E-ISSN: 2676-6167 | P-ISSN: 2538-5100

Journal of Applied Research on Industrial Engineering

www.journal-aprie.com

J. Appl. Res. Ind. Eng. Vol. 10, No. 1 (2023) 45-55.

Paper Type: Research Paper

Lean at Home: Applying 5 Whys and Lean PFMEA to Home Projects

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Citation:

Keyser, R. S., & Pooyan, P. (2023). Lean at home: applying 5 whys and lean PFMEA to home projects. *Journal of applied research on industrial engineering, 10*(1), 45-55.

Received: 20/12/2021 Reviewed: 23/01/2022 Revised: 09/03/2022 Accepted: 20/04/2022

Abstract

Root Cause Analysis (RCA) techniques are often applied to problems in the workplace; however, they may also prove very useful to home projects. This research explores the application of two RCA techniques in home projects: 1) 5 Whys to determine the root cause of a home air conditioning unit that runs continuously but does not cool, 2) an innovative Lean PFMEA to repair a John Deere riding mower that starts, then stops. Employing the 5 Whys technique led to the discovery of incorrect color-coded wiring from the original air conditioning unit to the thermostat. Lean PFMEA enabled a correct diagnosis and resolution of the mower start/stop issue via a Kaizen event, grass clippings in the fuel line, which was remedied by cleaning the fuel tank and replacing the fuel lines, fuel filter, and carburetor. These techniques provide Lean methodological approaches to problem-solving, which often leads to reduced homeowner aggravation, repair time, and repair expense.

Keywords: 5 Whys, Lean PFMEA, Home projects, Lean, Root cause analysis techniques.

1 | Introduction

John Krafcik is credited with making popular the term 'Lean', named after the world-famous Toyota production system, which focuses on waste elimination, shorter lead times, frequent changeovers, smaller lot sizes, and reduced inventories [1]. Lean was initially implemented in the automotive industry with great success, and the adoption of Lean production systems soon spread across many manufacturing industries worldwide. Today, the Lean philosophy is used in many service industries as well, such as healthcare [2]-[4], education [5], [6], and restaurants [7], yielding similar successes.

Lean can also be practiced in home applications and the literature reveals sparse research in this area. For example, Keyser [8] demonstrates how Root Cause Analysis (RCA) techniques, such as 5 Whys, Cause-and-Effect diagram, and Fault Tree analysis can be used to diagnose problems in home projects, Martinez [9] explores the possibility of applying Lean thinking in the Personal and Household Services (PHS) sector in the Czech Republic, and Brown et al. [10] studied the application of lean principles in the construction of Quadrant homes, resulting in the construction of a completed house in exactly 54 days.

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https://doi.org/10.22105/jarie.2022.320848.1410

This research discusses examples of how the 5 Whys and Lean PFMEA techniques can be used to diagnose problems encountered with home projects. More specifically, these techniques are used to identify possible causes leading to a failure. Once all possible causes were identified, steps were then undertaken by the homeowner to remedy home project issues.

2 | Literature Review

'Lean' philosophy was first introduced by John Krafcik [11], and became popular as a world-class manufacturing and management theory by Womack et al. [1] in their best-selling book, "the machine that changed the world". Lean progressively offers an interconnected socio-technical framework with a primary focus on making changes based on the needs and purpose of the enterprise [12], [13]. As such, the Lean skills can provide an ideal platform to provide sustainable production lines with fewer physical effort, less resources, less time, more quantity [1].

The new paradigm follows the basic philosophy of Lean thinking as the conversion of waste into customer-defined value. This is achieved by identifying value from customer standpoint, classifying the value stream while eliminating all steps with no value, creating a tight sequence of value-creating steps to flow smoothly towards the customer, developing systems to downstream customers, pulling value from the next upstream activity, and undertaking continuous improvement to a state of perfection [13]-[15]. Since its birth, the powerful concept of lean thinking has been widely extended from its original application in auto manufacturing industries into other economic sectors, including healthcare, education, food service, construction, electronics, printing industry, and even home projects. For example, in healthcare, the application of lean principles reflected in: reducing medications errors in Norwegian hospitals [16]; improving the efficiency and effectiveness of a clinical or an administrative process inside an Irish hospital [17]; tackling cultural performance and operational issues at a macro-level to improve patient care while simultaneously reducing costs [18]; focusing on eliminating waste as perceived by patients hence maximizing quality and safety for the patients [19]; increasing teamwork, creating user friendly work areas and processes, changing management styles and expectations, increasing staff empowerment and involvement, and streaming the supply chain within the perioperative area [20]; achieving a significant reduction in both the number of hospitalization days and the number of patients affected by healthcare-associated infections in the general surgery departments [21]; and improving technique to build an Adult Sickle Cell Disease Medical Home [22].

Furthermore, in education, the effect of lean implementation has introduced a pathway: to map the student value stream starting with kindergarten and look at all activities, in the classroom and beyond, to analyze where value is added and where waste is created [23]; to achieve rational and optimal educational system by providing quality in the learning experience, method of delivery, and student outcomes [24]-[26]; to improve administrative processes through an innovative and engaging learning experience by involving undergraduate students instead of employees [27]; to elaborate different approaches to quality improvement in education by dealing with the problem of improving technology supports and services for instructional purposes in a US school district system [28]; to propose a waste management framework in the Brazilian Education System that allows universities to organize their activities and select tools or practices to optimize their efforts to create value for final users [29]; to bolster students' learning through problem solving in a virtual simulation environment [30]; and to mitigate six common types of mistakes made by teachers in a high-school environment [5].

Similarly, in food service, the adaptation of lean strategy provided a roadmap: to understand contextual factors and to analyze the benefits and barriers of improving operational efficiency and productivity among the European food Small and Medium-sized Enterprises (SMEs) [31], [32]; to lay the foundations for the Greek food sector to be competitive in a global scenario of an economic downturn [33]; to fill the gap on the lack of knowledge while developing a tailor-made framework for companies and practitioners in the European food SEMs to increase the production efficiency [34]; to bring out pertinent factors and useful insights from a Norwegian dairy producer toward greater environmental sustainability in fresh-food supply chains [35]; to create valid and reliable multi-item measurement scales in identifying potential improvement opportunities to enhance food industry firms' performance and competitiveness [36]; and to reduce the waste costs such as time and food, increase employee utilization while lowering labor costs, operate at a more efficient inventory level, and improve the profitability in the selected American restaurant categories [7].

Similarly, in other economic sectors, the lean approach has offered an implicit strategy: to increase efficiency without compromising occupational health and safety of workers in manufacturing industries [37]; to develop sustainable building rating systems while reducing the environmental impact of construction [38]; to create a more reliable and quick work flow in design and construction of a capital project while delivering value to the customer [39]; to remove the bottlenecks affecting quality and productivity in electronics repair industries [40]; to assess the impact of lean and green practices on an organization's effectiveness and competitive advantage [41], [42] in manufacturing and service sectors [43] as well as ecological and social objectives [44]; and to address key organizational factors to successfully implement strategies and systematically adopt change in printing industries [45].

As part of the lean philosophy, RCA establishes a practical and structured approach to identify causal factors and to resolve underlying problems. RCA offers a management practice tool to enable companies to achieve organizational improvement and operational efficiency with the goal to unravel the underlying problematic issues and to propose a resolution to tackle or eliminate them altogether [46]. The process involves with the data collection, cause charting, root cause identification, mitigation strategy, and active implementation [47]. RCA includes a variety of analytical methods and techniques such as the Six Sigma methodology, the 5 Whys technique and the Failure Modes and Effect Analysis (FMEA).

John and Kadadevaramath [48] applied the Six Sigma methodology, including brainstorming and principal components analysis techniques, to improve the resolution time performance in software development. In the insurance industry, whereas Sarker et al. [49] employed Six Sigma, including process mapping, stepwise regression, and FMEA to analyze insurance claim submissions in order to reduce claim processing cycle times, John and Parikh [50] applied the Six Sigma methodology, including statistical analysis, dynamic regression, and integer programming to reduce the daily backlog percentage of accident and injury claims of an outsourcing insurance claim processing process. Lean models and frameworks were established to integrate lean tools with ISO 9001: 2015 requirements [51]; for improving the reliability of lean systems [52], and for understanding change in a lean environment [53].

Whereas lean thinking and lean principles have been successfully applied in manufacturing and service industries with great impact; its application in home projects has been less visible. This research explores the effect of lean thinking and strategies to diagnose problems encountered with home projects by using appropriate methodologies such as 5 Whys and an innovative lean PFMEA technique

The 5 Whys technique offers an interrogative scientific approach to explore the cause-and-effect relationships underlying a particular problem by repeating why 5 times to unravel the nature of the problem while suggesting a potential resolution to such problem [46]. The 5 Whys is attributed to Sakichi Toyoda, the founder of the Toyota Motor Corporation, for developing the technique during the evolution its manufacturing methodologies and processes. Ohno [12], the architect of the Toyota Production System, described the 5 Whys method as the basis of Toyota's scientific approach by repeating why five times until a countermeasure becomes apparent to offer resolutions and to mitigate the risk and prevent the issue from recurring [54]. The tool has widespread use beyond automobile industry; and if performed effectively, it can help transform a reactive culture or one that moves from one crisis to the next into a forward-looking culture or an organization that solves problems before they may even occur or escalate into a full-blown crisis [55].

Similarly, the FMEA provides a powerful design tool yet subjective analysis for the systematic identification of possible Root Causes and Failure Modes and the estimation of their relative risks [56]. FMEA is applicable at the various levels of system decomposition from the highest level of block diagram down to the functions of discrete components [57]. The FMEA team determines the effect of each failure, identifies the single crucial failure points, ranks each failure according to the criticality of the failure effect and its probability of occurring. The causes of failure are said to be Root Causes and may be defined as mechanisms that lead to the occurrence of a failure. The timing of the FMEA analysis is essential; and the main goal is to ideally determine and then limit or avoid potential risks within the early stages of product design or process development [58]. Conducting an FMEA on the existing products or processes may also yield benefits to ultimately achieve higher reliability, higher quality, and enhanced safety. Recent modifications to traditional FMEA include implementing an ordinal rating scale for risk analysis in radiation oncology [59]; combining FMEA analysis with identification of key determinants in building industry supply chains [60]; applying a new Doubly Technique for Order of Preference by Similarity to the Ideal Solution (DTOPSIS) approach within a fuzzy PFMEA for rankings of listed failure causes in the milk process industry [61]; and integrating lean with PFMEA in the automotive industry [62].

Keyser and Pooyan| J. Appl. Res. Ind. Eng. 10(1) (2023) 45-55

3 | Applying Lean at Home

Example 1 (5 Whys). Air conditioning unit runs continuously, but does not cool home.

In this example, a new Honeywell thermostat (*Fig. 1*) was installed to replace the original thermostat that was approximately 20 years old.

Fig. 1. New Honeywell thermostat.

The homeowner followed the wiring installation instructions in the owner's manual (*Fig. 2*).

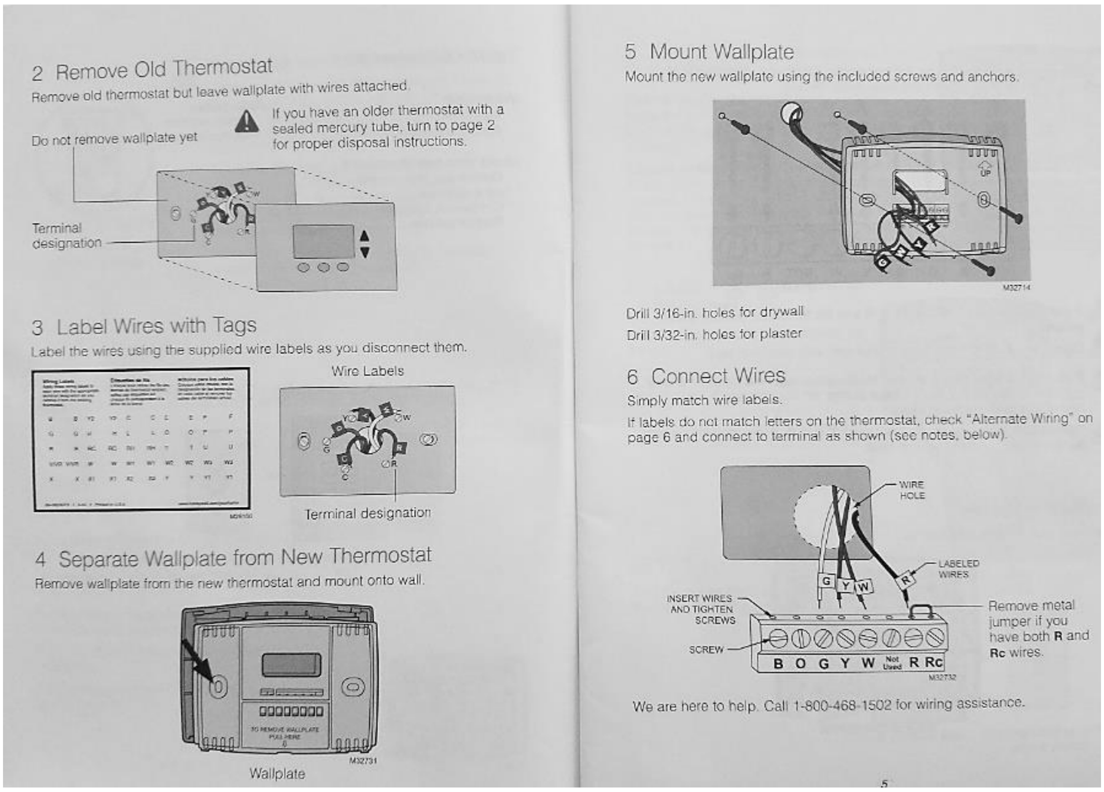

Fig. 2. Wiring instructions for Honeywell thermostat.

After installation, the thermostat ran continuously, did not cool the home, and would rarely turn off. The 5 Whys technique in *Fig. 3* was used to diagnose this issue.

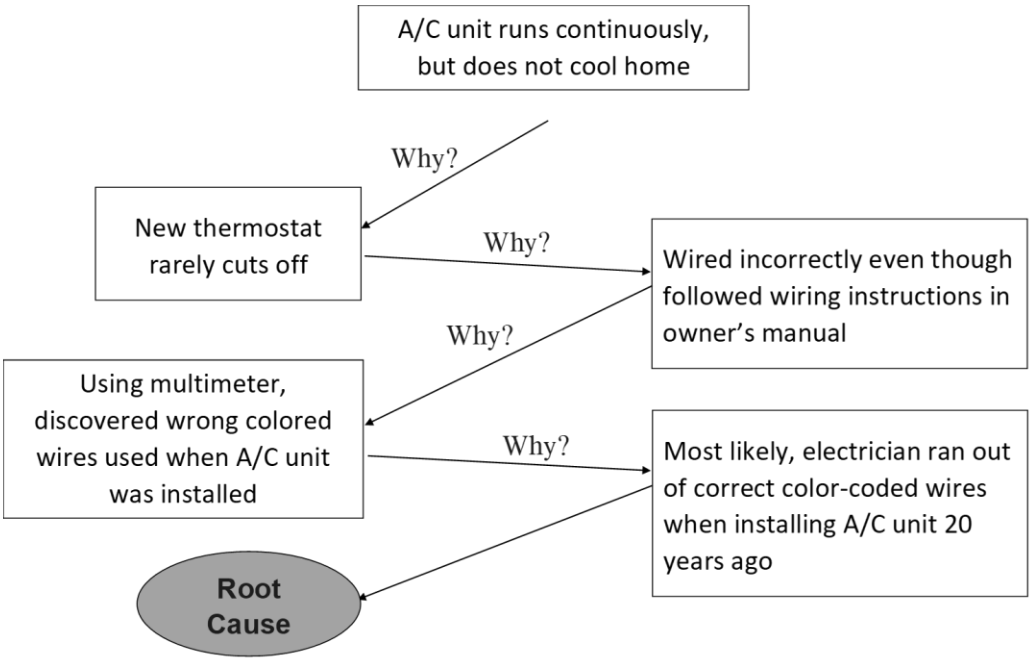

Fig. 3. 5 Whys diagram for diagnosing issue.

Solution

Once a multimeter was used to test voltage, current, and resistance, the root cause became readily apparent. Matching the color-coded wires to the contacts shown in the wiring instructions proved futile because two of the color-coded wires used in the original installation were incorrect. A plausible reason is that the electrician may have run out of the correct color-coded wires to properly install the original thermostat. By matching the wrong color-coded wires to the proper contacts corrected this issue. As a result, both the thermostat and HVAC system now run as intended.

Example 2 (Lean PFMEA). Why John Deere X304 Mower starts, then stop.

An innovative lean Process Failure Modes and Effects Analysis (PFMEA) allows for a structured way to diagnose a problem by identifying key process steps, then listing all failure modes, their effects, and the possible causes of those effects according to the severity and likelihoods of occurrence and detection, along with current controls in place, and then recommended lean actions.

In this example, a John Deere X304 riding mower would start every time, then stop. This provided great consternation to the homeowner, so a lean PFMEA was employed to determine all possible root causes as shown in *Table 1*.

The troubleshooting focus of this problem was abated to; 1) starting the mower, 2) the fuel system, as indicated in the process step column on the lean PFMEA chart. The mower started each time using a standard work procedure of inserting and turning the ignition key while the right foot simultaneously depressed the brake pedal, so that was not the problem. Preventive maintenance measures were applied as; 1) the date code on the battery indicated the battery was determined to still have a long useful life, 2) both sparkplugs were removed to check the sparkplug gap, and the sparkplug head was then cleaned on a wire wheel before re-installing. The problem-solving focus then centered on the fuel system, since this category had the highest RPN scores.

Keyser and Pooyan| J. Appl. Res. Ind. Eng. 10(1) (2023) 45-55

An overall 6s inspection of the mower exterior followed, particularly around the engine area. Upon removal of the fuel filter, grass shavings were observed inside the fuel filter, as shown in *Fig. 4*.

Fig. 4. Grass shavings visible inside fuel filter.

The result of a Kaizen event required replacing the fuel filter rather than cleaning it since the fuel filter was a sealed unit. But how did grass shavings get into a sealed fuel filter? Further visual inspection revealed that the fuel filter is connected by a fuel line on both the top and bottom ports of the fuel filter. The fuel line from the bottom port of the fuel filter is connected to the fuel tank. The fuel line from the top port of the fuel filter is connected to the carburetor.

Table 1. Lean PFMEA on why John Deere mower would start, then stop.

Procrss Step/ Function	Potential Failure Mode	Potential Failure Effects		Potential Causrs of Failure		Current Process Controls: Prevention			Recommended Action(S)	Responsibility	Action Taken				
What Is the Process Step, Change of Feature under Investigation?	In What Ways Could the Step, Change or Feature Go Wrong?	What is the Impact on the Customer If this Failure is not Prevented or Corrected?	Severity (1-10)	What Causes the Step, Change or Feature to Go Wrong? (How could it Occur?)	Occurrence (1-10)	What Controls Exist that Either Prevent or Detect the Failure?	Detection (1-10)	RPN	What Are the Recommended Actions for Reducing the Occurrence of the Cause or Improving Detection?	Who is Responsible for Making Sure the Actions are Completed?	What Actions were Completed (and When) with Respect to the RPN?	Severity (1-10)	Occurrence (1-10)	Detection (1-10)	RPN
Start mower	Missing key	Mower wont start	8	Forgot where key is located	10	Store key in same location each time	1	80	6s	Operator	Designated top right tray in rolling toolbox	8	1	2	16
	Broken key	Mower wont start	8	Turned old key too hard	10	Replace old key	1	80	jidoka	Operator	Replace worn key	8	1	2	16
	battery	Mower wont start	8	Batterys useful life ended	10	Check date on battery label	3	240	Preventive maintenance	Operator	Replace battery every 3 years	3	2	2	12
	Brake pedal not depressed	Mower wont start	5	Forgot to depress brake pedal when turning key	3	Familiarization with start-up procedure	3	45	Standard work	Operator	Depress brake pedal when starting mower	1	1	1	1
	Sparkplugs	Mower wont start	6	Dirty sparkplugs	8	Visual inspection	3	144	Preventive maintenance	Operator	Annual replacement during tune-up	2	1	2	4
	Old gas	Mower starts, then dies	8	Gas stored too long in gas container	3	Visual inspection	8	192	Poka-yoke	Operator	Put label on gas container with data purchased	3	1	2	6
	Gas tank clogged	Mower wont start	8	Debris entering gas tank	8	Non- sealed system	10	640	kaizen	Operator	Visual inspection of clean gas poured in gas tank	8	1	2	16
	Fuel line clogged	Mower starts, then dies	8	Debris entering fuel line	9	Non- sealed system	10	720	kaizen	Operator	Inspect fuel line before each use	8	2	4	64
	Fuel filter dirty	Mower starts, then dies	8	Debris entering fuel filter	10	Visual lnspection	6	480	Visual management	Operator	Inspect fuel filter before each use	8	1	1	8
	Carburetor clogged	Mower starts, then dies	8	Debris entering carburetor	10	Non- sealed system	10	800	kaizen	Operator	Visual inspection of carburetor before each use	8	2	7	112
						Total		3421			Tatal				255

Keyser and Pooyan| J. Appl. Res. Ind. Eng. 10(1) (2023) 46-56

Solution

This Kaizen event allowed for a structured approach to the homeowner in tracing the origin of grass shavings into the fuel filter via the fuel line back to the fuel tank. It was suspected that grass shavings entered the fuel tank most likely from grass debris around a moist spout on the gas container when filling the gas tank for the most recent mowing. The grass shavings worked their way down in the gas tank to the port entering the fuel line which allowed grass shavings to travel to and enter the fuel filter, and then continued out of the top port of the fuel filter through the fuel line into the carburetor. Since the John Deere mower was already 14 years old, the homeowner decided to replace the carburetor along with the fuel lines and fuel filter (see, *Fig. 5*). The gas tank was removed and thoroughly cleaned. The gas container spout was also cleaned of moisture and debris. By taking these action steps, the RPN was significantly reduced from 3, 421 to 255 and the John Deere X304 riding mower runs like new again.

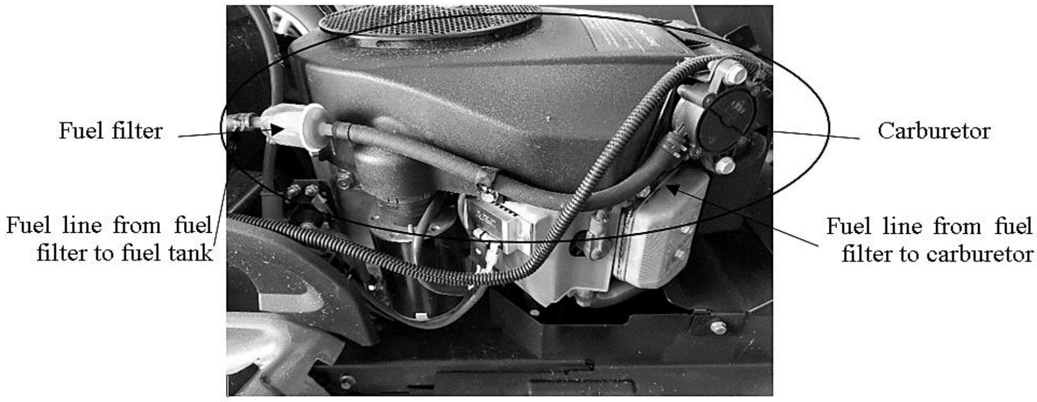

Fig. 5. Replaced fuel filter, fuel line, and carburetor.

4 | Conclusion

The 5 Whys technique was used to diagnose why a newly installed thermostat ran continuously and yet did not cool the home. The use of a multimeter led to the discovery that the wrong color-coded wires were used to connect the outside air conditioning unit to the wall thermostat during the initial installation of the air conditioning unit some 20 years ago. Lean PFMEA was used to determine why a John Deere X304 riding mower would start, then stop. The severity of potential failure effects, the likelihood of occurrence of the potential causes of those effects, and the likelihood of detecting those causes based on current controls in place was analyzed. A total RPN of 3,421 was calculated for the current state in which the focus abated to; 1) starting the mower, 2) the fuel system. A Kaizen event led to discovery of causes and corrective actions, such as cleaning the gas tank, replacing the fuel lines, fuel filter, and carburetor, reducing the overall RPN to 255. With regard to the fuel system, the RPN was significantly reduced from 2,832 to 206. Corrective actions restored the mower back to an operable state.

5 Whys and lean PFMEA are practical methodological techniques that can help diagnose root causes in malfunctioning equipment. This, in turn, can lead to a more rapid repair and restoration of homeowner equipment previously deemed inoperative.

5 | Areas for Future Study

Lean applications can be easily adopted for home use. Areas for future study include applying 6s and visual management techniques to organize a home interior/exterior, garage, or workshop; mistake-proofing common tasks conducted around the home by the homeowner, such as using ladders; creating checklists to perform intermittent activities, such as changing the oil in a car, proper tire rotation on a vehicle, and starting equipment that requires a sequence of steps; applying setup time reduction techniques for washing the car, doing the laundry, installing fixtures (such as lights or ceiling fans, etc.), painting, assembling a bicycle, or doing yard work.

Funding

No funding supported this research.

Conflicts of Interest

All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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