Life cycle assessment of clothing libraries: can collaborative consumption reduce the environmental impact of fast fashion?

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Abstract
Fast fashion is a clothing supply chain model that is intended to respond quickly to the latest fashion trends by frequently updating the clothing products available in stores. The shift towards fast fashion leads to shorter practical service lives for garments. Collaborative consumption is an alternative way of doing business to the conventional model of ownership-based consumption, and one that can potentially reduce the environmental impacts of fashion by prolonging the practical service life of clothes. In this study, we used life cycle assessment to explore the environmental performance of clothing libraries, as one of the possible ways in which collaborative consumption can be implemented, and compared the advantages and disadvantages in relation to conventional business models. Furthermore, the key factors influencing the environmental impact of clothing libraries were investigated. We based our assessment on three key popular garments that are stocked in clothing libraries: jeans, T-shirts and dresses. The results showed the benefits of implementing clothing libraries associated with the garments’ prolonged service lives. Therefore to achieve environmental gains, it is important to substantially increase garment service life. Moreover, the results quantitatively demonstrated the potential risk of problem shifting: increased customer transportation can completely offset the benefits gained from reduced production. This highlighted the need to account for the logistics when implementing collaborative consumption business models.

Keywords: Problem shifting, Apparel, Climate change, Ecotoxicity, Eutrophication, Water use

Highlights
• Environmental advantages and disadvantages of clothing libraries for collaborative fashion consumption were compared with conventional business models.
• The influence of key variables on different phases of the life cycle in the clothing libraries scenarios was identified.
• To achieve environmental gains, it is important to substantially increase garment service life and to consider the logistics.
1. Introduction
“Fast fashion” is a clothing supply chain model that is intended to respond quickly to the latest fashion trends by frequently updating the clothing products available in stores (Byun & Sternquist, 2011; Moore & Fernie, 2004). Major retailers, for example H&M and Zara, have adopted fast fashion by introducing new clothing designs to stores every three to five weeks (Hu et al. 2014). With rapidly shifting fashion trends, the practical service life of clothes (how long they are actually worn) is short, well below the technical service life (how long they could be worn, even if they are no longer in fashion). Furthermore, clothes may not be taken care of properly and may be disposed of without much thought. This makes fast fashion an important driver of environmental impacts (Roos et al., 2015).

Collaborative consumption is an alternative way of doing business that can potentially reduce the environmental impacts of fashion, by prolonging the practical service life of clothes. Collaborative consumption has been defined as “people coordinating the acquisition and distribution of a resource for a fee or other compensation” (Belk, 2014), which can include the renting, trading, swapping and borrowing of goods (Piscicelli et al. 2014). Collaborative consumption is part of the so called “sharing economy”, which has gained increased attention in recent years (Belk, 2014). Apart from collaborative consumption, a plethora of similar and related terms have emerged, for example “commercial sharing systems”, “product-service systems”, and “access-based consumption” (Belk, 2014).

There is considerable hope that collaborative consumption and other sharing economy business models will transform society and reduce environmental impacts (Mont, 2002; Botsman and Rogers, 2010; Gansky 2010; Armstrong and Lang, 2013; Heinrichs, 2013; Agrawal et al., 2015; Pedersen and Netter, 2015). Several studies have evaluated the environmental performance of various business models of the sharing economy (Goedkoop et al., 1999; Tukker, 2014; Agrawal et al. 2015), including the reuse of clothes (Woolridge et al., 2006; Farrant et al., 2010). These studies show both opportunities and potential pitfalls of collaborative consumption. A potential pitfall is the risk of rebound effects that offset the environmental gains. For example, Leismann et al. (2013) hypothesised that the impact of more frequent transactions of goods (e.g. related to transportation and/or packaging) may be higher than the impact reduction in production.

In the fashion industry, an example of a collaborative consumption business model is the clothing library, in which a monthly membership fee allows members to borrow a specific number of clothing pieces in a set time, typically a few weeks. Successful small scale enterprises in Sweden demonstrate the business potential of clothing libraries, including Lånegarderoben (www.lanegarderoben.se) and Klädoteket (www.kladoteket.se). From the perspective of the user, clothing libraries can maintain or even increase the speed of fashion, as each user may update his/her wardrobe at least as frequently as with conventional fashion consumption. On the other hand, from the perspective of the clothing item,
clothing libraries can slow down the speed of fashion, assuming that each item is used more times before disposal compared to conventional fashion consumption. In this way, clothing libraries can prolong the practical service life of clothing items, and reduce the production of new clothing and the associated environmental impacts. However, while Leismann et al. (2013) made a qualitative hypothesis regarding the general idea of clothes swapping, no previous study has quantitatively assessed whether the environmental gains in production induced by clothing libraries could be offset by environmental losses elsewhere in the product life cycle. This topic is explored in this article, for the geographical context of Sweden, by means of the following research questions:

1. What are the environmental advantages and disadvantages of clothing libraries in relation to conventional business models?
2. What are the key controlling factors influencing the environmental impact of clothing libraries?

2. Method
In order to assess the environmental impact of clothing libraries, life cycle assessment (LCA) was conducted according to the ISO 14044 standard (ISO, 2006). Three different garments were analysed: a 100% cotton T-shirt, a pair of 98% cotton/2% elastane jeans and a 100% polyester dress. Statistics on Swedish fashion consumption were used to select these garments so that they together would provide a representative picture of the Swedish fashion consumption in terms of material production, fabric construction, finishing, customer behaviour and end-of-life handling. For details on selection of garments, see Roos et al. (2015).

GaBi software was used for modelling the product systems (www.gabi-software.com). Background processes were modelled with data from databases, mainly the Ecoinvent database (Hischier, 2003).

2.1 Goal definition, functional unit and system boundaries
The goal of the study was to assess the environmental impacts associated with different clothing library setups. Therefore, 12 scenarios representing different types of clothing library business models were created. These scenarios were compared with the baseline scenarios reflecting a regular fashion business model, i.e. that the customer purchases and owns the clothing. The functional unit was defined as “one average use” of each of the three garments. “One use” means using the garment at some point within a 24 hour time period. The choice of one use as the functional unit was made to facilitate evaluation of the influence of interventions to prolong the service life of the garment (i.e. more users during the garment’s life cycle).

This is a cradle to grave LCA study, spanning from raw material extraction to end of life treatment. The life cycle of each garment included fibre, textile and garment production, distribution,
wholesaling and retailing, use (including the customer’s transportation and laundry) and end of life handling, as shown in Figure 1.

![Figure 1: Life cycle phases included in the baseline scenarios and the clothing library scenarios](image)

2.2 Selection of impact categories and characterisation methods
The focus of the study lay on investigating environmental impacts for climate change, fresh water consumption, fresh water ecotoxicity and fresh water eutrophication since these environmental impacts appeared to be among the indicators with highest relevance for the clothing sector (Roos et al. 2015). Results for land use, human toxicity and acidification were excluded from this paper since result for the land use was correlated with freshwater consumption, results for human toxicity were correlated to fresh water ecotoxicity, and results for acidification were correlated with freshwater eutrophication. Results for the excluded impact categories are provided in Roos et al. (2015). The characterisation models used in this study were global warming potential with a 100 years perspective (GWP100) excluding biogenic CO2 emissions (IPCC 2013), consumptive freshwater use (Swiss Ecoscarcity model) (Frischknecht and Knöpfel , 2013) , ecotoxicity potential (USEtox model) (Rosenbaum et al. 2008) and freshwater eutrophication potential (EUTREND model) (Struijs et al. 2009) as implemented in GaBi v 6.0 (Thinkstep, 2015).

2.3 Life cycle inventory
2.3.1 Scenarios
In this study, we aimed to map the life cycle of garments in a way which is statistically representative of Swedish fashion consumption, both in terms of production and use. For the fibre, fabric and garment production phase it was assumed that each garment was produced in the three countries that dominate clothing imports to Sweden – China (32% of clothing imports to Sweden), Bangladesh
(11%) and Turkey (6%)% (Statistics Sweden, 2014) – and that retailing, use and end of life handling occur in Sweden.

For construction of the clothing library scenarios different parameters were varied including: (i) the extension of the garment’s service life (two or four times the garment’s service life assumed in the baseline scenarios; to make this feasible one may have to extend the technical service life of current garments, or only use particularly durable garments), (ii) the type of customer transportation (the same means of transportation as in the baseline scenarios for medium impact, or low or high impact means of transportation, respectively), and (iii) whether the setup is an offline (physical store) or online (internet, with a pick-up point for deliverables) solution (this influences mode of transportation to and from the store/pick-up point and distances). The scenarios are shown in table 1.

Table 1: Collaborative consumption scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Service life compared to baseline</th>
<th>Type of customer transportation</th>
<th>Type of setup</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x2</td>
<td>Medium impact customer transport : 50% car/50% bus to/from store or pickup-point</td>
<td>online</td>
</tr>
<tr>
<td>2</td>
<td>x4</td>
<td>Medium impact customer transport: 50% car/50% bus to/from store or pickup-point</td>
<td>online</td>
</tr>
<tr>
<td>3</td>
<td>x2</td>
<td>Medium impact customer transport: 50% car/50% bus to/from store or pickup-point</td>
<td>offline</td>
</tr>
<tr>
<td>4</td>
<td>x4</td>
<td>Medium impact customer transport: 50% car/50% bus to/from store or pickup-point</td>
<td>offline</td>
</tr>
<tr>
<td>5</td>
<td>x2</td>
<td>Low impact customer transport: Bike/walk to/from pickup-point</td>
<td>online</td>
</tr>
<tr>
<td>6</td>
<td>x4</td>
<td>Low impact customer transport: Bike/walk to/from pickup-point</td>
<td>online</td>
</tr>
<tr>
<td>7</td>
<td>x2</td>
<td>Low impact customer transport: 100% bus to/from store (e.g. city centre)</td>
<td>offline</td>
</tr>
<tr>
<td>8</td>
<td>x4</td>
<td>Low impact customer transport: 100% bus to/from store (e.g. city centre)</td>
<td>offline</td>
</tr>
<tr>
<td>9</td>
<td>x2</td>
<td>High impact customer transportation: 100% car to/from store</td>
<td>online</td>
</tr>
<tr>
<td>10</td>
<td>x4</td>
<td>High impact customer transportation: 100% car to/from store</td>
<td>online</td>
</tr>
<tr>
<td>11</td>
<td>x2</td>
<td>High impact customer transportation: car to/from pickup-point</td>
<td>offline</td>
</tr>
<tr>
<td>12</td>
<td>x4</td>
<td>High impact customer transportation: car to/from pickup-point</td>
<td>offline</td>
</tr>
</tbody>
</table>

The use phase includes the customer’s transport to and from the store and the residential laundry. The influence of the type of customer transportation was explored in the clothing library scenarios by assuming scenarios with medium, low and high transportation impacts. Medium impact transportation is 50% car/50% bus for both online and offline scenarios (this is the same ratio between car and bus as
High impact transportation is 100% car for both online and offline scenarios. Low impact transportation is using bicycle or walking to the pick-up point for the online scenarios, and using 100% bus for the offline scenarios (these assumptions are further discussed below). The datasets used for transport modelling for the car and bus were the Ecoinvent v2.0 datasets “RER: transport, passenger car” and “CH: transport, regular bus”, respectively (Spielmann et al., 2007). For the baseline scenarios and the offline scenarios we assumed a customer transport of 17 person-km/kg of purchased garment based on Granello et al. (2015). For online scenarios, transportation distance from the customer’s home to the pick-up point (where the online orders are delivered) was assumed to be one third of the distance in the offline scenarios. This change in distance between the physical stores in the offline scenarios and the pick-up points in the online scenarios is an estimation based on the fact that pick-up points in Sweden typically are located in small stores closer to residential areas than city centres or shopping malls (the normal locations of physical clothing stores). Furthermore, the possibility of home delivery was not explored as clothing most often renders a size of packages which, in Sweden, seldom is home delivered. Furthermore, as mentioned above, the differences in distances between online and offline scenarios influenced our assumptions of modes of transport: as pick-up points in the online scenarios can be assumed to be within walking distances to the home of many customers, we assumed that the low impact transport mode for the online scenarios to be bike or walking. In contrast, as the distance to physical stores are longer, we assumed the low impact mode of transportation in the offline scenario to be public bus. In building the scenarios, our aim was to reflect on the main uncertainties of relevance for clothing libraries in Sweden. In studies of clothing libraries in other geographical contexts, other assumptions and scenarios might be relevant to set up, e.g. because of differences in city planning, urban density, postal services, and other factors potentially influencing the logistics of collaborative consumption.

In the clothing library scenarios, the store could take responsibility for some of the laundry and thus do this more efficiently, but there could be more frequent laundry compared to the baseline scenarios (e.g. the customer washes the garment before handing it back to the store, the store washes the garment, and then the customer washes it before use). Therefore we assume the garment is washed, dried and ironed in the same manner as in the baseline scenarios when the customer does the laundry at home. For the laundry phase, Swedish conditions were assumed, therefore the Ecoinvent data set “Electricity, low voltage, at grid/SE S” (Frischknecht & Faist Emmenegger 2007) was used to model the electricity use.

Table 2 summarises the specification of each garment and the use phase parameters for the baseline scenarios and the clothing library scenarios. The average number of uses per garment in the baseline scenarios – which determines the actual service life of the garment – is estimated based on the number of garments an average Swede purchases per year according to Swedish statistics on net annual imports of garments in 2008 (Statistics Sweden, 2014) and the SMED study of the textiles flow in Sweden (Carlsson et al., 2011). The number of days each garment is used per year and number of
washes per garments life cycle are based on a study of customer behaviour carried out by Gwozdz et al. (2013) and on a survey among 225 Swedish fashion customers carried out by Granello et al. (2015); also, some complementary assumptions were necessary. For further details on the data inventory, see Roos et al. (2015). In the clothing library scenarios, more customers are assigned to each garment compared with the baseline scenarios. Since this number is an estimate, the effect of the choice of number of customers on the environmental burden was tested by a sensitivity analysis, in which we halved and doubled the number of customers per T-shirt service life in scenario 3 (22 customers), i.e. we varied the number of customers who rent the garment from the clothing library (assuming the number of uses per service life remains the same).

Table 2: Garments specifications and user behaviour for the baseline and clothing library scenarios

<table>
<thead>
<tr>
<th>Garment</th>
<th>T-shirt</th>
<th>Jeans</th>
<th>Dress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>110 g</td>
<td>477 g</td>
<td>478 g</td>
</tr>
<tr>
<td>Textile material</td>
<td>100% cotton</td>
<td>98% cotton</td>
<td>100% polyester</td>
</tr>
</tbody>
</table>

**Baseline scenarios**

<table>
<thead>
<tr>
<th>Medium impact transportation</th>
<th>50% car</th>
<th>50% car</th>
<th>50% car</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% bus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low impact transportation</td>
<td>100% bus</td>
<td>100% bus</td>
<td>100% bus</td>
</tr>
<tr>
<td>High impact transportation</td>
<td>100% car</td>
<td>100% car</td>
<td>100% car</td>
</tr>
<tr>
<td>Customer transport distance</td>
<td>17 km distance back and forth</td>
<td>17 km distance back and forth</td>
<td>17 km distance back and forth</td>
</tr>
<tr>
<td>Number of uses</td>
<td>22</td>
<td>200</td>
<td>10</td>
</tr>
<tr>
<td>Number of uses per laundry cycle</td>
<td>2</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Number of customers per service life</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Collaborative consumption scenarios – twice (“life x2”) and four times (“life x4”) the garment service life**

| Number of uses before disposal (life x2) | 44 | 400 | 20 |
| Number of uses before disposal (life x4) | 88 | 800 | 40 |
| Number of customers before disposal (life x2) | 11 | 10 | 15 |
| Number of customers before disposal (life x4) | 22 | 20 | 30 |

3. Results and discussion

To acquire an overall perspective regarding the environmental impact associated with each collaborative consumption scenario, the results for climate change, freshwater eutrophication,
freshwater consumption and freshwater ecotoxicity are shown for the medium transport impact scenarios. The results are normalised to the baseline scenario with medium impact transportation results, which are shown with black bars in figure 2. The results for low and high transport impact are shown in error bars for each scenario. For details on the absolute value of the results, see Roos et al. (2015).

![Figure 2: Normalised results of environmental impact potential indicators of one use of a T-shirt for the medium transport impact baseline and clothing library scenarios, the results related to low and high impact transport for each scenario are shown as error bars. (In the legend: life x2 and life x4 mean: two or four times longer garment service life compared to the baseline scenarios). This implies 44 or 88 uses before disposal, and 11 or 22 customers before disposal, respectively.]

The results for global warming show the online scenarios lead to more savings comparing with the offline scenarios. The offline scenario which doubles the garment’s service life and which has the highest transportation impact potentially leads to 26% higher global warming potential compared to the baseline scenario with medium impact transportation. It is necessary to lengthen the service life by a factor of four for the improvement in global warming potential to be independent of the transportation used.

In terms of freshwater eutrophication, the online scenario with four times longer service life and low transportation impact potentially leads to 60% lower impact. Among the medium transportation impact scenarios, the online scenarios lead to lower impact compared with the offline scenarios.

The results for freshwater consumption show savings up to 75% in the clothing library scenarios in comparison with the baseline scenario with medium impact transportation. For freshwater consumption the type of transportation does not play a major role since most of the water consumption
is related to the production phase. Since there were no major variations in the results due to the type of transportations in the scenarios, no error bars are shown for this indicator.

The results for freshwater ecotoxicity potential show that assumptions regarding the type of customer transportation have considerable influence on the environmental burden. Online services with walk/bike transport leads to 35% savings in ecotoxicity potential comparing to the baseline scenario with medium impact transportation.

Figure 3: Normalised results of environmental impact potential indicators of one use of a pair of jeans for the medium transport impact baseline and clothing library scenarios, the results related to low and high impact transport for each scenario are shown as error bars. (In the legend: life x2 and life x4 mean: two or four times longer garment service life compared to the baseline scenarios. This implies 400 or 800 uses before disposal, and 10 or 20 customers before disposal, respectively.)
Figures 3 and 4 show the normalized results of the assessment of the environmental burden of a pair of jeans and a dress respectively. The results for global warming potential and freshwater consumption for both a pair of jeans and a dress are similar to those of the t-shirt.

Regarding freshwater eutrophication potential, all clothing library scenarios show more saving than the baseline scenario for a pair of jeans. The results for the dress show the robust difference of results with respect to a change of type of transportation with the exception of the offline scenario with a doubling of the service life.

Considering freshwater consumption, all clothing library scenarios are more favourable than the baseline scenarios and leads to up to 75% savings. For the dress, the clothing libraries scenarios are more favourable in terms of freshwater consumptions compared to the baseline scenario with medium impact transportation.

In terms of freshwater ecotoxicity potential, all medium and low impact customer transport scenarios are more favourable to the baseline scenarios for the pair of jeans. On the other hand, the results of ecotoxicity for high impact customer transport scenarios are up to 38% higher than the baseline scenario with medium impact transportation.

For a dress, the results in relation to freshwater ecotoxicity potential for medium impact customer transport for both online and offline scenarios are up to 3.4 times higher than the baseline scenarios. Since major ecotoxicity impacts are related to the customer transportation activities, only the low
impact customer transportation online collaborative consumption scenarios showed less environmental burden comparing to baseline scenarios.

The overall results for online scenarios show more environmental benefits compared to offline scenarios due to the closer package pickup-point to customers (one third of the distance). This underlines the importance that the locations of stores and/or pickup points are close to customers or accessible by public transportation.

One surprising result from the assessment of the collaborative consumption business models was the increase of freshwater ecotoxicity potential especially in scenarios using high impact transportation systems. It is possible that this represents an imbalance between the level of detail in LCI data for textile production compared with transportation – toxic emissions from the production phase are seldom inventoried satisfactorily in the database data (Roos, 2016). USEtox was the characterisation method used in this study and while this consensus method covers most chemicals, it lacks characterisation factors for many textile chemicals (Roos & Peters, 2015). On the other hand, the toxic emissions from energy production and transportation systems are relatively well inventoried and characterisation factors are typically available for the main toxicants, so that these processes tend to dominate toxicity calculations.

The previous discussion has enabled us to identify the scenarios exhibiting the greatest absolute deviation from the baseline scenarios. In order to illustrate the influence of key variables on different elements of the life cycle, Figure 5 shows each life cycle phase contribution to the global warming potential for the baseline scenario with medium impact transport and the collaborative consumption scenarios: the “high transport impact, life x2, offline” scenario is the worst case scenario and the “low transport impact, life x4, online” scenario is the best case scenario for the T-shirt.
Figure 5 shows which processes that contribute the most to the carbon footprint for the different life cycle phases. The results in figure 5 quantitatively indicate the significant contribution of use phase transport in the collaborative consumption scenarios. One can observe the burden of production in Asia and the Middle East being exchanged for transport impacts in Sweden – an example of geographical problem shifting.

In the baseline scenario, statistics on Swedish apparel imports and a survey of Swedish user behaviour were used to determine the actual service lives of average garments purchased in Sweden, as well as laundry practices and the customer’s transportation to and from the retailer. The results show that the customer transportation has a bigger impact on global warming potential comparing with laundry, which contrasts with many previous studies. This is both because previous studies often exclude the customer transportation, and because they often overestimate the importance of the laundry, because the number of uses per garment life cycle is based on technical service life rather than actual user behaviour (Roos et al. 2016). The comparable low laundry contribution of our study is also due to the geographical context. In Sweden, the energy used for laundry has a relatively low carbon intensity (nuclear power, hydroelectricity and wind provided 81% of local power in 2014 (SCB, 2015)), and tumble drying is not used as frequently as elsewhere (tumble drying usually is the key electricity consuming process in LCA studies (on garment level) where laundry dominates the global warming potential results).

The results for the two other garments follow the same trend, as shown in the supplementary material. The results highlight the need to account for the logistics when implementing a collaborative
consumption business model, for example by locating a physical rental service or clothing library in locations close to customers and/or public transportation.

Figure 6 shows the results of the sensitivity analysis on global warming potential in which we varied the number of customers per T-shirt service life in scenario 3. In this sensitivity analysis we varied the number of customers per T-shirt service life in scenario 3 (life x2, medium impact transportation, and offline). In other words, the number of customers who rent the garment from clothing library is changed (but the number of uses per service life remains the same). See Figure 6 for results.

Figure 6 shows that the number of customers per garment life cycle can considerably influence the environmental impact of clothing libraries, as more customers mean more transport to and from the store (offline scenario) or pickup point (online scenario). So the frequency of garment transactions, and the number of uses per customer, matter greatly. These factors can be influenced by the setup of the clothing library membership system, for example by the number of clothing pieces the customer can borrow within a set time period, and the length of that time period. Fewer items and a longer time period could give an incentive to reduce the number of customers per garment life cycle, which would be environmentally preferable. Also, the payment system could matter. For example, if the customer has to pay for each clothing transaction, that could reduce the number of transactions and the associated environmental impacts. Overall, the setup of the membership system, and its influence on the frequency of transactions, is particularly important for clothing libraries in locations that induce user transportation with high environmental impact (e.g. remote areas with poor access to public transportation). Similarly, the setup of the membership system is less important in locations that
induce user transportation with low environmental impact (e.g. downtown areas with good access to public transportation).

Previous studies show that reusing garments can reduce the environmental burden of clothing since the environmental burden associated with reuse of garment is insignificant in comparison with the saving due to replacement of virgin materials (Woolridge et al., 2006; Farrant et al., 2010). Moreover Woolridge et al. (2006) show the energy consumption of the retailing and distribution activities associated with second hand clothes are much lower than the energy consumption associated with the production of virgin materials. Previous studies with a specific focus on collaborative consumption discussed the idea that leasing garments can potentially contribute to more efficient resource use (Agrawal et al., 2015; Leismann et al. 2013). In our study, the results of different environmental impact categories show there are potential benefits (per garment use) of implementing clothing libraries if the garments’ service life is prolonged, but it is important to achieve a substantial increase of service life for environmental gains to occur. Moreover, Leismann et al. (2013) hypothesized the existence of a negative environmental rebound effect in collaborative consumption due to increased transportation. This hypothesis is confirmed by our quantified results showing that increased customer transportation in some scenarios (i.e. offline, high impact customer transportation) can offset the environmental gains from reduced production. This is a classic example of problem shifting between life cycle phases, which underlines the importance of adopting a life cycle perspective when studying of the environmental implications of various business models.

Since the geographical focus of our study was Sweden, further investigation is needed for evaluating the outcome of environmental impacts associated with setting up clothing libraries in other countries. Since the supplier countries we used in our assessment dominate global clothing supply, the key point of differentiation when this type of assessment is applied to other cities or countries may well be parameters such as transportation and laundry impacts, as these can be expected to be different in different countries. The range of per kilometre transportation impacts in our study may be similar in other urbanised western communities, but transport distances can be very location-specific. Laundry habits may differ elsewhere and the impacts will be higher in countries with carbon-intense electricity supplies, so that the laundry may play a larger role in the overall climate change assessment.

In this study, we focused on the controlling factors which can directly affect the environmental impacts of different clothing library scenarios, such as the extent to which the service life is actually prolonged, the number of customers per garment service life, and the transportation modes of the customer’s journeys. Then there are other, indirect factors influencing these direct environmental drivers, related to the customers’ attitude and adaptation towards these new business models, as studied e.g. by Pedersen and Netter (2015). Evidence from their study show there are some limiting factors in relation to expansion of clothing libraries including limited human and financial resources.
and conventional owner-ship consumption patterns. Such factors were outside the scope of the present paper.

4. Conclusions
One of the current concerns in relation to fast fashion is that customers discard garments before the end of their technical lifespan. In this context, interventions that increase the practical service life of garments are expected to be environmentally beneficial. In this study two research questions were addressed:

1. What are the environmental advantages and disadvantages of clothing libraries in relation to conventional business models?
2. What are the key controlling factors influencing the environmental impact of clothing libraries?

The research questions were addressed through studying 12 clothing library scenarios and comparing them with scenarios reflecting regular fashion business models. The results of different environmental impact categories showed potential environmental benefits (per garment use) of implementing clothing libraries if the garments’ service life is substantially prolonged.

In order to illustrate the influence of key variables on different elements of the life cycle, the contribution of each life cycle phase to the global warming potential was measured. The results quantitatively demonstrated the potential risk of problem shifting: increased customer transportation can offset the benefits gained from reduced production. This highlights the need for accounting for the logistics when implementing collaborative consumption business models.

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