the characteristics of the contexts of particular distribution

arrangements. These features then will determine what aspects of sustainability that deserves investigation.

In the same way this context will be decisive for the characteristics that should be taken into consideration in the three network layers. So far also these features have been taken into account in terms of general dynamics. In reality, however, distribution arrangements are characterized by considerable variation in these respects. They rely to different extent on customization, the activity interdependence shows variation among arrangements and the occurrence of specialized actors differs. It might also be that some arrangements are characterized by an opposite direction when it comes to dynamics, for example less reliance on customization, reduced dependence among activities and a movement towards multi-functional actors.

Our framework for analysis of sustainability in distribution networks has been derived analytically. Adjustments and modifications of this general frame must be based on empirical investigations in various distribution contexts. Such studies will enhance the understanding of the interplay between different aspects of sustainability and the features of activity patterns, resource constellation and actor webs.

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