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Citation for the original published paper (version of record):
Kurdve, M., Nilsson-Linden, H., Johansen, K. (2026). Crisis resilience through a remanufacturing supply of electronics. 12TH SWEDISH PRODUCTION SYMPOSIUM, 2026, 1342.
http://dx.doi.org/10.1088/1757-899X/1342/1/012027

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IOP Conference Series:
Materials Science and
Engineering

PAPER • OPEN ACCESS

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To cite this article: Martin Kurdve *et al* 2026 *IOP Conf. Ser.: Mater. Sci. Eng.* **1342** 012027

Crisis resilience through a remanufacturing supply of electronics

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Abstract. The increasing frequency of global supply chain disruptions, exemplified by the Covid-19 pandemic, has exposed vulnerabilities in the provision of critical electronic components. This study investigates the potential of remanufacturing electronic products as a strategy to enhance crisis resilience and secure supply chains, focusing on the Swedish societal context. Through the analysis of three distinct remanufacturing business models—Contracted Remanufacturer (CR), Original Equipment Remanufacturer (OER), and Independent Remanufacturer (IR)—the research explores the prerequisites, challenges, and opportunities associated with emergency production via remanufacturing. Data were collected in a comparative study through study visits, interviews, workshops, website analysis, and expert consultations focusing on three companies that do remanufacturing of electronic components: one in each business model category (CR, OER, IR). Findings reveal that remanufacturing can restore used electronic parts to a condition equivalent to new, offering a viable alternative for emergency supply, particularly for spare parts. However, significant supply chain challenges persist, including access to design specifications, software, and variability in core conditions. OERs benefit from internal design knowledge, enabling better quality assurance, while CRs and IRs face greater hurdles in scalability and quality control. This study concludes that developing flexible, quality-assured remanufacturing capabilities is strategically important for crisis preparedness. Achieving this requires coordinated efforts at the company (micro), supply chain (meso), and societal (macro) levels, including regulatory support and collaborative procurement strategies. These efforts are essential to ensure the continuity of societal infrastructures dependent on electronic components during crises.

Keywords: Remanufacturing, Emergency production, Security of supply, Critical components, Electronic products

1. Introduction

In the last decade, uncertainty has increasingly defined the organisations operations from a global context [1]. Swedish preparedness faced significant challenges during Covid-19, where a lot of manufacturing SMEs was affected by lock-down and lack of material [2]. Shortcomings in Sweden's healthcare supply preparedness and the need for capacity for renewal became apparent. Challenges with the provision of personal protective equipment could in some cases be solved by rethinking and working in collaboration between industry and government [2,3]. Swedish authorities have since then been tasked to analyse and increase security of supply for critical products and components by the Swedish Civil Contingencies Agency – MSB2409 [4].

Swedish manufacturing is progressing in building resilience and sustainability through circular economy, with that, it is suggested that industries should pursue resilience strategies to address increasingly unpredictable sustainability issues [5]. Uncertainty levels, reflected in external economic, environmental, political, social, and technological context have increased recently [6]. A lot of societal critical systems are dependent on electronic components, and the worldwide electrical and electronics product market was 3,5% of global GDP in 2022 [7]. The supply of products has over the past decades become more vulnerable to disruptions due to globalisation, outsourcing and cost efficiency trends [8] as well as the ongoing transition towards electrification and circular economy [7]. This indicates that security of supply at the company (micro) and societal (macro) levels are interconnected and interact with one another. A supply chain (meso) perspective is needed to consider, to clarify the linkages between company and society levels [10]. Uncertainties that occur in disrupted global supply chains imply a need for managing emergency production where an option could be that raw materials and components are domestically sourced [11]. Such supply chains are dependent on global stability since many key production sites of chips and critical raw materials are in Asia. Here, domestic remanufacturing may be an easier path for emergency production of critical products to societal critical functions. When it comes to critical electronics components, remanufacturing could be one way to secure the supply chain for managing an emergency production. Based on this, a managerial question that arise in the need for preparedness is when order-based remanufacturing is a viable emergency production option and what obstacles exist to prepare for such emergency production for different actors. In practice, also the preparation of purchasing organizations, public or private, for such emergency production needs consideration. Furthermore, it is crucial to reflect on what types of remanufacturing suppliers can be considered in which situation. The purpose of this paper is to explore remanufacturing as a possibility to manage a supply chain in case of emergency production, especially for products that consist of electronic components that control functionality in societal infrastructures that must work in a crisis. Therefore, the paper will be guided by two main research questions:

RQ1: What is needed for a resilient supply of remanufactured electronics to manage up-scaling of domestic production?
RQ2: How can customer organisations prepare for a resilient circular supply of remanufactured electronics to manage and be prepared for emergency shortages?

2. Resilience and remanufacturing

2.1 Resilient supply and emergency supply
Parts or resources that are critical for the societal function must be secured by authorities on a macro level that are responsible for assuring the societal function – MSB2409 [4] (2024). The continuity planning of such societal functions and their supply chain thus need to consider possible disruptions or shortages of supply. The risk of shortage may be handled by various resilient supply chain management strategies on a meso level, where resilience is the ability of a system to return to its original state or move to a new more desirable state after being disturbed [12]. Resilient supply chain strategies include inventory management (e.g. emergency stockpiles) and multiple sourcing [13], sometimes involving demand forecasting [14] et cetera, and viability of options depends on which type of suppliers and their location [15]. Here alignment in the supply chain [16], to fit objectives, structures and process of actors in a supply chain, or production system, is crucial for resilience, and access to data on material content and supply

chain visibility of critical and conflict materials can be crucial [17], to decide between own or contract manufacturing or remanufacturing [18]. In case of emergent need in the society (macro level), regular emergency production can involve ramping up new production locally in companies (micro level) which works for many products where raw material, competence and production processes are available [11].

There have occurred severe disturbances of electronics supply in the past and Europe's electronic production is only 10% of its demand [19] (EU2023/1781). EU has listed 30 metals and minerals, many needed in electronic components, that are classified as critical due to their economic importance and supply disturbance risk [20]. Even when some of these minerals are mined in e.g. Sweden, the refining process is often located overseas. Also, fabrication is to a large extent located in America or in Asia [21]. Since electronic products are complex, containing several different materials of which some are classified as critical and there are long supply chains, regular emergency production is not an option since there is a lack of raw materials, competence and process equipment. Here, repair, refurbishing and/or remanufacturing can be an alternative, considered by different level actors (companies-micro, government-macro) [22]. Other supply chain resilience strategy routes, e.g. when global supply chain fails, involve regional local on-demand production or emergency production using e.g. additive manufacturing [23], where products failure, wear, uncleanliness et cetera can be reutilized after a shorter process than new manufacturing, especially well-suited for emergency spare part supply. According to Ishak et al [7], electronics supply chain disturbances enduring one month or more occur every 3.7 years (in Malaysia, but with global supply chains this would be the case also in Europe). Five supply chain weak points likely to be impacted during disturbances are: planning and procurement networks, logistics and shipment systems, financial durability, product complexity, and corporate stability. Collaboration and transparency in the supply chain are important measures to improve resilience of the supply chain.

2.2 Core sourcing and remanufacturing, refurbishing or repair of electronics

Remanufacturing of, for example, automotive parts have been in place for decades [24]. Remanufacturing is an industrial process where used parts (cores) are restored to an as good as new or better condition, often with the same quality, functionality, and warranty as new products [25]. This means that the function and service life are the same or better than in the original product. In cases where these criteria are not fully met, refurbish or repair may be ways to restore critical functions although service life or functions deemed less critical are not restored. Refurbishing resembles remanufacturing, but it excludes alterations that impact the product's safety, original functionality, intended use, or classification [26] (SS-EN 45553).

In circular component flows such as remanufacturing, refurbishing or repairing, an essential activity for the company (micro-level) is the sourcing of core for these processes. It can include a combination of processes where direct order-based processes are combined with ownership based, service-contract-based, deposit based, credit based, buy back based and/or voluntary-based. Irrelevantly, different business models come into play, where for example remanufacturing could be done inhouse at the manufacturer (Original Equipment Remanufacturer (OER), as lego-production at a Contracted Remanufacturer (CR); or by an Independent Remanufacturer (IR) [25,27]. For these actors, core sourcing is a key activity, combined with of course the remanufacturing process and the redistribution of remanufactured products [28]. The process itself usually includes the collection of cores and a combination of inspection, disassembly, cleaning, replacement of parts, reprocessing, assembly, testing and storage [26,29].

In emergency situations, the full-service life of a new product may be less critical than the assurance of critical functions. A special case may be if cores are taken from one used product, but these are processed and repurposed and supplied as part to another product [30]. For electronics, an update or upgrade of software may be a substantial part of the function of the product or part and thus need to be taken care of within the remanufacturing/refurbishing. For electronic parts, assessment, reprogramming and testing software with the physical part may be critical. Some major limitations in remanufacturing concerns collection of cores, production planning (due to variability in core status) [25] and legal limitations to remanufacturers access to product and software design specifications [31, 32], although some legal concerns maybe will be disregarded in a crisis. Remanufacturing holds several challenging aspects. For OEMs, it can involve e.g. lack of knowledge and/or experience of remanufacturing, product take-back strategies and reverse logistics [33]. However, in the electronic industry a novel framework for reverse engineering obsolete single-layer printed circuit boards (PCBs) has been proposed. This involves data acquisition, image processing, CAD editing, PCB fabrication, and circuitry testing, allowing for the reproduction of equivalent PCBs to be used as spares [34]. This has traditionally been done manually, and research about how to automate some tasks in a disassembly and reassembly process have been explored in parallel with the evolvement of smaller industrial robot in human-robot collaborative layouts [35]. Due to the increased focus on circular economy, OEMs analyse how to develop their business models for the new market regulations related to the ongoing green transition. An OEM that would like to utilize remanufactured components in the same assembly line as for new components, there is a need to reflect the production system development [36]. Here, four enabling systems must interact – the human system, the technical system, the information system, and the management and goal system [36].

2.3 Emergency remanufacturing of electronics cases
Remanufacturing electrical and electronic products has been researched for several years, and in-depth understanding of advantages and challenges has been published through case studies researching different perspectives on production of several types of products to reach circularity. Hatcher et al. [37] show that remanufacturing can recover valuable material and reduces hazardous waste, but Chinese electrical and electronic products are not designed suited for remanufacturing processes and although products may be designed for recycling, this does not mean that they are designed for remanufacturing, where the aim is to recapture functioning parts. However, the ongoing green transition in combination with more functions and systems is controlled and monitored continuously, which demands stability in electronic components and products. The maturity of reusing and remanufacturing electronics differs over the globe, and the Gulf Cooperation Council has noticed that today electronics waste is sent to recycling centres and turns out as landfills, with the political challenges to manage the environmental impact [38]. Here, one way to reduce e-waste has been identified as developing and implementing industrial remanufacturing and guidance for engineers and other stakeholders to adopt remanufacturing principles. However, to manage potential higher volumes and quality in electronic remanufacturing, there is a need for more industrialized remanufacturing processes [39].

3. Research methodology/approach

An analysis of Swedish semiconductor supply [40] was used as basis for the problematisation and focus on electronics supply. With limited domestic supply of several of the components needed for electronics, a study of remanufacturing options commenced. Three different types of suppliers of remanufactured electronics were considered, Original Equipment Remanufacturer (OER) where remanufacturing is done by the OEM, Contracted Remanufacturing (CR) where the final costumer/user or the OEM contracts the remanufacturing to a lego-remanufacturer, and an Independent Remanufacturer (IR) of small electric and electronic equipment that buys, repairs, and sells IT equipment. Here we have adopted the Micro Meso Macro perspective on the unit of analysis for techno-economical systems [10]. Recognising that societal level resilience (macro) is not a linear aggregation of the companies' resilience (micro), this study leverages meso-level supply chain resilience to support macro-system resilience analysis. It has previously been used

IOP Conf. Series: Materials Science and Engineering **1342** (2026) 012027 doi:10.1088/1757-899X/1342/1/012027

to investigate the concepts of sustainability and circular economics on business model as micro (company level) and policy as macro (society), where the industrial ecology (supply chain) provides a meso perspective connecting micro and macro [41].

In this paper three small-scale electronics remanufacturing companies in Sweden were studied. As preparation within each study the companies' websites marketing offers, and environmental management information were searched for background information. Data were collected in a comparative study through study visits, interviews, workshops, website analysis, and expert consultations focusing on three companies that do remanufacturing of electronic components: one in each business model category (CR, OER, IR). The companies were chosen based on comparative inference where cases are identified based on certain characteristics (in this case remanufacturing business model) and with the possibility to generate material that provide variation [42].

Company A is a CR, or lego-remanufacturer that works mainly with automotive complex parts remanufacturing. The company is part of a larger consortium in the circularity business. Their electronics remanufacturing is currently lower volumes than for their mechanical products, but they foresee an increase in electronics remanufacturing. Currently most of the parts they remanufacture are spare parts for vehicles that are no longer in full-scale production, but where spare parts, maintenance and repair services are ongoing to a rolling fleet. The study was performed during research project study visits and workshops with the company in 2023 and in 2024. First workshops around their strategic outlook were done digitally and a then an on-site linewalk and project workshop discussing the future path of their remanufacturing business development (micro). A second visit with observations on a line-walk and interviews with two key individuals (the electronics remanufacturing workshop production leader and the sales and marketing manager) in an open question interview around emergency supply considerations and possibility to do remanufacturing contracted by authorities (meso/macro).

Company B is an original equipment supplier of power electronics and mainly produces new modular products, but as a service for regular customers they also take back and remanufacture old modules as an OER. The company was part of an industrial competitiveness and sustainable development program for electronics industry where one of the authors participated as green lean coach (interactive research). Increased circularity and remanufacturing/refurbishing was identified as one development path. The remanufacturing study was then performed in two visits 2024 and 2025 where the logistics and planning manager and the remanufacturing workshop leader participated and were interviewed in an open question interview around their remanufacturing operations (micro) and considerations with regards to supply chain disruptions and resilience (meso).

Company C is a full-scale IR of common consumer electronics selling to both organisations and private consumers. They remanufacture, refurbish and recondition electronic products from a variety of different brands. The study was performed in two research project study visits and workshops in 2024. The first visit included line-walks, discussions on supply chain and company business (system macro and meso level) with the sustainability manager and circular economics project manager together with remanufacturing personnel from visiting companies. Additionally, a dismantling workshop was performed on computers and mobile telephones with technology and micro level consideration. Questions regarded remanufacturing challenges but not specifically emergency supply or crisis scenarios.

To add in depth understanding of technologies applied and their consequences on the micro level an electronics design expert at RISE was interviewed in the analysis phase. The companies remanufacturing operations were explained, then open interview questions were used following the remanufacturing process operations; assessment, cleaning, replacing parts, testing and certifying. A summary of empirics is listed in table 1.

Table 1. Empirical data for each part of the study.

	Business type	Data input
Company A	CR	Web, line walk interview (2), workshop
Company B	OER	Web, line walk interview
Company C	IR	Web, line walk interview (2), workshop (2)
Electronics expert	Research institute	Interview

4. Findings

4.1. Study A, Contract-Remanufacturing (CR)

Company A is a lego-remanufacturer that mainly does spare parts remanufacturing on a contractual basis for several industries with main customers being OEMs in the automotive industry sector. The general remanufacturing business involves complex mechanical parts on a large scale and a remanufacturing workshop for electronics in a (so-far) smaller scale. The electronics remanufacturing includes cleaning, opening, assessing (fault identification), removal of resin, disassembly of faulty components, reassembly application of new resin and lid, reprograming, test and packaging. Assessment and testing are critical operations that take most of the lead-time. Sometimes the fault cause is not possible to identify. Correct testing often requires having the OEM software specification. For a full product the main function and thus testing may be figured out without specification but for a circuit board component it may often be difficult to figure out all signals and answers. The technical limits of electronics remanufacturing are perceived as lower than economical and legal limitations. Reverse engineering of the functionality may be needed but needs larger scale to be economically feasible. If there is an abundance of cores to use as donor products and if these have several different sub-components that fail, most electronics can be remanufactured. Experience from both periods with semiconductor shortages and wafer shortages have shown this. Using cores as donors, four cores may give three remanufactured products.

The company is often dependent on contractual agreements with the OEMs. Even if parts function could be assessed and replacement parts can be applied, in most electronics the OEM controls the software and after reassembly software needs to be reapplied. So far, the business has not been concerned about the special case of emergency remanufacturing in case of crisis shortage of electronic parts. Any contract with local government for emergency supply of electrical parts would still in most cases be dependent on agreements for remanufacturing and reinstallation of software, but sometimes own programming restoring simple functionality could be done. In a force majeure situation some of the legal limitations of remanufacturing may become different, this is not anything the company has investigated. The economics however is such that the in the low automated process that was in place at time of the study require much manpower and rather skilled and knowledgeable personnel, why it would be better to have a circular remanufacturing business ongoing before a crisis occurs. The process requires some initial investment both in equipment and product analysis that will mean also considerable time to initiate. The company says a preferred business model would be to have a low remanufacturing volume in the normal state and they could then be contracted for a ramp-up of capability within a response time. Further discussion on how the business model for emergency remanufacturing would be needed.

4.2. Study B, Own-remanufacturing (OER)
Company B produces several power electronic products and sells large volumes of a standardized modularized high voltage cabinet. The regular linear production is performed in a manual assembly line with six assembly and soldering stations in a line where over a hundred modules can be produced per week. After assembly products are tested, packed and shipped. Especially high voltage testing is a critical operation requiring skilled personnel.

Remanufacturing is performed on the same site in one of two parallel cells for disassembly and re-assembly. The yearly remanufacturing volume is equal to one or two weeks of regular production, i.e. rather small scale at the time of the study. The remanufacturing operation is operated by two of the most skilled engineers with decades of experience in the company, knowledgeable in both product and production design as well as testing. No automation devices have been installed to scale up the remanufacturing. Remanufacturing is currently run to give regular customers extra service, often the service providers have a couple of remanufactured products in store and sell these only if the old cores are handed in. The reason for using remanufactured modules is either because they are faster (for odd modules that are built to order) or cheaper for the customers. The products are usually critical components for their customers' operations. The remanufactured parts are only used in aftermarket currently and are sold as "refurbished" based on the connotation that they are not sold "as new" although they are usually upgraded with new software and some wear-parts are changed, the final testing and requirements are the same as for new products.

Some cores are too worn out to go into remanufacturing, but they are not used as donors to get spare parts at the moment. New replacement parts (same as used on the linear product line) are used instead. In most cases, for each product the same components fail and are replaced. So, using a donor would not work if the donor had the same fault. However, the needed parts are well known and kept on stock. The remanufacturing responsible operator states that they have enough flow of cores, and many products have similar needs for replacement components. Two components are pointed out that are always replaced to new, and another part is replaced if it is from a certain previous supplier where they were not satisfied with long term quality. Other parts are replaced if visual assessment or testing give at hand that they do not work. Since the products are modular and must be backward compatible in both hardware and software the design does not change much from year to year.

All regular customers, both from industry and community, are given opportunity to buy both new and remanufactured products. The company does not mention any cannibalisation of business between the two businesses. There have not been any emergency plans for how to handle either raised demand or shortage of components until recently with trade wars upcoming and no customers have yet required any emergency remanufacturing capacity to ensure electronic parts in a crisis scenario. Since many of the products are used in production plants in the electronics industry, good supply chain communication has been easy to maintain.

4.3. Study C, Independent-Remanufacturing (IR)
Company C sells remanufactured consumer electronics, mainly PCs laptops and similar at similar warranty but lower price than new equipment. They operate it on a large scale, and operations include certified clearing memories, sorting, cleaning, fault investigation, disassembly, cleaning and checking/replacing parts, sorting, reassembly, and packaging. They mainly work with products available at a certain threshold volume for consumers and with businesses/organizations. They have several contracts with authorities and public organizations including schools and municipalities, and supply these regularly with a part of the volume of new

computers, mobile phones and IT-equipment. This service can continue in case of crisis. They develop their own tests and use certified test protocols when open available. The used equipment is purchased from companies that do not want to use these anymore. Products that cannot be remanufactured are used as donor cores for spare parts that need to be replaced in other cores. Logistics is an important part of their operation since they handle so many different brands and designs. Also, management of software and updates. Information security on some parts means that they only handle products that can be accessed (unlocked) and cleared.

4.4. Technology considerations, interviews with electronic expert

In the expert interview the studied companies (micro level) processes and technology hinders and opportunities were discussed and how a crisis could affect the system (macro level). Fault detection of incoming cores was deemed critical, here ultrasound and x-ray may be additional technologies to use in tracing faults. New development in AI may give solutions both to support fault tracing and testing after remanufacturing. Possibly AI could be used in the future for improving programming and reversed engineering. Several risks for hidden new faults in the disassembly/dismounting and following reassembly and soldering of components were mentioned by the expert for products where parts are soldered onto the electronic product. Risks included: quality of soldering joints, loosening of gold-plated contacts, surrounding components to the replaced components may be damaged in the disassembly. Also cleaning chemistry may affect components and after remanufacturing a possible need for replacement of surface treatment to have a fully functional and high quality of remanufactured parts was mentioned. This means that there may be a significant rate of unsuccessfully remanufactured parts, and full inspection and testing after remanufacturing is thus critical. Here product design knowledge and understanding of functional design and what is designed into software vs hardware become critical knowledge that often is bound to the OEM.

Some limitations on what electronic parts can be remanufactured were also discussed. Components that are plastic compound moulded into its casing may be impossible to remanufacture with high quality, i.e. products may be designed to be almost impossible to remanufacture. Products not produced anymore where old cores are used as donors may have aged components that need new replacement parts. Sometimes this is hindered by certifications and quality standards.

4.5. Key findings and analysis

With regards to technical aspects, product quality and control the OER was deemed by the electronic expert to be more manageable and possible to start on company level even after a crisis occur. To start lego-remanufacturing as CR or IR after a crisis occurs without a previous agreement with an OEM can be difficult for many spare-parts, where drawings, and software specifications may be missing, and glues and molding compounds make remanufacturing almost impossible. On macro and meso level it becomes important to have technology control on the micro level. However, an IR or CR may have a much broader product range and can thus from a societal level cover a broader range of products than OERs can.

Table 2. Micro and meso level comparison.

	OER	CR	IR
Access to cores (meso)	Through regular distribution channels	Through the contractor (OEM or final users)	From final users
Access to replacement parts (meso)	Same as for new production	From OEM supplier or from donor cores	Donor cores or worst case new spare parts.
Test & verification (micro)	Same as for new production	Decided with contractor	According to general certification protocols
Access to software (SW) and SW-updates (micro and meso)	Same as for new production	Preferably through contractor, but worst-case reverse engineering of SW	General SW products (e.g. Bios, operative systems etc. are available on market

5. Macro level analysis and discussion

The results indicate that remanufacturing could be one major route to secure the supply chain for critical electronics components in an emergency production. For crisis, where order-based remanufacturing is a viable emergency production option, preparedness includes the study of obstacles that exist for different actors, purchasing organizations and different remanufacturing types of actors.

The studies highlight challenges of remanufacturing business. Especially for CR and IR who have the advantage of being specialised in remanufacturing and having remanufacturing operation competence internally. Here, limitations and hinders were found in access to cores [25], access to specifications [31, 32], access to software, and risks for products being damaged during the process. In a situation of crisis, for the CR, stocks of replacement parts are easier accessible than for the IR. IR risks the lack of access to cores and/or spare parts, as these might be held at the OEM. However, the IR could provide the OEM with access to skills and educational opportunities, which the OEM might lack. In such cases, the OEM and the IR could develop co-dependence in a state of crisis.

In the OER case, company B, these hinders were lower in the studied case. With access to design specifications and knowledge on the original production of the parts, risks and hinders are minimised. In the company, remanufacturing competence was available and with ramped up internal training, company B could increase its remanufacturing capacity.

For an OEM that currently does not do any remanufacturing, the initiation of such processes, such as setting up workstations for disassembly and training personnel, could be substantial. This is in line with arguments made by, for instance Kurilova-Palisaitiene et al [33] which highlight e.g. the lack of take back practices as a challenge, as well as for lack of qualified workforce and from Wlazlak & Johansen [36] that highlight the complexity to develop a remanufacturing system with integrated goals and management for combining human, technology and information systems in a development of remanufacturing systems. In those cases, either a collaboration with a CR like company A or preparing for low volume remanufacturing as in company B are possible development paths.

For authorities who need to assure their critical functions continuity, some hinders should be addressed already in the sourcing of critical spare parts and in the procurement requirements. If the parts are already marketed by domestic IR, some share of the sourcing could be done through IR to ensure continuation of this business. If parts are sourced locally or regionally, address the availability of remanufactured spare parts from the OEM. If they have or can set up local OER it should be done before a crisis occurs. If parts are sourced from abroad, check if local lego-CR may be possible as multiple sourcing strategy [13], and make sure specifications of design and software's are made available for local CRs use in case of crisis.

This paper provides examples of situations and challenges that purchasing organisations need to contemplate in preparing for a resilient, circular supply of remanufactured electronics in a crisis. It contributes with emergency production aspects and societal resilience on a macro level when considering remanufacturing, connected through meso to the companies' micro level business and technology, based on empirical findings from three companies. Insights can be utilized as input for the preparedness of a resilient supply of remanufactured electronics and the up-scaling of domestic production.

6. Conclusion

To conclude there are several challenges but also strategic motivations to develop flexible and quality assured remanufacturing capability of electronic products and components to be prepared for potential societal crisis or for supply chain disturbances. The need for companies to be prepared are highlighted from a societal perspective with identified advice for preparedness related to planning, practice, educate and strengthening the company resilience [43]. However, the challenge is complex and could be reflected on three levels, micro (company), meso (between companies here reflected as the supply chain) and macro (society with legislation and regulations) to manage a future crisis related to electronics as well as developing engineering solutions [22, 41].

Macro: Society must have a management overview related to which functions must be controlled in a crisis to secure that the supply chain as well as the companies have had the possibility to develop the right capabilities and collaborations.

Meso: In the supply chain a crisis challenges distribution as well as the needs for components and material. Here is a need for flexibility in how to share information as well as how to define the requirements for components and product needed.

Micro: Companies must develop the capability to remanufacture electronic components and products efficiently and with high flexibility due to crisis can demand fast change overs. Here is a need for understanding and developing the remanufacturing system.

Acknowledgements /funding

The expert interview and one studied company was performed within a project funded by Swedish contingency agency (Myndigheten för Samhällsskydd och Beredskap, MSB) within the project (MSB 2022-09211) Resilient material- och produktförsörjning i händelse av kris och konflikt Resilient materialförsörjning (Resilient supply of materials and products in case of crisis and conflict). Two companies were studied within the project REMARKABLE - Remanufacturing – key enabler to future business funded by the Swedish energy agency (Energimyndigheten) in the RE:Source funding program and the project Innovating remanufacturing: disassembly and exploration of new practice in test facility environment (2024-02979) in Vinnovas Net Zero program and are connected to the Strategic Research Area (No 0219, 201) Excellence in Production Research (XPRES). One of the studies was initiated through the program "Smartare Produktionslyftet" (smarter production leap) where a start program for green transition was performed. Thanks to the employees at the companies, everything presented is due to their work to improve remanufacturing. The work is continued within the Vinnova funded Susteq project (2024-00789) within Chalmers Area of Advance Production.

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