Reverse Logistics of Lithium Batteries: Sustainable Guidelines for Businesses in Finland

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Abstract

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This research-based thesis aims to suggest useful concepts from reverse logistics for businesses to use in lithium battery waste management. The research is divided into an introduction, theoretical framework, methodology, empirical research and discussion.

The usage of lithium batteries has increased over the recent years, especially with the growing popularity of electric vehicles. The usage rate is only expected to increase further, which might result in large lithium battery stockpiles in the environment. Due to this concern, businesses should find solutions in the sustainable disposition of Li-ion batteries.

The target of this thesis is to present reverse logistics as a sustainable tool for lithium battery waste management. The main goals are to support the sustainable benefits of reverse logistics, assess the benefits of third party logistics (3PLs) and view the possibilities of reverse logistics in Finland. The desired outcomes are to propose reverse logistics concepts to manage Li-ion batteries sustainably and suggest the demand and possibilities of the industry.

To support the findings of the theoretical framework, the author has carried out qualitative research. The qualitative method of choice included two semi-structured interviews with businesses in different sectors of the lithium battery industry. To analyse the qualitative data, thematic analysis was utilised in combination of secondary data from existing theory.

At the end, the author proposed suggestions from the overall research. The results suggest that reverse logistics can be seen as a sustainable option for lithium battery waste management. 3PLs are a valid component in reverse logistics, which has a demand for more service providers. Reverse logistics in Finland can include several opportunities, as the Li-ion battery industry has many businesses operating in all major sectors.

Keywords
Reverse logistics, sustainability, 3PL, lithium battery

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1 Introduction

This thesis will propose reverse logistics as a tool for businesses to dispose of their lithium batteries in an efficient way. The target is to propose sustainable reverse logistics concepts for lithium batteries, which will hopefully encourage businesses to dispose of their lithium batteries properly. Additionally, the author will provide explanation to why third-party logistics providers are a key aspect in reverse logistics, but also analysing the lithium battery industry from Finland's perspective.

In this chapter, reverse logistics of lithium batteries as an important area for a research will be explained and supported the author. The specific targets will be defined with the introduction of the research question and supportive investigative questions. The international aspect of the thesis topic as well as its benefits for businesses will be discussed, and in the end, the most relevant keywords have been defined for the reader to gain a better understanding of the topics.

1.1 Background

During the past decade, the amount of various rechargeable devices such as laptops and phones owned by a household have grown significantly. According to Statista (2016), it is estimated that in 2020 a single person will own roughly 3 network connected devices globally. (Statista 2016). The revolution of modern technology doesn't stop there, as the deployment of electric vehicles and installations of charging stations have also seen an increase during the decade, with the past 5 years seen the most drastic development. (IEA 2019). The figures are expected to grow exponentially in the next decade, as especially the demand of electric vehicles will continue to increase.

While there is no denying that electric vehicles are a key solution for finding a more sustainable alternative for transportation, they including other devices containing lithium batteries hold a significant environmental hazard. As the popularity of EVs (Electric Vehicles) and handheld devices continue to grow, so do the stockpiling of their batteries after they have reached the end of their functional use. (IEA 2019). According to Jacoby (2019), it is estimated that by 2030 the world will produce 2 million metric tons of spent lithium ion batteries waste annually, with the majority of them having a high risk of ending up in landfills. These huge amounts of lithium batteries should be managed with sustainable actions like reusing or remanufacturing and other sustainable methods to minimise the potential risk. The sustainable disposition however can still be a complicated and expensive process for many businesses, which is why third-party logistics providers can be beneficial to cooperate with.

1.2 Targets of Research

This research-based thesis aims to propose suggestions for sustainable waste management of lithium batteries, with implementing the concepts and theory of reverse logistics. The research question will be “How can reverse logistics serve as a sustainable solution for lithium battery waste management?”. For achieving the best possible outcome in this research-based thesis, the author has created supportive investigative questions listed below:

IQ 1: What are the sustainable benefits of reverse logistics of lithium batteries?
IQ 2: How beneficial is outsourcing a reverse logistic function to a 3PL?
IQ 3: What are the possibilities of reverse logistics of lithium batteries in Finland?

With table 1 below, a visualisation of an overlay matrix has been created to explain the gathering of data and to support the targets of the research. The theoretical framework will be further discussed in chapter 2, and methodology of the empirical data will be introduced in chapter 3. The explanation and presentation of the empirical researcher will be discussed in chapters 4 and 5, each representing their own purpose. The ultimate goal of the research, theory and empirical data is to provide quality results for the thesis which are relative to sustainable reverse logistics of Li-ion batteries.

Table 1. Research methods and targets

Research phase	Phase 1	Phase 2	Phase 3
Respondent	Ride Hoop	Finnish lithium battery material recover company	Independent analysis on the process
Data collection method	Interview and qualitative methods	Interview and qualitative methods	Benchmarking and examining the results of empirical research in combination of own conclusions
Data analysis method	Thematic analysis, various thematic analysis approaches	Thematic analysis, various thematic analysis approaches	Authors' individual suggestions based on all data researched
Relationship to the RQ and IQ: s	IQ 1	IQ 2	IQ 3

1.3 Demarcation

Below on table 2, the subjects which are relevant to include in this thesis have been listed. Since the main target is to identify the sustainable value of a reverse logistic process specifically for lithium batteries, the demarcation will be centred around those subjects. The topics which were thought to be relevant are naturally the lithium batteries themselves and the concept of reverse logistics, while also looking into sustainable logistics solutions. The author wanted to also examine 3PLs offering a service for lithium batteries waste management, and if outsourcing can be considered as a valid option in the reverse logistics process.

Table 2. Demarcation

Subjects focused on	Reasoning
Lithium batteries	Main problem for which sustainable solutions will be proposed
Reverse logistics	The potential tool which can be used in sustainable waste management of Li-ion batteries
Sustainable logistics	Since reverse logistics could be considered as a highly sustainable option for logistics, the study will go more in-depth about sustainable logistics
Third-party logistics	Valid option to be considered in the potential reverse logistics process

1.4 Business Case

The author suggests that this thesis will prove useful to companies who are dealing with lithium batteries and need to find solutions to dispose of them properly. As we might face the potential concern of excessive lithium battery stockpiling in large quantities in storages and landfills as soon as the end of the decade, this thesis will aim to give businesses an overview of the situation including proposed sustainable suggestions and ideas. The suggestions are based on reverse logistics being a potential tool in minimising the stockpile risk.

This thesis will hopefully provide clarity and guidance to reverse logistics process being a sustainable solution for Li-ion battery disposal. With presenting the suggestions, theory and perspective from the interviews it could encourage companies to reconsider their approach to Li-ion battery disposal. In addition to businesses receiving suggested guidelines, this thesis is aiming to provide businesses an overall perspective of the Li-ion battery industry in Finland, and what types of methods are currently in use. The thesis writer will look to benefit from researching a topic which might not be as discussed as some other green logistics or supply chain subjects.

Besides the businesses who would benefit from disposing of their batteries in a sustainable manner, this study could be useful for the potential third-party logistic service providers who can offer a service dealing with the actual waste management process of the batteries. With the introduction of demand for sustainable solutions for lithium batteries, it can be assumed that more 3PLs will be encouraged to be involved and be a part of a company’s reverse logistics process. This could have a positive effect on the expenses and costs associated with Li-ion battery disposal, which can further encourage sustainable disposal of lithium batteries.

Since the main purpose of this thesis is to give businesses sustainable alternatives for battery disposal, the ideas are proposed to be implemented in a business process. Models and theory will be proposed for companies to apply, as well as the assessment on the viability of outsourcing a business function to a 3PL. With the gathered data from the interviews, and conclusions drawn from the overall research, these final suggestions are proposed by the thesis writer.

1.5 International Aspect

While the primary focus of this thesis will be more on the reverse logistics methods for lithium batteries in Finland, the topics and subjects this thesis aims to address could affect many countries within the EU. The ideas provided and suggested in this thesis can be used as guidelines by any company in the world, and since the more glorified environmental hazard could already be in effect at the end of this decade, it would be beneficial for businesses to make actions already today. Even though the EU may have its own set of environmental guidelines compared to other parts of the world, the same theory and concepts should be able to apply into the majority of business processes globally.

1.6 Key Concepts

Logistics in business is a major part of a company’s supply chain, which shortly refers to the businesses’ forward and reverse flow and storage of goods, services or information. CSMP (Council of Supply Chain Management Professionals) also describes logistics as the ability to meet customer requirements, especially when talking about the retail industry. Essentially, logistics management is all about effectively managing not only the flows and storage, but also planning, implementing and controlling elements which help the business to efficiently meet customer requirements from the birth of the product to its end user. (Murphy & Knemeyer 2015, 21-22.)

Reverse logistics can be described as the flow of goods which are returned back to the supply chain. The reason for this could be repairs, product returns or most importantly the return of a product which has come to the end of its life cycle, thus needing to be recycled or dismantled. (Harrison & van Hoek 2011, 141.) In this thesis, reverse logistics will be examined as a sustainable solution for business dealing with lithium batteries.

3PL is an abbreviation of Third-Party Logistics provider, which refers to a business who provides various value-added logistics services for their customer. A company often chooses a 3PL for a business function they don’t have the resource to manage, or if a certain logistics provider is known for being an expert in that field. The business function can be for example manufacturing, transportation or packaging. (Grant 2012, 272.)

Supply chain is a connection of companies acting in consecutive stages of production of a certain product, from its primary producer to the final consumer. (van Weele 2014, 53.) The length or amount of acting parties in the supply chain is dependent on the product and market size.

ISO refers to International Organisation for Standardisation, which is a non-governmental organisation who provide international guidelines and standards for services and products. These standards are made to ensure quality, safety and efficiency, and for business they can be described as strategic tools for reducing costs and waste, minimizing errors and increasing productivity. (ISO 2019.)

Lithium ion batteries are a more advanced form of a battery, which have grown to become an effective choice for rechargeable devices. Today, these types of batteries can be found in laptops, smart phones and other handheld electronics, but because of their high density of energy, lithium batteries are also used in electric vehicles or EVs. (Insideevs 2019). While this high energy density is what makes the lithium battery such a popular choice for many rechargeable devices, it is also one of the main factors why lithium batteries are considered as a hazardous good especially during shipment.

2 Models for Sustainable Logistics

Since the use of more sustainable alternatives for transportation such as EVs, and the use of various household devices continue to increase, the decision of what to do with the materials at the end of the product's lifecycle is inevitable for every company associated with lithium batteries. As studies have already estimated, by the end of the current decade lithium ion battery landfills may continue to grow exponentially and start to become a serious environmental hazard if businesses do not start to make preventive measures.

With reverse logistics, businesses can find ways to manage their spent and unused lithium batteries in a sustainable manner. It is also important to acknowledge how logistics has overall changed towards a more sustainable direction. The role of reverse logistics can be seen as a part of these trends, and various EU directives and standards can be seen as supporting businesses in making these sustainable actions. Finally, the role of third-party logistics providers has to be evaluated, as they can be an important option for companies to utilise the proposed ideas properly.

2.1 Evolution of Logistics

As logistics is a broad concept consisting of many different areas, its relevance today continues to get more impactful. Like all business industries, it continues to grow and evolve, and with the issues concerning global warming also logistics has started to take on sustainable business approaches. During the recent years, more environmentally friendly approaches for companies to handle their logistics such as green logistics and green transportation have become increasingly popular, and sustainable mindsets can be seen in even entire supply chains.

With the rising trend of sustainability, the concept of Corporate Social Responsibility (CSR) can be seen to impact the way how businesses approach their business strategies. This has reached the supply chain management and logistics industries as well, as companies have started to change their strategy with taking sustainable initiatives. One of the biggest changes relates to how companies have started to measure their performances in different areas. (Grant, Trautrims & Wong 2013, 209.)

Grant & al. (2013) suggest that traditionally supply chain and logistics performance have been measured with quantitative data involving cost-, time- and accuracy- related metrics. In the new mindsets of sustainable and green logistics, the measurement focus has been transferred towards elements which can help to reduce a company's carbon footprint and fight climate change. To help businesses achieve these goals in Finland, organisations, standards and other legislations in the EU have been implemented. (Grant & al. 2013, 209-210.)

2.1.1 Environmental Guidelines in the EU

As mentioned in the previous chapter, companies today have tools and guidelines to maintain their sustainable mindset. These tools can be referred to as Environmental Management Systems or EMSs, which consists of standards introduced by the ISO and EMAS, an abbreviation of the EU's Eco-Management and Audit Scheme. (Grant & al. 2013, 210.) Additionally, EU has set certain directives to support companies working specifically with lithium batteries.

Table 3 contains the most relevant standards introduced by the ISO to help increase the sustainability efforts of businesses in the EU. The first standard is the ISO 14001, which is a general standard for business to improve their environmental management. The ISO have also introduced the standard ISO 14031, which provides more specific guidelines for companies to track their attempted sustainable actions, classified into three sections. If a business complies with these above-mentioned standards effectively, an individual auditor may reward them with a certification. (Grant & al. 2013, 210-211.)

The directives and standards explained in table 4 are not associated with ISO, although serving similar purposes. The EMAS standard for instance is very similar to the ISO 14001 except for auditing requirements. The last two directives of table 4 are more related to lithium batteries, as for example the Directive 2006/66/EC is referred to as the battery directive. The directive demands for solutions for waste battery collection in all EU countries and puts pressure on the manufacturer to create clear instructions for disassembly. The final directive is the WEEE directive, which has targets to minimize the environmental damages caused by electric appliances and reduce the amount of them thrown in the environment with recycling and reuse options. (Grant & al. 2013, 210-211.)

Table 3. International environmental guidelines for businesses in the EU (adapted from Grant & al. 2013, 210-211)

Standard	Explanation
ISO 14001	Sets the standard for establishment and improvement of environmental management. Aims to encourage companies to improve on their own environmental management. Audits are made, but compliance to the standard is not ultimately required to keep a certificate (Grant & al. 2013, 210.)
ISO 14031	Provides specific guidelines for a business of any size how to utilize environmental performance evaluation, and how to select the correct environmental performance indicator. It is divided into three classifications: MPI, OPI and ECI. (Grant & al. 2013, 210).
ISO 14031 MPI	The first classification of the ISO 14031 refers to as the Management Performance Indicators. It measures for instance environmental costs and realised environmental targets the company has put out. (Grant & al. 2013, 210.)
ISO 14031 OPI	The second classification of the ISO 14031, which stands for Operational Performance Indicators. These showcase for example the average fuel consumption of used vehicles or amount of raw materials used per product in production. (Grant & al. 2013, 210.)
ISO 14031 ECI	The final classification of the ISO 14031is referring to Environmental Condition Indicators. This indicates relative examples of environmental conditions which are affected by activities of an organisation, such as contaminant concentration in ground or surface water. (Grant & al. 2013, 210.)

Table 4. EU sustainability directives for businesses (adapted from Grant & al. 2013, 210-211)

Directive	Explanation
EMAS standard	Is similar to the ISO 14001 in structure but differs in audits. EMAS standard has mandatory three-year audits which statements are made public. (Grant & al. 2013, 210-211.)
Directive 2006/66/EC	This directive can be referred to shortly as the Battery directive. It requires all EU parties to create solutions for the end user for waste battery collection, but also the battery manufacturer must provide clear instructions for battery disassembly. (Zhao 2017, 343.)
WEEE	A directive set by the EU, which has a primary target to prevent the environmental damages of Waste Electrical and Electrical Equipment. Its secondary objective is to find reuse and other recycling options for said equipment in order to reduce the amount of them thrown in the environment. (Zhao 2017, 343.)

2.1.2 Sustainable Choice Assessment

Once a company has identified their guideline to follow while pushing towards sustainable actions, they would require certain tools to assess their upcoming decisions and to follow their preferred guideline. Factors such as economic viability, environmental sustainability or the feasibility of technology should be usually considered by businesses when making further corporate decisions. (Grant & al. 2013, 215.) These decisions could be for instance the choice of widening railway routes to increase railway traffic with the cost of deforestation.

With the example mentioned above, the relationship between society and the SCM and logistics industries will eventually be affected by corporate decisions. With the framework of DPSIR, decisions affecting the environment can be defined, scoped and addressed. (Grant & al. 2013, 215.) Essentially, DPSIR consists of five factors which help businesses give perspective on their choices they make, which are further explained in table 5 below. In this explanation of DPSIR, the same example of widening railways has been used.

The first factor of DPSIR is called a driver, which is always some sort of an act or demand by the society. It results into pressure, which is an action to address the social demand. This will result into state changes and impacts often on the environment, but also generally in the ecosystem. For the prevention of these changes, the society reacts with often implementing a legal constraint or other economical instrument, as suggested by Grant & al. (Grant & al. 2013, 215).

Table 5. Explanation of DPSIR in the context of widening a railway route (Adapted from Grant & al. 2013, 215)

Factor	Explanation	Railway
Drivers	Key demands by society, responsible for creating Pressure	Desire for needing faster transportation
Pressures	The results and impacts of the driver	Widening the railway
State changes	Results of the pressure	Deforestation
Impacts	Changes to the ecosystem	Potential loss of habitat, visual negative impact for property owners, effects on global warming
Response	Society's attempt to minimize the effects	Legal constraints or economical instruments

DPSIR can give businesses operating in supply chain management or logistics a sustainable perspective on what types of effects certain choices might have. If DPSIR is applied to the context of lithium batteries, the driver can be for instance the need for more sustainable automotive solutions, resulting in increased electric vehicle production, which leads to increased popularity of EV usage. The impact can be that spent batteries are thrown into the environment and creating large stockpiles, resulting in society responding with various regulations and directives.

2.2 Reverse Logistics as a Sustainable solution for Supply Chains

As introduced in the previous section, the trends of sustainability and regulations could be primers for businesses in the SCM industry to implement sustainable business processes. With the ideas of sustainable and green logistics continuing to develop, the concept of reverse logistics should additionally be considered as one of the key tools for companies to use. To understand the purpose of reverse logistics in context of lithium batteries, it is important to first identify the different battery segments and types available in the worldwide market. By making the distinction, the various models and concepts which will be proposed in this thesis will be easier to understand and apply. The type of the battery additionally concerns the entire function of the supply chain, as the reverse logistics process can be affected by it.

When it comes to the worldwide battery market, it can be divided into three major segments proposed by Schultmann, Engels & Rentz (2003). The first segment refers to starter batteries and large accumulators, which are usually associated with industrial-sized purposes, such as in the use of EVs. The second and third segments can be described as non-rechargeable portable batteries also known as “primary” batteries, and rechargeable portable batteries known as secondary batteries. (Schultmann, Engels & Rentz 2003, 57-71.)

The use of secondary batteries has grown significantly with the popularity and innovation of tech-products, such as in laptops, mobile phones and other handheld devices. The batteries containing lithium, nickel and other recoverable materials are usually found in all battery segments, especially in EVs and the before mentioned electronic devices. (Schultmann & al. 2003, 57-71.) With the various battery segments and types introduced, the concept of a simplified supply chain and reverse logistics will be easier to comprehend in the appropriate context.

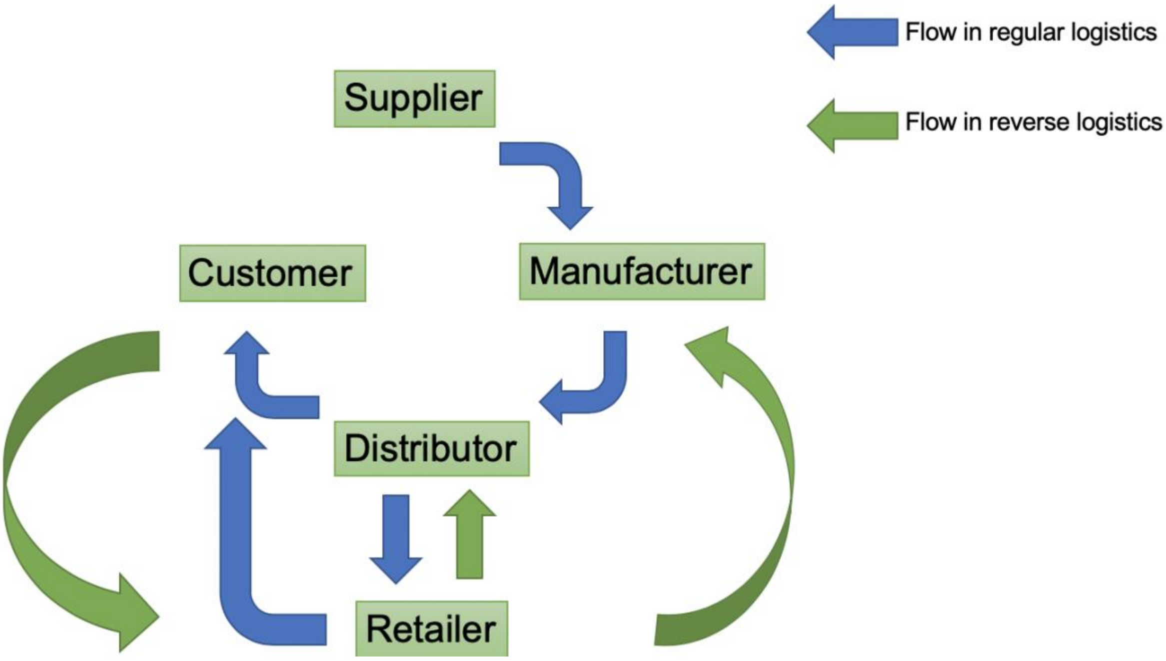

Figure 1. Visualisation of flows in regular- and reverse logistics of a supply chain (adapted from Krumwiede & Shau 2002, 327)

To simplify the function of reverse logistics, figure 1 above depicts a common supply chain of a product and how the flow between reverse logistics and regular logistics differs. A simple supply chain usually consists of a supplier, manufacturer and a distributor, ending to the end customer or user. (Krumwiede & Shau 2002, 327.) Depending on the product, a retailer is a common additional supply chain mode to provide the product to the end customer.

As shown on figure 1, reverse logistics reverses the flow of the product, usually initiated by a product return by the customer. Again, depending on the product, the customer can use retailers as a middle hand in the returns process before the distributor potentially gets involved. The flow of reverse logistics usually ends at the manufacturer where key choices are made to the product, such as if to refurbish or remanufacture the product or dispose of it, as will be apparent in the context of lithium batteries. (Krumwiede & Shau 2002, 327.) It should be noted that figure 1 above is a broad and simplified visualisation of the flow of reverse logistics and can serve as a basic overview.

2.2.1 Reverse and Green Logistics

While reverse logistics is a part of ensuring good customer satisfaction, refurbishing and further repacking damaged goods and remanufacturing, when talking about the waste management of lithium batteries, reverse logistics should be considered as an idea to recycle and manage waste properly. It can be compared to material recycling and waste management in theory, since according Grant et al. (2013), they both aim to minimize costs, retrieve some value from reverse flows and also to meet the environmental and legal requirements. (Grant & al. 2013, 151.)

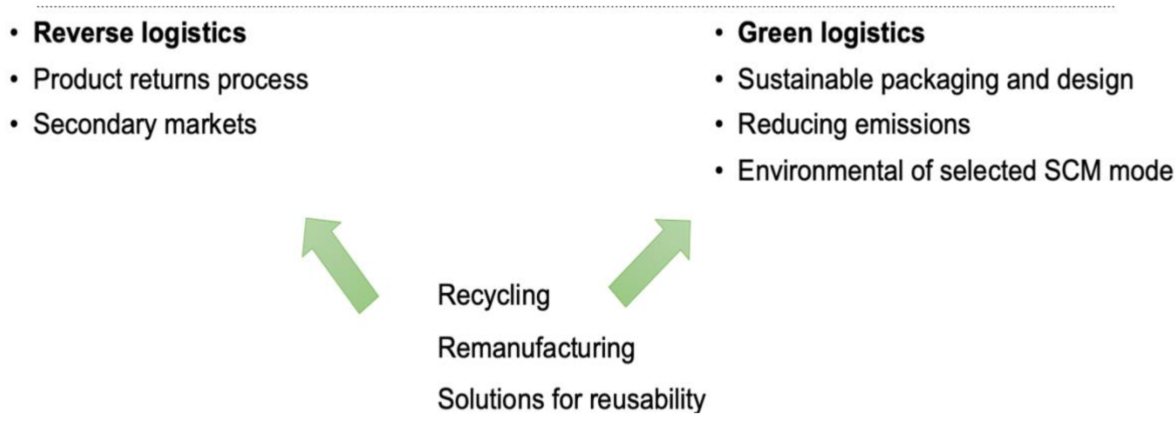

Figure 2. Similarities of green and reverse logistics (adapted from Rogers & Tibben-Lembke 2001, 131)

With figure 2 above, the similarity between green logistics and reverse logistics can be further distinguished. As shown, green logistics has the main purpose of having a sustainable mindset in every aspect. Rogers & Tibben-Lembke (2001) suggest this shows in for instance in sustainable packaging, reducing emissions or considering environmental aspects in a specific supply chain mode, like warehousing. While reverse logistics covers the process of product returns and the potential of secondary markets with returned products, it is important to understand is how recycling, remanufacturing and utilising alternative solutions for product reuse are also its key functions. The same elements are additionally part of green logistics, which emphasises the connection between the two. (Rogers & Tibben-Lembke 2001, 130-131.)

2.2.2 Closed-loop System

With the basic concept of reverse logistics being defined, it is important to recognise other models which are often associated with a business obtaining a reverse logistics process. One of the more common models is the idea of a closed-loop supply chain, where the product returns process or reverse logistics have been taken into consideration, redesigning the entire supply chain. (Govindan, Soleimani & Kannan 2015, 602).

While the closed-loop system is affected by the product, since the main purpose of this thesis is to provide suggestions for lithium batteries, a closed-loop system presented in this chapter has been made with Li-ion batteries taken into consideration.

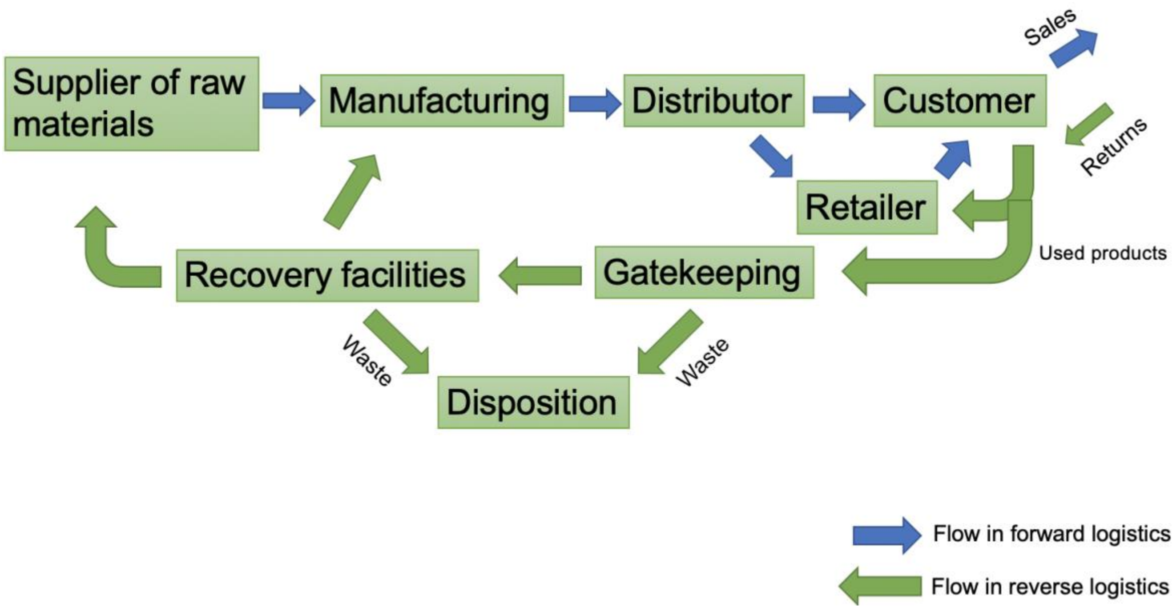

Figure 3. Closed-loop supply chain (adapted from Govindan & al. 2015, 602)

Figure 3 shows how the closed-loop system redesigns the traditional supply chain and even the reverse flow supply chain. The traditional purpose of the closed-loop system is the idea that product returns are all taken into consideration in addition to forward logistics flow and the process of reverse logistics has been considered with added modes. The added modes are gatekeeping or return evaluation, recovery facilities and the process of product disposition. (Govindan & al. 2015, 602.)

The process of reverse logistics in the looped system is again most likely initiated by a product return, which could be for instance a customer returning a handheld device containing a rechargeable lithium battery to a retailer, or a large battery within an electric vehicle being returned. Depending on the case, the returned product is retrieved by the business with the retail serving as an optional middle-hand. With the returned product at the company's possession, one of the more critical aspects of reverse logistics will be taken into action, which is the process of gatekeeping.

Gatekeeping can be defined as the action of screening the product and deciding its further steps. With gatekeeping or return evaluation, the business decides whether to refurbish or remanufacture, reuse or dispose of the product. The decision is naturally affected by the condition of the product, but a company might have additional purposes in mind.

Gatekeeping also aims to maximise the life cycle of the product, and even if the product ends up in disposition, the goal is to recover valuable materials as effectively as possible with recycling. (Cherrett, Maynard, McLeod & Hickford 2010, 243-246.)

With the final mode added to the closed-loop system, the recovery facilities have an important role in the system. These facilities serve as an option for businesses where the product is sent for material recovery or proper recycling. (Cherrett & al. 2010.) The author suggests that companies dealing with lithium batteries have commonly outsourced this function to a 3PL, as the recycling and recovery process of lithium batteries can prove to be difficult.

2.3 Reverse Logistics as a Tool for Businesses

When it comes to the logistics of disposing and potentially reusing spent lithium batteries, companies can use elements of reverse logistics to utilize in their own hazardous waste management. Reverse logistics is considered as a larger concept with various strategies, suggestions and different proposals for companies to manage their waste properly, and even potentially recover recycled materials. (Grant & al. 150-151.) This thesis strongly suggests that the same ideas can be implemented by business dealing with lithium batteries, as proposed in this chapter.

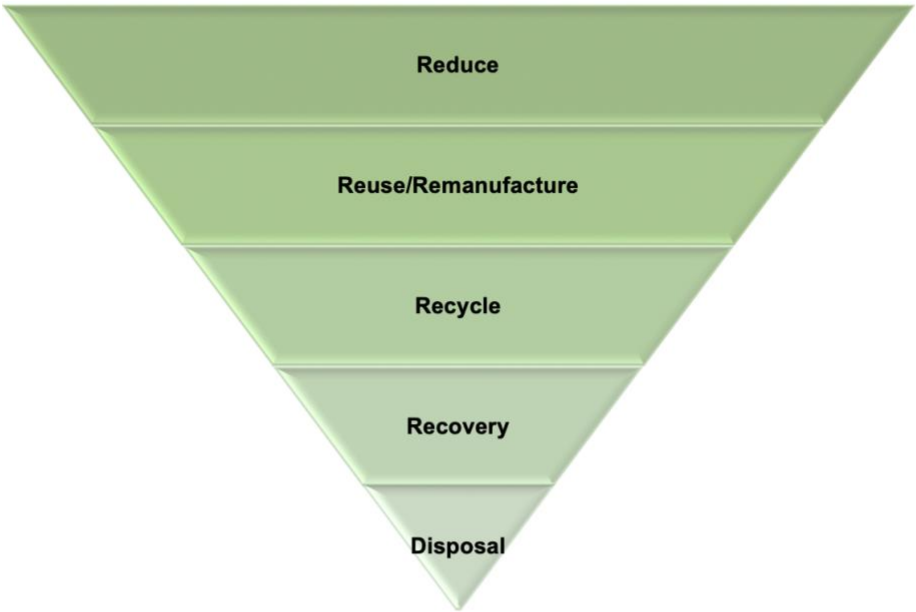

Figure 4. Hierarchy of waste management in reverse logistics (adapted from Grant & al. 2013, 151)

The important role of reverse logistics for businesses can be further supported by the hierarchy of waste management depicted in figure 4. In the logistics environment, reverse logistics has a significant role with the intent to reduce overall waste, reuse or remanufacture otherwise unusable products, and utilise proper recycling and disposal of products at the end of their life cycle. It also aims to recover valuable materials and components in the process. (Grant & al. 2013, 151.) With the hierarchy of waste management in figure 4, the descending order shows the preferred actions to ensure sustainability, with disposal being the last resort of outcome. This concept of hierarchy could be used as an additional primer for increased sustainable thinking for business in the Li-ion battery industry, especially when dealing with their disposal.

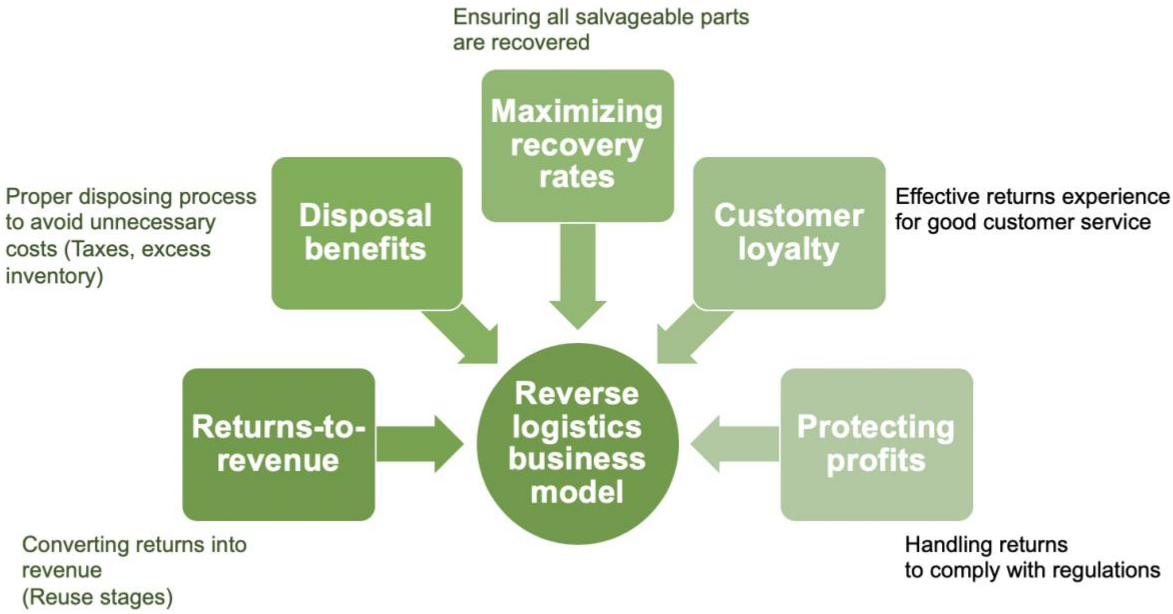

Figure 5. Reverse logistics business models for companies (Adapted from Myerson 2015, 162-163)

When thinking of reverse logistics as a strategy, businesses can utilize many types of models to actually impact their revenue in a positive way as suggested by Myerson (2015) in figure 5. The first business model is called returns-to-revenue, where companies aim to create revenue from their returned products, by for instance refurbishing, recycling or reusing hem. (Myerson 2015, 162-163.) In the case of lithium batteries, returned batteries can be further reused as will be explained further in this thesis.

The second model is the idea of disposal benefits. Disposal benefits relates to the knowledge of where the properly disposed product ends up, thus helping companies to follow for example the EU directives and standards introduced earlier. Myerson also mentions how it can reduce additional costs related to excess inventory, taxes or insurance. The final business model which companies handling lithium batteries can take into consideration is the concept of maximising recovery rates. This refers to the idea that returned products have often salvageable parts and materials which companies should recover and reuse or resell further. (Myerson 2015, 162-163.) Lithium batteries especially contain valuable parts which businesses should salvage, as will be determined further in this study.

The last two business models of figure 5 won't necessarily translate to impacting revenue with Li-ion batteries but are still important in order to understand the concept of reverse logistics. With the model of customer loyalty, the idea is to handle product returns the best way possible to ensure good customer service and maintain good reputation. (Myerson 2015, 163). The business model of protecting profits also relates to product returns, as it is the mentality of handling returns appropriately to avoid government regulation penalties, such as those set by country-individual consumer safety organisations. (Myerson 2015, 163).

2.3.1 Product Recovery Options

Since a key part of reverse logistics is to ensure that all attempts to reduce the carbon footprint of a product are exercised, businesses should think of methods to recover products efficiently. With the importance of gatekeeping introduced earlier in this chapter, these certain methods can further assist in maximising the sustainable aspect of gatekeeping. The usage of these methods as a concept is referred to as Product Recovery Management (PRM). (Grant & al. 2013 156-157). According to Grant & al. (2013), the target of PRM is to reduce the overall waste of the products which companies are handling in their reverse logistics and proposes five major product recovery options. (Grant & al. 2013 156-157).

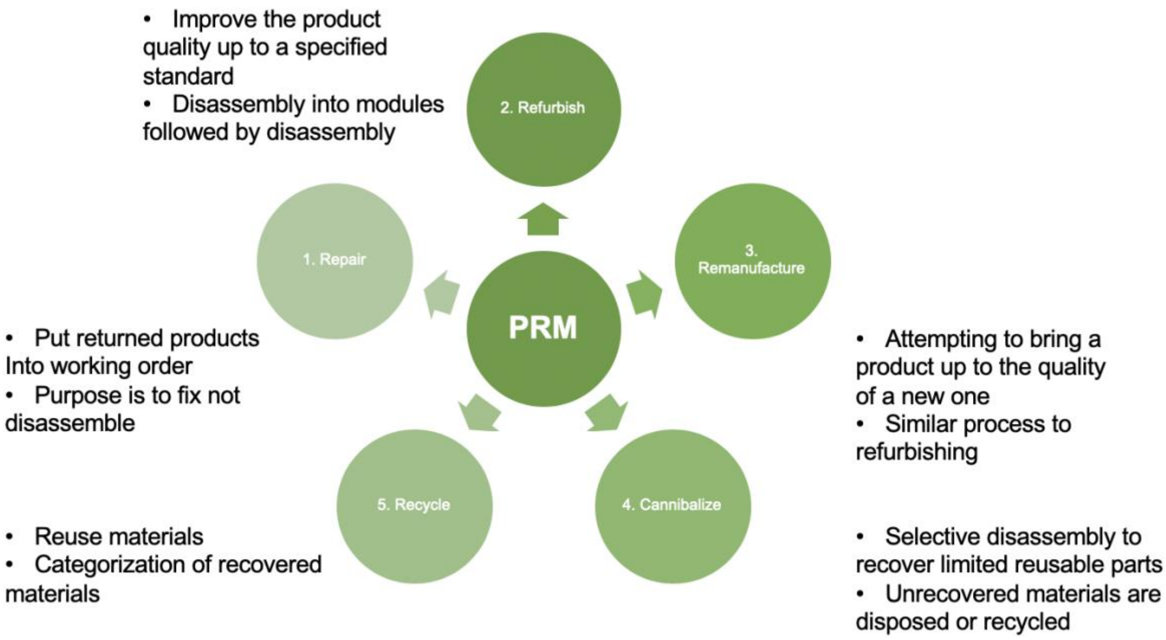

Figure 6. Product recovery options in PRM (Adapted from Grant & al. 2013,156-157)

As depicted in figure 6, companies should consider five different product recovery methods when dealing with products in their reverse logistics processes. (Grant & al. 2013, 156-159). It is to be noted that for lithium batteries not every option can be considered viable, and many methods are product specific, but they are important to understand the PRM concept as a whole. Similar to the hierarchy of waste management, PRM methods can be defined into an order according to their sustainable impact. (Grant & al. 2013, 156-159).

The first proposed PRM method businesses may want to consider in reverse logistics is the option to repair the product, where the goal is to fix the returned product without disassembly. (Grant & al. 2013, 157). Even though products containing lithium batteries such as mobile phones and laptops are repairable, the batteries themselves are not suitable for repair, thus the method isn’t considered valid to the writer. The second preferred recovery option, refurbishing, is somewhat similar to repairing, where the attempt is to return the quality of a used product to a specified level. (Grant & al. 2013, 157-158). Disassembly is often involved where the product is broken down into smaller modules and later reassembled into a refurbished product. (Grant & al. 2013, 157-158).

The third recovery method is remanufacturing of a product. This method has a very similar process to refurbishing, except the quality of the remanufactured product is higher opposed to a refurbished one. (Grant & al. 203, 158.) When speaking of remanufacturing in the context of Li-ion batteries, this thesis will explain further the potential opportunities it might contain.

The two final proposed recovery options in PRM could be considered applicable in reverse logistics of lithium batteries and are strongly related to each other with small distinguishable differences. Cannibalisation relates to the attempts to recover and salvage limited amount of parts of otherwise unusable products. (Grant & al. 2013, 158). This could be compared the acts of gatekeeping as it shows certain similarities.

While cannibalisation is the recovery process of the product, the fifth and final PRM method, recycling, is the actual categorisation and reusage of the recovered materials. The categorisation means that the depending on the quality of the product, it can be either used to make original products or as other material in other products. (Grant & al. 2013, 158.) As a whole, PRM is a valid tool for business dealing with lithium batteries to implement in their reverse logistic process, although in some scenarios selective usage is preferred.

2.3.2 Product Collection Schemes

The growing concern of lithium battery stockpiles in the future is one of the major reasons why sustainable solutions to their disposal should be considered. One of the factors businesses operating especially with handheld devices would also want to consider, is how to get the customer involved in the process. This way the returns have the potential to be more continuous and coherent, which further emphasises the value for a sustainable reverse logistics process.

To promote customer engagement in the reverse logistics process, businesses can introduce various product collection schemes for more efficient returns. These collection schemes can also be described as incentives or ways to encourage the consumer to return the product, instead of throwing it away or otherwise disposing it inappropriately. (Grant & al. 2013, 160.) As mentioned earlier, some of these collection schemes can prove especially useful for business who handle product returns for mobile phones, laptops and other rechargeable devices.

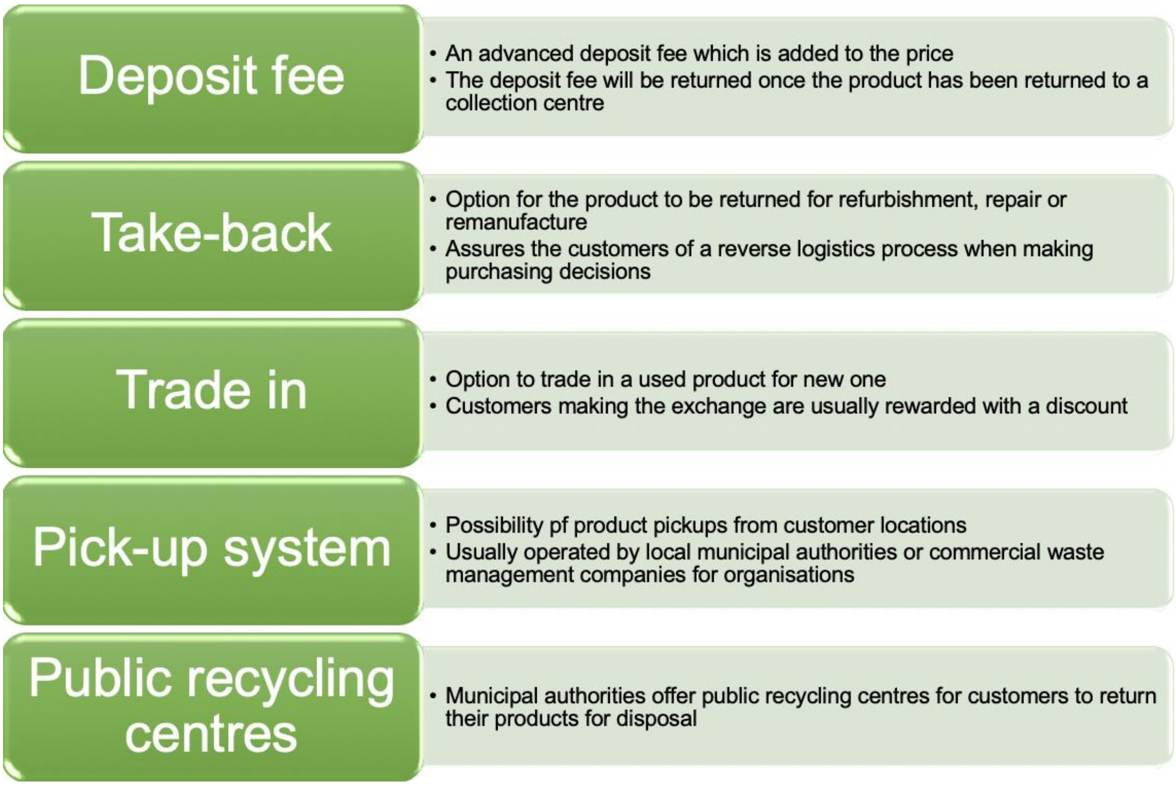

Figure 7. Product collection schemes in reverse logistics. (Adapted from Grant & al. 2013, 160)

The first collection scheme as shown on figure 7 is a suggested added deposit fee on the product. This is a common system used for beverage packages in Finland, where customers will receive the added deposit back once they return it to a collection centre. (Grant & al. 2013, 160.) While this can be an effective concept and serve as an incentive for customers to encourage recycling, the writer suggests it would be too complicated to standardise this type of system, and to apply it with lithium batteries.

The second collection scheme is all about giving the customer an option to return used products for repair, refurbishment or remanufacturing. The strength of this collection scheme is that the businesses offering this system communicate their sustainable mindset to the customer with presenting a reverse logistics process. (Grant & al. 2013, 160.) This idea could be also beneficial for companies operating with lithium batteries to highlight their reverse logistics actions.

The third collection scheme on figure 7 should be especially considered by companies and retailers doing business with laptops, mobile phones or other products with rechargeable batteries. The idea of the trade in-collection scheme is that businesses can offer a service to their customers where used or spent products can be exchanged for a new one, with a discounted price. (Grant & al. 2013, 160.) Companies could use these returned products further for instance in the context of PRM to maximise the efficiency of their reverse logistics.

With the fourth and fifth collection schemes, the systems are designed to give the customer an option to dispose of their used products using services offered by local municipalities. The pick-up system is a scheme where products can be picked up from customer locations for commercial organisations to use in their waste management. As for the concept of public recycling centres, it serves as an option for the customer to return their used products for proper recycling. (Grant & al. 2013, 160.)

Similar to the first collection scheme on figure 7, the last two collection schemes are difficult for individual companies to regulate, so they aren't primary options for businesses to implement in the reverse logistics of lithium batteries. Companies could still benefit from maintaining relationships with municipal commercial organisations, in terms of optimising Li-ion battery disposal and promoting a sustainable mindset. They are additionally important to realise to understand the potential of collection schemes.

2.4 Role of the 3PLs

With the concepts of reverse logistics introduced to help businesses sustainably dispose of lithium batteries, business would need resources to properly utilise these concepts. According to Jacoby (2019), the recycling process of lithium batteries is a complex one requiring additional resources and competence. As it can be imagined, few businesses especially those in Finland have the ability to utilise reverse logistics concepts internally, which is why 3PLs would be considered. Since the choice of cooperating with a 3PL in reverse logistics could be seen as a viable option, it is important to understand how they can be used and what strengths they possess.

While outsourcing a company's logistics services could be seen as a constant solution for businesses, there are also occasions when companies may rely on 3PLs on a situational basis. This can be referred to as occasional use of a 3PL, and there are numerous reasons why a company would choose to go with this business solution. Rushton, Croucher & Baker (2014) propose these reasons to be for example weekly or seasonal demand peaks, spot hires or sudden additional resource requirements. Additionally, reverse logistic operations and the management of unusual products such as hazardous materials are also common instances where 3PLs are used in an occasional manner. (Rushton, Croucher & Baker 2014, 575-576.) This is extremely important to understand, as the outsourcing of lithium batteries fit into this category.

When a company is contemplating the use of a potential 3PL service provider to partner up with, there are certain advantages and disadvantages which 3PLs bring along. 3PLs provide their own expertise which allows the other business to focus on their own core strengths. According to Myerson (2015), Third party logistics provides also bring a good amount of flexibility to a company, such as in geographic locations, resources, workforce size, service offerings but also in technological aspects. The final reasons why a company might choose a 3PL could be because of logistic costs savings in a certain area or due to the 3PL having the resources for more expanded logistic capabilities. (Myerson 2015, 194.)

While third party logistic providers can bring value and upside to a company's business areas, they also have negative aspects which businesses have to assess upon making the final decision. One of the strongest features of the 3PLs is that a company can leave a business function to the hands of a 3PL being an expert in that field, but the result may still be unfavourable if the company loses control in that particular business function overall. This relates to the other issue which companies might have to deal with when cooperating with 3PLs, and that is dependency concerns. (Myerson 194-195.) In order for a company to minimize these two risks, they have to build strong relationships with their logistics providers to ensure quality.

In addition to dependency issues and a company having the potential risk of losing control of a business function, 3PLs may prove to be more expensive in relation to what the internal logistics solution would have been as suggested by Myerson. (Myerson 2015, 194-195.) An example of this would be in the consumer market of handheld electronics. If a business can find a solution within the company to efficiently collect spent electronics from their customers in order to salvage the battery materials, a third-party solution would be unnecessary. It's an example of why company's need to thoroughly assess the viability of a potential 3PL before outsourcing the service elsewhere.

Even with the potential risks, 3PL service providers in Finland might be one of the more reliable choices when speaking of the reverse logistics of lithium batteries. In this context, the outsourced service would be the waste management of mentioned batteries which the company would pay for the expertise as part of their reverse logistics process. Since earlier sections suggest that disposal should be the last considered option and lithium batteries have a reusable quality, the choice of which function to outsource should be again thoroughly assessed to ensure that the capabilities of the batteries are being used.

2.5 Conclusion

In this chapter the most relevant concepts and theory regarding reverse logistics of lithium batteries have been introduced, and what aspects businesses in Finland should consider while applying them to their own business processes. The author has clarified the elements which might not serve purpose in the context of Li-ion batteries while also emphasising the importance of others. The option of considering a 3PL has additionally been proposed, including its strengths and weaknesses.

The theoretical framework covers different concepts and theory from reverse logistics and sustainable logistics relevant to disposing of lithium batteries. The proposed theory and concepts have parts which might not all be suitable to the topic, but they are still important to understand on a larger scale. The most relevant and useful suggestions have been highlighted and shown with figures and tables, in attempt to simplify the actual theory.

One of the main drivers why companies would choose to apply these above-mentioned concepts, is to overall aim for sustainable solutions. Supporting companies to make these decisions are the several regulations and directives introduced by the EU, but also sustainable supply chain management which has grown to be an important trend in the industry to reduce global warming. Besides the potential of making sustainable actions, businesses have to face the reality that if they do not take preventive measures, the lithium battery stockpiles might be an actual problem as soon as the end of this decade.

Reverse logistics in a supply chain has been visualised and explained, with lithium battery segments taken into context. Reverse logistics was further explained with the closed-loop supply chain, and what additional modes are relevant to it. The purpose of these additional modes such as gatekeeping and disposition are all vital for reverse logistics to function properly.

The main purpose of reverse logistics as a tool for businesses dealing with lithium batteries is to give them an effective waste management solution when the batteries have reached the end of their usage. Models such as PRM, hierarchy of waste management, collection schemes and the various reverse logistics business models have all elements which companies in Finland can utilise. As outsourcing the waste management in Finland is also a valid option, companies can also choose to cooperate with a 3PL to make their revere logistics process more efficient.

Since the waste management and disposition of lithium batteries can be a complicated process, the option of outsourcing the function to a 3PL can be considered as a viable one. 3PLs have their strengths and weaknesses, and they can certainly be looked upon as a strong choice to be a part of the reverse logistics process. Still, one of the key aspects which businesses have to emphasise on is the proper screening of the 3PL and assessing completely their validity and fit to their purpose.

3 Methodology

In this chapter, the author presents once more the targets of the thesis with explaining the research question and investigative questions. The empirical research method is also been introduced to support the theoretical framework in chapter 2. Additionally, the strategy and method of how the gathered data is being analysed is explained. At the end, the author clarifies the purpose of the two conducted interviews, and how the decoding is being utilised to introduce the results.

3.1 Targets of Research

The purpose of chapter 2 was to provide theoretical background for the overall targets of this thesis, which will be repeated here to clarify the methodology. As mentioned in the introduction, the research question this thesis is guided by is “How can reverse logistics serve as a sustainable solution for lithium battery waste management?” The research question is been supported by investigative questions listed below:

IQ 1: What are the sustainable benefits of reverse logistics of lithium batteries?
IQ 2: How beneficial is outsourcing a reverse logistic function to a 3PL?
IQ 3: What are the possibilities of reverse logistics of lithium batteries in Finland?

Table 1. Research methods and targets

Research phase	Phase 1	Phase 2	Phase 3
Respondent	Ride Hoop	Finnish lithium battery material recover company	Independent analysis on the process
Data collection method	Interview and qualitative methods	Interview and qualitative methods	Benchmarking and examining the results of empirical research in combination of own conclusions
Data analysis method	Thematic analysis, various thematic analysis approaches	Thematic analysis, various thematic analysis approaches	Authors individual suggestions based on all data researched
Relationship to the RQ and IQ: s	IQ 1	IQ 2	IQ 3 and RQ

3.2 Qualitative Method

To support the validity of the theory in chapter 2 and to answer the research targets, the empirical data has been gathered with qualitative research. According to Bauer and

Gaskell (2000), Qualitative research is referred to as addressing social realities and interpreting them and rarely involves numbers or figures. One of the most common qualitative research methods are in-depth interviews, which are used in numerous prior researches. (Bauer & Gaskell 2000.)

With the selected qualitative method choice, the author decided to gather the empirical information of reverse logistics of lithium batteries by conducting interviews. The interviews were designed to be semi-structured, with open-ended questions from the author, visible in the appendix. These in-depth interviews functioned as the primary data collection method, which were further supported by secondary data. The secondary data was gathered from other researches and theory and are combined within the empirical research sections.

The choice to utilise interviews as the predominant qualitative research method was further supported by the number of potential participants available to the writer. The participants were considered as professionals of the lithium battery industry, with knowledge from different sectors.

To analyse the gathered qualitative data effectively, the qualitative analysis method of utilising thematic data analysis has been chosen. Since the purpose of the interviews was to gain supportive perspective on the reverse logistics of lithium batteries, categorisation and coding the results which are typical for thematic analysis will provide a better understanding of the discussion. (Braun & Clarke 2012.) The categorisation and breakdown have been divided into subchapters in both chapters 4 and 5, with each subchapter representing a theme decoded from the interviews.

As typical of a thematic analysis, the author has identified the empirical findings from the interview with themes linked to this thesis. The coding of these themes has been driven by a combination of inductive and theory-driven data approaches. This means that the data within the interview has been analysed with the data provided, in combination and relation of existing theories. (Braun & Clarke 2012.) These theories can be familiar from chapter 2, but some additional studies and concepts are introduced to support specific findings of the thematic analysis.

3.3 Interview with Ride Hoop

To gain a better perspective on what existing methods companies might utilise when dealing with the disposal of lithium batteries, the author had the target to contact businesses in Finland operating with electric vehicles. The objective was to find out if businesses have thought of any processes to efficiently handle the waste management of lithium batteries, and what challenges they might have currently. The additional objective of the first interview was to discuss of the lithium battery stockpile situation, and what solutions or methods the companies might have in order to minimise the potential risk.

With the first interview, the author contacted Tony Kuitunen, the Chief Hardware Officer of Ride Hoop. Ride Hoop is a Finnish company offering electric scooters for their customers in Helsinki for easy and environmentally friendly commuting. Their service is based around an app which Hoop users utilise to locate the available scooters, check how much their ride cost while containing other features. (RideHoop 2019.) The interview took place in the form of a phone call on the 12th of March in Finnish, with the results and answers being interpreted into English to author's best knowledge.

After the results gained from the interviews, the overview and conclusion for EV lithium battery waste management has been clarified. The results are formed with the information gained from the interviews, but also in relation to the theoretical framework presented in chapter 2. With the combination of theoretical and empirical research, the most relevant results have been made to support the viability of reverse logistics for lithium-ion batteries.

3.4 Interview with a Finnish Material Recovery Company

The purpose of the second interview was to gain more information of the benefits and usefulness of outsourcing a certain reverse logistics function to a third-party service provider. The interview was also approached to give an idea to the reader how complicated the actual process of disposing spent lithium ion batteries can be, and what factors are affecting it. In addition, this part of the empirical research was designed to give an overview on how well Finland is prepared for the overall sustainable lithium battery disposal, but also the scale of the Finnish lithium battery industry.

For the second interview, the author contacted a Finnish company who are specialised in the recovery and recycling of high-cobalt lithium ion batteries found in everyday handheld devices. Their role is in the assortment and material recovery when the batteries arrive to them in cooperation with Recser Oy, who handles the majority of battery collections in Finland. (Company x 2020.) The interview was held on the 17th of March by telephone, and it was done in Finnish. By appreciating the request of the interviewee, the name of the company and interviewee have been kept anonymous. Results and answers from the interview have been interpreted from Finnish to English to the best knowledge of the author.

4 Reverse Logistics at Ride Hoop

In this chapter the author will go more thoroughly into what types methods companies can utilise when dealing with the disposal of lithium batteries not suitable for their primary use. The more specific viewpoint from a business dealing with EVs has been chosen for empirical data. The first conducted interview was with Ride hoop, from which the empirical data has been gathered in combination with existing theory. The interview has been decoded into themes of subchapters with thematic analysis to present the findings efficiently.

4.1 Life Cycle of an EV Lithium Battery

When speaking with Mr. Kuitunen from Ride Hoop, the first objective was to find out how RideHoop handles its electric scooters when they have reached the end of their usage stage. The objective was to address the sustainable perspective which this thesis aims to cover. At RideHoop, several sustainable efforts have already been put into action comparable to the elements of reverse logistics.

When a scooter is returned to Ride Hoop and it has been screened as unusable, every part which is still functioning are targeted to be used in remanufacturing. The unused parts which are not suitable to make new electric scooters are disposed of, but valuable materials such as cobalt and nickel are attempted to be salvaged. (Kuitunen 12 March 2020.) These actions are similar to the concepts of PRM and reverse logistics business models, as presented in chapter 2. With the waste management, RideHoop has outsourced the service to a 3PL (Kuitunen 12 March 2020). This further emphasises their value in reverse logistics.

The lithium batteries used as the primary source of power for their electric scooters are also saved, if they are screened as still functional in some way. While the possibilities of the battery being reused is known, the problem is that there is a certain amount of regulations that the company has to comply with, which reduces their options. There is also a certain amount of unclarity of where precisely the spent batteries are suitable for reuse. (Kuitunen 12 March 2020.)

With the example of Ride Hoop attempting to reuse their lithium batteries, it would be fitting to introduce the typical life cycle of a lithium battery used in electric vehicles as a power source. One of the more effective ways businesses can attempt to utilise to reduce stockpiling lithium batteries, is to try and extend the lifecycle before disposition. To extend the lifecycle, the lithium battery may have a purpose for alternative usage, as shown on figure 8 below.

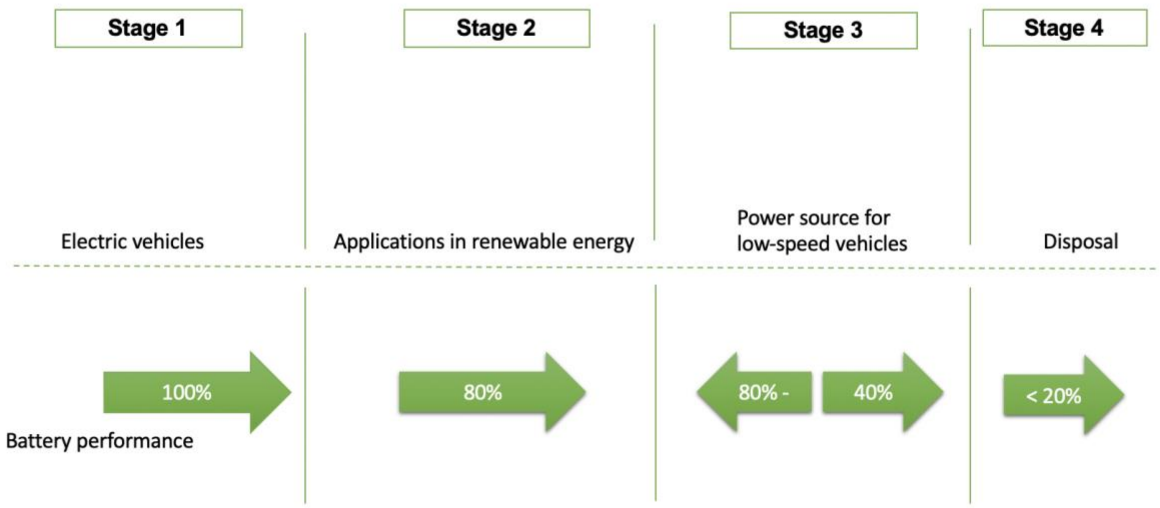

Figure 8. Example lifecycle of a lithium battery concerning the EV industry (adapted from Zhao 2017, 38)

The typical of life cycle of a lithium ion battery can be divided into four stages described in figure 8. The first stage showcases the lithium battery's primary use, which is in this example the power source for an electric car. Recent research has shown that the average lithium ion battery used in electric cars is guaranteed to operate for a minimum of 8 years and 100 000 miles. (Insideevs 2019.) This refers to the optimal power which the battery can provide, as the power of a lithium battery will fade as time progresses.

According to an EV standard, a lithium ion power battery powering electric vehicles has to have a performance capacity of 80% or higher, or it will be replaced with a battery possessing a higher capacity rate. While they are no longer able to satisfy the functions of an electric vehicle, with still relatively high performance-capacity left, lithium ion batteries can be used as a viable power source in other areas, also visible in figure 8. Lithium ion batteries still containing high capacities of power have the potential to be used in for instance a business' energy storage system to maintain the power level for further use. This further usage can be occasional use as output power for renewable energy power generators, like solar power and wind power, as suggested by Zhao (2017). (Zhao 2017, 38-39.)

In addition to their flexibility in renewable energy, according to Zhao, spent lithium ion batteries have the potential to be used as power sources for smaller or low-speed electric vehicles such as electric bikes. (Zhao 2017, 39.) As shown on figure 8, the usage of the still functioning lithium battery should be ultimately determined by its battery performance level.

Once the batteries have the reached the end of their practical and reuse -stages, they naturally need to be disposed of. While the proper disposition is not seen as part of the lithium battery life cycle, reverse logistics would suggest that it should be a key component to be considered. Overall, the typical life cycle of a lithium battery should be considered by each business dealing with them as a key tool to extend its usage time.

4.2 Reverse Logistics Applications

The discussion with Mr. Kuitunen further lead into the collection of malfunctioning or otherwise unusable electric scooters. Since Ride Hoop is a shared service of electric scooters, it is common that the scooters which have technical issues are left out in the environment and the company could be unaware of the whole scenario. Since sustainability and environmentally friendly actions are one of the main drivers of reverse logistics, these kinds of occurrences are something which businesses would want to avoid.

With Ride Hoop, the retrieval of these malfunctioning scooters is being monitored with the help of their application, but also their customers. In the case of malfunctioning scooters, approximately one third (1/3) of the instances are reported by their own customer base. The process is made simple for the customer, as they can contact customer service directly with the Hoop application, who will then take further actions. In many cases the customer is compensated if the ride is haltered or delayed due to the scooter malfunction, which further encourages them to be in contact with the company. With the rest of the instances, RideHoop also takes initiative by monitoring the condition of the electric scooters with their own systems and collecting the ones which aren’t operating properly. (Kuitunen 12 March 2020.)

The example of encouraging the customer to be a part of the collection process can be compared to the collection schemes presented in chapter 2. It could be referred to as a combination of the trade in- and pick-up- system, as it offers the similarities of the customer being involved in the pick-up process with the incentive of an offered reward. Even though the collection in the example of Ride Hoop isn’t directly linked to waste management, by having a system where the return rate is aimed to be maximised for repairs and potentially for remanufacturing can be looked as an element of reverse logistics.

The system which Ride Hoop has at the moment is functioning well according to Mr. Kuitunen, and at the moment there isn't a simple or immediate solution on improving it. When discussing of a potential increased incentive-based encouragement for customers to be even more active in the collection process, it would require increased control to supervise which isn't their primary objective at Ride Hoop. Mr Kuitunen also mentions that their current system is suitable for now, but it has potential to be improved at some point in the future if examined more thoroughly. (Kuitunen 12 March 2020.)

4.3 Regulations

Since the main objective for this thesis is to identify reverse logistics as a sustainable tool for handling lithium batteries, the discussion was guided by the waste management of industry-sized batteries as a part of the reverse logistics process. The issue which Mr. Kuitunen pointed out was that legislation and regulations regarding lithium batteries are complicated and need to be clarified to help businesses comply with them. (Kuitunen 12 March 2020). While this thesis isn't going to propose suggestions based on legislative improvements due to the author's inability to make statements on that regard, clarifying some regulations concerning lithium batteries in Finland and the EU would be still beneficial to present. One of the more relevant regulations in Finland is the "battery directive" and the WEEE directive set by the EU, which guides businesses to handle the battery disposal in an environmentally friendly manner.

In addition to the directives affecting the entire EU, precise guidelines for regulations regarding lithium-ion battery waste management and storage in Finland can be identified. Since the risks regarding transportation will be presented further in this thesis, the focus of the regulations is more towards spent lithium battery disposal, which is highly relevant to reverse logistics. The following clarification of regulations have been interpreted from Finnish to English to the best ability of the writer.

In Finland, lithium -ion batteries and battery cells are under the responsibility of the manufacturer or importer, which means that they are responsible for the waste management of each battery they have put out to market. With handheld devices containing lithium batteries and lithium battery cells, the distributors of these batteries are responsible for receiving spent lithium batteries from the users without any extra costs. The return of the product containing these batteries is not bound to the purchase of new ones. The responsibility of the manufacturer and importer is set by the Finnish waste act (646/2011) and regulations set by the Finnish Council of State (520/2014). (Gaia Consulting 2019.)

When it comes to the industry-sized batteries in Finland, a specific recycling system hasn't been set, but some regulations under the producer responsibility are in effect. For instance, businesses selling electric bikes are responsible for receiving and accepting returned lithium batteries which are spent, used or defective, but there aren't any standards or regulations in their storage. For electric cars, a system for producer responsibility for lithium batteries has been made, and a similar pilot is on the works for lithium ion battery products of large quantities. (Gaia Consulting 2019.)

4.4 Future Measures

To conclude the discussion with Ride Hoop, the final theme which was decoded from the interview was the overall viewpoint of the lithium battery stockpile situation, and what actions can be taken in order minimize its effects. In this part of the open-ended discussion, the target was to define if businesses were aware of the potential concern and if preventive measures had already been considered. This final theme was to give perspective on the whole situation and what potential risks are involved.

In addition to the regulations and directives which have been presented, another topic which was relevant to the future measures of lithium battery waste management is the role of the 3PLs in managing the disposal. Since the lithium batteries used as the primary power source for the scooters at Ride Hoop can be considered industry-sized, by outsourcing the waste management to a 3PL the process can be done professionally. The problem here is that due to the complicated nature of the battery and its recycling process, outsourcing the service can be very expensive according to Mr. Kuitunen. (Kuitunen 12 March 2020).

In addition to the high costs of outsourcing, Mr. Kuitunen mentioned that 3PLs may have transparency issues. It is possible that the service is not done entirely in Finland, and some part of the process is taken care of in other parts of Europe, which affects the reliability of the 3PL. (Kuitunen 12 March 2020.) These are all related to assessment of the 3PL presented in chapter 2, as it underlines the fact that thorough assessment is crucial before choosing to outsource the service.

The conclusion of the discussion was that even though the stockpile situation can be a reality in the future and solutions are needed to prevent it, the unclarity of regulations and the outsourcing being such an expensive solution hinder the progress. For Ride Hoop, it is currently more beneficial for them to store batteries in storages rather than disposing of them sustainably. Mr Kuitunen also concludes, that for the foreseeable future, they will have to wait for the price of the 3PLs to decrease. (Kuitunen 12 March 2020.)

4.5 Results Conclusion

This chapter has presented a thematic analysis of an interview with Ride Hoop. The results have been categorised as themes into various chapters, which have been decoded from the answers provided by the interviewee. An approach has been taken where existing concepts have been referred with the results to support the relevance of the study and discussion. The decoding and interpretation has been done from Finnish to English to the best knowledge of the author, following the ethics of thesis guidelines without any conflicts of interest.

The categorisation of themes has been divided into four (4) chapters: Life cycle of a lithium battery, reverse logistics applications, regulations and future measures. Each chapter includes insight from the interviewee and theory from known sources which support the viewpoints.

By assessing the results from a sustainable reverse logistics perspective, the disposition of unusable scooters and spent batteries at Ride Hoop possess similarities with the hierarchy of waste management in chapter 2. Since on of the main objectives at the company is to reuse or remanufacture old parts and batteries before disposition, it supports the hierarchy depicted in figure 4 in the correct order. Reverse logistics elements such as PRM and reverse logistics business models are additionally apparent. To support the reverse logistics attempts further, it would be important to consider the lithium battery life cycle to extend the battery’s usage.

In addition to some reverse logistics elements evident with Ride Hoop, some evidence of the viability of 3PLs can already be noticed from the discussion. To salvage valuable materials, Ride Hoop has outsourced the waste management to a 3PL, which supports the suggestion that 3PLs could be seen as a necessity in the reverse logistics of Li-ion batteries. Aside from the waste management activities, other reverse logistics concepts can be seen. The system which Ride Hoop uses to collect the unusable scooters can be compared to the collection schemes presented in chapter 2. The customers are being involved in the collection process with an incentive, and the collection process is similar to the pick-up system in the schemes.

As noted in the discussion, one of the hinderances in the development of proper disposition of lithium batteries is the various regulations in Finland. With the regulations and directives of battery disposal explained, it supports the general directives set by the EU and gives a better perspective of the responsibilities for the producers and importers. The directives introduced give an additional idea of the industry sized lithium battery regulations and which types of acts are considered for the future.

With the final part of the discussion, the potential concern of lithium battery stockpiles was addressed, and how 3PLs can serve as options in helping with the battery disposal. The complications of the 3PLs had been discussed, including the transparency issues and high prices. While the author wasn't able to do further research or conduct more interviews to support these statements, these can all be reasons for businesses not deciding to go further with their battery disposal. For reverse logistics to be functioning properly, it would be beneficial for the 3PLs to be reliable and offer an affordable service, even though the latter is not determined by the 3PL itself.

5 3PL as an Option for Lithium Battery Recovery

With the gained perspective from a company utilising some concepts of Li-ion battery waste management, the author thought it would be beneficial to gain perspective from businesses offering a service to deal with the said batteries. It was important for the study to find out what logistical risks or complications a 3PL can identify when dealing with lithium batteries, and to gain insight from another viewpoint on the potential battery stockpile concern. In addition, the author was curious about the actual process of disposing of the lithium battery, and how if possible, the potential valuable materials can be recovered.

5.1 Challenges in Li-ion Battery Disposal

While discussing with the Finnish company specialising in recovering valuable materials from lithium ion batteries, the interview was first focused on gaining additional information about the actual process. With acknowledging a certain method associated with material recovery of lithium batteries, the potential complexities involved in the process were easier to understand. Since material recovery is considered as one of the sustainable disposal options, it was important to also gain a perspective of the challenges concerning the overall process of lithium battery disposal.

The method which the interviewed company is using to recover materials from high-cobalt batteries is a two-part crushing method, to make the material recovery safe. The company uses this method to salvage the materials which they want to recover, and the separation is done manually. The salvageable materials are mostly nickel, cobalt and copper which are valuable metals used for instance in lithium battery remanufacturing. (Representative company X 17 March 2020.)

With the process of material recovery simplified, the next objective was to realise the potential challenges in the process from the company's perspective. One of the challenges raised in the material recovery process is the potential decrease of high-quality metals used in the batteries themselves, resulting in overall value reduction of the process. (Representative company X 17 March 2020.) While this concern might mostly affect businesses in the recovery sector, it can also result into reduced remanufacturing of new lithium batteries due to low-quality metals, ultimately having a negative impact on the idea of companies utilising reverse logistics.

One the challenges which the interviewed company identified and are currently developing on, is the ability to recover materials from large industry-sized cell packets, such as those found in EVs. Due to their growing popularity, it would be beneficial for them to be involved as one the businesses able to recover valuable materials from them. (Representative company X 17 March 2020.) This shows how the size of a lithium battery affects the overall disposition and recovery process.

The other challenge which can affect multiple third-party providers offering recycling, material recovery and other waste management services is that the lithium batteries might come in different forms and may have drastic differences. With this estimated theme becoming more common, it would become difficult to standardise the recovery process. This means that for instances Li-ion batteries used in various handheld devices and different EVs contain various materials, which are harder to separate from the actual materials meant to be salvaged. This makes the process of manual separation more difficult. (Representative company X March 17 2020.)

5.2 Risks Concerning Lithium Batteries

To gain a better understanding of lithium batteries as a product, one of the topics of the discussion was their physical risks businesses need to consider in their functions. The purpose of this theme was to identify what potential risks lithium batteries contain during transportation and storage, and how business and 3PLs at the end part of reverse logistics handle these risks. With the risks identified, it gives an improved logistical perspective of what measures need to be considered when speaking of reverse logistics of Li-ion batteries.

Lithium batteries are considered as hazardous materials, and companies responsible for their storage and shipment should be aware of the associated risks. Lithium batteries are known to cause fires or even explosions in certain conditions especially during shipments, which is why packaging them should be done with utmost care. According to the University of Washington, (2018) fire hazards are associated with the above-mentioned high-density feature of the lithium battery, combined with their flammable electrolytes. The incidents of explosions are usually started by a “thermal runaway” within the battery cells, which can occur in certain conditions. (University of Washington 2018, 2.)

University of Washington (2018) proposes that thermal runaways can be caused by physical damages which the lithium battery has received, including electrical abuses like overcharging, or if the lithium battery is exposed to suddenly elevated temperatures. If the lithium battery comes to contact with any of these elements, it may produce a thermal runaway resulting the battery becoming overheated. A different kind of thermal runaway may occur if the battery is in defect condition from the manufacturing process, such as having imperfection or contaminants. University of Washington also suggests that if the lithium battery cell case fails due to its defect condition, it will release toxic and flammable gasses with certain pressure, depending on the cell construction. (University of Washington 2018, 2.)

University of Washington explains how in any case of a thermal runaway, the end reaction can be anything similar to a road flare, a thick smoke, a small burn or even an explosion. The severity of the reaction is affected by the combination of size and amount of the batteries, their state of charge, quality of their construction and their chemistry. (University of Washington 2018, 2-3.)

At the interviewed company, an adapted method is being used to ensure safety when the lithium batteries are shipped to them. The shipment is done with barrels loaded to a parcel, which contain the batteries within large waste bags. The bags contain insulator-related materials, which prevent the lithium batteries from touching each other and thus preventing short circuits and other hazards. (Representative company X 17 March 2020.)

5.3 Perspective for the Future

Similar to the discussion on chapter 4, the final objective was to gain perspective what types of trends can be expected with the overall waste management of lithium batteries. It was also important for this thesis to find out from the perspective of a company working in material recovery how the scenario is developing towards the end of the decade. The perspectives on the same topic gained from two businesses from different sectors gives this thesis greater importance and value.

Since one of the key topics this thesis has been concentrating on is the potential stockpile scenario of lithium batteries in the future, it was one of the topics to conclude the discussion. When thinking from Europe’s and more importantly Finland’s perspective, it seems that the preparations have been made in some regard, even though the Li-ion battery quantities aren’t close to the ones in for example China. (Representative company X 17 March 2020). Finland is not seen as one of the countries critically affected by the potential concern, but they are still ready for it and developing solutions. (Representative company X 17 March 2020).

Finland is one the countries with good refineries of cobalt and nickel, which as mentioned earlier are the more valuable metals salvageable from lithium batteries. The cells and modules which are key leftover parts can additionally be handled for instance at the interviewed company. (Representative company X 12 March 2020.) In addition to the multiple refineries and competence in material recovery, Finland is also working on multiple projects in improving for instance the ability to recycle Li-ion batteries. This is further supported by the report of Business Finland executed by GAIA Consulting and Spinverse (2019), where Finland's know-how and understanding on battery recycling has been described as being on a respectful level. (Adolfsson-Tallqvist & al. 2019, 42-43).

When it comes to the overall scenario of the Li-ion battery industry, Finland has many elements suitable to succeed in many of its business sectors. Finland's network of companies in the lithium battery value chain can be considered vast in all major sectors, including material production, cell and battery manufacturing, Li-ion related applications, recycling and reuse. Finland's strengths are especially in the manufacturing and applications sectors, as Finnish companies are actively developing applicable solutions for Li-ion batteries, like electric buses and batteries for heavy-duty machinery, as presented in the report from Business Finland and GAIA consulting. Each sector has multiple companies operating, although sectors involved in reverse logistics (reuse, recycling) have currently fewer businesses compared to other sectors. (Adolfsson-Tallqvist & al. 2019, 29-41.)

The interviewee mentions one of the more interesting trends overall in the EV industry, which is that manufacturers are looking to keep the usable materials from the disposal process and recycling. (Representative company X 17 March 2020). This means that reusing the batteries might not give the value which recycling offers. In this matter, the recycling can be ultimately seen as a more beneficial solution to be considered.

Whilst the concept of reusing batteries has been practiced in some parts of the world, it remains to be seen which direction will ultimately be the more useful solution. Aspects which will most likely impact the potential trends in lithium battery waste management are the ongoing and increasing demand of the batteries, but also how technology evolves in material recovery. If the quantity of lithium batteries grow as expected and material recovery and recycling will become more efficient, it could be more beneficial for businesses to make new, high-quality batteries from recovered materials instead reusing them. (Representative company X 17 March 2020).

5.4 Results Conclusion

This section has presented a thematic analysis of an interview with a Finnish company specialising in material recovery of high-cobalt lithium batteries. The purpose of this interview was to gain a perspective and insight from a 3PL dealing with lithium batteries and have an open-ended discussion of the topics this thesis aims to cover. The results of the thematic analysis have been presented and categorised into chapters, with a similar approach to section 4 of presenting data from the qualitative method and combining existing theory. The decoding and interpretation has been done from Finnish to English to the best knowledge of the author, with the ethics of the thesis guidelines been followed. With respecting the interviewees request, their name and company have been kept anonymous.

The discussion was started by simplifying the lithium battery material recovery process and what types of challenges are involved. An example was given from the interviewed party that a crushing method can be used to separate the desired materials. These materials are various valuable metals such as cobalt and nickel.

One of the challenges in material recovery from the company's perspective is the potential decrease of high-grade cobalt batteries, which lowers the overall value of the recovery process. The other challenge which can also affect other businesses handling Li-ion battery waste management is standardising the process. Since lithium batteries can come in many sizes and contain different materials depending on its function, it becomes more difficult to separate the desired materials. These challenges are important to realise as they can be hindrances to the reverse logistics process from the 3PL perspective.

Following the challenges in recovery process, the risks which are associated with Li-ion batteries have been explained. Lithium batteries are considered hazardous substances and need special preparations especially during shipment. An example was presented by the interviewed party of an adapted method of handling spent li-ion batteries, which follows the same principles as in the existing theory.

The discussion was ultimately concluded with the perspectives for the future of lithium battery waste management and the trends potentially affecting reverse logistics. The overall scale of the lithium battery industry in Finland has also been briefly acknowledged. The potential trends discussed is mainly relative to the overall Li-ion battery waste management, and depending on the development of technology, it remains to be seen if battery recycling will become the more suggested option.

6 Results

The conclusions have been gathered in combination of the theory introduced in chapter 2, decoded data of both interviews, but also with the author proposing own suggestions. The validity of the results and qualitative analysis is being assessed, with the chapter concluding in the authors recognition of personal learning.

6.1 Validity of the Research

As explained in chapter 3, the primary data collection was dependent of the data gained from the interviews. The discussion of the interview was guided by the target to answer investigative questions 1 and 2, and to gain additional supportive insight for the thesis topic. The author additionally gathered secondary data which were thought to be relative to the primary data and combine them in the form of thematic analysis.

When it comes the validity and reliability of the study, the author suggests the results to be accurate, comprehensive and following the ethics of a research-oriented thesis. Even though the author interpreted the results from Finnish to English over a phone call, an assumption can made that the answers provided by the interviewees hasn't lost their value. The author followed the ethical guidelines by respecting the request of the second interviewee and kept the names anonymous. While this can have an effect on the validity and reliability of the research, the answers which the author received were considered valuable to be included.

The first interview was conducted to provide additional information on how a business having an electric vehicle as their product can deal with Li-ion battery disposition and waste management. By assessing the quality of the results, the author believes them to be valuable in terms of the overall target, which was to gain supportive information and insight from a professional in the specific business sector. The linkage between the primary data and secondary data can be seen as apparent, and the quality of the secondary data can be identified as valid and relative to the thesis.

The second interview had the purpose of involving the insight of a company offering a service relative to the lithium battery disposal and waste management. The author had an additional target of gaining information about the process of Li-ion battery recovery, and what challenges it might involve. As explained earlier, even though the delicate information of the interview was kept anonymous for the reader, the author claims that the information provided can be considered as valuable nonetheless.

It is to be noted from the data results that the number of secondary data was fewer, although it shouldn't diminish the overall value of the interview. Even though the decoded results aren't necessarily all directly linked to existing theory, the answers still provide valuable insights to be considered further. Overall the author suggests that both interviews and their decoded data serve a purpose for this thesis, and they provide valuable data to support the targets of this research

6.2 Reverse logistics as a Sustainable Method for Lithium Battery Disposal

This thesis has evaluated the importance of reverse logistics as a sustainable solution for businesses dealing with lithium battery waste management. The theoretical framework has proposed existing theories and concepts of reverse logistics, which the author believes are applicable and relevant to the thesis topic. The empirical section has provided additional insight from professionals of the lithium battery industry, with the author utilising qualitative methods to analyse them.

To simplify the key results of the research, the justification has been made in terms of how well the research question has been answered, which was determined as "How can reverse logistics serve as a sustainable solution for lithium battery waste management?". To simplify this, the categorisation of dividing the investigative questions into subchapters has been made. Within each subchapter, each investigative question has been evaluated individually and what findings this thesis proposes in supporting them.

6.2.1 Sustainable Benefits of Reverse Logistics of Lithium Batteries

The overall results from this thesis suggest that reverse logistics can provide multiple sustainable benefits for lithium battery waste disposal. As described in earlier sections, while reverse logistics is commonly utilised for instance in retail with efficient product returns, the main value it can give to businesses is the sustainable concepts it proposes.

The research suggests that the mindset which could guide business in utilising reverse logistics is the recent development and trend of sustainability in business functions. Concepts like DPSIR, standards within the EMS and regulations like the battery directive set by the EU all additionally support the aspects of the trend. With the evolution of green logistics, the concept of reverse logistics can additionally be considered as one of the major sustainable developments in the SCM industry.

The proposed concepts of reverse logistics like PRM, hierarchy of waste management, collection schemes and other reverse logistics business models are all designed to have a sustainable effect on a company’s business practices. The writer suggests that all of these concepts have elements which businesses can utilise in lithium battery waste management. In addition to their environmental aspects, they can obtain added benefits.

While the sustainable benefits are applicable for all battery segments introduced in chapter 2, the added benefits proposed by the author can be dependent on the Li-ion battery type. For instance, when talking about spent secondary lithium batteries used as primary sources for handheld devices, ideas of collection schemes can be especially applied to involve the customer and minimise the number of devices thrown away. The handheld devices can also benefit from efficient material recovery, which a business responsible of their disposal can use to make new batteries from acquired raw materials.

With other battery segments, the sustainable concepts evident from reverse logistics can be also applied for additional purposes. In the industry-sized lithium battery sector, remanufacturing and material recovery can beneficial in terms of making new batteries from recycling. The writer also proposes the idea of extending the industry-sized battery life cycle, which further supports the theory of Li-ion battery reusage. This reverse logistics element can give the lithium battery, which is not suitable for the primary use of for example an EV, a usage purpose in other areas. As presented on Figure 8, the purpose can be in for instance in the form of a power source for generators or smaller electric vehicles.

The purpose of reverse logistics as an option for Li-ion battery waste management was also supported in the empirical research with the interview with Ride Hoop. As presented with thematic analysis, some implementations of reverse logistics at Ride Hoop can be noticed, with an adapted method of a collection scheme, and the target to reuse spent parts from scooters and even Li-ion batteries to make new ones. While it has to be noted that the process can’t be yet simply standardised due to unclarity of regulations as proposed by the interviewee, the indications of revers logistics concepts being utilised support the importance of this thesis topic.

Since this thesis has identified the primary environmental threat of lithium ion batteries, all aspects of reverse logistics can be considered as usable tools in minimising it. One of the main goals of the thesis was to address the potential Li-ion stockpile concern, which is why the value of reverse logistics as a sustainable idea has been examined. The author therefore suggests that the first investigative question has been thoroughly covered with relative results.

6.2.2 Benefits of Outsourcing a Reverse Logistics Function to a 3PL

With the second investigative question, the objective was to assess the viability of outsourcing a reverse logistics function to a 3PL. This thesis has explained how the disposal process of a lithium battery can be complicated, as there are various aspects to be considered. Due to the complexity of the disposal, it can discourage businesses in not relying on the ideas of reverse logistics but finding cheaper, easier and unsustainable solutions. Third-party logistics providers can serve as viable solution for this matter, even though their selection might not be self-evident. To properly assess their viability, the author has created a SWOT analysis for 3PL selection.

To explain the purpose of the presented analysis, the brief explanation of SWOT would be first necessary. SWOT is directly translated to Strengths, Weaknesses, Opportunities and Threats, and its purpose is to help businesses identify these elements within their operations. It is typical for a business utilising this analysis to improve on their strengths, address their weaknesses and utilise or counter their opportunities and threats, as suggested by Dyson (2004). (Dyson 2004, 632.) The swot analysis presented below is not addressed to any specific company and is solely made for the purpose to efficiently explain the benefits of a 3PL in terms of outsourcing a reverse logistics function to them.

Figure 9. SWOT analysis of 3PLs in the Li-ion battery sector

The SWOT analysis of the 3PLs operating with Li-ion batteries presented in figure 9 first addresses their strengths. One of the upsides which 3PLs possess is that they are usually experts in a specific field. This applies also to the third-party logistics providers of lithium batteries, like those operating in material recovery as explained in chapter 5 of the empirical research. Since the overall disposition and recycling process of lithium ion batteries can be difficult to be executed sustainably, and companies often don't have the resources or expertise to manage it internally, the author suggests that the 3PLs major strength is in their professionalism.

Apart from the expertise 3PLs provide, they also offer the sustainable aspect to a reverse logistics process. Since reverse logistics has been determined as a highly sustainable solution for lithium battery waste management, 3PLs often have a huge role in offering the various sustainable services for businesses. These services can be in recycling, material recovery, remanufacturing or some other service, providing for instance solutions to reuse lithium batteries and extend their life cycle.

Since lithium batteries are considered as hazardous products, they need to be managed safely with necessary precautions. This study proposes that 3PLs are a sufficient choice in this regard. Since the major risks lithium batteries contain are usually associated with transportation and storage, the empirical research shows that 3PLs are aware of them and can utilise adaptable methods to manage the process safely.

The next stage of the SWOT analysis is the authors view on the potential weaknesses of the 3PLs. This thesis suggests that one of the weaknesses 3PLs currently have is their high costs, for instance in the proper recycling of lithium batteries. This can be strongly related to the complexity and requirement of resources for the process, which results in the expenses being so high. When thinking of the industry in Finland, there are relatively fewer businesses offering services in the recycling sector, also having a potential effect on the prices.

One of the ideas which came up during the thematic analysis of the first interview, is that some 3PLs may have transparency issues in the overall process. The idea proposes that some functions of recycling is not operated in Finland, but in other parts of Europe. The author wasn't able to support this statement with additional research due to limited availability of interviews, but the topic brought out by the interviewee was still interesting enough to be considered as a potential weakness. The statement could also show connection to the transparency issues which are generally associated with 3PLs.

The opportunities of the 3PLs was mostly based on the thematic analysis results of both interviews, with the theme of future perspective being the main focus. The first two considered opportunities for third-party logistics providers can be linked together, as they are both dependant on each other. Since an assumption can be made that lithium batteries continue to increase in usage due their ability to be applied in multiple purposes, it further increases the risk of the lithium battery stockpiles. With the increase in their popularity, the thesis suggests that it can encourage more 3PLs to start operating in the sectors which might have currently fewer companies.

The third opportunity this thesis proposes for 3PLs is the possibility of establishing strong business relationships. Since businesses are most likely in need of expertise to handle the disposal of lithium batteries, those 3PLs which can offer strong relationships with the other party have high potential to be reliable components in their processes. This opportunity could have further importance if the demand for 3PLs grows in the future.

The final stage of the SWOT analysis outlines the potential threats which third party logistics providers might face as being a beneficial solution for Li-ion battery waste management. The trends of the lithium battery industry can be potential threats, while also being opportunities. As discussed earlier, it is still uncertain what kinds of trends are expected in the near future, and for the 3PLs the threat is that the costs continue to increase due to lack of progress made in the Li-ion battery industry. This means that if for instance the potential of more effective lithium battery recycling and waste management is not realised, it might discourage many companies to not implement 3PLs as a part of their reverse logistics. This can potentially lead to fewer new third-party logistics providers coming to the industry, eventually maintaining the increase in their costs.

The above assessment suggests that the overall benefits and opportunities of 3PLs outweigh its disadvantages, even though the current price of the operations can be high. The author proposes that this assessment has given an updated perspective to the industry, with presenting the potential demand for more businesses to offer recycling services, and that it would result in the prices to become more competitive. These suggestions and proposals have been made with neutral opinion not favouring any specific party, but to support the possibilities of reverse logistics of lithium batteries and how 3PLs can be a key aspect in the process.

6.2.3 Possibilities of Reverse Logistics of Lithium Batteries in Finland

As described in the key points taken from the Business Finland report, the lithium battery industry in Finland can be seen as comprehensive, having businesses operating in all major business sectors. This has been further supported by empirical research, as the second interview proposed the ideas of Finland having strengths and professionalism in many areas. Finland has especially strengths in its refineries for spent Li-ion batteries. These refineries serve a key role in manufacturing new Li-ion batteries from materials which have been recovered from spent ones.

In addition to the strengths, expertise and multiple operators in the lithium battery industry in Finland, the author suggests that the EU directives and other regulations set by the Finnish Council of State can be primers for increased reverse logistics operations in Finland. Ongoing projects in development such as the one related to the recycling of Li-ion batteries also indicate that sustainable solutions for lithium battery waste management may have demand.

The interview in chapter 5 pointed out a potential trend in the EV industry, as businesses are looking to keep the raw materials from recycling processes, and it is seen as a more valuable option compared to battery reuse. The author proposes this trend as an opportunity to the Finland Li-ion battery industry, as the recycling and disposition sector has currently significantly fewer operators compared to other sectors. This can be further supported by the other proposed perspective for the future, as if the technology in recycling continues to develop and Li-ion battery usage rates continue to increase, recycling can be seen as the favoured option compared to battery reusage. It will be interesting to see how or if the trends will be affected in the near future.

While Finland may not be the primary threat regarding the lithium battery stockpile scenario, the expertise and overall scale of the industry suggest that they are prepared. An assumption can also be made that Finland has potential demand for more 3PLs and various providers of Li-ion battery disposition. Finland has already established a strong position in many sectors of the Li-ion battery industry, but sectors related with reverse logistics are fewer in numbers.

Overall, the author believes that businesses in Finland have the potential to utilise reverse logistics effectively. Since the concepts of reverse logistics this thesis suggests are thought to be suitable for lithium battery waste management, an assumption can be made that Finland has demand for especially these sectors. Since the disposal and recycling of lithium batteries is a complicated process to be done internally, businesses are dependent of professionals, as imminent from earlier. If more companies in Finland would start operating in recycling, material recovery and other services dealing with Li-ion batteries waste management, this study shows that it can have a positive impact for the opportunities of reverse logistics.

7 Discussion

This final chapter will present the summary of the overall research. The author will also suggest further study for the topic of reverse logistics of lithium batteries. In the end, the author of this thesis will present his own reflection of the research and evaluate his own learning.

7.1 Summary

Overall the results suggest that this thesis has provided a comprehensive overview on the subject of reverse logistics of lithium batteries and provided relevant sustainable guidelines for businesses. Relevant theory regarding reverse logistics concepts and informative empirical research has been presented, and all support the targets of the thesis. The main research question and the investigative questions supporting it have been answered successfully according to the author, and the results have been presented thoroughly for the reader.

Ultimately, the author believes that this thesis could be useful for businesses operating in the Li-ion battery industry and are looking for sustainable alternatives for their disposition. This research could also be valuable for 3PLs working in the same industry, as it showcases the demand for more service providers in specific sectors. The potential and possibilities of reverse logistics in Finland have also been presented. In addition to all, the author believes this thesis has provided a sustainable perspective to the Li-ion battery disposal, and how the risk of potential environmental hazards could be reduced.

7.2 Further Study

With the main objectives of this thesis successfully reached, there are still a few areas which could be useful for future research in the context of reverse logistics of lithium batteries. As mentioned in the previous section, it will be interesting what kinds of trends will be apparent in the future of the Li-ion battery industry, and it remains to be seen which disposal method of lithium batteries will turn out to be the more beneficial one for businesses. A further study could be focused on these effective trends of Li-ion battery disposal, and how companies are utilising it.

Since this thesis took the logistics approach of reverse logistics concentrating more on the disposition and sustainable aspects, a further research could be done involving potential manufacturers from Finland and designing a reverse logistics process entirely domestically. Since the majority of lithium batteries in Finland are imported from other parts of the world, an interesting study could be about the complete flow of the battery, involving all business sectors of the Finnish Li-ion battery industry. This could further emphasise the potential and possibilities of the overall industry in Finland.

7.3 Authors Reflection

My thesis process started in August of 2019, where the thesis planning course took place. Back then I was committed to find a commissioning company for which I could complete my thesis, as I thought it would bring more value to the thesis process. I spent the rest of 2019 searching for a potential commissioning company while having an accepted thesis plan ready, but aside from a few promising discussions no binding agreements were made.

Fortunately, in January of 2020 I was approached by one of my contacts to consider the subject of lithium battery logistics. I was immediately interested about the topic, as it was rather unique and highly relevant. After a few discussions with my contact I ultimately decided to concentrate on lithium battery disposal and approach it with the reverse logistics aspect.

I believe I managed to find good theory supporting my topic, and the two interviews I managed to organise included interesting and valuable data. The subject of reverse logistics was relatively new for me, but I felt motivated to do research on it. My motivation to succeed was further increased by involving lithium batteries to the research, as they are a discussed subject in many ways. It should be mentioned that due to the current circumstances resulting from the COVID-19 pandemic, the availability of potential interviewees was negatively impacted. I was unable to gain interview confirmations after the social distancing measures were put in place in Finland.

While researching this thesis topic I gained valuable knowledge about reverse logistics, and how versatile it can be in terms of waste management. I was extremely satisfied to notice that I was able to find the connection between reverse logistics models, and how they are suitable when dealing with lithium batteries. Additionally, it was beneficial for me to expand my knowledge by studying the technological aspects and recycling processes of lithium batteries.

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Appendices

Appendix 1. Interview Form for Interview 1

INTERVIEW 1. Discussion with RideHoop 12 March 2020.

The following interview has been interpreted from Finnish to English. The interview was done in the form of a phone call.

1. Could you shortly introduce yourself?

- Position
- Roles

2. When the EV has reached the end of its usage time, what kind of a disposal process it takes?

3. How are spent lithium batteries handled at your company?

4. What challenges do you see in the disposal of lithium batteries?

5. In a potential case of a scooter malfunctioning, how involved are the customers in not leaving it in the environment?

6. Could you involve customers more, and encourage e.g. collection points for unusable EV's?

7. What is your overview of the situation for eventual stockpiles of lithium batteries?

Appendix 2. Interview Form for Interview 2

INTERVIEW 2. Role of Outsourcing, 17 March 2020

The following interview has been interpreted from Finnish to English. The interview was done in the form of a phone call, and as requested by the interviewee, the company and interviewee will remain anonymous.

1. Could you shortly introduce the main functions of the company?

2. What are the challenges of the disposal of lithium batteries from your business perspective?

3. Could you briefly describe the recovery process of lithium batteries?

4. What risks do lithium batteries contain in transportation/storage? Do they concern your business operations?

5. What is your viewpoint on the lithium battery stockpile situation we might have at the end of the decade?