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Lean Maintenance and Repair Implementation - A Cross-Case Study of Seven Automotive Service Suppliers

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Abstract

Maintenance and repair as well as after-sales services are of increasing importance for positively impacting customer satisfaction. However, though highly established in production environments, literature is sparse on lean management applications in service environments. In this research, we aim to understand the status quo of lean management implementation in maintenance and repair-shops in the automotive industry. Based on a profound and systematic literature review and on a cross-case analysis of seven repair-shops - on the basis of document analysis, semi-structured expert interviews and on-site visits - we identify performance potentials and recommendations for industrial maintenance and repair practice.

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1. Introduction

After-sales services such as maintenance and repair are becoming increasingly crucial in commercial settings. These services provide constant touchpoints between the company brand and customers extending well after the point of sale, and were found to contribute to continuous customer satisfaction, brand loyalty, and re-purchases [1]. Successful after-sales services increasingly contribute to firm revenue streams. Depending on the industry, firms generate between 30% to 50% of their revenue through after-sales services, and can sometimes even exceed revenue generated from the sales of original products [2-3]. Already as early as the 1990s, researchers have shown that rather than being a “necessary evil” or simply “nice-to-have”, successful after-sales services can strongly contribute to the strategic competitive advantage of manufacturing firms [2] [4-5]. However, despite their long-standing and ever-growing importance, research on the efficient delivery of after-sales services has received significantly less attention than efficient manufacturing. Consequently, operational performance and productivity measures of the latter persistently overtakes that of services [6]

One of the focal approaches studied in operations management to achieve efficient and effective manufacturing is the lean philosophy, and its rich variety of methods and tools. The concept of lean manufacturing was originally developed for and deeply rooted in the context of automotive production [7], and was pivotal in transforming manufacturing processes. The lean management approach to improvement of costs, time and quality performance indicators has since been widely adopted and applied in new industries such as lean software development [8] and lean administration [9]. Lean approaches have since also extended beyond a shop-floor granularity and into an organization-level, such as the lean organization or start-up [10] as well as an inter-organizational level, such as the lean supply chain [11]. The application of the lean optimization

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approach to services in particular, dubbed "lean-services", has grown into a distinct field since the original coining of the term by [12]. However, despite a steadily increasing growth of research on lean-services since 2008, the crux of articles remains anecdotal, and rather narrowly focused on banking services, healthcare, or education [13]. Significantly less of the research in this stream has been carried out on the applicability of lean approaches to the optimization of after-sales services in general, or those in the automotive industry in particular, despite the deep roots of the lean approach in this sector.

In this paper, we aim to address this gap, and assess to what extent lean principles can be applied in the context of after-sales services, focusing specifically on after-sales maintenance and repair in the automotive industry. The rest of the paper is structured as follows; in section 2 we briefly outline our chosen research design of a systematic literature review (SLR) and multiple-case study. In section 3, we provide key insights from the state-of-the-art and in section 4, insights from the findings derived from the cross-case analysis. Lastly, in section 5, we conclude with ending remarks on the potential for lean implementation in maintenance and repair after-sales services, and provide recommendations for further research.

2. Methodology

In order to address this gap, we take a two-step research approach. First, we conduct a rigorous systematic literature review (SLR) to offer initial insights on the status-quo of lean services. Second, we empirically compare the status-quo of lean implementation in seven automotive repair and maintenance shops, and offer insights on the extent to which lean principles can address the challenges noted by managers in the organizations. For this purpose, we also draw on the general categorization of seven Mudas (wastes) introduced by Taiichi Ohno in Toyota's Production System (TPS) [7].

The SLR process began by querying the two databases Web of Science and Scopus, using the keyword "lean service*", and restricting the query to journal articles and conference proceedings, in the English language. This resulted in 149 hits. After removing 45 duplicates the titles and abstracts of the remaining 103 papers were screened to ensure a strong focus on lean principles and methods, as well as a strong relevance to services or application in a service context. Additionally, at this stage, 8 conference papers were removed due to lack of access. The distilled 57 papers were included in the final review and systematically coded along standard dimensions.

For the empirical component of the research design, we chose an exploratory, multiple case-study approach to complement and build upon existing knowledge in the field. Case-studies are particularly appropriate for answering research questions relating to "how" or "why", in situations in which the researcher has no ability to create a controlled environment of the event studied as it involves a strong behavioral component [14]. The exploratory nature of the design is particularly useful for the under-researched industry at the heart of this research, namely, after-sales automotive maintenance. We began our research through five prominent original manufacturers of cars, headquartered in Germany, as well as the North German Technical Inspection Association (TÜV Nord, referred to henceforth as TÜV). An authorized repair-shop was studied for each of the organizations, with two studied for one of Manufacturer A, thus a total of seven cases of were compiled. For an overview of the cases' characteristics please see Table I, (Man. A1 and Man. A2 refer to two different repair-shops of the same manufacturer).

Data was collected through intensive primary data collection from three different types of sources. First, multiple site visits were carried out, to at least one authorized repair-workshop of each manufacturer. Secondly, both on-site as well as phone interviews with the key staff involved in planning and control of the workshop were carried out. Thirdly, master-data received from the workshops' management system was received where possible. The variety and richness of the data collection methods helped ensure high levels of triangulation. For example, self-reported information from interviews was balanced against evidence witnessed during on-site visits. This triangulation is particularly crucial when discussing topics relating to waste or inefficiencies. Lastly, our findings were reviewed and discussed in a workshop ran with experts from one of the original automotive manufacturers of the cases discussed, which is headquartered in Germany and runs over 700 repair-shops.

Table I. Overview of Cases Selected

	Man. A1	Man. A2	Man. B	Man. C	Man. D	Man. E	TÜV
Demand							
Employee count	3	8	9	39	15	32	5
Workstation count	4	9	10	40	N/A	35	2
Maximum throughput	N/A	5 vehicles concurrently	N/A	30 vehicles concurrently	40 vehicles concurrently	N/A	2 vehicles / hour
Jobs/day	2-4	4-7	~20	~100	~20	~100	~16
Demand Peaks	Pre-vacation peak	Pre-vacation peak	Tire-changing season	Tire-changing season	Tire-changing season	Tire-changing season	Specific months
Capacity							
Forecasting Method	No forecasting	No forecasting	Forecasting on experience	Data-driven forecasting	Forecasting on experience	Forecasting on experience	Data-driven forecasting
Scheduled vs. Walk-in customers	50% vs. 50%	30% vs. 70%	80% vs. 20%	70% vs. 30%	50% vs. 50%	N/A	100% vs. 0%

3. Findings from the Systematic Review of Literature

3.1. Services addressed in lean-service literature

Services can be defined as *"An activity or series of activities of more or less intangible nature that normally, but* *not necessarily, take place in interactions between the customer and service employees and/or systems of the service provider, which are provided as solutions to customer problems.*" [15] (p. 27). Consequently, in comparison with manufacturing, services are more intangible, more focused on activities rather than goods, produced and consumed simultaneously rather than distinctly, and therefore, by default, involve some degree of customer participation in the production process, which is not strictly required for the manufacturing of products [15-16].

In addition to their distinction from manufacturing, services also differ greatly amongst themselves, with many service-typologies proposed in the service management literature. One of the more established typologies is the "service process matrix", which was first proposed by Schmenner [17] and later empirically verified and refined by Verma [18]. The crux of this classification is conducted along two key dimensions; the degree of labour intensity required to perform the service, and the degree of customer interaction, or customization, necessary for its performance (see table II, "service category"). We first utilize this framework to derive the overview of services studied in lean service literature, as summarized in Table II. The findings in the table indicate that all service categories are covered to various degrees, however, two key insights remain.

Table II. Focus of lean-service literature.

Service Category	Typology Positioning	Illustrative Examples	Papers with this Service (n / %)	Illustrative Examples
Service Factories	Low labor intensity, low customer interaction & customization	Fast-food chains, call centers, containerized shipping	13/57 (22.8%)	Sprigg and Jackson [19] (call-center), Bowen and Youngdhal [12] (airline, fast-food)
Service Shops	Low labor intensity, high customer interaction & customization	Hospitals, Repair-shops	9/57 (15.7%)	LaGanga [20] (health-center), Chougle et al. [21] (car-repair)
Professional Services	High labor intensity, high interaction & customization	Lawyer services, emergency healthcare, private banking, catering	3/57 (5.2%)	Pan et al. [22] (catering), Weisher and Giles [23] (emergency health)
Mass Services	High labor intensity, low customer interaction & customization	Schools, commercial banking	18/57 (31.5%)	Petrusch et al. [24] (higher education), Swank [25] (banking)
Specific services not specified	NA	NA	17/57 (29.8%)	Systematic reviews such as Gupta et al. [26], multiple industry surveys such as Hadid et al. [27]

First, lean-service literature tends to view services as the anti-thesis of manufacturing, instead of building on or adopting the rich theories (for example, the previously utilized service typology) already established in service literature. In many papers, the specific services studied were either not described at all or briefly described. The type of service studied needed to be deduced by the readers implicitly, and therefore also the subsequent relevance and positioning of the study to broader service literature. Instead, papers in the field tend to differentiate the services studied based on the industry in which they are performed. Though beneficial to a degree, differentiation by industry has limitations particularly in the case of services, as multiple kinds of services take place simultaneously within a single industry, and even company. For example, the healthcare industry can refer to both the general operations of large hospitals, emergency ambulance services, or a specific surgery performed by a doctor.

Second, though all types of services are addressed in literature, the focus of research is not evenly distributed (see Table II). Research on the application of Lean in services focuses on mass-service provision (a third of papers). The prevalence of research on mass-services seems to be particularly driven by the interest in applying lean to commercial banking activities, with 10 papers out of the 17 papers studying mass-services focused on the finance industry. This is followed by research studying service-factories, service-shops and only 5% of research also studying professional services. Service-shops are studied in literature primarily in the context of the healthcare industry, in hospital or health-center operations (n=5). Other papers study services in maintenance departments of manufacturers (not after-sales; see Sum et al. [28]), as well as after-sales maintenance and repair (n=3; conceptual paper by Dombrowski and Malorny, [3]; case-study of Toyota by Resta et al. [6]; text-mining approach by Chougle et al. [21]). The relative lack of research focus on applying the lean approach to optimize professional services, such as those provided by lawyers for example, can at least partially be explained by the higher premium such services often charge, and the relatively weaker significance of improving operational performance. This argument, however, does not apply to service-shops in general, and after-sales services in the automotive sector in particular.

When excluding fast-growth consumer markets such as China, the automotive sector has witnessed very limited strong growth opportunities from sales of original vehicles, with fierce competition amongst manufacturers [29]. The growing structural production overcapacity in markets such as Western Europe is pushing manufacturers into the service domain, and particularly into after-sales [6] [29]. Authorized dealerships are noted as a crucial link in this new paradigm [1]. In the study by Devaraj et al. [30], who assess different factors impacting customer repurchase decisions, the authors note that "*Brand loyalty and repurchase intentions are affected by both the quality of the vehicle manufactured and the quality of service delivered by the dealer during repair and maintenance incidences*." (p.435). In fact, in their model, customer satisfaction with these services was the strongest factor impacting a re-purchase. The authors note the strong practical consequence this has for manufacturers interested in stimulating revenue through repeat purchases, and further indicate that *"This explains the quality assurance programs many Japanese manufacturers deploy at dealerships [...]"* (p.435). Subsequently, there is increasing practice-oriented relevance for improving operational performance in the automotive after-sales market, particularly maintenance and repair.

3.2. Lean principles and waste addressed in lean-service literature

The drive for applying a "leaner" approach in services began in 1972, when Levitt advocated for a changed manufacturing-service paradigm in industry in general. Levitt [31] argued for focusing on the (in)efficiency of services and taking a "Production-line approach to service". He used examples such as McDonalds (a mass-service) to show the strong benefits this can catalyse to operational efficiency. However, the specific concept of a "lean-service" as related to the lean-manufacturing approach introduced in the Japanese automotive industry [7], began only after lean-manufacturing increased in popularity in the United States of America (USA) [13] and the term lean-service was first coined in 1998 by Bowen and Youngdahl [12]. The early conceptualizations of "lean-service" were primarily reliant on anecdotal examples and lacked rigid empirical backing in general and lack of empirical evidence for theory building and conceptualizations in particular [13]. This also mirrors the popular methodologies for studying lean-services in research today (see Figure I), with half of the literature body consisting of either conceptual papers (n=13; 23%), or findings derived from a single case study (n=17; 30%). Fewer papers base their findings from cross-case comparison (n=9; 16%) or surveys (n=8; 14%).

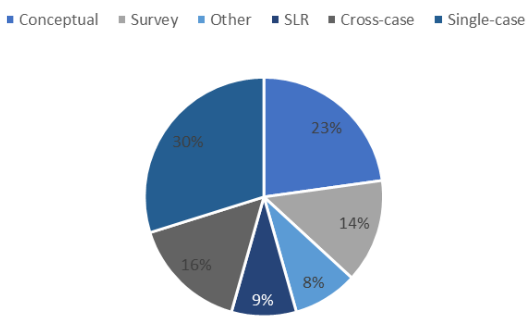


Fig. I. Distribution of methodologies used in lean-service literature

Seddon et al. [16] articulated a gap created through a lack of focus on empirical backing, concluding that many articles *"[…] suggest lean tools will be usefully applied with adaptation but we learn little about what adaptations might be necessary nor why they may be needed."* (p.8). This also has direct implications for practice. Barraza et al., [13], specifically stress that empirically strengthening theory-building on lean-services is not a matter of pure "semantic abstraction", and articulate that a strong *"gap between theory and practice […] indicates a clear need for a more complete and thorough definition of what Lean Service actually means so that when the time comes to apply its methodologies, the ensuing confusions, frustrations and failures [in companies] can be avoided and the Lean Service will be more effective and efficient"*. (p. 372).

4. Findings from the Cross-Case Analysis

4.1. Overview of the after-sales maintenance and repair process

In this section, we briefly provide an overview of the processes carried out in automotive maintenance and repair service-shops. An overview of the idealized service overview, consisting of seven steps, is visualized in Figure II, and an overview of processes based on site-visits and interviews is provided in detail in the following text and summarized in Figure III.

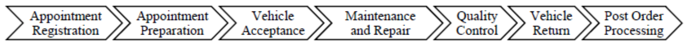


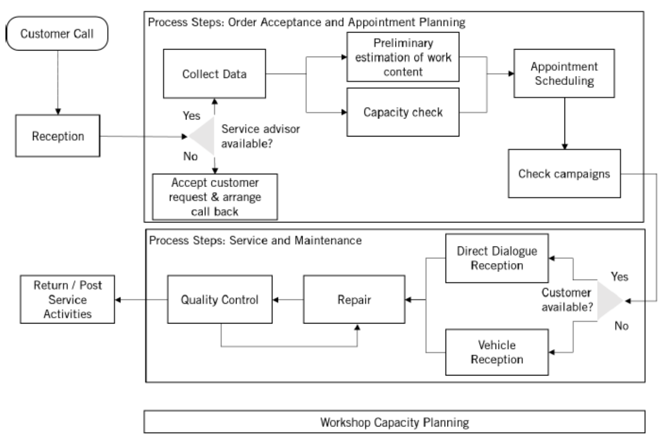
Fig. II. Stylized process of maintenance and repair
Source: Adopted from internal document of one of the original manufacturers

The first two sub-steps take place prior to the actual acceptance of the vehicle and performance of the repair. During the **appointment registration**, a customer contacts the service-shop via telephone, email or by physically arriving at the shop (walk-in customer) to provide the initial details on issues with the vehicle, and request service. Based on this information and taking into consideration mandated repairs required from the manufacturer, a service agent will determine root causes, estimate required work content and consult planning agents or software regarding the workshop's capacity. The customer is then communicated the expected time for vehicle acceptance and of the vehicle return. The **appointment preparation** consists of gathering more information based on the vehicle identification number (VIN), such as possible additional repairs required by law, even though they are not the immediate concern of the customer (silent recalls). For example, a workshop is legally required to replace previously identified parts that have exceeded their safe use life cycle. All of this information, as well as whether or not previous maintenance work has been completed on the vehicle, can be accessed by the workshop through the manufacturer's centralized system. Based on this, the agent also communicates to procurement the necessary parts to be delivered or purchased from the spare-part warehouse.

The next two steps involve the vehicle acceptance and carrying out the actual maintenance and repair. During **vehicle acceptance**, the customer physically delivers the vehicle at the workshop and a physical inspection by a service agent is carried out using a standard checklist for physical problem manifestations and a handheld test device for a readout of any error messages relating to an electronic controller malfunction. At this stage, potential job extensions are identified and recommended to the customer. A second inquiry to the spare-part warehouse is made by procurement, to ensure all the parts required also for the job extensions are available. An updated total processing-time is communicated to the customer based on the average processing times for each expected repair provided by the manufacture. Expected cost of repair is communicated, and the vehicle is placed in an inventory buffer area until the allocated processing start-time begins. The next step involves the **maintenance and repair** procedures. The vehicle is allocated to a specific mechanic, who clocks in the system the processing start-time. At this point, if the mechanic detected additional, previously unnoticed, work-content that needs to be carried out (job extension) the new processing time is recalculated, an inquiry regarding the capacity of the workshop is made, spare parts availability communicated once more to the warehouse. If the work-extension is related to road safety, and is therefore mandatory to be carried out, it is simply communicated to the customer. If it is not related to road safety, the repair-shop contacts the customer for approval of the new work content and due date. If space capacity, spare parts availability, and technician availability needed for the job-extension is immediately ready, the work on the vehicle proceeds. Otherwise, the vehicle either occupies a work-station while waiting for further work to be carried out, or is re-assembled to a form that can be driven, and moved to the vehicle buffer area, where it awaits further work. When the planned work-content is finished, the finished time is clocked for the job number, and the job is verified in the planning system as finished.

The last three steps are a quality control, return of the vehicle to the customer, and post-order processing. After the job is officially listed as finished in the system, the repair-shop manger preforms a **quality control** using a check-list and test-drive. If the quality control reveals that rework is needed, the process of capacity assurance and recalculation of due date ensues, in a similar fashion to the previous step (maintenance and repair). If the control proves satisfactory, the final invoice is calculated. The vehicle is then cleaned and **returned** to the buffer area, waiting for the customer's pick-up. Then, some **post-order processing** is carried out. The customer is asked for qualitative feedback on the service experience and complaints. Possible rework is discussed here as well.

Fig. III. Process visualization of the maintenance and repair service



4.2. Identification of waste, root causes, and potential for lean implementation in the vehicle repair-shop service

In this section, we provide an overview of the wastes identified in the processes of the car maintenance and repair service, taking into consideration data from both interviewee responses but also site visits and internal documentation. Due to space considerations, we focus on the materialization of the three most influential Mudas identified, but a summary of the materialization of all waste categories is provided in Table 2 (for an overview of responses per case, please refer to the appendix).

Defects. In lean manufacturing, the waste of rework involves work in progress or final goods of faulty quality or containing errors, which therefore need to be scrapped or reworked. This understanding applies similarly in after-sales maintenance services. Rework will occur whenever the repaired vehicle either does not meet quality standards throughout the steps of the repair process (defects in work in progress), or, ultimately, if the vehicle has to be returned to the workshop by the customer (defect in the final good). Additionally, defects can be understood as mistakes or errors not only in the physical good, which is the core of manufacturing, but also in the process of service provision itself. For example, errors in identifying all the issues with the vehicle or their full extent, which required extensions to the original work-content assessment for the job. One respondent (Man. B) mentioned that *"This estimation [initial estimation of work required] will be based purely on the experience of the service agent. You can get lucky or you can [also] not be lucky with this."* This particular error was highly prevalent in all cases.

In the context of repair shops, two possible root causes for this waste were gauged. First, one can consider the uncertainty surrounding technical execution required for certain work content. Some steps could require technical capacity or know-how beyond what is readily available. However, in most cases uncertainty regarding technical execution as well as of work-content, as well as lack of technician capacity were disregarded by most interviewees as occurring seldom or very seldom (see appendix). Though, this uniformity could also result from the fact that these dimensions can be seen as a repair shop's principal selling proposition and therefore, interviewees would be reluctant to admit this as a treat even if it were the case. Nevertheless, a second possible root cause for defects and subsequent need for rework was identified. In all repair-shops included in this study, no standardized quality controls were present throughout the repair processes. None of the cases seemed to have a systematic approach for striving for zero defects within their processes, only a standard quality control at the end, after the vehicle had gone through the various procedures and utilized subsequent resources of the shop (i.e. space, employee time, etc.).

The effort, cost and issues associated with job extensions and re-work can be considered as directly resulting from "defects" or mistakes in previous steps of the service. These in turn greatly impact the repair-shops. In fact, these are the most frequently occurring self-reported problem by interviewees across all cases. Particularly job extensions occur very frequently, with one interviewee quantifying this as occurring in 20% of all their jobs, and another stating that in many cases extensions can increase the throughput time by up to two weeks. These can take place after delivering the vehicle, the initial diagnosis is wrongly made, and the corrective action will exceed the time initially allocated to this job. Most of the interviewees stated this to be an inherent problem in maintenance, and therefore, cannot be fully eliminated but can be reduced. Both extension of work and rework, are a significant area where maintenance organizations could see improvement potential. As previously mentioned, most cases stated that most of the work content requires standard procedures, it appeared in both the site-visits and interviews that there was no standard quality control system in place, until the very last final inspection. For example, the respondent from TÜV noted that "*We don't really have any bottlenecks in the process but we do have rework so to say: if a vehicle fails our tests [final inspection] then it will have to return to the workshop when it has been fixed somewhere else, but this is registered as a new customer, not so much an open process on our side.*" In another case, when asked how mistakes and rework is minimized in the repair-shop, the interviewee noted that they *"have a quality check at the end"* (from Man. A2). However, by establishing a continuous and systematic focus on quality during the maintenance process, rather than only during the final inspection, the organizations could reduce the identified wastes and improve time related performance indicators. One example could be implementing poke yoke principles (simple quality assurance steps).

Waiting. In lean manufacturing, the waste of waiting involves idle time, of employees or machinery. For example, an employee waiting for a machine to finish in order to continue processing a part. In services, waiting can similarly be found, and occurs when waiting for a workshop space to become available, in case the planned space is nonetheless still occupied by a vehicle that was previously delayed or required job extensions, waiting for specialized technicians or additional technicians, etc. The root causes of most of the waiting that occurs in the repair shops was assessed through the interviewee responses as related to the core input for the service, namely, waiting for the car itself. For example, in order to counter variability in customer arrivals, Man B note that "*We keep one of our mechanics unscheduled every day, he will provide capacity for these unplanned situations"*, should they occur. Additionally, waiting for parts was seen as significant and essential by the two repair-shops located outside Germany (Man. A1 and Man. A2). Third, a lack of technician capacity was noted by one manufacturer as a significant problem (Man. B), but the issue was raised by two additional cases. A common practice of the cases studied is to manage the lack of technician capacities by lending technicians from other dealerships seems a common in all cases except Man. A1, Man. A2, and the TÜV. Such lending is often unexpectedly needed, which could also result in waiting for technicians.

Although the Muda itself can be understood similarly in both manufacturing and services, the root causes of waiting in the context of the services studied is noticeably more complex, particularly when referring to the waiting time for the vehicle itself. This waste involves the inherent characteristic of services, whereby customer simultaneously take the role of core suppliers, delivering the key input necessary to initiate the service process. Lack of customer adherence to the predetermined time of arrival was noted as one of the most serious root problem in three of the cases (Man. A1, Man. A2, Man. D, see appendix). Waiting for parts could be explained by the significant delays noted in waiting for spare parts in areas relatively far from the central or even regional manufacturer warehouses. The impact of waiting time, particularly in relation to waiting for the vehicle, significantly impacts repair shop performance. a significant number of manufacturers claimed in the interviews that a tight planning was made difficult by customers who would miss their allocated slot for the vehicle reception (in most cases a 30-minute time slot is provided for each incoming customer). Additionally, in the case of Man. A1 this was noted as a frequent reason for increased throughput time.

The extent to which implementing the solutions proposed in lean manufacturing, such as implementation of just-in-time, could be applied as-is in the context of services is questionable, as the position of clients as both end-customers and core suppliers results in an inherently more delicate context than found with traditional suppliers in manufacturing. Due to this characteristic, implementing lean solutions such as JIT and their enforcement in the context of repair service is more nuanced, and might result in adversely impacting customer satisfaction, despite potentially positive impact of waste reduction. Nevertheless, two manufacturers noted that they actively attempt to 'educate' their customers to be punctual. In addition to whether JIT should be implemented, the extent to which traditional lean methods like JIT are able to be implemented at all in the context of repair services is not straightforward. Requirements for JIT, such as a continuous flow and levelled "production", is inherently difficult in the repair services due to the unique role of the customer in services. Therefore, in most cases, repair shops do not implement a JIT or similar lean approaches, but rather, all cases resort to building up inventory in the form of time-buffers and systematic under-utilization, to account for and mitigate damages, already during the capacity planning stage. For example, Man. C and Man. E plan only up to 80% of their possible capacity, to account for the previously discussed variability. This and particularly the time-buffers set in place for vehicle delivery, correlate with the Muda of inventory, which is discussed in more length in the following sub-section.

Inventory. In lean manufacturing, inventory refers to more raw-material, parts, or work in progress available than is needed for the next step of processing, as well as final products in storage. This can refer to either un-intentional build-up of inventory due to issues such as bottlenecks or production disruptions, as well as intentional building-up of physical inventory buffers. In the services studied, inventory can similarly refer to parts on the workshop floor that are either removed or installed on the vehicle, or the number of vehicles parked on the shop floor either waiting for processing or being processed (work in progress). However, one of the most prevalent manifestations found in the cases were time-buffers for incoming inputs (in the case of the repair services studied, referring primarily to the vehicles themselves). More specifically, in order to combat the lack of adherence of customers to the agreed upon delivery schedule (discussed in the previous section) all cases either deliberately incorporated buffer-times already during the capacity planning phase, on top of the usual time-window planned for vehicle delivery (Man. A1, Man. A2, Man. B, TÜV), sometimes of up to 50% on top of average time allocated. The build-up of time buffers primarily occurred due to the disturbances in scheduling, particularly by customers. The systematic under-utilization was seen as a preventive buffer to combat the highly prevalent rework and additional, unexpected work, discussed in the section on defects.

The impact of time buffers and physical inventory in the repair shops corresponds to a degree with the more often discussed issues in the manufacturing context, such as tied up capital and depreciation. Primarily, these buffers aggravate decreased performance in time-related indicators such as throughput times, as well as lack of physical space (sometimes categorized in lean-manufacturing as a waste category on its own). In particular, the impact of inventory on available space was gauged by interviewees as only a marginal or moderate concern. However, the two largest repair-shops considered it a significant and even essential waste. These two repair-shops were significantly larger than the other cases, with a throughput of 100 vehicles per day, as opposed to a maximum of 20 (vehicles per day) in the other cases. The interviewees in these two shops continuously stressed the impact of the limited space, both in the shop-floor itself, as well as the parking lot, which one interviewee essentially equated to a final goods storage. The strong impact of space limitations resulting from "final-goods" inventory was illustrated by the interviewee in Case E, who noted that very often, they had to turn willing customers away only because there was no more physical space for more vehicles to be stored until finished vehicles were removed from the storage. Additionally, during the workshop floor visits conducted it became clear that even though the smaller repair-shops did not consider inventory and its possible negative impact to be a problem, very considerable amounts of parts-inventory were detected. However, when asked during the interviews about inventory and space, interviewees from smaller shops often simply took it as a given state. For example, Man. B noted "*We have the space we are given and we have to work with it.*" Therefore, despite being prevalent across all cases, attention to inventory and an understanding of the importance of inventory reduction was strong mainly in the larger repair-shops, in which the lack of space was also directly related to more strategic and long term performance, such as expansion of their customer-based and growth of revenue.

Table III. Comparison of waste in manufacturing and the services studied.

Muda	Materialization in Lean Manufacturing	Perceived Importance in Services Studied	Materialization in Services Studied
De-fects	Work (final product or in progress) of faulty quality or errors, cost and effort needed in fixing defects or faults by scrapping or rework.	Essential.	Defects in the core process of vehicle repair, defects in adjunct processes such as faulty identification of necessary work-content
Wai-ting	Idle time of employees or machinery. E.g. waiting for inputs of a process or readiness of machinery, for quality control, for repair etc.	Essential.	Waiting for customers who do not adhere to schedule, lesser degree: waiting for spare-parts, waiting for specialized technicians.
Inven-tory	More raw-material, parts, or work in progress available than is needed for the next step of processing.	Moderate (*triangulation through site-visits)	Inventory of parts, vehicles on which maintenance is on hold taking up workspace and time-buffers in capacity planning.
Move-ment	Movement of employees that does not add value (movement without parts/goods). E.g. employee searching for needed inputs or tools.	Minor.	Movement of employees, e.g. searching for tools, movement for the purpose of communicating.
Trans-por-tation	Movement of material or products that does not add value. E.g. moving work in progress between processing steps, or from/into storage.	Minor.	Delivery of spare parts from the manufacturer's warehouses, the vehicle itself moved between workstations
Over-prod-uction	Manufacturing ahead of demand that results in produced goods that are not demanded by end-customers.	N/A	Possible minor manifestation from site visits: Internal orders; a vehicle from dealership is damaged occupiyng space and resources in the shop.
Over-proce-ssing	Production resources that are utilized to process products in an excessive manner, or excessive features (e.g. unnecessarily strict tolerances)	N/A	Possible minor manifestation from site visits: Orders rushed to be finished as early as possible, earlier than expected by customer.

5. Concluding remarks

The context of this paper was set in the highly competitive automotive sector in West Europe, where after-sales services such as maintenance and repair are becoming increasingly crucial for the bottom-line of manufacturing firms. Despite their importance, productivity measures of such services severely lag behind those achieved in production [6]. Lean-manufacturing philosophy, principles, and tools were pivotal instruments in orchestrating operational excellence in manufacturing, but literature remain relatively sparse on lean management applications in service environments, or "lean-services". This gap in literature is surprising given the growing practical relevance of leaner after-sales services, and constitutes the backdrop for our research. In this paper, we aimed to assess the current status quo of lean management implementation in maintenance and repair-shops in automotive industry.

Despite our efforts to ensure a systematic and reproducible approach in our review of literature, and triangulation efforts in our multiple case study design, several limitations remain. First, the case-study samples were collected from organizations from Germany and two in continental Europe, so even though some regional differences were observed, the generalizability of findings to other market contexts could be limited. Future research on the topic could increase both the sample-size studied, as well as the geographic diversity of cases in order to be able to draw conclusions that are more generally applicable also to manufacturers in different markets. Secondly, gathering primary data on the topic of operational inefficiencies and potential improvements could incur a certain degree of bias from respondents. Though we attempted to mitigate this by both ensuring anonymity as well as carrying out site-visits, which indeed proved useful for triangulation purposes, further research could benefit from incorporating a quantitative approach to their research design.

Nevertheless, several interesting insights emerged from our research design. Our systematic literature-review on lean services, revealed that the breadth of work on lean services tends to focus on administrative improvements for mass-services in commercial baking, or alternatively, operational improvements in service-factories, such as fast-food chains. Secondly, there is a dearth of papers that derive their findings on the applicability of lean-management concepts based on an analysis of multiple cases. Our cross-case analysis of seven repair-shops has provided an assessment of the applicability of the traditional understanding of waste from manufacturing, in a service environment. Additionally, the root causes of such wastes and their importance in service environments, was compared with the focus they receive in manufacturing literature. Overall from our findings from literature and practice, we can conclude that the status-quo of lean implementation in repair-shops is at a budding stage and still under-developed. Additionally, a recognition of the impact of waste on performance indicators such as processing-time and due-date reliability, though slightly varied between the repair-shops, was generally lower than would be expected in manufacturing organizations. However, the potential extent to which implementing lean principles can benefit operational performance of these services proved greater than originally anticipated from the overview of existing literature.

Although existing literature tends to stress the importance of altering principles and tools to fit the inherent nature of services, our empirical findings show that this is not the case for all Muda categories. Concrete first-steps of operational improvement can already be implemented with little alteration. For example, the zero defects principle and corresponding programs, such as total quality program, and methods such as Poke Yoke, might not require such alterations in order to address the high levels of rework and extension of work that was prevalent throughout all cases. These can already be used in order to provide effective operational wins. On the other hand, certain methods were found to certainly prove less applicable in the context of reducing waste in repair-shops. For example, JIT delivery is a popular approach in manufacturing for inventory reduction, which is a growing concern for the repair-shops. However, it would require the organizations to implement a tact or continuous flow, which none of the organizations studied were able to achieve, given the high variability of demand. Additionally, the greatest challenge for the repair-shops was not necessarily associated with delivery of spare-parts, often discussed in after-sales literature, but rather in customer adherence to the scheduled delivery of the vehicle. Therefore, unlike supplier development programs often utilized in manufacturing context, any approach to address this waste in service contexts must consider the unique positon of the customer as a simultaneous supplier of the key input to the process.

6. References

1. Miriam Borchardt, Marcelo Souza, Giancarlo M. Pereira, Claudia V. Viegas, "Achieving better revenue and customers´ satisfaction with after-sales services: how do the best branded car dealerships get it?", International Journal of Quality & Reliability Management, https://doi.org/10.1108/IJQRM-01-2017-0016
2. Agrawal, N., Agrawal, V. & Cohen, M. 2006, “Winning in the Aftermarket”, Harvard Business Review, 84(5), p.129.
3. Dombrowski, U. & Malorny, C.; 2018 "Methodological approach for a process-orientated Lean Service implementation" in: 10th CIRP Conference on Industrial Product-Service Systems, Procedia CIRP, 73; Linköping, Sweden, pp. 235-240
4. Milind M. Lele. 1997. "After-sales service - necessary evil or strategic opportunity?", Managing Service Quality: An International Journal, Vol. 7 Iss 3 pp. 141-145 http://dx.doi.org/10.1108/09604529710166914
5. N. Saccani L. Songini P. Gaiardelli, 2006. "The role and performance measurement of after-sales in the durable consumer goods industries: an empirical study", International Journal of Productivity and Performance Management, Vol. 55 Iss 3/4 pp. 259 - 283
6. Resta, towards a framework for lean opertions in product-oriented service systems
7. Womack, J. & Jones, D. 2003, Lean thinking: banish waste and create wealth in your corporation, Simon &Schuster UK Ltd, London.
8. Poppendieck, Mary B, and Thomas David Poppendieck. 2003. Lean Software Development: An Agile Toolkit. Boston: Addison Wesley.
9. Chiarini, Andrea. 2013. Lean Organization: From The Tools Of The Toyota Production System To Lean Office. Milan: Springer.
10. Blank, Steve. 2013. "Why The Lean Start-Up Changes Everything". Harvard Business Review. https://hbr.org/2013/05/why-the-lean-start-up-changes-everything.
11. Ben Naylor, J, Mohamed M Naim, and Danny Berry. 1999. "Leagility: Integrating The Lean And Agile Manufacturing Paradigms In The Total Supply Chain". International Journal Of Production Economics 62 (1-2): 107-118. doi:10.1016/s0925-5273(98)00223-0.
12. Bowen, David E., and William E. Youngdahl. 1998. " “Lean” Service: In Defense Of A Production - Line Approach". International Journal Of Service Industry Management 9 (3): 207-225. doi:10.1108/09564239810223510.
13. Manuel F. Suárez-Barraza , Tricia Smith & Su Mi Dahlgaard-Park (2012) Lean Service: A literature analysis and classification, Total Quality Management & Business Excellence, 359-380, DOI: 10.1080/14783363.2011.637777
14. Eisenhardt, Kathleen M. 1989. "Building Theories From Case Study Research". Academy Of Management Review 14 (4): 532-550. doi:10.5465/amr.1989.4308385.
15. Gronroos, Christian. 1990. Service Management And Marketing: Managing The Moments Of Truth In Service Competition. New York: Lexington Books. p.27

16. Seddon, John, Brendan O'Donovan, and Keivan Zokaei. 2020. "Rethinking Lean Service". In Service Design And Delivery. Springer US.
17. Schmenner, Roger. 1986. "How Can Service Businesses Survive And Prosper?". Sloan Management Review.
18. Verma, Rohit. 2000. "An Empirical Analysis Of Management Challenges In Service Factories, Service Shops, Mass Services And Professional Services". International Journal Of Service Industry Management 11 (1): 8-25. doi:10.1108/09564230010276924.
19. Sprigg, C.A. & Jackson, P.R. 2006, "Call Centers as lean service environments: Job-related strain and the mediating role of work design", in: Journal of Occupational Health Psychology, Vol. 11 (2), pp. 197-212
20. LaGanga, L. R. 2011, "Lean service operations: Reflections and new directions for capacity expansion in outpatient clinics", in: Journal of Operations Management; Vol. 29 (5); pp. 422-433
21. Chougle R., Rajpathak, D. & Bandyopadhyay, P. 2011, 'An integrated framework for effective serice and repair in the automotive domain: An application of association mining and case-based-reasoning', in: Computers in Industry Vol. 62 (7), pp. 742-754
22. Pan, W-T.; Leo, Y.; Zhu, W. & Lin, W.-Y. 2017, A Data Mining Approach to the Analysis of a Catering Lean Service Project in: Intelligent Automation and Soft Computing; Vol. 23 (2); pp. 243-250
23. Weihser, P. & Giles, D. 2018, "Establishing an ambulatory care service using point-of-care testing diagnostics", in: British Journal of Hospital Medicine, Vol. 79 (9), pp. 520-523
24. Petrusch, A.; Roehe Vaccaro, G. L. & Luchese, J. 2018, "They teach, but do they apply?: An exploratory survey about the use of Lean thinking in Brazilian higher education institutions", in: International Journal of Lean Six Sigma
25. Swank, C.K. 2010, "The lean service machine", in: Harvard Business Review, Vol. 81 (10), pp. 123-129
26. Gupta, Shradha, Monica Sharma, and Vijaya Sunder M. 2016. "Lean Services: A Systematic Review". International Journal Of Productivity And Performance Management 65 (8): 1025-1056. doi:10.1108/ijppm-02-2015-0032.
27. Hadid, W.; Mansouri, S. A. & Gallear, D. 2016, "Is lean service promising? A socio-technical perspective", in: International Journal of Operations and Production Management, Vol. 36 (6), pp. 618-642
28. Sum, F. F.; de Paula, I. C.; Tortorella, G.; Pontes, A.T. & Faco, R.T. 2019, Analysis of the Implementation of a Lean Service in a Shared Service Center: A Study of Stability and Capacity in: IEEE Transactions on Engineering Management
29. Godlevskaja, Olga, Jos van Iwaarden, and Ton van der Wiele. 2011. "Moving From Product ‐ Based To Service ‐ Based Business Strategies". International Journal Of Quality & Reliability Management 28 (1): 62-94. doi:10.1108/02656711111097553.
30. Devaraj, Sarv, Khalil F. Matta, and Edward Conlon. 2009. "Product and Service Quality: The ANTECEDENTS OF CUSTOMER LOYALTY IN THE AUTOMOTIVE INDUSTRY". Production And Operations Management 10 (4): 424-439. doi:10.1111/j.1937-5956.2001.tb00085.x.
31. Levitt, Theodore. 1972. "Production-Line Approach To Service". Harvard Business Review. https://hbr.org/1972/09/production-line-approach-to-service.

Appendix A.

Table III. The status-quo of self-reported prevalence of the different waste categories and performance tracking in repair-shops

Dimension	Characteristic	Man. A1	Man. A2	Man. B	Man. C	Man. D	Man. E	TÜV
Mudas	Do you observe waste in your processes?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Waiting	Essential	Significant	Significant	Moderate	Moderate	Moderate	N/A
	Transport	Moderate	Moderate	Marginal	Marginal	Marginal	Marginal	N/A
	Inventory	N/A	Marginal	Marginal	Significant	Moderate	Significant	N/A
	Space (added following site visits)	Moderate	Marginal	Marginal	Significant	Moderate	Essential	N/A
	Rework	Significant	Significant	Moderate	Significant	Significant	Moderate	Moderate
	Movement	Moderate	Moderate	Marginal	Moderate	Marginal	Significant	N/A
KPIs	Does the OEM set KPIs?	Yes	Yes	No	No	No	No	No
	Are start and end times measured?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Is due date reliability measured?	No	No	No	No	No	No	No
	Importance to customer: Due date reliability	Moderate importance	Moderate importance	High importance	Moderate importance	Moderate importance	Moderate importance	High importance
	Importance to customer: short TTP	High importance	High importance	High importance	High importance	High importance	High importance	High importance