Supply Chain Management and the Circular Economy: Towards the Circular Supply Chain

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Abstract

Circular modes of production, known as the circular economy, are welcomed in political and business circles to overcome the shortcomings of traditional linear operating models. Academic literature on the circular economy is nascent however and little attention is given to supply chain management implications, regardless of the relevance of supply chain innovation towards a more resource efficient and circular economy. Based on a review of the literature, this article presents preliminary propositions concerning implications for the development of what we term 'circular supply chains', defined here as the embodiment of circular economy principles within supply chain management. Our propositions are based on the following arguments: a) a shift from product ownership to leasing and access in supply chain relationships; b) the relevance of structural flexibility and start-ups in regional/local loops; c) open and closed material loops in technical and biological cycles; d) closer collaboration within and beyond immediate industry boundaries; and e) public and private procurement in the service industry as a lever for the scaling up of circular business models. We discuss what these circular economy principles mean in terms of supply chain challenges and conclude with limitations and future research agenda.

Keywords: Circular economy, closed-loop, strategy, structure, relationships.

1. Introduction

This paper explores the implications for supply chain management (SCM) in circular supply chains (CSC) given the considerable rise in interest in the circular economy (CE) by both practitioners and theorists (EMF and McKinsey & Company, 2012, 2013; EMF *et al.*, 2015; Yuan *et al.*, 2006; Tukker, 2015; Webster, 2015; WEF *et al.*, 2014), and the relevance of supply chain innovation in the transition towards a CE (Aminoff and Kettunen, 2016). Previous scholars have argued for the need for CE and SCM research to be combined (Sauvé *et al.*, 2016; Schulte, 2013; Seuring, 2004), hence we adopt this view as our starting point with which to develop a framework of propositions. Our aim is to first examine links between traditional SCM, sustainable SCM and the CE. We then highlight the sources of value creation in a CE and discuss the implications for SCM in terms of opportunities and challenges in the transition towards CSCs. In short, we ask: *what are the implications for supply chain management in circular supply chains?*

We adopt a systematic literature review as our methodology, used to initially identify 84 papers which were reduced through a filtering process to papers using a selection of keywords that specifically cover both the circular economy in general (n = 34) and supply chain implications specifically (n = 21) (e.g. Tranfield *et al.,* 2003; Denyer and Tranfield, 2009). In order to conduct our review consistently across traditional SCM, sustainable SCM and CE, we used as our principle search terms: 'circular supply chains', 'circular economy', 'closed loop', 'sustainable supply chains', 'reverse logistics' and other combinations comprising similar terminology. The theoretical perspective of each paper was identified and recorded in a database along with methodology, unit of analysis and reported findings. From this review we identify themes that link CE to SCM, which are then used to develop a set of propositions building on both these review papers and the practitioner literature. As an overall trend, the following chart shows that from around 2012 published research on CE and the implications for SCM have risen rapidly to 2016 (figure 1), with relevant articles continuing to emerge in 2017 (e.g. Geissdoerfer *et al.,* 2017; Genovese *et al.,* 2017)

Figure 1: Trends in number of publications linking CE and SCM by year

One of the challenges to linking the CE with SCM is that CE research is conducted across a diverse set of disciplines ranging from environmental economics to management science. The chart in table 1 shows the journals which were included in our review.

Table 1: Journals used in the review

The review in section 2 is conducted systematically, starting with circular economy, and then supply chain management and the links with sustainability. The reporting in section 3 adopts an analysis or synthesis approach to the literature, using propositions to frame circular supply chains and the implications for supply chain management. Section 4 concludes with contribution, managerial implications, limitations and recommendations for further research.

2. Bridging CE and sustainable supply chain literature

2.1 The Circular Economy

There are many definitions of the CE proposed in both political circles (e.g. EC, 2015; UNEP, 2010) and practitioner literature (e.g. Accenture, 2014; EMF and McKinsey & Co, 2012; 2013; EMF *et al.,* 2015; WEF *et al.,* 2014). One of the most recent is from the European Commission, who posits:

> *'In a circular economy the value of products and materials is maintained for as long as possible; waste and resource use are minimized, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value'* (EC, 2015, 1).

Because of assumptions around living systems as a viable model for the sustainable and sustained development of socio-economic systems (EMF and McKinsey & Co, 2012; 2013; Sauvé *et al.,* 2016), the CE seeks to eliminate the concept of waste. Waste is seen as 'food' insofar as valuable materials are managed within technical and biological cycles (EMF and McKinsey & Co, 2012). 'Technical nutrients' (e.g. metals) are designed to be suitable for reusing, refurbishing, remanufacturing and recycling for a consecutive number of cycles of production and use at the highest quality. 'Biological nutrients' (e.g. biodegradable materials) serve a restorative purpose: they are designed to return to nature to build natural capital either directly, or at their end of use across different supply chains (ibid).

As presented by the Ellen MacArthur Foundation and partners, CE thinking is not new. Origins can be found in economics (Boulding, 1966; Pearce and Turner, 1990), industrial ecology (Frosch and Gallopoulos, 1989; Lifset and Boons, 2012) management and corporate sustainability literature (e.g. Benyus, 2002; Braungart and McDonough, 2002; Guide and Van Wassenhove, 2009; Lovins *et al.,* 1999; Pauli, 2010; Stahel, 2006), whose concepts have started to impact the business community. Business models aligned with the performance economy (Stahel, 2006) based on offering access rather than selling goods to satisfy customers' needs have emerged across some sectors (e.g. mobility, construction tools, lighting, aerospace), with the potential to spread further because of advances in information & communication technologies and increasing environmental awareness from consumers (Lacy and Rutqvist, 2015). Industrial symbiosis - a field of industrial ecology literature - proposes the exchange of by-products, materials and energy between companies in the same geographical vicinity such as eco-industrial parks (Chertow, 2000) is gaining traction in China (Murray *et al.*, 2015), although widespread diffusion is still missing (Holgado *et al.*, 2016), with the exception of the eco-industrial park at Kalundborg in Denmark (Gregson *et al.*, 2015). While the application of green and sustainable supply chain practices have been increasing for several decades (Genovese *et al.*, 2017), it is within supply chains for consumer goods where most environmental impact may reside (McKinsey & Co, 2016).

Although CE thinking is not new, it is only recently that it has gained attention from the business community. This may be explained not just in light of the worsening ecological trends, but also because of changing socio-economic and regulatory landscapes. Resource price volatility caused by growing modern economies, a burgeoning of middle-class consumers entering the market, increases in the sharing/renting economy, rising regulatory pressures impacting on climate change and waste: all pose questions for the feasibility of traditional, linear operating business models following the 'take-make-dispose' approach (Accenture, 2014; WEF *et al.*, 2014). Current macro-economic, regulatory and ecological trends are raising the attractiveness of more resource efficient business practices to stay competitive. Yet there are differences between CE thinking and its predecessors. Indeed, CE thinking emphasizes economic and business opportunities (Aminoff and Kettunen, 2016; Velis, 2015), which is perhaps not surprising as it seeks to engage the business community, a significant lever in any transition (Franklin-Johnson *et al.*, 2016). The practitioner literature views the CE as '*an economy that provides multiple value creation mechanisms which are decoupled from the consumption of finite resources*' (EMF *et al.*, 2015: 23). The EMF estimates that in the transition to a CE, consumption of primary materials in the European Union (EU) could fall significantly in the food, construction and mobility industries '*as much as 32% by 2030 and 53% by 2050*' (EMF *et al.*, 2015: 15). This would have a positive effect on the competitiveness of EU manufacturing firms given that materials and components account for 40-60% of their total costs, and that Europe depends hugely on imports of resources such as fossil fuels and metals in the measure of about 60% (ibid). In addition to the economic and business opportunities, it is argued that the CE can build prosperity without further depleting natural capital (CISL, 2015; Gregson *et al.*, 2015; Murray *et al.*, 2015; Schulte, 2013) and in doing so, it is also consistent with principles of inter and intra-generational equity as raised in the 1987 Brundtland Commission Report (Ghisellini *et al.*, 2016). Therefore, an initial impression of the CE is that it does appear to address the three pillars of economic, environmental and social sustainability, as discussed further.

Despite the CE gaining momentum in political and business circles, its discussion within academic circles is more embryonic (e.g. Murray *et al.,* 2015; Antikainen and Valkokari, 2016; Geissdoerfer *et al.,* 2017). Literature on the topic is fragmented and spread across a number of more established fields, giving limited attention to implementation and the implications for business models and supply chains (Aminoff and Kettunen, 2016; Lewandowski, 2016; Lieder and Rashid, 2016). This is despite the significance of SCM in terms of innovation and transitionary capability towards the CE (Aminoff and Kettunen, 2016; Hopkinson *et al.,* 2016), and the substantial implications of CE principles for current SCM practice (Nasir *et al.,* 2016; Genovese *et al.,* 2017). Acknowledging these somewhat limited discussions in the literature from a business perspective of CE, this paper seeks to conceptualize the implications for SCM (Table 2).

Table 2: CE themes with implications for SCM

Section 2.2 now considers sustainable SCM, including a brief review of lean thinking and closed-loop supply chains (Linton *et al.,* 2007; Wells and Seitz, 2005) for their links with CE and the design and management of circular supply chains (Aminoff and Kettunen, 2016; Genovese *et al.*, 2017).

2.2 Supply chain management and sustainability

The concept of supply chains and consequently SCM arose in the early 1980s due to the increase in global sourcing, and was used to describe the complexity of business-to-business and business-to-customer networks. What we term 'traditional' SCM was first developed as a purchasing and logistics concept (Cooper and Ellram, 1993), although has become closely associated with operations, especially the performance-based control of material and information flow between collaborating organizations (Defee and Stank, 2005; Cooper *et al.,* 1997; Hines *et al.,* 2000; Hult *et al.,* 2007). A central paradigm of emerging supply chain literature at the time was to foster a better understanding of the elements '*characterizing* *strategic decisions that lead to supply chain structural development and performance*' (Defee and Stank, 2005: 28). One of the most popular definitions of SCM is Christopher's (1998: 5) '*the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole*'. The emphasis on cost and throughput illustrates the traditional language of supply chains, where the system is geared towards linear thinking around inputs and outputs. SCM focuses on multiple customer-supplier dyads, starting with raw material extraction through production to final end customers or consumers (Harland, 1996). Supply chains tend to be depicted as a focal firm with upstream and downstream relationships (Christopher, 1998), although whether supply chains are simple linear structures, or more like networks with interconnected supply chains is the subject of some debate (Lamming *et al.,* 2000). A typical example of traditional, linear supply chains therefore is the fast-moving consumer goods (FMCG) sector, which focuses on high levels of efficiency, volume throughput and customer responsiveness (e.g. Van Hoek, 1999; Handfield and Bechtel, 2002; Holweg, 2005).

One of the most significant developments in supply chain strategy has been the adoption of lean supply chains (Womack and Jones, 2003; 2005; Hines *et al.*, 2004). Different to the approach of the CE where waste is considered as 'food', lean thinking is presented as a practical, step-by-step approach to eliminate waste in all its forms (e.g. inventory, waiting, unnecessary movement etc) and can be applied to almost any organization, enterprise or supply chain context (Womack and Jones, 1994; 1996; 2003). More recently, the connection has been made between Lean and sustainability (i.e. 'Lean and Green') by scholars linking the efficiency paradigm of 'doing more with less' with minimising the use of resources and output of industrial emissions in order to protect the natural environment (King and Lenox, 2001; Simpson and Power 2005; Mollenkopf *et al.,* 2010). While there is ample evidence to demonstrate the benefits of this as an incremental approach (e.g. Womack and Jones, 1994; 1996; 2003), industry has yet to adopt Lean and eliminate waste with sufficient resolve to meet the complex operational challenges presented by sustainability, such as the implementation of a low carbon strategy (Correia *et al.*, 2013). A further issue is that efficiency-focused supply chains are at risk of disruption in industries facing turbulent and volatile markets, particularly those with fluctuating commodity and raw material prices. As world markets are increasingly disrupted by abnormal weather, terrorism, sole commodity ownership (e.g. China), and price volatility (e.g. grain, oil, gas), the traditional practice of supply chains designed exclusively around single strategies such as Lean or Agile is coming to an end (Christopher and Holweg, 2011). Supply chain designers can no longer assume a stable operating environment (Womack and Jones, 1994; Christopher, 2000), and are shifting towards more flexible methods which counter the effects of constant disturbance. Christopher and Holweg (2011) argue that the SCM principle of controlling an end-to-end process to create a seamless flow of goods must be questioned, where assumptions over long-term stability no longer hold true. Managing supply chains in an age of constant turbulence may mean '*embracing volatility as an opportunity rather than viewing it as a risk*' by understanding its nature and impact, and shifting the exposure to risk by considering methods such as dual sourcing, asset sharing, postponement, flexible labour, rapid manufacturing and outsourcing (Christopher and Holweg, 2011: 63).

Supply chain management's associations with sustainability owe much to the early interest in closed-loop reverse logistics, product recovery and remanufacturing literature (Thierry *et al.*, 1995; Fleischmann *et al.*, 1997; Jayaraman *et al.*, 1999; Guide and Van Wassenhove, 2009; Loomba and Nakashima, 2012). Sustainable supply chain management (SSCM) is now recognised as a term in its own right (Seuring and Müller, 2008; Carter and Rogers, 2008) and includes a range of associated topics including environmental and social goals (Govindan *et al*., 2015), the need to understand value creation as opposed to damage limitation (Krikke *et al*., 2013) and the importance of strategic supplier partnerships in creating this value (Sarkis *et al*., 2011; Bell *et al*., 2013; Insanic and Gadde, 2014).

Carter and Roger's seminal SSCM framework (2008) was arguably the first to demonstrate the relationship among environmental, social and economic performance within a SCM context. Building on Elkington's concept of the triple bottom line (1998, 2004), they suggest that at the intersection of all three factors '*there are activities that organizations can engage in which not only positively affect the natural environment and society, but which result in long-term benefits and competitive advantage for the firm*' (Carter and Roger, 2008: 364). Calling for greater vertical integration between buyers and suppliers as means of reducing uncertainty and resource dependency towards achieving long-term economic sustainability in a period of dwindling resources, the authors draw on multiple theories (e.g. Resource-based view, Transaction Cost Economics) and examples of closed loop industrial activity.

The decision to adopt a closed loop supply chain approach shows that the organization has begun to consider the issues of environmental management and product lifecycle, and can distinguish traditional supply chains from more sustainable closed loop supply chains (Guide and Van Wassenhove, 2003). Yet introducing a closed loop or ‘reverse logistics’ supply chain into the business is not simple, particularly as product recycling is rarely considered as a value creating system (Guide *et al.,* 2003). Closed loop supply chains started with the application of new industry standards and focusing on green or eco-efficiency issues. This meant working with suppliers to reduce the impacts of products and processes. Closed loop supply chains require considerable investment in resources, initially in understanding the configurations of information flows and parts distribution that serve the product whilst in use, and then developing a collection system which takes back or ‘harvests’ the product at its end-of-life, (e.g. Loomba and Nakashima, 2012) while securing the cooperation of customers, suppliers and not-for-profit organizations (Kumar and Malegeant, 2006). The process of product disassembly and remanufacturing can be particularly difficult as the condition of used products may vary greatly, can be distributed across the world and, even if retrievable, they may have to be discarded if damaged beyond repair. A combination of increasingly stringent legislation (e.g. European law on vehicle scrapping & disassembly) and manufacturer led initiatives means most industry sectors have active recycling schemes in operation, such as photocopiers, computers and electrical products, although some end-of-life products can be transported large distances for treatment at low cost but has transport-related environmental impacts and sometimes social exploitation issues (Spengler and Schröter, 2003).

Closed loop supply chains are not only challenging in their design and operation, but have important implications for the supply chain (Savaskan *et al.,* 2004). They must combine both traditional supply chain activity centred on efficient distribution, as well as reverse supply chain activity such as the returns process, product repair / refurbishment, testing and sorting, and remarketing (Guide *et al.,* 2003). Yet despite reverse logistics systems being practised since the 1920s (e.g. automotive), the strategic intent required to integrate the concept of the closed loop supply chain into mainstream business activity is still lacking. Closed loop or reverse systems are typically treated as a silo, isolated from the core business, where common activities are yet to be established and not fully understood in different contexts because of variations in product complexity and perceptions in managerial importance (Johnsen *et al.,* 2014). Haake and Seuring (2009: 9) argue that although many companies have adopted sustainable procurement and supply strategies and are demanding minimum performance from their suppliers, current approaches using SSCM frameworks reveal ‘*some shortcomings in their ability to be comprehensive’*. They argue that the chief cause of the failings of SSCM is the inadequate approach when overall impacts along an entire supply chain are considered. Table 3 presents some of the key issues faced by SCM in terms of sustainability and closed loop supply chains.

Table 3: Key issues for SCM

3. Circular Supply Chains: implications for Supply Chain Management

While the previous section reviewed developments in SCM and CE, here we analyse the implications for the development of CSCs defined as the embodiment of CE principles within supply chains. First we compare traditional, sustainable and circular supply chains. Then, we present our framework consisting of five propositions in support of CSCs and discuss future supply chain challenges.

Until comparatively recently it was rethinking value at the product's traditional end-of-life phase that created new opportunities in terms of recycled component materials, with facilities installed in the supply chain to enable remanufacturing and repair (Guide and Daniel, 2000). Yet the practitioner literature on the CE introduces more comprehensive notions of value creation deriving from a more efficient and productive materials usage and defined as the power of the 'inner circle', 'circling longer', 'cascaded use' and 'pure inputs' (EMF and McKinsey & Co, 2012, 30-31; EMF and McKinsey & Co, 2013: 33-34). According to *the power of the inner circle* some end-of-life strategies create more economic and environmental value than others because they retain much more of a product's embedded materials, energy and labour (EMF and McKinsey & Co, 2012; Gorissen *et al.,* 2016; Nasr and Thurston, 2006). End-of-life strategies should be pursued as follows: 1) maintenance to prolong durability; 2) reuse for the same purpose with either little or no change; 3) refurbishment/remanufacturing involving replacements of some relevant components and recovery of components to be used within a new manufacturing process respectively and 4) recycling, i.e. the recovery of materials for the same or different purposes (EMF and McKinsey & Co, 2012). Recycling is the least valuable options since it generally takes the form of down-cycling rather than of up-cycling (ibid), with materials losing quality and thus suitability for use within subsequent production processes (Braungart *et al.*, 2007).

The hierarchy of strategies explains the *power of the inner circle* mechanism: '*tighter loops, those closest to the original product serve best value…while outer loops…provide less* *value'* (Webster, 2013: 552). Clearly, understanding of how customers use and dispose products, i.e. expanding supply chains reach, is crucial to reap the benefits of *the power of the inner circle* (Timmermans, 2016). Digital technologies which collect and analyse data across the supply network enable companies to better understand customers' preferences and thereby capture value (ibid).

Figure 2: Traditional, sustainable and circular supply chains

Based on the previous literature review, figure 2 compares CSCs with traditional and sustainable supply chains, highlighting the importance of key elements and how they may change according to prevailing conditions or SC approach. We choose as our foundation common elements such as strategy, structure, focus and flow, identified from our literature review as constructs commonly adopted in emergent supply chain research (e.g. Cooper and Ellram, 1993; Defee and Stank, 2005). Scale and scope were also added as a result of our investigation of CE literature, particularly the 'short and cascaded use' aspect of material and resources (EMF and McKinsey & Co. 2012).

3.1 CSC propositions and framework

In this section we develop propositions based on the potential impact of CE on supply chains, with the supply chain challenges presented after each proposition.

An important element in the transition from traditional or sustainable supply chain management towards CSCs is *'the power of circling longer'* which involves extending the period of time during which materials are kept in use (EMF and McKinsey & Co, 2012). This can be achieved by prolonging products durability or increasing the number of consecutive cycles of remanufacturing, repair, refurbishing and recycling (ibid). The *powers of the inner loop and of circling longer* are relevant when considering the durable components of a product, and less so when considering consumable ones. In a CE 'consumables' are made of biological, non-toxic and restorative nutrients that can be returned to nature with no risk of harm (EMF and McKinsey & Co, 2012). Consumables have a very short life span (e.g. food), though for other products (e.g. packaging materials and textiles) it is possible to extend usage and thus increase resource efficiency (EMF and McKinsey & Co, 2013). Textiles could benefit from design for reparability and durability (ibid). The company *Patagonia*, for example, designs sport clothing that lasts longer and it is suitable for repair and recycling at the end of its useful life (Bocken and Short, 2016). On the other hand, durables are made of technical nutrients (e.g. metals) that are not suited to the natural environment but to consecutive cycles of production and use (EMF and McKinsey & Co, 2012). Durables are not exchanged through a traditional sale transaction but rather are leased, rented or shared (ibid). Some companies have already adopted servitized elements of circular business in their supply chains where selling a service means customers pay only for what they receive, with the firm retaining ownership of the lighting system e.g. Philips, 'Pay per Lux' (Ledvance, 2015), or aero engine e.g. Rolls Royce, 'Power by the hour' (The Economist, 2009), and meeting the associated long-term maintenance and repair costs. As information technology develops, customers can upgrade their systems thereby raising efficiency, bringing further benefits as well as controlling the flow of material returns using digitally enabled systems. Advances in digital technologies are now sufficiently developed to facilitate CE implementation on a large scale (Lieder and Rashid, 2016), offering opportunities for monitoring product performance over the lifecycle, tracking and improving resource usage across the supply chain (Lacy and Rutqvist, 2015; Preston, 2012), and enabling closer customer relationships to facilitate product-service continuation or renewal (Lacy and Rutqvist, 2015). Hence, our first proposition:

$P_{1:}$ Supply chain relationships will change in CSCs, shifting from product ownership towards greater emphasis on leasing and service based strategies enabled by digital systems.

Strategic purchasing in the services sector represents a major shift in focus for a profession still dominated by products, components and raw materials. If a transition towards CSCs is to be achieved, procurement policy must shift the current emphasis on 'best cost' sourcing and pricing towards a more services friendly, relationship-based approach which recognises the value of techniques such as lifecycle analysis, leasing and through-life management. Some high value products, such as photocopiers, lend themselves easily to new procurement techniques (e.g. pay-per-print), but there is also opportunity to analyse the full range of assets used in the service sector. In order to maximise value and extend life of products, different types of customer and supplier relationship strategies are needed which deploy new incentives around percentage utilisation of assets.

Whereas the powers of the inner circle and of circling longer create opportunities for value creation via circulating materials within the same supply chain, *the power of cascaded use* suggests that value can be created and captured by flowing materials across different supply chains (EMF and McKinsey & Co, 2012). This principle could be applied to consumables. Food for example is contributing significantly to the generation of waste whereas it could be returned to the natural environment once energy and other nutrients are recovered. Indeed, agricultural waste in a CE is: a) reused where possible (e.g. reuse of wood); b) treated for bio-chemical feedstock extraction (e.g. orange peels treated to obtain sugars and bio-ethanol) (Balu *et al.*, 2012), and c) sent to anaerobic digestion (EMF and McKinsey & Co, 2012). Anaerobic digestion is a natural process involving micro-organisms such as bacteria, which in the absence of oxygen converts the organic waste into two different products (DECC and DEFRA, 2011). One of these is called digestate which is a fertiliser; the other is biogas - a mixture of carbon dioxide and methane - which can be used in combined heat and power engines to produce heat and electricity. Anaerobic digestion is more environmentally sound as it avoids generation of further greenhouse gases (GHGs) emissions through landfill, with additional benefits deriving from the production of renewable forms of energies and biological fertilisers (ibid). The latter could be used to restore soil degradation, one of the most serious environmental externalities deriving from food production, which also prevents soil from retaining carbon (EMF *et al.*, 2015). For example, British Sugar has increased its revenue streams and reduced costs via converting waste streams and even CO_2 emissions from its core business of sugar production into inputs for other product lines such as tomatoes, bio-ethanol and animal feed (Short *et al.*, 2014). However, preventing food waste in the first place is one of the aims of a restorative and regenerative CE, with positive economic, environmental and social implications (e.g. reduced costs in the food supply chain, reduced GHGs emissions and better food security) (WRAP, 2015). All of the above mechanisms for value creation are enabled by *the power of pure inputs* (EMF and McKinsey & Co, 2012). For materials to circulate properly within technical and biological cycles, their purity and quality are essential features. These can be maintained if aspects such as design for disassembly, ease of identification of components and exclusion of any toxic materials is observed, with after-use collection improved so that contamination is avoided.

The sources of value creation have major implications for SCM. Most supply chains are still linear in structure, with increased globalisation of business operations meaning that products components are sourced worldwide (Preston, 2012; Velis, 2015; WEF *et al.*, 2014).

This could represent a barrier to the recovery of materials, since the points of manufacture and use are located in different and often very distant regions. While closing the loop across global supply chains is still in its early stages and when implemented will involve high value products, it seems that it is within regional and local loops that the majority of opportunities for the development of CSCs lies because of the reduced geographic barriers (WEF *et al.*, 2014). This is not surprising considering that the CE takes its inspiration from the functioning of living systems. Here, cyclical patterns are not only closed and thus waste is turned into food, but they are also local and decentralised (Nielsen and Müller, 2009). For example: '*the blossoms of a cherry tree bring forth a new generation of cherry trees while also providing food for micro-organisms, which in turn nourish the soil and support the growth of future plant-life*' (Braungart *et al.,* 2007: 1342). On the other hand, within socio-economic systems, cycles of materials have become increasingly global and open with significant levels of leakage (Nielsen and Müller, 2009). Such 'linear lock-in' and geographic barriers raise important questions for the development of CSCs. For instance, could small-medium enterprises (SMEs) break linear lock-in because their size provides an in-built structural flexibility? And, are CSCs more likely to be developed from start-ups rather than from large incumbent firms attempting to transition their existing supply chains, where regional or local businesses may offer a better chance for CE adoption? Recent research shows that it is start-ups that may offer the greatest potential for sustainable business model innovations (Bocken *et al.,* 2016a). In addition, regional/local CSCs would be in line with the developing concept of redistributed manufacturing, which consists of reshoring large-scale manufacturing sites to more local, smaller ones (Prendeville *et al.,* 2016). Redistributed manufacturing is crucial to a more sustainable manufacturing industry and clearly intertwined with the CE, with one city based project analysing the impact of localised and small-scale manufacturing plants on UK city resilience (Freeman *et al.,* 2016). Hence, the second proposition:

P_2: CSCs requires structural flexibility and reduced geographic barriers with SMEs and innovators within regional/local loops playing an important role in their implementation.

The introduction of new actors and subcontractors as shorter product cycle loops are introduced means new risks for conventional supply chains. As the CE model advocates more cascaded use, horizontal collaboration across traditionally competing supply chains will emerge, introducing challenges around 'coopetition' and difficult decisions over whether to share knowledge of material reprocessing, design and/or technology. Greater flexibility may be required in the future as buyers and suppliers choose to collaborate via inter-connected knowledge networks, rather than in-house R&D or stand-alone supply chain partnerships. On the other hand, the downside of flexibility i.e. asset underutilization, may be minimized if assets can be shared and reused for other purposes, as is the case for wooden pallets for example, but this may require greater level of product standardization to minimize process redesign for adaptation towards asset re-use.

CSCs expand the range of environmental and economic value that is created beyond those attainable within so-called closed-loop supply chains. As noted earlier, the power of cascaded use suggests that value creation stems from flowing materials across different supply chains (EMF and McKinsey & Co, 2012). For instance, textiles can be designed without the use of chemical substances and when reuse is no longer possible, natural fibres can be used as secondary raw material serving insulation and filling purposes eventually returning to nature at the end of their useful life (ibid). Cascading materials across different supply chains creates additional revenue streams via selling secondary raw materials that can be used for the manufacturing of a different product and thus expanding further downstream a company's supply chain. In addition, due to increased environmental regulation, resource price volatility and supply risks, the providers of high quality secondary raw materials may gain competitive advantage (Lacy and Rutqvist, 2015). Hence, the third proposition:

P_3: CSCs must consider both closed and open material loops in technical and biological cycles.

SCM professionals should view value not only in terms of a reduced waste approach (i.e. Lean), but in how shorter loops can maximise the value of materials use and productivity. More co-operative customer and supplier relationships during downstream collection and return will help extend product life as their use is cascaded across further cycles of repair, reuse, refurbish etc. This means different incentives will be needed to encourage customers and suppliers to engage in material return, invest in remanufacturing, and generally improve the overall quality of material input.

The opportunities for value creation identified in the *powers of the inner loop, of circling longer* and *of cascaded use* can be captured if the principles relating to *the power of pure inputs* are implemented first (EMF and McKinsey & Co, 2012). In a CE, the design of products acknowledges technical and biological cycles. Therefore, CSCs could be implemented only if products are designed in accordance with the requirements of these cycles. A significant change in design practices is therefore crucial to implement CSCs (De los Rios and Charnley, 2016). Design for a CE should be incorporated in the early stages of the design process since product specifications cannot be modified easily once they are defined (Bocken *et al.,* 2016b). The resulting supply chains would be in contrast with traditional closed-loop supply chains where returning products are not intentionally designed and thus manufactured to enable closing the loop (Lieder and Rashid, 2016; Rashid *et al.*, 2013). Hatcher *et al.,* (2011) argue that despite increasing attention devoted to design for remanufacture, there is neither uptake in this type of design or of remanufacturing activities. Nasr (2016) laments the lack of significant scale in global remanufacturing, with Souza (2013) confirming that the relationship between new product design and recovery at end-of-life is an area that merits further exploration. After the RSA's launch of the Great Recovery Project, it was concluded that '*the design of our products is far from being circular ready*' (RSA, 2016: 5) where only a few products are designed for full end-of-life recovery (e.g. upcycling). Further, when better designs do appear, the lack of a sound business case may prevent the necessary investment from taking place (ibid). The RSA identifies four design typologies that would enhance the circularity of products, namely: *design for longevity, design for service, design for re-use in manufacture,* and *design for material recovery* (RSA, 2016: 14). If these design strategies are combined both resource reutilization within production processes and higher durability are achieved (Lacy and Rutqvist, 2015). Similarly, Bocken *et al.,* (2016b) and Lieder and Rashid (2016) have argued that business model innovation and product design strategies are needed to support the transition towards a CE with Bocken and colleagues identifying several design strategies for 'slowing resource loops', enabling the slowdown in the rate of resource utilization, and design strategies for 'closing resource loops', enabling increased circularity in resource utilization. The first set of strategies includes: *design for reliability and durability, design for ease of maintenance and repair,* and *design for upgradability and adaptability* (Bocken *et al.,* 2016b: 310). The second set includes: *design for a technological and biological cycle, as well as design for dis- and reassembly* (p. 311), which underlines the role of supplier involvement in CSCs.

Other issues affecting the application of *the power of pure inputs* are product composition and after use collection. Ever more complex and novel materials which can be difficult to identify and separate at the end-of-life stage are now used in the manufacturing processes of products, with after-use collection methods often compromising the purity and quality of materials (WEF *et al.,* 2014). Both aspects; composition and after-use collection, are negatively affecting the plastics industry. The lack of coordination within plastics supply chains has hindered plastics circularity so far, with the consequence that 95% of plastic packaging value is lost after its first use and creating significant negative environmental externalities, for instance *'there may be more plastic than fish in the ocean…by 2050*' (WEF *et al.,* 2016: 29). Materials proliferation is developing faster than after-use sorting and separation systems. The recent European Commission CE white paper confirms that there are structural barriers to the uptake of secondary raw materials usage across Europe, such as the uncertainty surrounding material composition, which the EC is committed to overcome through the development of quality standards especially for plastics (EC, 2015). At the World Economic Forum (January 2017), a 'global plastic protocol' was launched to start laying the foundations of global standards for plastic packaging and after-use treatments (WEF *et al.*, 2017). Such challenges which relate to product design, composition and after-use collection require the implementation of what Winkler (2011: 244) defines as '*sustainable supply chain networks*'. These represent an extension of the traditional view of SCM, since multiple actors (i.e. suppliers, customers, collection and sorting facility agents) are engaged in strategies seeking to achieve not just cost efficiencies and customer satisfaction, but designing out the concept of waste from the outset in the transition towards a CE (ibid). New suppliers and customers bringing innovative ideas from outside the industry sector may be needed to fill demand for returned products, such as in the carpet tile and composite textile sector (Miemczyk *et al.,* 2016). In the light of the discussion on pure inputs, designers should also be incorporated in these networks, and regulators should facilitate the uptake of these practices within the industry by devising standards for material composition and after use treatment.

Clearly the CE requires a high degree of cooperation (Antikainen and Valkokari, 2016; Green Alliance, 2013), which is perhaps not surprising given the level of functioning the CE is modeled on, similar to that of an ecosystem where both elements of competition and cooperation is required to enable it to thrive (Sauvé *et al.*, 2016). The Green Alliance, a British think tank, has warned that the move to cooperate over the scaling up of circular industrial systems is threatened by competition law, which may create unease in some corporations over the decision to co-operate together (Green Alliance, 2013). This is not because competition law prohibits collaboration, but because the law lends itself to various interpretations over exactly what constitutes a monopoly, and where lawbreakers may incur high penalties. Regulatory intervention at the government level and from the European Commission is thus welcomed to provide clarity on the law so that it does not impede CE collaboration (ibid). Hence the fourth proposition:

P_4: CSCs are enabled by close supply chain collaboration with partners within and beyond their immediate industrial boundaries, including suppliers, product designers and regulators.

In terms of innovation in the move towards CE, CSCs require a conceptual shift from products and ownership, to access to services. CSCs are not only closed loop, but also open with regard to the opportunity for materials to flow across different supply chains, and within technical and biological cycles. New product development processes therefore will involve suppliers as part of early supplier involvement, looking at new ways to extend product life through additional of services and finding different uses for products as they reach the end of the cascade (e.g. old car tyres converted to floor chippings). Ultimately, the way products and supply chains are designed will reduce the demand for recycling, although a prolonged period of transition involving the accommodation of 'traditional, waste-based thinking' is expected before the full benefits of circular systems can take effect.

While manufacturing companies can develop their own CSCs and assist others manufacturers in improving the circularity of their products by supplying recoverable components, the contribution that the tertiary sector can bring towards the scaling up of more CSCs cannot be overlooked. EMF and McKinsey & Co (2012) have argued that service providing companies, as buyers of products, are important levers for the development of circular business practices. Using their procurement policies, they not only could improve efficiency in their own asset utilisation and thereby reducing the risks and the costs associated with capital investments (e.g. leasing assets), but also promote the uptake of circular business practices upstream of their own supply chains. For instance, suppliers could be asked to reduce or use returnable packaging in their deliveries. The tertiary sector (i.e. services) contribution to the development of more circular business practices could be very significant considering that services account for over 70% of the EU's gross domestic product and employment (EC, 2016) and 78% of GDP in the USA (World Bank, 2017). Large service organizations (e.g. health, finance) are particularly suited as their bargaining power and thus ability to influence supplier behaviour is higher. Both private and public sectors could act as levers for change, particularly the public sector with its large purchasing power (Walker and Brammer, 2012) by stimulating demand for more sustainable products and services (Uyarra *et al.*, 2014). Public procurement across the EU accounts for 18% of the EU's total GDP (EC, 2015) and thus the public sector as a whole could be a significant lever through its choice of purchased goods (Correia *et al.*, 2013). The European Commission's recent CE paper seeks to take action on green public procurement by revising or setting new standards that accord with

CE principles (EC, 2015). However, there is little research on whether service sector procurement policies include circularity-based clauses. One example of buying guides for European financial services shows that while there are requirements for recycling/takeback for IT, this does not go much beyond current legal requirements (Johnsen *et al.*, 2014). Hence, the fifth and final proposition:

P_5: Procurement policies both in the private and public sectors of service organizations are an important lever for the transition to CSCs if they go beyond minimum legal requirements to include the CE principles.

The issue of economies of scale will require more horizontal collaboration across supply chains and between industrial sectors to maximise the opportunities for high volume production. This aspect may require cross-industry standards via legislation, although is more likely to emerge as voluntary cooperation between corporations. Given the significant contribution of services to GDP in western countries, involving the tertiary sector as well as manufacturing is crucial in the transition towards the CE and CSCs. We raise the question whether it is within more regional rather than global loops that CSCs are likely to be developed, and where start-up companies and SMEs are likely to have the capability to drive innovation towards CSCs and bypass the 'linear lock-in' of larger corporations. The issues affecting the introduction of new product designs and after-use collection methods means that traditional structures around supplier-manufacturer-customer must be extended to include other actors such as designers, regulators and collection facilities for CSCs to succeed. The 'global versus local' debate is perhaps one of the biggest challenges facing the CE and transition to CSCs, because of the difficulties over reaching a global-wide agreement whose processes can be implemented at a local or regional level.

Table 4 Framework of CSC propositions

This section has presented CE thinking and discussed the implications for SCM through our formulation of propositions, concluding each section by considering the implications in terms of future challenges. Our framework of CSC propositions in table 4 builds on the elements of supply chain strategy, structure, flow, focus, scale and scope, derived as themes from the literature review, reflecting the changes anticipated in SCM and the shifts needed to achieve implementation. Such proposed changes to current models of business practice will not occur overnight however, with some structural elements taking longer across some sectors and requiring considerable effort and resources. In our conclusion, we now summarize our contribution in terms of outcomes and propose a future research agenda of opportunities to explore CSCs.

4. Conclusion

In this paper we have traced the origins of CE thinking and its more recent developments, exploring traditional and sustainable SCM before considering the implications for what we term CSCs. Our contribution is as follows: first, from the literature we distinguish and define traditional, sustainable and circular supply chains. Second, given the limited attention that supply chains have received in the context of the CE (Aminoff and Kettunen, 2016; Lieder and Rashid, 2016), we propose five preliminary propositions as a framework which supports CSCs and yield insights into the CE and SCM. Sustainable business models and SCM are closely connected in the sense that the configuration of supply chains can affect the development of a sustainable business model, and vice versa (Lüdeke-Freund *et al.*, 2016). Yet these two literature streams have a tendency to remain separated rather than inform each other. By contrast, we start to lay the foundations for a more integrated discussion and to consider what the implications are for SCM in a CE. Third, based on CE principles, we discuss the key supply chain challenges facing managers, namely: extending the shifting perceptions of value, mitigating risk through structural flexibility, introducing early supplier innovation, more strategic services, and the issue of global vs. local distribution of production.

In terms of a future research agenda, one major finding from our investigation was not only the lack of literature bridging CE and SCM, but also very little information on the practical side of how to introduce CSCs in a real-world context. Although cases on sector-specific recycling and reverse logistics currently exist, there are no large-scale industrial examples of CE principle adoption, hence the motivation for our study. We argue that the concept of CSCs supported by propositions now provides a theoretical basis for a more practical phase of investigation into the practicalities of widespread implementation. This is increasingly relevant given the recent launch of the European Union's 'Circular Economy

Package' and the 2017 release of British Standard 8001 'Framework for implementing Circular Economy principles in organizations'.

It may also be appropriate to consider policy implications for the scaling-up of CSCs, specifically from an energy perspective. Stahel and Reday-Mulvey (1981) observed that two-thirds of energy consumption in the construction industry takes place during the extraction of raw materials (e.g. steel). Consequently, the substitution of virgin raw materials with secondary raw materials could lead to significant energy savings. Though the CE reduces virgin materials consumption, is less wasteful and thus less energy intensive than a linear economy (EMF and McKinsey & Company, 2012; ZWS, 2015), some recycling processes are either energy intensive (e.g. recycling of chemicals) (Bjørn and Hauschild, 2013; Rammelt and Crisp, 2014) or in other cases (e.g. glass recycling) demand almost the same amount of energy as that needed for the production from virgin materials (Allwood, 2014). Despite the CE relying only on renewable energy (EMF and McKinsey & Co, 2012), recycling and reprocessing facilities need reliable energy sources to run consistently (Remsol, 2014). One of the problems of renewable energy is intermittent supply due to variation in weather conditions (Parente and Feola, 2015), though energy storage may offer a solution (Miser, 2015). Questions remain however over the appropriate energy mix that can satisfy CE requirements.

The tertiary or services sector is another relevant opportunity to advance research at the intersection between SCM and the CE. Service providers can be an important lever in the development of CE-oriented practice in the business context as buyers of products (EMF and McKinsey & Co, 2012). The service sector has received little attention compared to manufacturing companies in corporate sustainability studies (Etzion, 2007; Maas *et al.*, 2014). The scaling-up of more circular business models and thereby of CSCs is also dependent upon funding to enable investment in infrastructures, new technologies and research in alternative and renewable materials. Yet the financing of circular business models is not without challenges because of the different forms of capital needed, types of business model implemented and cash flow changes in companies, as in the case of usage or performance based contracts (ING, 2015). Access to financial resources therefore is one of the key obstacles encountered in the setting up of circular business models (Roos, 2014). Crowdfunding is one emerging approach which may suit the more collaborative approach to business growth as envisaged by the CE, hence future studies could explore developments in the financial sector that lift barriers which prevent circular business models from gaining access to capital investment.

While we acknowledge the limitations of this paper in terms of its almost exclusive basis on the literature (both scholarly and practitioner based), we encourage other scholars to continue and extend our work into the realms of practical CE implementation, using empirical research and case study investigations to demonstrate the role of supply chain innovation in the transition towards the CE. This paper adopts a western perspective, yet for China and India the CE represents a significant opportunity. Some argue that it is in China where implementation of the CE is most advanced (Murray *et al.,* 2015), and recent research shows that India could benefit from CE implementation by 624 billion dollars per year in 2050 (EMF, 2016). Our ultimate aim is to encourage other investigators to test these concepts and propositions, offering further insights into the potential of the CE and advance our understanding of supply chain practice and theory.

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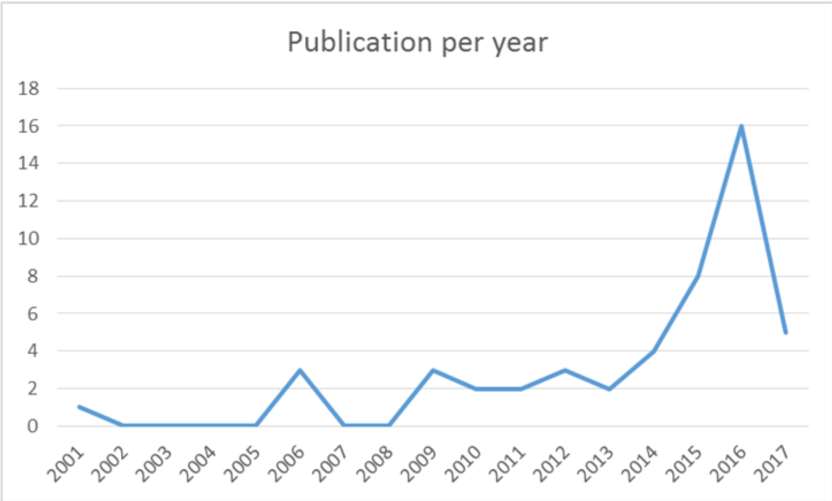
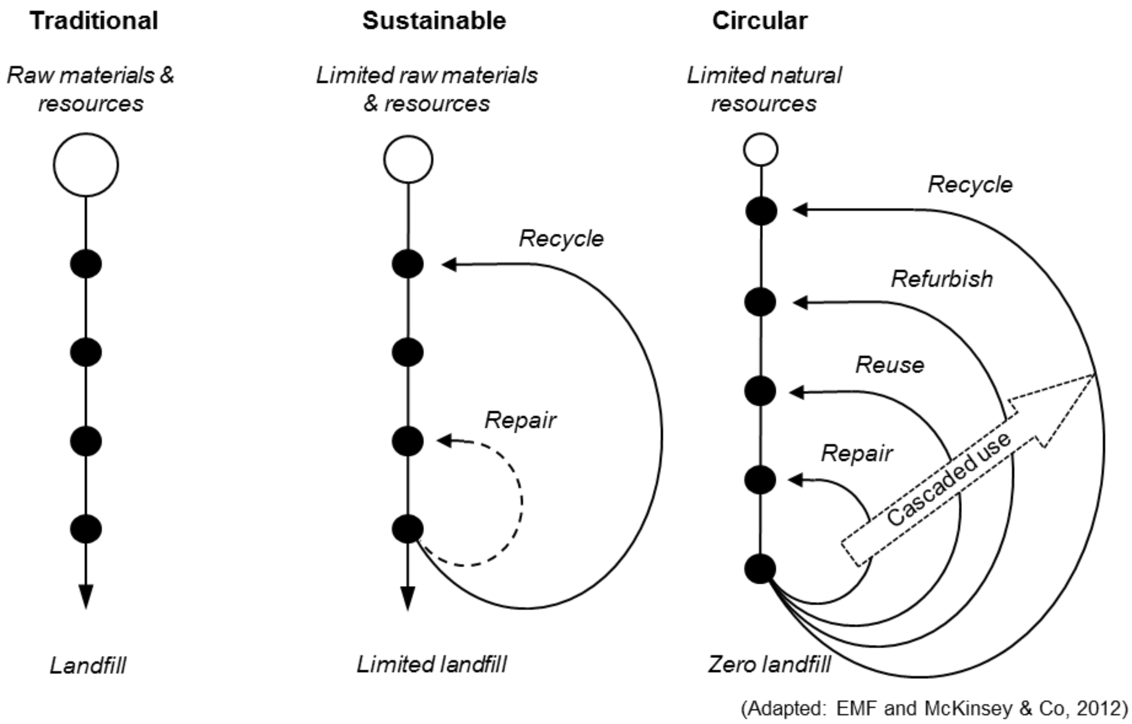


Figure 1: Trends in number of publications linking CE and SCM by year



	Traditional supply chains	Sustainable supply chains	Circular supply chains
Strategy	Component price	Cost of ownership	Leasing and service outcome
Structure	Linear and open	Partially closed	Closed, short and cascaded loops
Flow	Input-output	Mixed throughput	Biological and technical cycles
Focus	Efficiency	Customer effective	Collaborative value capture
Scale	High volume	High-medium volume	Medium-low volume
Scope	Global	Global and regional	Regional and local

Figure 2: Traditional, sustainable and circular supply chains

Journal Title	***No.***
Business Strategy & the Environment	2
Chinese Management Studies	2
Comparative Economic Research	1
Ecological Economics	1
Economic Horizons	1
Economy & Society	1
Environmental Science & Technology	1
Greener Management International	1
Habitat International	1
International Journal of Environmental Technology & Management	1
International Journal of Production Economics	4
Journal of Agricultural & Environmental Ethics.	1
Journal of Business & Industrial Marketing	1
Journal of Cleaner Production	21
Journal of Industrial Ecology	9
Journal of Transport Geography	1
Logistics Management	1
Omega	1
Supply Chain Management Review	1
Systems Research & Behavioral Science	1
Thunderbird International Business Review	1
Total:	*54*

Table 1: Journals used in the review

Table 2 CE themes with implications for SCM

Theme	***Issue***	***Key references***
Business strategies	Ownership models Business Models Leasing	Hawken *et al.*, 2000 Aminoff and Kettunen, 2016 Lieder and Rashid, 2016 EMF and McKinsey & Co, 2012
Structures	Closed loops Cascaded Loops	Braungart *et al.*, 2007 EMF *et al.*, 2015 EMF and McKinsey & Co, 2012; 2013
Flows	Technical (long cycles) Biological (short cycles)	Lovins *et al.*, 1999 Braungart *et al.*, 2007 EMF and McKinsey & Co, 2012; 2013
Priorities	Value capture, broad view of value (natural capital)	Murray *et al.*, 2015; Schulte, 2013; EMF *et al.*, 2015
Scale and scope	Cope with lower volumes Local & decentralised	WEF *et al.*, 2014 Nielsen and Müller, 2009

Table 3 Key issues for SCM

Theme	*SSCM issue*	*Key references*
SC strategy	Beyond a 'cost & price' focus towards triple bottom line Lean and green Cost of ownership and lifecycle Volatility risks	Seuring and Müller, 2008; Carter & Rogers 2008 King and Lenox, 2001; Simpson and Power 2005; Mollenkopf *et al.*, 2010 Christopher and Holweg, 2011
SC structure	Beyond connected dyads Networks including non-economic actors	Harland, 1996;
Flows	Reverse logistics, Closed loop, global flows of supply and waste products (e.g. steel, e-waste)	Guide *et al.*, 2003 Govindan *et al*., 2015 Spengler and Schröter, 2003
SC Priorities and Focus	Efficiency vs Effectiveness Value (social, externalities)	Sarkis *et al*., 2011; Bell *et al*., 2013

Table 4 Framework of CSC propositions

Theme	***P_x***	***CSC proposition***
Strategy	P_1	Supply chain relationships will change in CSCs, shifting from product ownership towards greater emphasis on leasing and service based strategies enabled by digital systems.
Structure	P_2	CSCs require structural flexibility and reduced geographic barriers with SMEs and innovators within regional/local loops playing an important role in their implementation.
Flow	P_3	CSCs must consider both closed and open material loops in technical and biological cycles.
Focus	P_4	CSCs are enabled by close supply chain collaboration with partners within and beyond their immediate industrial boundaries, including suppliers, product designers & regulators.
Scale & Scope	P_5	Procurement policies both in the private and public sectors of service organizations are an important lever for the transition to CSCs if they go beyond minimum legal requirements to include CE principles.