Using the Lean Six Sigma Methodology to Reduce Mouse Cage Sanitation Time for Animal Care and Use Programs

Jamison V Kovach* and Ansupa Dash

Although efficient sanitization is a high priority for Animal Care and Use Programs (ACUP), the cage sanitation process for animals used in biomedical research can be labor-intensive. To increase the efficiency of sanitation services provided by ACUP, the current project used the Lean Six Sigma methodology to reduce the time to sanitize mouse cages by implementing countermeasures to reduce causes of waste within this process for the Animal Care Operations (ACO) group at a leading public research university. Lean Six Sigma was selected for use in this project given its goal to make organizations' routine operations flow as smoothly and efficiently as possible and its applicability to biomedical and research settings as discussed in the literature. Through observation of the ACO's existing mouse cage sanitation process and brainstorming sessions with the ACO staff, the existing process was mapped, a baseline measurement of the current process performance was established, the process was analyzed to identify potential causes of waste, and appropriate countermeasures were implemented to improve the process. These countermeasures involved actions specifically targeted at reducing process delays, which included implementing new procedures, clarified schedules, and visual controls. As a result of this project, ACO's average mouse cage sanitation process cycle time was reduced by 35 min, and the time saved was reinvested within the ACO to provide technicians additional time to complete other valuable tasks and thus support animal research endeavors at this university.

Abbreviations: ACO, animal care operations; ACUPs, animal care and use programs; FMEA, failure modes and effects analysis

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Given their biologic similarities to humans, biomedical research often uses animals (for example, mice, rats, rabbits, monkeys) to develop methods for preventing and treating illness and diseases; therefore, biomedical research studies typically require high-quality, cost-efficient animal care services.²⁸ Research institutions often provide these services through centralized animal care and use programs (ACUP), which provide veterinary care and housing for animals while ensuring compliance with regulations for the use of research animals.¹⁷ Because the environment in which research animals are housed may affect study outcomes, efficient sanitization is a high priority for ACUP;²¹ however, cage sanitation processes can be labor-intensive.

To increase the efficiency of sanitation services provided by ACUP, a project was initiated to investigate the mouse cage sanitation process. Using an action research approach,^{7,26} investigators worked closely with the Animal Care Operations (ACO) group at a leading public research university to reduce the time spent sanitizing mouse cages. This project was of interest to the ACO because technicians needed additional time to complete other tasks to support animal research endeavors. The current study demonstrates how the Lean Six Sigma methodology, which is a structured process improvement approach for systematically reducing waste and improving process performance,²³ was used to address this issue. This project involved mapping the existing process, determining a baseline

measurement of the current process performance, analyzing the potential for waste within the process, and implementing countermeasures to improve the process. Lean concepts have previously been applied in ACUP for process improvement activities,^{6,25,35} including task scheduling for technicians²⁰ and facility operations.^{4,19} In addition, ACUP have used Lean and other methods to support improvement and process redesign efforts,^{3,13,22} some of which have focused on designing and improving cage sanitation processes.^{18,38}

This case study was conducted at the University of Houston (Houston, TX). To ensure that research programs comply with all federal regulations for animal use, the university has maintained AAALAC accreditation since 1986. The ACO group has 3 full-time veterinarians, which are board-certified in laboratory animal medicine, and 13 technicians and other staff members. Research animals are housed in 2 facilities, and rodents are housed by using a cage-level barrier system. The ACO staff has extensive experience with laboratory animal species, anesthesia, surgery, and a variety of research techniques, in addition to its traditional roles of animal procurement, husbandry, veterinary care, and hands-on training.³⁶

Materials and Methods

The materials used in this case study consisted mainly of information obtained through detailed observation of the ACO's existing mouse cage sanitation process, as well as brainstorming sessions with the ACO staff. The Lean Six Sigma methodology provides a disciplined approach for improving process efficiency by identifying how waste occurs, as well as implementing countermeasures to reduce its occurrence.^{1,27} As is typical in

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Project Management Program, University of Houston, Houston, Texas

*Corresponding author. Email: jkovach@uh.edu

Suppliers	Inputs	Process	Outputs	Customers
UH Division of Research	ACO staff	1. Unload mouse cages and lids from mouse cage tower	Clean mouse cage towers	UH biomedical researchers
	Empty dirty mouse cages and lids	2. Empty bedding into dumping station		
UH biomedical researchers		3. Place mouse cages and lids on wash rack		ACO staff
	Dirty towers	4. Move rack into washer		
		5. Initiate wash cycle		
Vendors		6. Remove rack from washer		Mice
	Washing equipment	7. Move tower(s) into washer		
		8. Initiate wash cycle		
		9. Remove tower(s) from washer		
	Cleaning supplies	10. Build tower with clean mouse cages and lids		

Figure 1. High-level overview of the ACO's mouse cage sanitation process, UH, University of Houston.

Lean Six Sigma projects, the current investigation followed the Define, Measure, Analyze, Improve, and Control methodology.³² This process improvement approach entailed first, in the Define phase, identifying the problem to be addressed, selecting the investigators, and defining the mission of the investigation. Next, the Measure phase involved documenting the current process and collecting data to evaluate the current process performance. The Analyze phase focused on investigating and prioritizing potential issues within the process that could lead to waste to determine the root cause(s) of process inefficiency. The Improve phase used brainstorming to generate ideas regarding possible process improvements and prioritization methods to determine the most appropriate countermeasure(s) to address each root cause identified previously. The selected countermeasures were then implemented to create a new process. Finally, the Control phase involved developing and implementing control measures to ensure that the savings generated as a result of using the new process would be sustained over time.^{9,15,28}

Define phase. The work in this phase involved assembling the project team, creating a project charter, and developing a project plan.²⁴ To ensure that those who were most knowledgeable about the process under investigation would have an opportunity to contribute to this project, the project team included the ACO's technicians (3), supervisors (2), and other staff (1), and the team was led by the Executive Director of the ACO, who is also the university's Attending Veterinarian. This team began by creating a project charter, which described the project's scope, objectives, and stakeholders, as well as team members' roles and responsibilities. The purpose of the current project is summarized in the following problem and mission statements. According to the problem statement, the "ACO has had an arithmetic mean of 94 min to sanitize mouse cage towers (100 cages) over the last 3 d (10 through 12 January 2018), resulting less time for technicians to complete other tasks to support animal research endeavors." To create more time for other tasks beyond cage cleaning, the mission of the project was to "reduce the arithmetic mean time for the ACO to sanitize full mouse cage towers to 60 min or less over the next 4 mo (by April 2018)."

In addition, the project plan outlined steps to guide how the project was to be conducted. The steps included: 1) mapping the ACO's current process for sanitizing mouse cage towers; 2) creating a measurement system to collect cage sanitation process cycle time data; 3) establishing a baseline measurement regarding the current process performance; 4) evaluating the process by using failure modes and effects analysis (FMEA); 5) prioritizing causes to determine the root cause(s) of waste in the process; 6) brainstorming and prioritizing ideas for countermeasures to address each root cause; 7) implementing selected countermeasure(s) for each root cause; 8) collecting data to measure the performance of the new process after it has been fully implemented; and 9) comparing baseline and new

process performances to determine the degree of improvement achieved through the project.

Measure phase. To develop a high-level understanding of the ACO's mouse cage sanitation process, the process was initially mapped by using a suppliers, inputs, process, outputs, and customers diagram (Figure 1).³⁴ The ACO's mouse cage sanitation process begins with a technician unloading dirty mouse cages and lids from a mouse cage tower (OptiMice, <https://animal-caresystems.com/products/optimice>). The process ends when a clean tower is filled with clean mouse cages and lids. The inputs to this process include ACO staff, empty dirty mouse cages and lids, dirty towers, washing equipment (model 9LAV9XL rack washer and model 9LATUN tunnel washer, Techniplast), and cleaning supplies. These inputs are supplied by the university's Division of Research and biomedical researchers, as well as various vendors. The output of this process is clean mouse cage towers, and the customers for this process include university biomedical researchers, ACO staff, and the mice that will be housed in the clean cages (Figure 1).

To understand the details of the ACO's mouse cage sanitation process, members of the project team shadowed those working in the process (that is, technicians sanitizing mouse cage towers). To document the step-by-step nature of this process, a 'swim-lane diagram' (also known as a cross-function flowchart) was created (Figure 2).³⁴ The process begins when the technician enters the cleaning room and turns on the washers. Given that this technician will be loading washers with dirty mouse cages and towers, this person is identified as the 'dirty-side technician'. In preparation for emptying dirty cages, the technician gets an empty trash bin, puts a new disposable bag in the bin, places the bin on the dumping station (that is, a metal cart for holding a trash bin), and moves the dumping station next to a dirty mouse cage tower. When the rack washer is not in use, the technician moves an empty universal rack (that is, a wheeled rack on which mouse cages are placed for transport into the rack washer) near the dumping station. From the mouse cage, the technician then removes the lid, places it on top of the rack, and then removes the feeder. When feed is present in the feeder, the feed is dumped into the dumping station, along with any dirty bedding in the mouse cage. When any bedding is left in the cage, the bedding is scraped into the dumping station. Finally, the feeder and cage are placed on the rack. This process is repeated until the dirty mouse cage tower is empty. Then, the rack is moved into the washer, and the wash cycle is initiated.

The technician unloading clean cages and towers from the washers is identified as the 'clean-side technician'. Once the wash cycle is complete, the clean-side technician removes the cages from the rack washer. When a clean tower is available, the technician unloads feeders and cages from the rack, places a lid on each cage, and places the assembled cage on the clean tower. This process continues until the tower is full (100 cages). Once full, towers of clean mouse cages are removed from the

Figure 2. Detailed depiction of the ACO's mouse cage sanitation process. When the tunnel washer is used instead of the rack washer (*), cages and feeders are placed directly in the tunnel washer, and lids are placed on a peg rack. The dumping station is a metal cart that holds a trash can; a universal rack is a wheeled rack onto which mouse cages are placed before being inserted into the rack washer. Rectangles represent tasks; diamonds indicate decision points; ovals are start and end points; and dotted line arrows show a pause in the process during which technicians wait for the wash cycle to end.

cleaning area. However, if a clean tower is not available when needed, the clean mouse cages wait while the dirty-side technician cleans a tower. To clean a tower, the dirty-side technician first determines whether the tower needs a chlorine flush. If so, the dirty-side technician moves the tower to the flushing area, connects the hose to the tower, and initiates the chlorine wash cycle. When the tower does not need to be flushed, it is directly moved into the rack washer, and the wash cycle is initiated. Once finished, the clean tower is removed from the washer and used for building a new tower of sanitized mouse cages by the clean-side technician. Finally, it is important to note that when the rack washer is in use, the dirty-side technician prepares the mouse cages for sanitizing by using the tunnel washer, following the same process as described for the rack washer, with the exceptions that cages and feeders are placed directly on the tunnel washer, and lids are placed on a peg rack for washing (Figure 2).

At the time that this project was conducted, a method for measuring the cycle time of the ACO's mouse cage sanitation process was unavailable. To establish a baseline performance measure for this project, a simple, manual measurement process was implemented. In this process, each technician recorded the sanitation process start and end times for each mouse cage tower on a sheet located on each tower (for example, remove the lid from the first cage on the dirty tower: 0955; finish placing the last cage on the clean tower: 1120). This sheet was removed from and then reattached to the tower after washing. To assist technicians in recording accurate times, wall clocks were installed on both the dirty and clean sides of the cage cleaning area. At the end of each cleaning shift, the supervisor collected the sheets from all clean towers and recorded the start and end times in a

spreadsheet. Because manually collecting these data added to the technicians' workload, the aim was simply to collect enough data to obtain a general idea about the current performance of the mouse cage sanitation process; therefore, data regarding the mouse cage sanitation process cycle time was collected over a 3-d period (10 through 12 January 2018). Then, the process cycle time was calculated by subtracting the start time from the end time for each of the 20 mouse cage towers that were cleaned during this time. According to this limited data set, the time to sanitize a single, full mouse cage tower (100 cages) ranged between 30 and 155 min, with an arithmetic mean of 94 min.

Analyze phase. To analyze the ACO's mouse cage sanitation process in detail, the project team members conducted an FMEA. This analytical method identifies and prioritizes potential issues within a process.³³ In this particular investigation, FMEA was used to guide project team members in identifying and prioritizing sources of waste in the mouse cage sanitation process according to their experience working in this process. As is typical in FMEA, a 10-point rating scale was used to evaluate each issue according to 1) the severity of the effect, where 10 represents a catastrophic event, and 1 represents an issue that is unnoticeable to the customer (that is, university biomedical researchers, ACO staff, and the mice that will be housed in the clean cages); 2) the occurrence of the potential cause, where 10 represents that the cause is almost certain to occur, and 1 represents that it is highly unlikely that the cause will occur; and 3) the current control's ability to detect or prevent the issue, where 10 represents that the control is nearly certain not to detect the issue or that there are no controls, and 1 represents that the control is almost certain to detect the issue. Once all aspects of the mouse cage sanitation process had been evaluated,

Table 1. Top-rated causes of waste in the ACO's mouse cage sanitation process

Process owner	Process step	Potential issue	Potential effect	S	Potential cause	O	Current control	D	Risk priority number
Clean-side technician	Place assembled cage on tower	Unable to place cage on tower	Delay in process	8	Clean towers not available	7	None	10	560
	Remove feeder and cage from washer	Cages not removed	Delay in process	8	Technicians not available	6	None	10	480
Dirty-side technician	Place dumping station near dirty mouse case tower	Bump into another technician's work-space	Interruption of work	4	Work performed in multiple places within the case cleaning area	8	None	10	320

D, detection; O, occurrence; S, severity

0700–0830	0830–1000	1000–1015	1015–1130	1130–1230	1230–1400	1400–1430	1430–1500
Health check, room X	Husbandry, room Y	Break	Cage wash, clean	Lunch	Cage wash, dirty	Housekeeping, level Z	Sanitation, support rooms

Figure 3. Example of an ACO technician's daily schedule.

the issues identified were prioritized according to their risk priority number, which is calculated by multiplying the ratings for severity, occurrence, and detection, to determine which items in the process represent the highest risk (Table 1). These items included 1) clean towers not available; 2) technicians not available; and 3) work performed in multiple places within the cage cleaning area.

Improve phase. To develop ideas for countermeasures that address the 3 root causes identified in the Analyze phase, two 30-min brainstorming sessions were held. Project team members were asked to each attend at least one of these sessions, and they were instructed to individually develop (prior to participating in these sessions) ideas for how to address the 3 root causes identified. During the brainstorming sessions, a round-robin approach³⁴ was used so that each team member shared one idea during each successive round until no further ideas could be developed by the participants. The ideas generated through brainstorming were then compiled into a single list that omitted duplicates. After three 20-min discussions held over the course of 2 wk, the project team came to a consensus regarding the selection and implementation of the following countermeasures. To address root cause 1—clean towers not available (which causes clean cages to wait)—a new procedure was implemented to ensure that at least one clean tower was available on the clean side before the sanitation process for a newly received dirty tower was initiated. For root cause 2—technicians not available—the supervisor, with input from technicians, developed a schedule to clarify technicians' assignments and tasks on a daily basis (Figure 3). To address root cause 3—work performed in multiple places—visual controls were implemented to designate and organize workspaces within the cage cleaning area to improve the logical flow of the work performed. That is, specific spaces within the cleaning area were delineated on the floor by using colored tape and labeled to clearly indicate the areas designated for staging towers, universal rack station, chlorine flush station, wash down, and dumping stations (Figure 4).

Control phase. To sustain the improvements made within the ACO's mouse cage sanitation process as a result of this project, a control plan was established. This plan included both monitoring (Figure 5) and auditing (Figure 6) mechanisms for the new

process. To ensure technicians are 1) using the new procedure for ensuring there is always at least one clean tower on the clean side before starting the sanitation process, 2) following their daily schedule, and 3) performing their work within the appropriate designated areas, the supervisor audited technicians through observation on a weekly basis by using a simple audit checklist (Figure 6). The supervisor then shared feedback regarding technicians' performance as a coaching mechanism to further improve technicians' performance relative to mouse cage sanitation.

Results

After the new process had been in use for several weeks, project team members collected data over 4 d (16 through 19 April 2018) to simply obtain a general idea regarding the performance of the new process. During this time, 27 mouse cage towers (100 cages each) were sanitized by using the new process. According to this limited data set, the time to clean one full mouse cage tower ranged between 38 and 92 min, with an arithmetic mean of 59 min; therefore, these results provide some evidence that this project achieved its goal of reducing the ACO's arithmetic mean mouse cage sanitation process cycle time to 60 min or less. The time saved was then reinvested within the ACO such that technicians had more time to complete other tasks, such as health checks, housekeeping, and so forth, to support animal research endeavors at the university.

Discussion

Although other process-improvement approaches exist, including Business Process Reengineering,¹⁶ Plan-Do-Check/Study-Act,^{10,11} and Total Quality Management,¹⁴ the current case study used Lean Six Sigma, given its applicability to biomedical and research settings.^{5,12,29,37} With its goal to make organizations' routine operations flow as smoothly and efficiently as possible, Lean Six Sigma was particularly well suited to address the focal problem in the current case study, in which there was an inherent need for quality control in the ACO, as well as the highly repetitive nature of their work relative to cage sanitation.^{8,30} It is important to note that this approach combines both the waste-

Figure 4. Delineation of task-specific areas in the cage cleaning area.

Operation	Control method	Control owner	Audit method (frequency)	Audit owner	Report audit results to
Clean tower not available	Use new procedure	Technicians	Observation, using audit checklist (weekly)	Supervisor	ACO Director
Technicians not available	Follow daily technician schedule				
Work performed in multiple places (undesigned)	Use marked areas for designated work				
Mouse cage sanitation process	Develop run charts of process cycle time	Supervisor	Review run charts (monthly)		

Figure 5. Control plan for the ACO's improved mouse cage sanitation process.

Question	Circle appropriate response	
Is at least one clean tower available on the clean side before the process is initiated?	Yes	No
Did technician perform his or her work within the appropriate designated area?	Yes	No
Is the technician following his or her daily schedule?	Yes	No

Figure 6. Audit checklist for the ACO's improved mouse cage sanitation process.

reduction methods of Lean, which are typically knowledge- and experience-oriented, with the variation reduction methods of Six Sigma, which are typically data-analysis-oriented, to support organizations in improving performance and achieving their strategic objectives.^{2,23,31}

For reference, the technicians at this facility work a 5-d week, in which cage sanitation is just one of several daily tasks (Figure 2).

The arithmetic mean number of mouse cages sanitized each week is 2625, and 100% of the ACO's cage census depends on the cage sanitation process. However, because no formal process for measuring the cycle time for the mouse cage sanitation process was in place, all data had to be collected manually by technicians. This method of data collection added to technicians' workload; therefore the sample size of process performance

measurements was limited to a few days each at the beginning and end of this project. Although outside the scope of the process investigated in this project, note that clean bedding (that is, a thin wafer of cotton fiber bedding that is the size of the cage floor) is added to clean mouse cages during cage change-out, which is performed within biosafety cabinets. In addition, clean cages are not sterilized prior to use unless they are used in an immunocompromised mouse colony.

Going forward, the ACO could consider implementing additional measures beyond supervisor-as-coach to control and continuously improve the new mouse cage sanitation process. For example, process audits could be conducted by technicians to repeatedly evaluate tasks within the new process to identify how well it performs and how it could be further improved. In addition, project team members acknowledge that their work probably was not solely responsible for the reduction in process cycle time achieved through this project. There are likely additional factors that were not considered in this study, and these factors require further research to understand their effects on the project outcome. Finally, because this report describes a case study performed at a single institution, the results obtained may not be generalizable to all research animal sanitation processes. However, the approach demonstrated may be useful for other ACUP in terms of providing guidance regarding how to conduct similar process improvement efforts within their institutions in the future.

In conclusion, the current single-institution case study demonstrates how to apply the Lean Six Sigma methodology to improve sanitation services provided by ACUP. This study successfully identified what the ACUP studied could do to reduce the arithmetic mean time to sanitize mouse cage towers. Comparison of the new process performance with the baseline measurement indicated that this project reduced the ACO's arithmetic mean mouse cage sanitation process cycle time by 35 min (37%). This reduction was achieved through 3 actions taken specifically to reduce process delays—new procedures, clarified schedules, and visual controls. The new procedure helps to ensure the availability of at least one clean tower on the clean side before the sanitation process for a newly received dirty mouse cage tower is initiated. The daily schedule posted by the supervisor helps to clarify technicians' assignments and the order of their tasks. Finally, the visual controls implemented help to clearly indicate the areas designated for particular work tasks within the cage cleaning area.

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