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More value from fewer resources: how to expand value stream mapping with ideas from circular economy

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Abstract

Purpose – The purpose of this paper is to discuss recent trends in the circular economy and investigate how value stream mapping (VSM) can be extended to more fully include some of the critical aspects of circular economy.

Design/methodology/approach – The findings are based on previous research that has explored the usage of VSM to include aspects of the environment and sustainability aspects. These ideas are then expanded to new ways to use VSM by mapping value of a product as it is; used, maintained, re-used, remanufactured, recycled, incinerated or used for landfill. The authors test out this approach through application in the waste management sector to identify possibilities for improvement and new business opportunities in what now is considered waste.

Findings – This paper introduces an expanded version of VSM that refines the existing Lean toolbox for exploring value and mapping value in a circular economy.

Practical implications – The aim of this paper is to expand the relevance and practical value of VSM as the world economy increasingly moves toward a circular one.

Originality/value – Today, VSM is a widespread method within Lean manufacturing that scrutinizes value creation within an organization or within a value chain. This paper describes how VSM can be refined to explore value streams in the afterlife of a product and explore waste as a resource utilization opportunity.

Keywords Lean, Value analysis, Reverse logistics, Sustainable supply chain management

Paper type Research paper

1. Introduction

To accelerate change toward sustainable manufacturing and a circular economy, a number of steps need to be taken to increase efficiency in manufacturing and resource utilization.

This study was carried out in the program *Interreg Sweden-Norway* financed by EU funds and Norwegian IR funds. The program's overall aim and objective is, through cross-border cooperation, to create the best conditions for an economically strong region with an attractive living environment. The particular project in which this study was conducted is called SMICE which aims at creating a long-term sustainable Jämtland, Härjedalen and Trøndelag.

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Increasing materials utilization requires enterprises to look at different ways to reduce, recycle, and reuse their raw and waste materials as well as extending the life cycle of their products.

Progress is being made in the sphere of industrial sustainable development. However, global challenges remain and they are significant (MacArthur, 2013) as global industrial systems are targeted to double output while using 50% fewer resources, and generating only 20% of current CO^2 emissions (Bocken *et al.*, 2013). This paper investigates how companies and industrial systems and networks might use value stream mapping (VSM) as a tool to enhance sustainability and accelerate change toward an eco-friendly, circular economy.

Today, VSM is a widespread method within Lean manufacturing that scrutinizes value creation within an organization, from start of production to finished goods. VSM can also be used to study value creation throughout an entire value chain. However, VSM in its conventional form does not explicitly take into account environmental and societal considerations or the new possibilities emerging from a circular economy. This paper describes how to change that by arguing that VSM can be refined to explore waste as a resource utilization opportunity.

When it comes to industrial operational processes, the concept "first things first" governs, and it means a rigorous focus on the success of the principle process that produces the main product or service. It is of paramount importance to have control of sales, manufacturing, logistics, delivery and so on, and use every opportunity to improve the efficiency of the main manufacturing process so as to maintain market share and to develop. Such focus may explain why successful and environmentally aware organizations can still have much to improve in terms of supporting processes like their material utilization.

The purpose of this paper is to discuss recent trends in the circular economy and investigate how VSM can be extended to more fully include some of the critical aspects of circular economy. We test out this approach through application in the waste management sector to identify possibilities for improvement and new business opportunities in what now is considered waste.

2. Introduction to value stream mapping

VSM has become one of the most popular and widespread development tools within the Lean community (Bicheno, 2015). It is a system level tool that maps material and information flows within an organization or throughout the whole value chain (Bicheno, 2015). These "streams" are mapped in order to understand the current conditions and also, maybe even more importantly, with the aim of finding a future state (Rother and Shook, 1999). The future state can be far-sighted, visionary, and hard to reach, or achievable after overcoming obstacles and conducting a series of improvements. The theory of VSM evolved quickly after it was first outlined as a series of tools by Hines and Rich (1997) and shortly after by Womack and Jones (1996). The latter vividly described the 319-day journey of a soft drink can and its flow from raw metal to finished product on a shelf in a store. However, the real mapping, or drawing of maps, started when Rother and Shook (1999) shared their pictures of current and future value streams. Since then their approach to VSM has been used in a semi-standardized way to guide organizations in their bigger picture planning and development of processes and supply chains.

The concept and usage of VSM has been expanded from the original internal company focus in a number of ways: toward "Seeing the whole" value chain (Jones and Womack, 2002); and further to product development (McManus, 2005); to including environmental impact and energy consumption (Mason *et al.*, 2008; Torres and Gati, 2009; Paju *et al.*, 2010;

Vinodh *et al.*, 2011; Brown *et al.*, 2014; Faulkner and Badurdeen, 2014; Vinodh *et al.*, 2016; Helleno *et al.*, 2017 and Garza-Reyes *et al.*, 2018); and as a tool to include waste management (Kurdve, 2015). There have been three phases to the evolution of VSM so far. The first was based on the concept of using various mapping tools to map or understand what happens in the value stream. The second, with the mapping tool from Rother and Shook, and the third phase use extensions of the original idea. In this paper, we refer to these extended value stream maps as VSMx. The three phases are summarized in Table 1.

2.1 What does a value stream map look like?

One of the overall goals and benefits of VSM is being able to visualize an operation effectively. The flow of material is drawn and shown using standardized symbols that show how value is added to the product step-by-step, as well as how and which information is supplied to each step (Rother and Shook, 1999). The difference between a VSM map and a process map is sometimes hard to pinpoint, but one very distinctive difference is the timeline that is always present in a value stream map (Rother and Shook, 1999). The presence of the timeline serves to put the value adding time in the perspective of the lead-time (Figure 1).

Another distinctive feature of a VSM is the data boxes, which are used to collect data needed from each process during mapping activities.

VSM is larger than a set of tools used to visualize the as-is state, it is also an improvement method in which the as-is state is first mapped, followed by a sketch of a to-be desired state, called the future state in VSM (Rother and Shook, 1999). Once both the current and future states have been mapped, the third step in the VSM method is to create an action plan that will lead to the future state.

VSM	VSM, VSM	VSM, VSMx
Tools and methods that evaluate and map the value stream	VSM – learning to see	Extending the VSM method
Hines and Rich (1997)	Rother and Shook (1999)	Various authors

Table 1.
Evolution of VSM

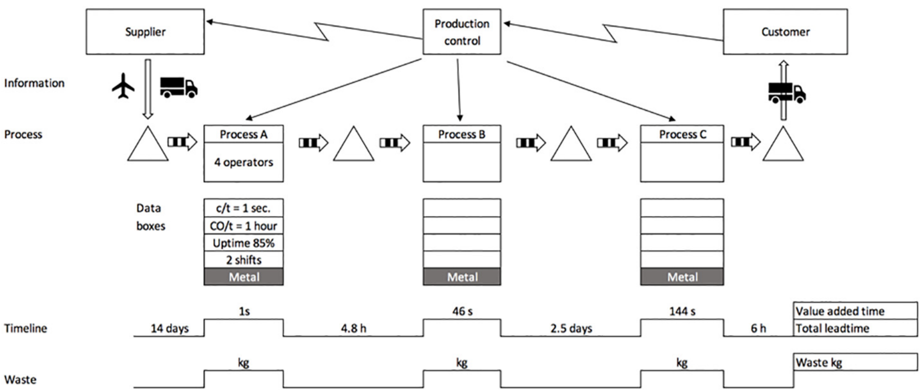


Figure 1.
VSM with information and material flows and the timeline at the bottom with value adding time in the top segments and non-value adding time in lower segments

2.2 Value definition within value stream mapping

Without a definition of value there can be no VSM. However, the definition of value is not very precisely defined within the VSM literature. In *Lean Thinking* (Womack and Jones, 1996) value can only be defined by the ultimate customer, but manufacturing companies build value into their products. Within Lean, identifying the value stream and defining what value creation is and what it is not is difficult (Womack and Jones, 1996). Nonetheless, the questions asked while analyzing value creation will eventually lead to an improved value stream. When value is understood and defined, the process of improving the value stream can start. Within Lean this can be done by waste removal, where waste, or *Muda*, is all non-value-adding activities (Womack and Jones, 1996).

2.3 Limits of traditional value stream mapping

For many years, organizations and enterprises have focused on processes and development of value chains (Porter, 2011). The aim of this has been to improve efficiency and to become more competitive. In this work, VSM is one tool that can help organizations to identify and reduce waste and improve creation of value. This is done by seeing the entire process or value chain from the perspective of a system. The reduction of waste can occur in many forms, not only the classical seven wastes as described by Liker (2005). However, VSMs shortcoming is that, to the best of our knowledge, it has not thus far systematically included the principles of a circular economy.

2.4 Expanding traditional value stream mapping – literature study from 2008 to 2018

A literature study was conducted with the aim of finding papers related to VSM and extended VSM that also considered aspects of the environment, sustainability, and the circular economy. The Scopus database was used for this, and the search words were "value stream mapping" AND" Sustainability", The search was limited to publications from 2008 onwards, which resulted in 50 hits. The first screening of these results included reading and evaluating the abstracts to assess their relevance to the field of interest. Fourteen publications passed this screening and were studied in more detail. The publications were categorized according to four identified subcategories, their type of study, main objective, kind of environmental parameter (s), and system limit. The main contents of the publications are summarized in Table 2. The studied papers can be divided into four distinct subcategories. First publications that includes some aspect of environmental mapping, secondly a category which integrates social sustainability aspects into VSM, thirdly VSM which incorporates logistics and lastly mapping of shop-floor mapping of waste material. The overall number of screened and analyzed publications is relatively small.

2.5 Model for expanding traditional value stream mapping

While some literature does appear to exist linking VSM to the circular economy, the concept of circularity as it is used within a circular economy has not yet found its way to practitioners that use lean tools such as VSM. We believe, and hope, that by including the thought models and thinking used in a circular economy, we will be able to extend the VSM concept even further. What would happen if we were able to include reusing and recycling at a material, component, and product level within manufacturing? What would happen if we included ideas like cradle-to-cradle (MacArthur, 2013), and in that context started thinking about what value means for customers when the traditional linear thought patterns of take-make-dispose are replaced?

Subcategory	Main objective	Example of mapped indicator	References
Environmental VSM Also known as: Sustainable value stream mapping, (Sus-VSM), E-VSM, e-VSM, VSM + LCA, Lean and green	Integrating environmental aspects into VSM. Uses the data box in VSM to collect environmental data	Energy, material consumption, process water, waste-water, emissions	Mason *et al.* (2008), Torres and Gati (2009), Paju *et al.* (2010), Vinodh *et al.* (2011), Brown *et al.* (2014), Faulkner and Badurdeen (2014), Kurdve *et al.* (2015), Vinodh *et al.* (2016), Helleno *et al.* (2017), Garza-Reyes *et al.* (2018)
Sustainable value stream mapping Also known as: Social sustainable value stream mapping, (sus-VSM)	Integrating social sustainability aspects into VSM. Uses the data box in VSM to collect sustainability data	Ergonomics, work hazards, work risk mapping	Brown *et al.* (2014), Faulkner and Badurdeen (2014), Vinodh *et al.* (2016), Helleno *et al.* (2017)
Logistics VSM	Integrating logistics aspects into VSM. Supply chain mapping	CO^2 emissions, logistics planning, on-time delivery, transportation waste	Mason *et al.* (2008), Suarez-Barraza *et al.* (2016), Garza-Reyes *et al.* (2018)
Waste flow mapping (WFM)	Integrating waste management into VSM	Waste in the following categories: Metals, combustible material, inert material, fluid waste, other hazardous waste	Kurdve *et al.* (2015)

Table 2. Summary of VSM literature with extended scope

3. Circular economy

Using global resources in an environmentally sustainable way has developed from first being an idea and theory, and the concept has evolved from ecological economics, environmental economics and industrial ecology (Ghisellini *et al.*, 2016). The objective is to identify sustainable business models that can move us from usage of materials to circulation of material in closed loops (Naustdalslid, 2014; Ghisellini *et al.*, 2016).

The concept of circular economy is covered in a review article by Ghisellini *et al.* (2016). Early development includes definition and modeling work, as well as identification of three categories of implementation: micro, meso and macro level. The micro level refers to a single company or the consumer. In this category, we find the formation of the fields of cleaner production, green consumption, and green public procurement, as well as product recycling, product reuse, scavenging, and decomposing of products. The middle level, or the meso level, (Ghisellini *et al.*, 2016) includes eco-industrial parks and systems. In these systems, industries and companies co-exist in symbiosis. This category also covers the concept of waste trade markets. On the macro level, regional eco-industrial cooperation is expanded to regions or cities. This is urban symbiosis. Collaborative consumption and zero-waste programs, and municipal solid waste management systems are also found at this level. All implementation categories and the different implementation levels are found in Table 3.

The circular economy is currently being encouraged in different ways. In China, for example, it is used as part of the scientific development and economic strategy formulated by the 16th Party Congress in 2002 (Yuan *et al.*, 2006; Naustdalslid, 2014). One of the goals of this strategy is harmonious development of the economy, society, and humanity by advocating balanced and sustainable development. With this policy-driven approach China as a country is trying to promote innovation and development to balance the environmental and social problems caused by its rapid and continuous economic growth (Ghisellini *et al.*, 2016; Yuan *et al.*, 2006). In other countries, a circular economy is seen as a tool for policy-driven initiatives that aim to control market conditions for consumers and companies. Initiatives are simultaneously being driven by environmental organizations and civil society calling for a greener and cleaner world and actively demanding policy and legislation that enhances the green transformation (Naustdalslid, 2011).

One way to describe the manifestation of a circular economy is using the 3R model (Naustdalslid, 2014), which includes these principles:

- reduction: the amount of material and other resources is reduced without affecting performance of the product;
- reusing: describes how the active usage and life-time of the product can be prolonged, or the product used for another purpose than what was initially intended; and
- recycling: the full circle recycling of material resources into usable recycled raw material.

The first principle, reduction, is very well established within manufacturing and is one of the points of departure for the scientific work of Taylor (2004). However, the second and third principles, reusing and recycling, have so far not been seen by manufacturing companies as a main objective for them. The market and business of reusing has mostly existed between individuals. The fact that a longer life of a manufactured product affects its second-hand value is likely to be a consideration for both consumers and manufacturers.

3.1 Life cycle assessment

The model that is currently most commonly used for quantifying the environmental impact of a product or system throughout its life cycle is the science-based assessment method referred to as life cycle assessment (LCA) (Winkler and Bilitewski, 2007). LCA provides a holistic view on the environmental performance of products, which has made it a critical tool for environmental policy decisions in public government and the manufacturing industry. As a holistic model, LCA is based on models that need extensive data collection and analysis

Table 3.
Classification of subjects and categories of implementation within a circular economy

Implementation at micro level (single company or consumer)	Implementation at meso level (eco-industrial parks)	Implementation at macro level (city, region, nation)
Cleaner production	Eco-industrial systems and symbiosis	Regional eco-industrial networks and production, eco-cities, urban symbiosis
Green consumption and green public procurement	Waste trade markets	Collaborative consumption
Product recycling and reuse. Scavengers and decomposers		Zero-waste programs, innovative solid waste management systems

Source: Adopted from Ghisellini *et al.* (2016)

to yield a result. This can become a complex process and consequently, LCA is mainly carried by scientists.

4. Results and findings

4.1 Waste as a resource

To test how a VSM may be expanded with aspects of a circular economy, we studied two cases in the waste management sector. Could value be identified in what is currently considered waste?

4.2 Case one – energy recovery, the EU directive and waste hierarchy

Energy recovery is one part of the waste hierarchy, according to the EU's prioritization scheme in its Waste Directive 2008/98/EC for the treatment of waste from an environmental point of view. The waste hierarchy lists waste prevention as the most desirable priority, ahead of preparation for reuse, recycling, other recycling (including energy recycling) and disposal (landfill or non-energy reclamation).

In 2015, 5.8 million tons of waste went to energy recovery at Swedish facilities (Source 2008/98/EC). The UK and Ireland have introduced landfill taxes that have gradually increased and Norway has introduced a ban on the disposal of biodegradable waste. Swedish waste incineration plants offer competitive reception fees for this waste as district heating networks allow efficient use of the energy in the waste. Additionally, the high Swedish taxes on fossil fuels mean that relatively expensive biofuels will become the main alternative for district heating production. The main waste streams exported from Ireland, Norway, and the UK are rejected from MRF facilities (Materials Recovery Facilities), MBT facilities (Mechanical Biological Treatment), and household and business waste that has undergone a varying degree of source sorting and/or post-sorting.

This indicates that there is potential for more sorting of waste to recycling from both MBT and MRF plants and through other sorting. There are two main reasons that explain why this is not currently done: first, the value of material being sorted does not compensate for the additional costs that an extended sorting entails, and secondly, for some material fractions there is no market.

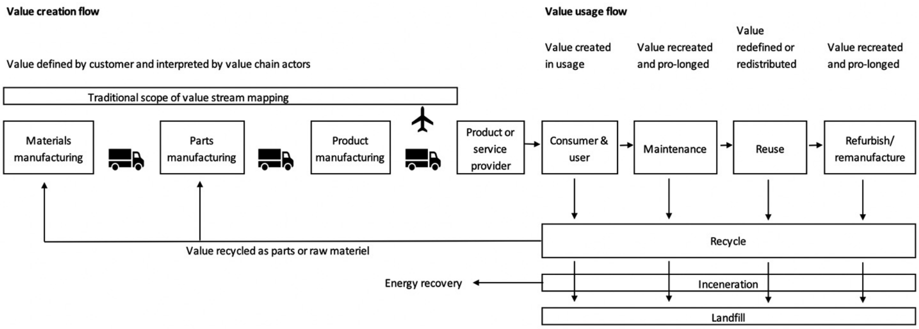
4.3 Case two – interview with a representative from the recycling industry

An interview was carried out with a representative from a waste disposal company Lundstam's, (Marktin, 2018) to learn about their line of business and how it is connected to a circular economy. The company is a regional enterprise in Sweden that works with recycling of waste from companies, producer-collected materials, household waste, and so on. The business model of the company is to collect, sort, and resell or dispose of material fractions. They handle and sort about 50 different fractions of material varying from paper, fiber, and wood to plastics and metal, which are then sold for reuse, disposed or used for energy recovery within Sweden and the EU.

Economic incentives exist that encourage Lundstam's customers to choose more circular solutions for managing their waste. The most costly option for them is to avoid sorting and having a plan for their waste. All improvements that Lundstam customers can find for the management of waste are directly profitable, and the higher up the recycling hierarchy, the more value the recycled material will have. In other words, managing waste means reducing costs (Figure 3). Handling waste efficiently, in such a way that enables companies to also purchase materials that are easily recyclable for their business, can result in lower costs. As a comparison, in Sweden the cost for disposal of waste that can be burned is €50–60 per 1,000 kg (Marktin, 2018).

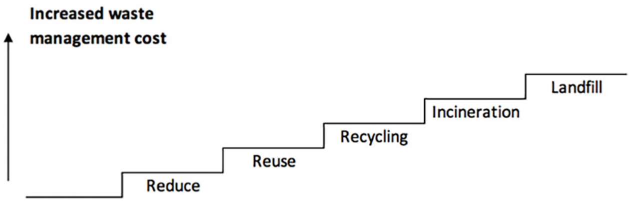
The recycled secondary material also needs to be of a sufficiently high quality to compete with virgin raw material. The level of profitability from sorting more fractions of material for recycling is dependent on the composition of the waste, which in turn depends on both the extent to which the waste has been sorted and the available collection systems. If the potentially recyclable material is contaminated with other waste, it is harder and more expensive to sort it for recycling than if the waste has been sorted from the beginning with the objective of recycling material (Marktin, 2018).

This might indicate that applying VSM to the waste management system could identify value opportunities and reveal hidden value by identifying value.



Notes: Two parts of the value stream can be seen, first the value creation flow from raw material to finished product at a service provider and secondly, the value usage flow from the user's first usage to end-of-life of product and value destruction, recycling, and energy recovery. Developed from McArthur (2013)

Figure 2. Extending VSM into the overall scheme of a circular economy, figure developed from McArthur (2013)



Notes: The cost difference between recycling more waste rather than sending waste for further treatment, incineration or disposal, may affect how waste is treated. The cost of disposal of waste decreases when Lundstam's customers move down the waste disposal staircase. This figure indicates that the highest cost for waste disposal is landfill, however this is not true for inert and organic materials suitable for landfill (Marktin, 2018)

Figure 3. Waste disposal staircase as described by Marktin (2018)

4.4 Consequences of value stream mapping application in a circular economy scenario

So how might we proceed with including the thought models and thinking used in a circular economy to expand the VSM concept even further? Where might the additional value be? We have modeled the consequences from several different perspectives.

4.5 Impact on consumer usage

In the first period of usage we would start by mapping value-adding time, in other words, when the product is used. The total lead-time would be the time until the product is not considered usable any more. The product is then considered to be at the end of its life. In this phase, we can increase the value-added time with respect to the total lead-time by either using the product more or shortening its lifetime. If we do not use the product, we will be in a value-missed regime where under-utilization consumes assets and material. Shortening a product's lifetime is instinctively unfamiliar, but if the product can be 100% recycled in an energy-efficient way, fast usage and fast material recirculation may be desirable.

However, the choices made by the general public constitute a competing behavior in this regime. For example, in the UK the number of garments purchased increased by 35% between 2000 and 2005 (Allwood *et al.*, 2011) and the average utilization of cars (utilization of car seats) was as low as 1.6% (Allwood *et al.*, 2011). If the cost of a new pair of trousers or the cost of owning a car is low many people might select this option.

4.6 Impact on consumer usage/maintenance

In this phase, the ability to maintain the product in a simple, cheap and environmentally sound way is of value for the customer. Not all products can be maintained though; one example would be disposable products.

4.7 Impact on reuse of value or redistribution of value

Here value-adding time can be increased if the product has a long lifetime and if the product has a market value in the redistributed form.

4.8 Impact on refurbishment or re-manufacturing of value

The objective here is to prolong value by refurbishing or remanufacturing the original value proposal of the product. This can include inspection, cleaning, disassembly, storage, repair, reassembly and testing, according to Allwood (2011). The outcome from using VSM in this value phase is connected to how efficiently value can be restored and brought back into usage. Disassembly followed by long time of storage is not effective in a VSM context.

4.9 Impact on recycling of value

The ability to recycle will increasingly receive more attention. The alternatives to recycling, incineration and landfill, are worse in terms of environmental impact. All products must be considered as recyclable, but the efficiency of the recycling is dependent upon design and choice of material. Part of the responsibility for making efficiently recyclable products falls on the manufacturer who can alter designs and choose to build the product from virgin or recycled materials.

The customer will also need to accept some responsibility since the cost of making recyclable products that can also be efficiently recycled, may be higher compared to products with the same function but with a lower degree of efficient recyclability. This gap would be interesting to investigate further. The gap is also an opportunity for policy makers. For instance, if the alternative cost for landfill or incineration is increased through taxation, manufacturers will rapidly seek new ways to improve recycling.

Other required behavioral changes would arise if the sharing economy and product leasing trends increased even further. For example, in Rome, car-pooling is very popular and has been promoted by the city council through initiatives such as favorable parking facilities for car-poolers. A measurement taken of car-pooling organizations showed that car-pooling cars are used on average as often as 3.7 times per day (Mugion *et al.*, 2018). This indicates that through the scheme, cars and space are being used more per person than before.

With manufacturers switching from being product suppliers to service providers their interest in the product's aftermarket life increases. Indeed, the aftermarket value becomes equally as important as manufacturing (Table 4). Please note that the ideal final results are to be seen as indicative of typical behaviors of the stakeholders.

5. Conclusions and discussion

5.1 Extending value stream mapping

Using life-cycle analysis results in a total environmental impact of a product, from cradle to grave. However, the dynamic aspects of the product lifetime and the value a product can achieve during its lifetime are not described within LCA in any great detail. The story is different with VSM, which looks at increasing the proportion of value-adding time in relation to total lead-time. This logic enables us to increase value-add by compressing the product lifetime or introducing sharing economies where the usage of products is increased.

We can speculate as to how the environmental challenges can be addressed, and how change can be accelerated. This can be done through legislation and policy, through public choice and debate, and through a reinvented capitalism (Porter, 2011). This new capitalism is made possible by company success and self-interest in philanthropy:

> Not all profit is equal. Profits involving a social purpose represent a higher form of capitalism, one that creates a positive cycle of company and community prosperity. (Porter, 2011, p. 15)

We should keep in mind though that not all capitalists are philanthropic but they all react to economic incentives. In Sweden today, those incentives are stimulating material recycling of waste. From a market perspective, it can be theoretically argued that the more expensive it is to deposit or incinerate waste, the greater the economic incentive for switching to recycling as the most economically advantageous alternative. However, just because there is an economic incentive that would prevent waste from occurring, there may be other reasons why this is not happening. In an article that studies mechanisms that prevent value co-creation in waste management industry

Table 4. Ideal final results for different stakeholders

	Ideal final result		
Value phase aspects	Customer/User	Product supplier and manufacturer	Service provider and manufacturer
Product life-time	Long or until end of technology life-time	Until end of warranty	Long

Svingstedt and Corvellec (2018) identify lock-in mechanisms that can explain slow or non-existent development of material recycling services. An example of lock-ins from Swingstedt *et al.* (2018) is a transactional business model there the waste management service provider (or the incineration plant) depends upon waste volumes for their operations.

5.2 Final thoughts

Goods produced from materials are essential to our way of living. From materials we build goods such as cars and washing machines, and the goods provide parts and components that become public transport and hospitals. These are all items and necessities that our societies are not willing to give up. Since the industrial revolution, manufacturing and consumption of raw materials have followed a linear route. This route has been: take, make, and dispose. This way of using materials is not sustainable, however. Today we know that the linear usage of material cannot go on forever. We also know that recycling material can reduce the need for virgin raw material. In some cases, recycling materials can be more cost-effective compared to using virgin raw material. This is certainly true for many metals such as aluminum.

With this new knowledge, and the need for circular material flows, companies need effective, easy-to-use tools to help analyze and make decisions on how to transform their businesses in the direction of a circular economy. In this paper, we have analyzed and tried to argue that VSM may be such a tool. The VSM method is well known in industry, it has been proven to reduce waste and reduce materials consumption, and produce products in a more efficient way. We propose that the same method can be used to "learn how to see" the value and the value stream of a product beyond its point of delivery to the customer. The value of the product is used, maintained, given new meaning, remanufactured and finally recycled. By looking at the value stream in this way, we close the loop, and construct a circular value stream.

The results from the analysis of using VSM in the back-end of the value stream are not novel in the sense that new insights have been found; indeed earlier findings have shown the same results. This is good news since the journey toward a circular economy cannot be made in one giant leap. This incremental journey will most likely be undertaken through a large number of baby steps. However, how do we know which steps to begin with? One answer could be to analyze what the customer value is, and improve the value stream using VSM, and in the analysis of what is value we can also include the next and future generations of customers.

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