Improvement of Crew Deployment Procedure

Implementing sustainable change to the daily deployment processes of tree crews at SavATree – Middleton

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Executive Summary

Quality management techniques have steadily progressed through the decades, from its foundation in early scientific management to the seminal post-World War II work of W. Edward Deming and Joseph Duran, continuing through the present day. Motorola's development of the Six Sigma discipline in the 1970s and 1980s, and the mass popularization of Lean Manufacturing in the 1990s, resulted in a modern wave of corporate quality management initiatives as well as a new group of practitioners and organizational theorists. Lean Six Sigma represents a synthesis of these two predominant schools of modern management thought, combining the structures and roadmaps of Six Sigma with the personnel empowerment philosophies signature to Lean Manufacturing, with an eye towards the latter's emphasis on continuous improvement. The study was structured in accordance with Six Sigma's Define-Measure-Analyze-Improve-Control framework (DMAIC).

SavATree is a privately-owned tree and lawn care company, operating as the third largest landscape management firm in the Northeast. SavATree has implemented Lean Six Sigma into their business, operations, and support process. Study was conducted at their Middleton branch, of the smallest branches in the company, serving Boston's North Shore communities. The goal of the project was to study the deployment processes of Middleton's work crews and propose solutions which would reduce their deployment time towards the company target of 15 minutes.

Middleton's tree crews were found to deploy in 20 minutes 16 seconds, or 35% longer than the company target. Based on the deployment behaviors observed, a flowchart of the crew deployment process was produced and an Ishikawa diagram of factors contributing to longer

deployment times was constructed. Analysis of those observations, and consideration of the logistical and financial concerns of the branch in question, lead to the creation and proposal of five improvement initiatives to branch management. These improvements focus on improving the flow of information from operations staff to crew leaders and members and expediting the daily equipment gathering responsibilities of crew members. The five process improvements proposed were:

- Updating the "Equipment Required" section of Middleton's work order template to more accurately reflect branch inventory, as well as requiring the operations staff to complete them for each job.
- Enforcing the operations staff's use of a weekly schedule board already in place at Middleton, allowing the tree crews advance notice of the equipment required for the next day's work.
- Staging the heavy equipment required for the next day's work at the end of the previous work day
- Construction of a secure staging bench on the shop floor, to allow light equipment to be staged for the next day's work at the end of the previous work day
- Restricting the operations staff's daily meetings to the crew leader, rather than the entire crew, allowing the crew members to complete deployment activities and receive relevant job information from their crew leader at a more convenient time.

These improvements could result in an estimated 4 to 5 minute reduction in deployment times, bringing Middleton's crews to within 1 minute of the target deployment time. The culture of engagement branch management has engendered with the staff should make these improvements both possible and sustainable in the long term.

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Project Overview

This study was conducted at SavATree's Middleton, Massachusetts office in order to improve the deployment time of the branch's work crews. Measurements found Middleton's crews deployed in 20 minutes 16 seconds, or 35% longer than the company target of 15 minutes. The study was conducted over the course of a month at the outset of the business's busiest production season, with the goal being to identify improvements to the deployment process which could be implemented with little capital investment or alterations to their leased facilities.

Rapid crew deployment is important to SavATree, especially during their busy season. Roughly 50% of Middleton's annual profitability is projected to be generated from production between late March and the end of June. The faster work crews are on the road, the more work they can accomplish. Hours spent in the shop are hours not billed to customers.

This report discusses SavATree and the operations environment of the Middleton branch, before proceeding into a brief overview of quality management techniques. The DMAIC framework native to Six Sigma provides the structure for discussion of the study at Middleton, including the data and information produced as a result as well improvements this report proposes to the crew deployment process. The proposed improvements could represent a 26% reduction in crew deployment time if implemented and properly controlled.

Company Background

Industry Partner: SavATree

SavATree is a privately-owned tree and lawn care firm with 32 offices serving 13 states and the District of Columbia, staffed by 855 full-time-equivalent employees and 146 seasonal employees. Founded in 1985 in Bedford Hills (NY), SavATree was the 16th-ranked landscape management firm in 2017, per the latest *Landscape Management* magazine LM150 poll, totaling $109 million in revenue[1]. They rank as the third-largest landscape management firm in the Northeast region, with $70.9 million in area revenue[2]. In June 2017, private equity firm CI Capital Partners purchased a majority stake in SavATree. While full details of the deal were not disclosed, CI Capital financed $105 million to recapitalize the company through Madison Capital Funding[3]. This transaction coincides with an increased focus on mergers and acquisitions growth which accelerated earlier that year. Over the last two years, SavATree has absorbed firms in Colorado, Virginia, Pennsylvania, Georgia, and Michigan.

SavATree divides its product offerings between three service lines: General Tree Care, Plant Health Care, and Lawn Care. General Tree Care includes health and risk assessment, pruning, and removal of trees, shrubs, and ornamental plants. The Plant Health Care line encompasses fertilization, pest control, and disease management of the same plants. SavATree's Lawn Care line focuses on turf seeding, fertilization, and pest/weed control.

SavATree has an internal mandate to incorporate the fundamentals of Lean Six Sigma across its service lines and support functions. The company holds Lean Six Sigma *kaizen* events to address high-impact issues at its various branches and utilizes lean techniques such as *kanban* ordering cards for its consumable supplies (e.g. hand-saw blades and protective gloves). Sarah Cummings serves as SavATree's Director of Continuous Improvement and supervises all Lean Six Sigma initiatives and events.

SavATree – Middleton

SavATree's branch in Middleton (MA), established in 1998, is one of the smallest locations within the company[4], servicing Boston's North Shore, including town such as North Andover, Marblehead, Gloucester, Newburyport, and Beverly. SavATree – Middleton (hereafter referred to as "Middleton") is staffed by 14 employees: a manager, three arborists, two administrative staff, and eight laborers (referred to as "crew members"). Russell Warnock (ISA Certified Arborist) serves as the branch manager, with the three arborists serving as treatment design and sales personnel. The administrative staff is comprised of an office manager and a sales assistant, with many finance and administration tasks fulfilled to centralized corporate personnel. An organization chart for Middleton has been included at full size in Appendix 1, and as a reference in Figure 1, seen below.

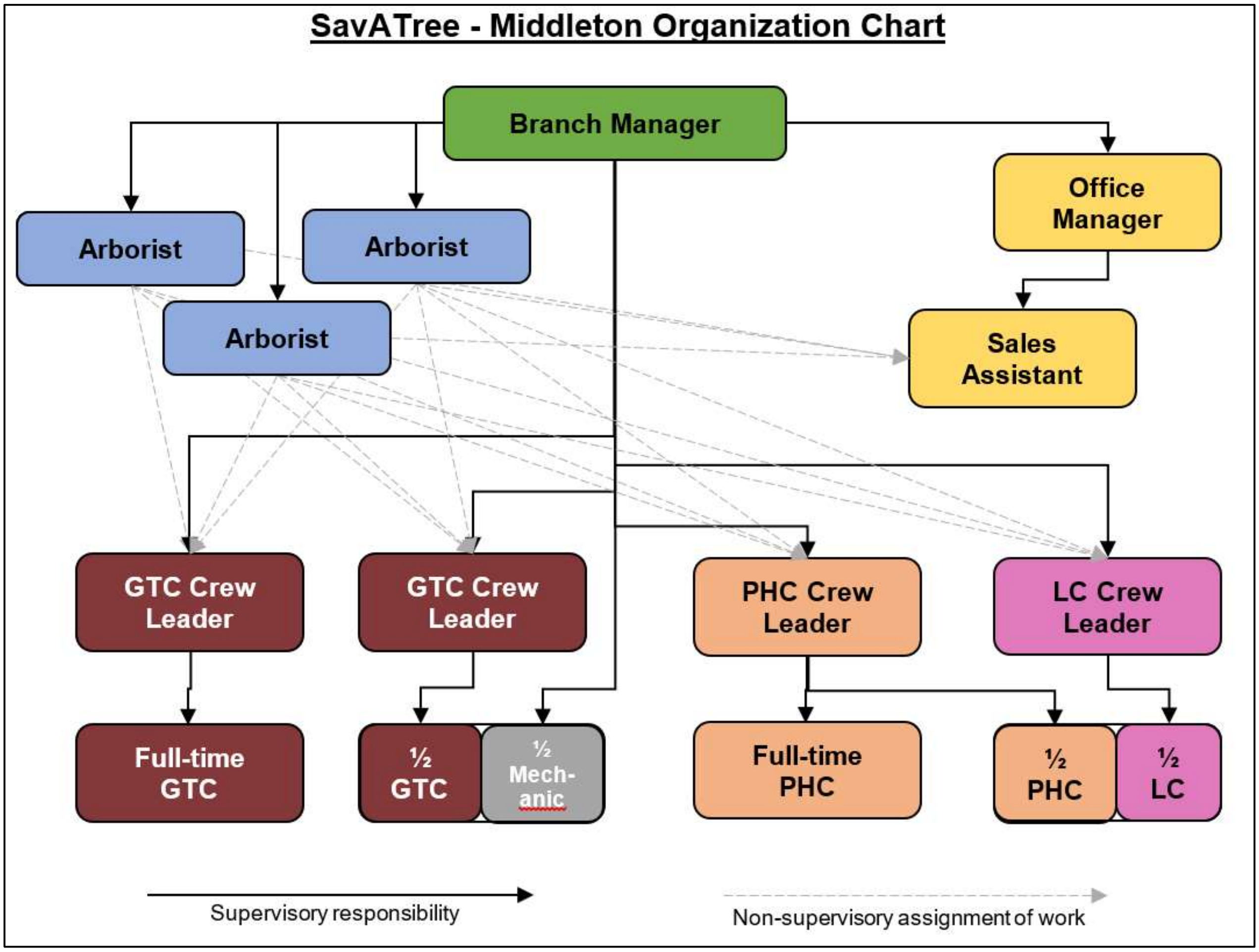

Figure 1: SavATree - Middleton organization chart

Middleton organization, sales, and operations

Middleton's certified arborists function as salespeople and operations leads for the crews assigned to them. Upon receiving or soliciting a sales lead, they perform their scientific analysis of the tree, plant, or lawn to determine a course of action. Trees may require pruning or outright removal, properties may require pesticide or fungicide treatments, and lawns may benefit from fertilization or aeration services. Once a customer has agreed to a service, the job is put into a queue by SavATree Corporate. Multiple factors are weighed when determining when a service will be performed; examples include the timeframe required for a service to be effective, the geographic grouping and heavy equipment requirements of certain work, and the schedule concerns of a customer. Routes are generated by SavATree's central operations service and communicated to branches on a weekly basis for General Tree Care crews, and a daily basis for Plant Healthcare and Lawn Care crews.

Middleton's labor force consists of eight crew members allocated across the three service lines, as well as a half-time equivalent allocation of one tree crew member as a mechanic. Below, Table 1 describes the current allocation of labor at Middleton.

	2019 FTE
Plant Health Care (PHC)	2.5
General Tree Care (GTC)	3.5
Lawn Care (LC)	1.5
Mechanic	0.5

Table 1: 2019 staffing allocation, SavATree Middleton

Work crews with multiple members have one member permanently assigned as the crew leader. These crew leaders are chosen for their experience and supervisory abilities. It is generally the responsibility of the crew leader to lead the deployment of the crew and run job sites, with the arborist consulting in-person on jobs to clarify fine details of the work to be performed.

Middleton Equipment

For the purposes of this report, SavATree – Middleton's equipment has been classified into two categories: light equipment and heavy equipment. Light equipment is defined as hand tools (e.g. pruning shears and handsaws) and power tools such as chainsaws and leaf/debris blowers. Heavy equipment comprises the road-legal vehicles (i.e. the various forms of work truck) and on-site vehicles (powered lifts, log-loading tractors, stump grinders) used by Middleton's work crews.

Middleton's heavy equipment consists of 9 trucks, 7 other large powered tools (some are self-propelled, others have integrated axles), and 5 trailers. These vehicles and tools are described further in Table 2 (below). The branch's light equipment consists of twelve chainsaws and 5 leaf blowers of various sizes and specifications, as well as numerous hand tools such as pruning shears, hand saws, manual aerators and compound spreaders, and backpack sprayers.

Service line	Qty.	Description
GTC	2 x	Closed-bed dump-body trucks
GTC	1 x	Bucket truck with 65 ft. boom
GTC	1 x	Log-loading tractor
GTC	2 x	Wood chippers
GTC	1 x	Stump grinder
GTC	1/3 x	Spider lift with 72 ft. boom* w/trailer
GTC	1 x	Chipper trailer
GTC	1 x	Log-loading tractor trailer
PHC	3 x	Open-top fluid-tank-equipped trucks
LC	2 x	Open-top fluid-tank-equipped trucks
LC	1 x	Aeration tractor
LC	1 x	Spray tractor
Floating	1 x	F-550 mason dump body pickup truck
Floating	2 x	Flatbed trailer

Table 2: SavATree - Middleton heavy equipment inventory

While the nature of Middleton's work regularly requires climbing gear (e.g. harnesses, ropes, carabiners, etc.) or other specialized protective equipment, SavATree follows a common industry

* Middleton shares the spider lift and its accompanying trailer with a neighboring SavATree office, located in Lincoln, MA. Middleton receives a one-third allocation of the lift, which is generally used when the work site is located in an area of a property that the bucket truck can not access.

practice of providing crew members a stipend with which to purchase their own equipment from a list of approved vendors and product lines.

Middleton Facilities

Below is a diagram (Figure 2) of the layout of Middleton's office and workshop at 206 S. Main Street. Their entire facility measures 6,526.25 square feet of interior space, with 1,152 sq. ft. finished as an office area and the remaining 5,374.25 sq. ft. used as shop space. During the winter, much of the open shop space displayed is occupied by the five open-top plant healthcare and lawn care trucks, which are stored in the shop to prevent unnecessary aging of the equipment. During the summer, trucks are stored in the fenced-in lot adjacent to the shop.

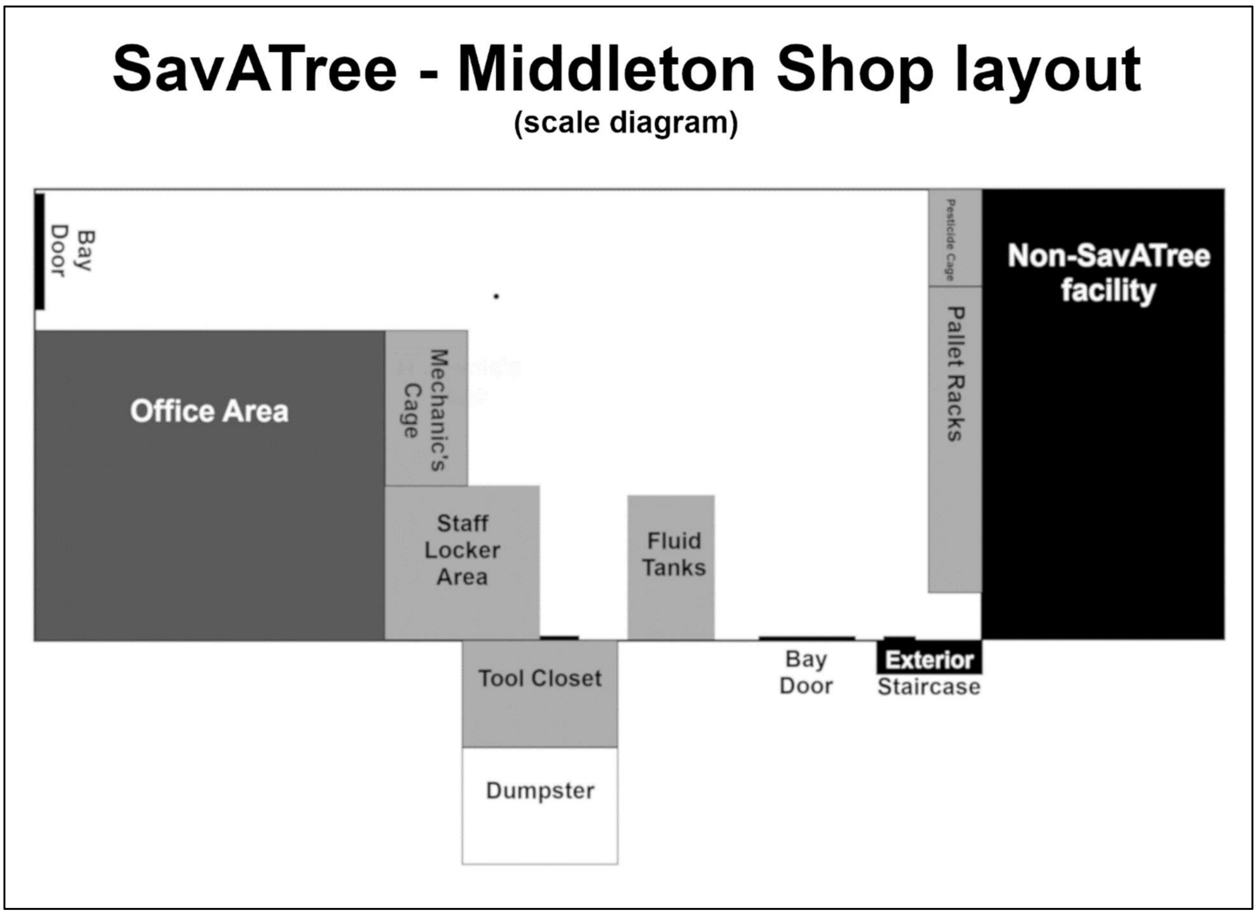

Figure 2: SavATree - Middleton shop layout (scale diagram)

Middleton shares a fenced lot (32,110 sq. ft.) with an automobile repair shop, which rents most of the available parking space and uses it to store their customers' vehicles. Their space (approx.. 17,048 sq. ft.) is overutilized, with their inventory often occupying the travel lanes in their assigned area. This leaves little navigable space between Middleton's leased parking area (approx. 4,342 sq. ft) and the travel lane adjacent to their shop, which functions as an impromptu loading area. During deployment activities, plant healthcare and lawn care trucks generally occupy the alcove by the bay door, to the right of the tool closet and dumpster enclosure, while the tree care trucks pull up in the travel lane, as demonstrated in Figure 3 (below).

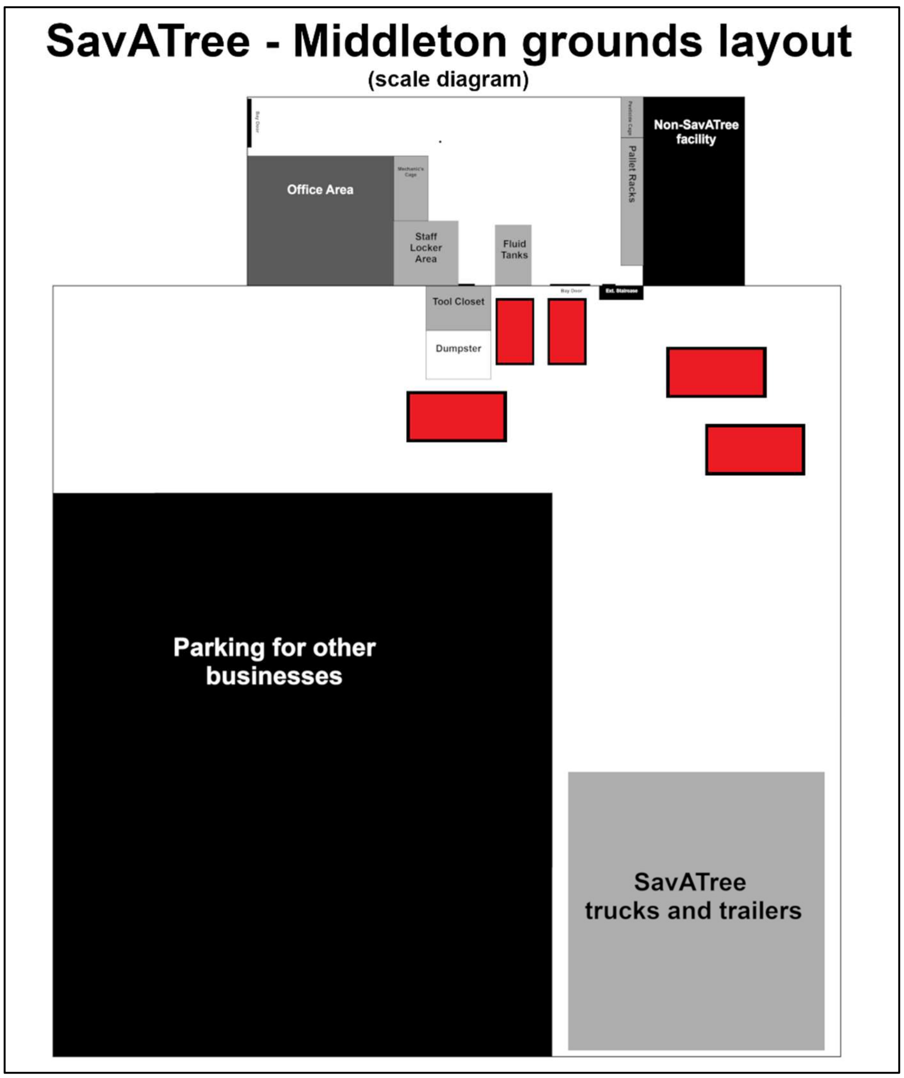

Figure 3: SavATree – Middleton grounds layout (scale diagram) with trucks in common deployment arrangement

Literature Review

I chose to my structure my study at SavATree – Middleton according to Six Sigma's DMAIC framework for process improvement to best conform to SavATree's Lean Six Sigma organizational philosophy. The staff is familiar with the basic tenets of Lean Six Sigma, having been studied in accordance with these methodologies before. Their preexisting level of comfort with Lean Six Sigma techniques offered an opportunity to reduce the cultural barriers to study that can exist in organizations. As such, I've produced a literature review providing a brief background on major quality management topics which influenced or define Lean Six Sigma. Pre-Six Sigma topics are discussed to introduce the foundational concepts Six Sigma later recontextualized. Six Sigma itself is discussed to provide working knowledge of the techniques it employs. Finally, an overview of Lean Management is provided to explain the philosophical concepts and management techniques employment by SavATree's implementation of Lean Six Sigma.

Pre-Six Sigma quality management topics

While indebted to the foundational work of early scientific management pioneers like Frederick Winslow Taylor[12] and Walter A. Shewhart, modern quality management techniques owe much to William Edwards Deming. A Yale doctorate-holding statistician, Deming found little purchase for his theories on process control and improvement in the American industrial sector, which was still charged with an Industrial Revelation-style fervor inspired by World War II.[13] Postwar Japan, embraced his ideas, however, and firms like Sony, Fuji, and (fatefully) Toyota[15] saw remarkable results. While he did not coin the terms Total Quality Management or Continuous

Improvement, Deming is widely recognized as one of the key forces in defining and popularizing the concepts they stand for.[14]

W. Edward Deming's emphasis on the empowerment and involvement of individual workers offers an alternative to the most extreme Taylorist visions of labor as an unthinking cog. His desire for decision makers to understand the hard and soft (quantitative and qualitative) environments a system both operates in and creates was, 69 years ago, prophetic to current understanding of systems design and engineering.[16] His contemporary, peer, and friend[17] Joseph Juran also worked in Japan during the same period, and created many techniques for quality analysis and implementation strategies that are still used today. Juran had already codified the Pareto Principle (80/20 Rule) in the 1930s, and went on to create the concept of quality teams.[18] His emphasis on measurement and quantification through all steps of a process (and its reform) is one of the cornerstones of modern quality control.

Juran and Deming's wide range of teachings have been studied and dissected over the past seven decades, but it is their work on quality control that has been most widely embraced, glorified, and propagated. Quality control of direct production inputs like materials and labor[16] seems like an elemental concept now, but elements must be discovered, defined, and named. Those elements can then be alloyed into something new that retains aspects of the old (like the application of quality control to non-production processes). Deming was known as a visionary philosopher, dreaming of a new reality; Juran was seen as the consummate practitioner, creating numerous methods that revolutionized his field.[19] It is truly fitting that the synthesis of their respective theories and practice (*lehr und kunst*, not to put to fine a point on it), would become one of the most popular modes of quality control over the past 40 years.

Six Sigma: History

Developed by Motorola over the 1970s and 1980s, and formally enacted as company policy in 1987, the core goal of Six Sigma is to reduce defects for any process such that output is considered defect-free within six standard deviations (statistical variable sigma: σ), which corresponds to 99.99966% quality or 3.4 defects per million.[16] This goal is tied directly to the process capability index (PCI) of the process in question. A process's capability index (PCI) is a measure of its production output which falls between upper and lower specification limits[45]. The goal of PCI study can be to reduce variation in a product or process, or design those processes to accept greater variation without compromising the quality of the output. A sample PCI equation for a process with both upward and downward variation is described in the equation in Figure 4 (below).

$$\hat{C}_p = \frac{Upper\ Specification\ Limit - Lower\ Specification\ Limit}{6\sigma}$$

Figure 4: Equation for a process capability index for a bivariate process with the specification limits centered around the mean.

PCIs can measure smaller-the-better (e.g. flux consumption in industrial welding) and larger-the-better (e.g. total yards of rope produced in a factory) process variation, study nominal variation (metrics with a specific target value, such are tire pressure or the number of chips in a pre-packaged bag) and can be adapted to processes with one-sided variation. In general, the capability index of a process can be thought of as the "common-cause" variation within a system.

That is: the variation which results from the process's environment when operating under "normal" conditions of production. This compares to "special-cause" variation, which can generally be thought of as "freak occurrences" or one-time events.

Capability indices can form the bedrock of Six Sigma study, as they provide baseline information about a process, which can be further analyzed to identify sources of common-cause variation and subsequently reduce them. After improvements, the PCI study can be repeated to test the ultimate effectiveness of the Six Sigma process.

In the years since its public breakthrough, Six Sigma has been hagiographized by industry figures and publications, giving rise to an entire cottage industry of authors and consultants.[21,22,23,24,25,26,27] It has also been criticized as a trendy collection of devalued buzzwords[28] overly reliant on rigid statistical adherence[29] that is, ultimately, a well-marketing repackaging of accepted quality management doctrine.[17] Even those critics, though, will often admit[30] the effectiveness[31] of Six Sigma's methods[32] agnostic of their other grievances.

Six Sigma: Methods

The scientific evaluation of Six Sigma variation lays the foundation upon which its overall methodology is built. Six Sigma uses a few key organizational structures and management techniques to reach its goal of improved quality:[33†]

[†] As an editorial note, it has been my experience that if you ask a room of 100 Six Sigma practitioners to define their work, you'll get 100 different explanations. This phenomenon may be attribute to the behavior remarked upon by W.B. Gallie in his 1956 article "Essentially Contested Concepts". As an extremely reductive explanation, Gallie proposed that there can irresolvable disputes between parties claiming the proper use of terms where the arguments

- **Customer-focused goals:** How is a product or process falling short of customer expectations? What are the defects, and what would success look like?
- **Team/project-centric organization:** Six Sigma initiatives work within a set scope, and are generally pursued by a team constructed of internal stakeholders across involved groups/disciplines (e.g. engineering, production, machine operation, warehousing) working to a fixed endpoint.
- **Dedicated personnel with specific training:** Six Sigma's hierarchical ranking of personnel and prescription of their duties is, to my estimation, both divisive within Six Sigma organizations and crucial to their success. Each Six Sigma rank has a specific responsibility within the quality process. Some, such as the Master Black Belt are intended to function at an executive management level, while others are involved in the ground-level study and analysis required by individual projects. Some ranks require years of experience, or at least participation in multiple Six Sigma projects. Most ranks require the passage of certification tests, which are often administered by universities or professional development organizations. The belt system was created by Mikel Harry[37], and can mean slightly different things to each organization or certification body (see footnote regarding "Essentially Contest Concepts").

are conducted entirely in good faith and, to the best knowledge of all sides to an argument, entirely within their view of the truth. Given that Six Sigma has been simultaneously developed practiced and redeveloped for over four decades, by academics and industrialists alike, the tree of knowledge for this discipline would more closely resemble a tall and tangled hedge maze.

My goal is to provide a useful summary of a cross-section of Six Sigma theory and practice, in plain language, based on my experiences in the workforce and 30 years of study by both academic and industrial sources.

- **A clear roadmap:** In conjunction with its reliance on dedicated personnel, the other powerful technique Six Sigma uses to reduce complicated organizational systems into easily digestible processes is through the use of frameworks. Examples of these frameworks include DMAIC (an acronym for its component steps of Define-Measure-Analyze-Improve-Control) or IDOV (Identify-Design-Optimize-Verify).[29] These frameworks offer a step-by-step recipe for all the necessary subprocesses that go into a Six Sigma project. There are many different frameworks, each intended for slightly different organizational fits, structures, and project goals. Some like are intended for process or product development, others are focused on the conceptual/innovative areas of a company, but the most common framework is DMAIC.[7] This framework will be discussed further in the section titled "DMAIC for Process Improvement".

Lean: A Brief Overview

Lean Manufacturing was developed at Toyota Motor Corporation during the same post-World War II period when Juran and Deming performed their seminal works,[39] and popularized in the western world by James P. Womack, Daniel T. Jones, and Daniel Roos their widely read and cited 1991 book *The Machine That Changed The World*. Lean focuses on the reduction of physical and time-resource waste within a production process[40]. Lean's influence on the development of Six Sigma is undeniable: Lean's value stream maps compare to the process flowcharts of Six Sigma, and both methods require a strong corporate culture dedicated to following through on their principles.

Lean's methods, though, tend to be more incremental in nature. While Six Sigma implements its improvements through projects, Lean's concept of *kaizen* (generally understood as "continuous improvement") promotes the empowerment of everyone involved in a manufacturing system, without regard certification levels, to tweak and slowly evolve processes.[41] Owing a debt to Juran's emphasis on applied practice, Lean has a specific emphasis on inventory reduction[42] through concepts like Just-in-Time (JIT) and methods such as *kanban* cards[11]. It also proscribes improvements to workspaces through its 5S framework.[43]

Lean is a topic worthy of just as much consideration and study as Six Sigma, but this report is focused on the work performed at SavATree, which utilizes a third quality management theory that brings together many of the techniques already discussed: Lean Six Sigma. In my observations, SavATree employs an implementation of Lean Six Sigma that stresses the technical study techniques native to Six Sigma, but coupled with the lessened emphasis on management hierarchy offered by Lean.

Lean Six Sigma:

Lean Six Sigma (LSS) is a synthesized discipline that incorporates aspects of Lean into Six Sigma structures and methods.[39] LSS maintains Six Sigma frameworks (such as DMAIC) and a project-centric focus, but generally offers more opportunities for organizations to employ the continuous improvement methodologies stressed by Lean.[44] Unlike standalone Six Sigma, LSS strives to involve non-Six Sigma personnel in projects and day-to-day improvements alike through *kaizen* events (projects or a step in a project that involves workers of all disciplines collaborating on an issue) or continuous feedback mechanisms employed by workers regardless of Six Sigma status.[41]

DMAIC for Process Improvement

A key component of Lean Six Sigma is the DMAIC framework for project-based process improvement.[6] DMAIC is an acronym for the five steps that comprise the method[7]:

- **Define:** Define the goals of the project, and the requirements necessary to reach them.
    - What is the problem, and what would a desired result of improvement look like?
    - What does the process in question truly entail? What are its technical subprocesses and support process dependencies?
    - Who are the internal stakeholders for this process? Who holds the responsibility for execution, and owns the responsibility for its outcomes?
- **Measure:** Collect data on the current status of the target process to establish statistical and qualitative baselines.
    - When evaluating processes for improvement (versus production environments), there may be limited room for application of traditional LSS metrics (defect rates, takt time, etc.).
    - For process improvement, process maps and other diagrams (e.g. flowcharts and spaghetti charts) may be coupled with Failure Mode and Effect Analysis (FEMA).
    - The key quantitative metrics for measurement with regard to process improvement are end-to-end time, subprocess time, rework rates, and failure rates.
- **Analyze:** Apply statistical and/or root cause analyses to the previously-gathered measurements to identify the source of defects or inefficiencies (e.g. slow lead time or underutilization) in the process.

  - What is the current performance of the process versus target performance?
  - What is impeding the current process? Can those obstacles be mitigated or does the process require alteration?
  - What level of resource investment would be required to improve the process?
- **Improve:** Determine courses of action which can address the root causes identified in the Analyze step, develop an implementation plan, and carry out the changes decided upon.
  - Synthesize the findings of the previous three steps to develop a course of action which addresses the source(s) of problems with the process.
  - Potential solutions can be tested in short-run trials.
  - Develop an implementation strategy that encompasses all of a process's points of contact within an organization (e.g. management, labor, support personnel)
- **Control:** Documentation of the updated process and continued monitoring to ensure that desired outcome is both achieved and maintained.
  - Does the enacted solution actually solve the problem? What are the quantitative gains in key metrics?
  - Detailed documentation of how the improvements were made and how the process is to be monitored in the future.
  - Are these improvements sustainable? How can they be sustained and further improved?

DMAIC is recognized as one of the bedrocks of quality management by practitioners[10] and academics[11] alike. Just as DMAIC is the backbone of Lean Six Sigma initiatives within SavATree, so it serves as both the framework for my work at their Middleton branch and the structure for this report. The remainder of this document will be organized in accordance with the five steps to the DMAIC method.

Methodology for Study and Improving Operations

The first two steps of the DMAIC framework discussed in the previous section will be carried out in the Methodology section of this report. The "Project Definition" chapter will explain some of the specific challenges posed to Middleton by its their facilities, equipment, and processes. As well as how this project was constructed to address them. The "Measurement through on-site study" section will discuss the tools and techniques used to conduct study at Middleton, the metrics identified as important factors in deployment efficiency, and the analytic tools constructed from this study,

D: Project Definition

Through discussions with the branch manager, the scope of this project was determined to be the improvement of Middleton's work crew deployment procedure. That is, reducing the time it takes for the crews to gather the equipment necessary for the day's work, load it into the work trucks, and depart from the shop. After observation in December 2018, a number of key bottlenecks in the daily deployment process were identified. These four issues are the focus for analysis and improvement, representing the most efficient vectors for reducing deployment.

- Slow access to the tool closet
- Inefficient equipment gathering and packing
- Trucks not being staged to the fullest extent the prior evening
- Poor access to trucks from loading area

Access to tool closet

The tool closet is home to the hand tools and light equipment used by SavATree's crews. The closet has a locked gate, with management, arborists, and crew leaders possessing the combination to the lock. Equipment like chainsaws and leaf-blowers are stored on a shelving unit, while small supplies such as handsaw blades are stored on a hole-and-peg board behind a locked gate. Crew members often make multiple trips between the tool closet and the staging area (outside the loading dock, down a flight of stairs) to gather the necessary supplies for their day's work. Just outside the tool closet is a cabinet for Personal Protective Equipment (PPE), and a workbench for fueling and maintenance of powered equipment.

Inefficient equipment gathering and packing

Middleton relies on its workers' expertise and experience to prepare for a day's work. These considerations include what equipment to take, how to prepare said equipment, and how to stow it on the work vehicles. A laborer's knowledge should be used to improve the institutional processes supporting them, reducing variation in that process. SavATree generally treats its trucks like work cells, labeling storage units within the trucks for their specific purpose (e.g. fertilizer storage or tool placement).

There are logistical concerns that prevent the full work-celling of trucks. During the main production season, Middleton's vehicles are stored outside. Equipment stored in open-top trucks could be unnecessarily exposed to the elements, and even equipment stored in enclosed vehicles could be damaged, lost, or stolen. Furthermore, a degree of flexibility is required by SavATree's business. Equipping all trucks for all their possible work assignments at all times would be prohibitively expensive, and even that does not account for equipment reallocation due to over/underutilization and down-time.

Currently, the equipment and supplies necessary for a day's work at Middleton are spread out across numerous locations in the shop, with no defined manifest or documented order of operations retrieval. There is room for improvement by working with labor to define and improve these processes, both systematically and through physical reorganization.

Incomplete truck staging

Through conversations with Branch Manager Russell Warnock and one of his staff (John Duffy, ISA Certified Arborist), it was revealed that there is often uncompleted work at the close of the day which, if done at night, could reduce deployment time in the morning. Since Middleton's trucks are stored outside, most equipment cannot be left on the vehicle overnight, but certain trucks have water or fertilizer reservoirs which are not always refilled upon their return to the shop.

Management has valid reasons for not enforcing stricter staging guidelines. The concentrated seasonal nature of SavATree's business can be grueling for its laborers, and he does not currently believe the benefits of pushing for more complete truck staging would outweigh the costs to morale during a time of year when patience and energy can run short. It could "feel like a punishment" to his staff, he said, and that is well-advised managerial discretion. Still, this is a limited but clear way to reduce deployment time. Solutions for enhancing end-of-day staging procedures will be studied and proposed.

Access to trucks from loading area

When stored outdoors, SavATree's trucks are located in a fenced-in yard, accessible from the shop via a raised loading dock and a set of stairs down to the parking lot level. Once the necessary equipment has been gathered, trucks pull up to loading area one at a time where the crews load the truck before pulling away to allow the next truck access. The fenced-in yard is shared with an auto body shop, which parks its vehicles in standard rows, preventing unrestricted navigability of the yard. As such, Middleton will not likely be able to alter access to their dock in a meaningful way.

Crews carry their equipment out of the shop, leaving it at the base of the stairs before retrieving their trucks from across the lot. Trucks are staged at the loading area and loaded with equipment, as well as filled with any chemicals or water necessary. Safety, equipment handing procedures, and efficiency concerns currently forestall the transportation of equipment directly to the trucks from the shop. There are multiple touches and smaller bottlenecks throughout this process.

M: Measurement through on-site study

Measurements were taken at SavATree – Middleton beginning on March 25th, 2019. Middleton's main production season generally begins in early spring (somewhere between late March and mid-April) and lasts until early summer (late June). Within SavATree, this timeframe is crucial to their success for the whole year, as roughly 40% of annual production (accounting for roughly 50% of annual profitability) must be completed within that period. This span of weeks at the beginning of their "busy season" seemed an ideal time to study Middleton's crew deployment.

There would be no loss of study days as a result of underutilization and few concessions made by the operations staff as a result of their backlog of work.

Metrics defined, measured, and calculated

In order to maximize the study period, measurement activity was focused on the metrics identified as most key to the Crew Deployment Process. The highest-level metric considered was Total Deployment Time (TDT). TDT is defined, for our purposes, as the time it takes on a discrete workday for a crew to leave the Middleton shop in their fully-equipped truck. Measurement began at the time the manager dismissed the crews from their daily morning meeting and ceased when a crew's truck makes its final approach to the exit of the shop parking lot. The only equipment necessary for these measurements was a digital stopwatch. SavATree has previously tracked this measurement and calculated its average for each branch, with Middleton deploying in an average of 23 minutes in 2018.

Beyond the time it takes for a crew to deploy, the effort required to ready their trucks is of note as well. A metric that contributes to both factors is Crew Distance Traveled (CDT). The greater the distance a crewmember must walk to gather the equipment and information necessary for a day's work, the more time they spend and energy they consume. CDT is defined, for our purposes, as the distance in feet a crewmember travels on foot through the deployment process. A distance wheel was used to collect this information.

Diagrams and rubrics constructed

In addition to distance traveled, this method of following a crewmember was used to construct spaghetti diagrams.[47] Spaghetti diagrams trace the path a worker travels through the work space in an effort to identify redundancies which could be eliminated through process improvement, workflow redesign, or workspace alteration. The overlay of many diagrams is essential to capturing many aspects of a process: where actors go, high traffic areas, bottlenecks, unnecessary steps, etc. Crucial to creating Spaghetti diagrams was the construction of a scale diagram at the outset of D-Term. Parts of three days were spent measuring the Middleton facility and producing the drawing in Adobe Photoshop. A copy of the daily spaghetti diagram template used for this project has been attached as Appendix 2 to this report.

Metrics & Rubrics	Summary Description	UOM	Input
Total Deployment Time (TDT)	Time it takes for a crew to leave the shop	mm:ss	Timer
Crew Distance Traveled (CDT)	Distance a crewmember travels on foot to fully deploy	feet	Measuring wheel
Spaghetti diagrams	Maps of the workspace tracing a worker's path through it as they complete a work process	*n/a*	On-site study
Process flowcharts	Trace flow of information, materials, and people through a process	*n/a*	Spaghetti diagrams / on-site study
Ishikawa diagrams	Organize factors that contribute to problems in a process into broad categories for eventual resolution	*n/a*	On-site study

Table 3: Summary of metrics to study and rubrics to construct at SavATree - Middleton

When shadowing a crew member, I hand-drew the path they followed through the office and numbered each leg of their path, corresponding each leg with the distance traveled as read off the distance wheel. When digitizing a crew member's path for a given day, I scanned the hand-drawn diagrams and aligned them with the digital template in Photoshop. I generated a line corresponding to the distance traveled for that leg (20 pixels was equal to one foot in my diagrams), and then traced them along the hand-drawn path.

Through the weeks of my study, I developed a working knowledge of the crews' processes and the duties required to fully ready their equipment and trucks for a day's work. Two key bottlenecks emerged from this study: the length of the crew's meeting with the arborist in charge of their jobs that day, and the length of time required to warm up a truck and ensure the proper heavy equipment for that day's work (log loader, stump grinder, wood chipper, etc.) is hitched for towing. These two tasks averaged 5 minutes 57 seconds combined, accounting for around 30% of all deployment time. They wound up being key areas of focus, and will be explored more fully in the Analysis and Improvements section.

Once the information from on-site study was collected, a process flowchart was constructed for the Crew Deployment Process. I created the flowchart by observing and documenting, throughout the study period, the steps the crew would take to deploy. I created a draft of the diagram and reviewed it with Middleton staff, who deemed it an accurate reflection of their processes. This flowchart provides a clear recipe of what goes into the tree crews' daily ready-up routine and, thus, the roadmap to altering it. When the flow of people, materials, and information is tracked throughout a process, insights into problems and solutions are far more easily illuminated. The full General Tree Care Crew Deployment Process flowchart can be found in Appendix 3, and will be discussed in detail in the Analysis section.

Overall comments on measurement process

SavATree – Middleton's staff, of all roles, were supportive and engaged with my study throughout the entire process. Management and operations staff were generous with their time and expertise in explaining aspects of the tree and lawn care industry, SavATree's corporate processes, and branch-specific concerns. Support staff availed themselves to me when I had questions or required assistance. Finally, the crew members themselves were a pleasure to work with. If they had been reticent, evasive, or disinclined to be studied, this study would have been difficult to complete and would have been unlikely to produce any meaningful results.

Results

A: Analysis conducted

Once the preparations for measurement were completed, I consulted with Branch Manager Warnock to determine the proper start to the study period. Monday, March 25th marked the day Middleton began operating two work crews, after reducing to one crew during the low production demands during the winter season. The move to two crews coincides with the resumption of normal operations activity at Middleton, meaning that data collected from that point on could be considered representative and reliable.

Study began on March 25th and continued until April 22nd. Of the 21 potential workdays for study, 15 days provided the conditions for data collection. One crew member was shadowed six times, another five times, and a final three times (this final crew member is the employee engaged as a part-time mechanic and participated in fewer normal deployments). None of the attempts at study resulted in unusable data.

Statistical Results

Overall, SavATree – Middleton's average Total Deployment Time (TDT) was measured at 20 minutes and 16 seconds. SavATree's target deployment time is 15 minutes, which makes Middleton's deployment 35% slower than desired. The standard deviation for TDT was 4 minutes and 6 seconds. Statistically, assuming deployment times take a roughly normal distribution, this would project Middleton to exceed the target deployment time 89% of days. Empirically, this result was observed to occur 87% of days. Figure 5 (below) shows a histogram of the distribution of observed deployment times. While a larger sample size would result in a smoother data visualization, the collected deployment times can be observed to conform to a left-skewed normal distribution.

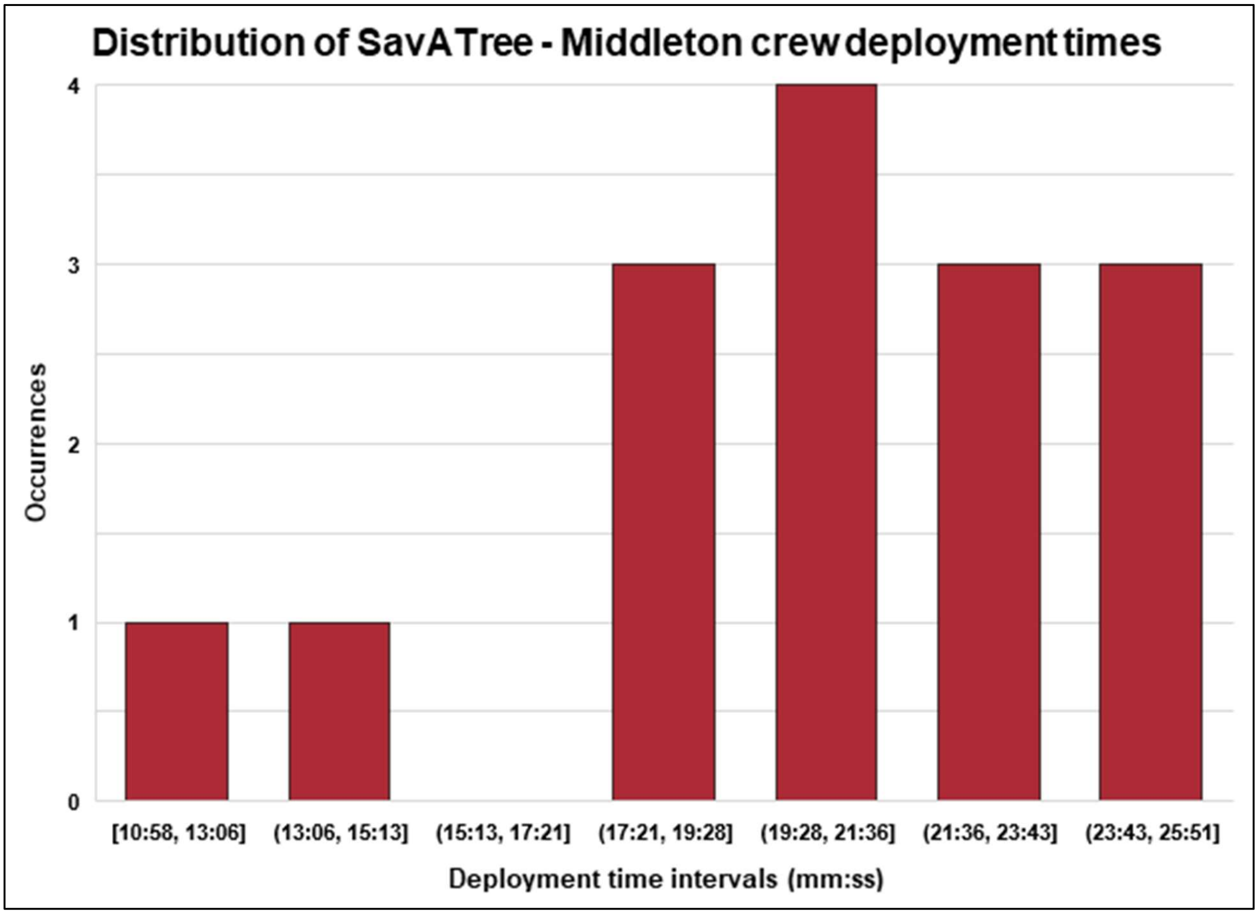

Figure 5: Distribution of measured crew deployment times at SavATree - Middleton

Middleton's tree crew members averaged a daily total of 1,113.5 feet traveled, with a standard deviation of 360.6 feet. The least traveled crew member averaged a full standard deviation less travel per day than the furthest traveled. A histogram of the distribution of Middleton's observed distances traveled (Figure 6) takes a slightly right-skewed normal distribution. SavATree does not prescribe any guidelines for Crew Distance Traveled (CDT), as each branch's facility is uniquely laid-out. CDT is a valuable metric for our purposes, however, serving as an avenue to measure the reduced fatigue on personnel or wear-and-tear on equipment that would result from proposed process improvements.

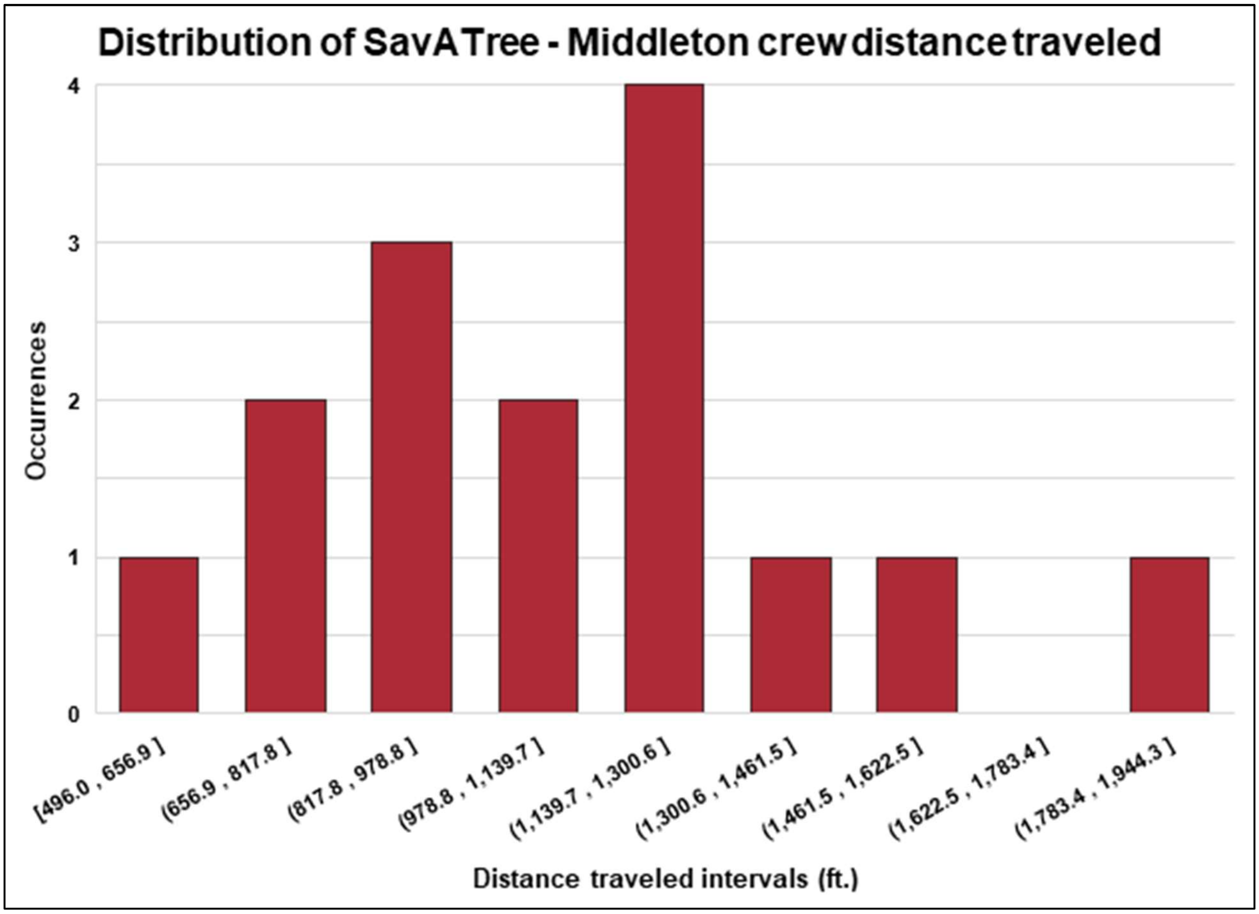

Figure 6: Distribution of measured crew distances traveled at SavATree - Middleton

Observed processes

Per Branch Manager Warnock, light equipment in the tree and lawn care industry is at risk of theft on job sites or in unattended shops due to its cost and utility and resale values. As a result, Middleton stores its light equipment in a locked 16' x 11' tool closet. This room is locked at night and during the day, once crews have fully deployed. While this precaution prevents the unnecessary loss of pricey equipment, the limited access to the tool closet and its fixed position in the facility complicate the deployment process. Each crew member can carry at most three pieces of light equipment at a time (one backpack-style blower and two hand-carried tools). Crews may need from three to six different pieces of equipment for a day's work, which requires crews to make two or three trips into the tool closet.

The weight and cumbersome nature of carrying light equipment by hand has resulted in the development of the following process for staging. Crew members will carry two or three pieces of light equipment 15 to 20 feet, from the tool closet to a certain area of the shop floor, until the necessary equipment is gathered. Examples of this behavior are shown in Figure 7, which shows detail inserts of spaghetti diagrams of the tool closet area for three separate days.

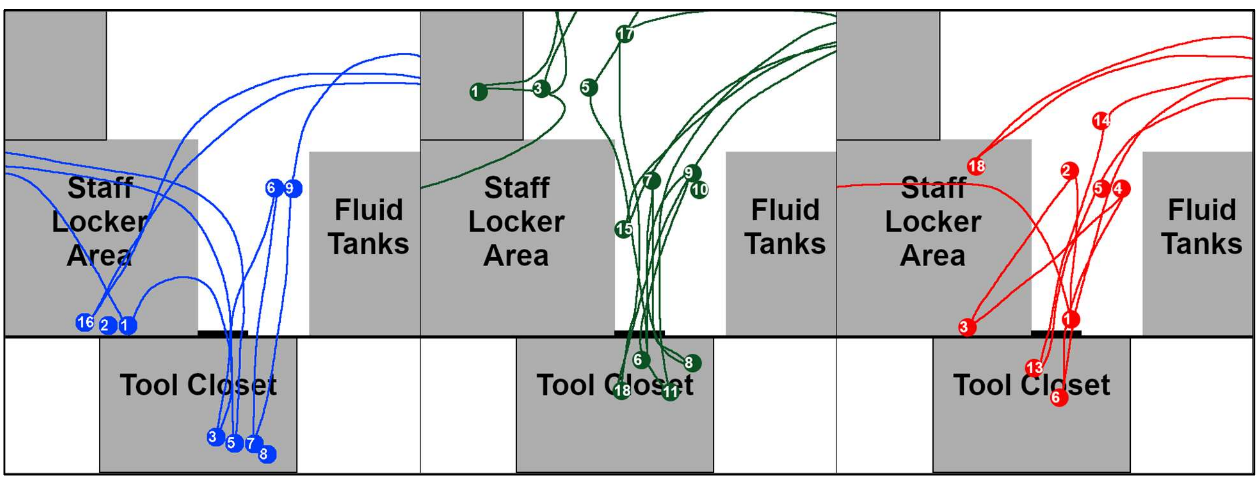

Figure 7: Detail of individual spaghetti diagrams showing tool staging behavior

Then, crew members will gather as much equipment as they can carry and move it around the fluid storage tanks (which prevent straight-line access to the exit, as demonstrated in the looping paths from the tool closet area to the rear exit seen in the spaghetti diagrams), out the back door, down a set of exterior stairs, where they set the equipment down at the base of the stairs, outside the shop. They then cross the parking lot, approximately 150 feet to the truck and trailer parking area. Once their truck has been readied, they pull it up to the loading area and place the light equipment into exterior compartments on the truck (as seen in Figure 7).

Figure 8: Chip truck with attached chip trailer pulled into loading area at back of Middleton shop

There are many benefits to the current process for deploying light equipment that the tree crews use. They minimize the distance their equipment travels (reducing wear-and-tear) and reduce the likelihood of a mistake resulting in the loss of equipment (i.e. a truck running over a leaf blower accidentally left in a travel lane). They also reduce the strain on their body, potentially avoiding the need to carry 90 to 100 lbs. of equipment 300 extra feet in total.

Figure 9: Photo of tree crew members loading a truck with light equipment

Spaghetti diagrams, deployment flowchart, and Ishikawa diagram

The first analytic diagram I constructed were the Spaghetti diagrams of Middleton's crew deployments. As discussed in the Measurement section of the Methodology chapter, these spaghetti diagrams traced the path of crew members through the facility as they completed the tasks necessary to deploy. I traced their paths by hand, recreated those diagrams in Adobe Photoshop, and overlaid them, both for the all GTC crew members and for each individual crewmember. These diagrams can be found in Appendix 4. A summary of each crew member's key metrics compared to the average for all GTC crew members is included in Table 4 (below).

There is a strong positive correlation between deployment time and distance traveled (correlation coefficient of .77).

Crew Member	TDT	% Δ Avg.	CDT	% Δ Avg.
A (red)	17:38	*-13%*	959.6	*-14%*
B (green)	20:35	*2%*	1,057.8	*-5%*
C (blue)	22:45	*12%*	1,295.2	*16%*
Avg.:	**20:16**		**1,113.5**	

Table 4: Average deployment time and distance traveled by crew member

The clear patterns that developed in these visualizations are borne out by Middleton's operational realities. GTC crews don't utilize any of the pesticides, fertilizers, or liquid treatments stored along the far wall of the ship, and thus rarely trafficked that area. The long alleyway at the top of the shop is generally left clear, to allow trucks to be pulled into the shop for maintenance or loading. A few shelving units are placed against the wall between that alley and the office area, and crew members occasionally needed to retrieve tools or supplies from them. The most heavily trafficked areas were the staff locker area and tool closet, where crew members retrieved the light equipment and other supplies they need for the day, and the area at the base of the stairs where they stage that equipment before pulling their trucks into the loading area. The arcing path between those areas, around the fluid storage tanks and down an exterior staircase, see a constant back-and-forth flow of people and equipment.

Much of the distance traveled by Middleton's crews accumulates in the crossing of the fenced lot to the parking area for trucks and trailers. This area is defined by Middleton's lease, and cannot be appreciably increased without incurring increased overhead costs. It also provides an unobstructed lane for their vehicles to approach the back of the shop, with little risk of damage to the cars stored by SavATree's neighbors in the rest of the lot.

The horizontal travel in the loading area of the lot, demonstrated in the spaghetti diagrams, is generally movement from one truck to another truck to change equipment or communicate with another crew member. The area to the right of the tool closet / dumpster enclose and the left of the staircase is generally occupied by the plant healthcare and lawn care trucks, which pull into that bay to have easy access to the fluid tanks and loading dock. Middleton staff generally park their cars in the area bounded by the left edge of the fence and the outcropping formed by the tool closet / dumpster area. Traffic to that area is most often to retrieve the gear tree crew members store in their personal vehicles, generally the climbing equipment they must purchase on their own.

The observations made, both as a result of the in-person shadowing and the construction of these diagrams, provided a number of useful insights which lead to the creation of a flowchart detailing the steps necessary for a crew member to deploy. The flowchart (found in Appendix 3), was reviewed by Middleton personnel and deemed accurate to their experiences. In creating and studying it, I found that the most time-intensive tasks were the ones involved in decision loops. If all members of a crew met with their assigned arborist, it completely halted the deployment process. If the truck a crew needed or desired to use didn't have the proper heavy equipment hitched to the back, it required multiple crew members to move trucks in and out of parking spots until they were configured properly. Finally, there was often idle time at the end of the deployment process where crews were waiting for one last piece of equipment, previously forgotten or overlooked, or waiting for management or an arborist to impart one last piece of information.

In addition to flowcharts, Ishikawa diagrams (named for their creator, the organizational theorist Kaoru Ishikawa) are useful in organizing the factors that contribute to problems in a process. I interviewed Middleton management, operations staff, and the crew members themselves to identify factors that resulted in the above-target deployment times at Middleton. I then organized them into six broad categories: Communication, Personnel, Environment, Process, Light Equipment, and Heavy Equipment. The full-sized diagram is listed in Appendix 5, with a smaller version in Figure 9 provided below for reference.

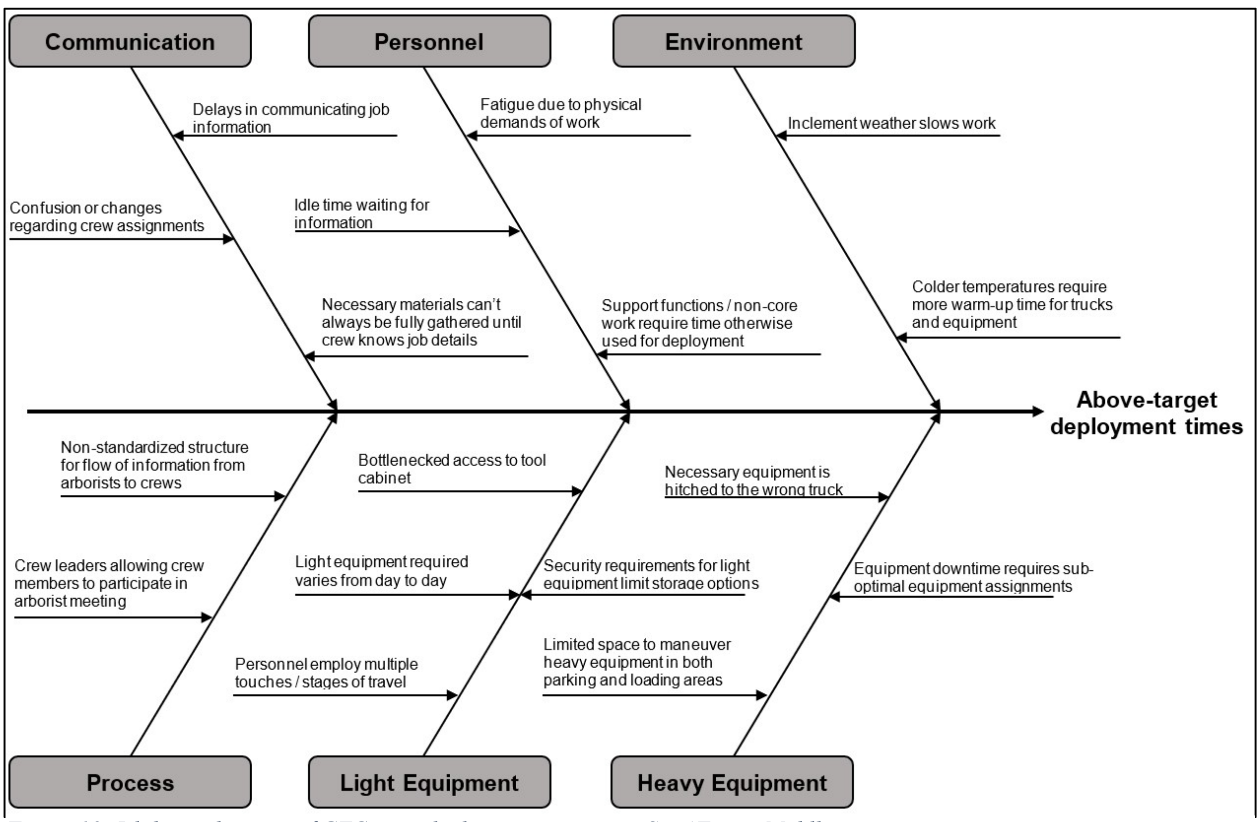

Figure 10: Ishikawa diagram of GTC crew deployment process at SavATree – Middleton.

While Ishikawa diagrams can't tell practitioners how, precisely, to solve a problem, these diagrams provide a list of sources of defects and demonstrate how they contribute to the issue at hand, assisting in root-cause analysis. My Ishikawa diagram proved useful in focusing my analysis on discrete issues and was key in communicating with Middleton management regarding proposed improvements.

Some of the factors contributing to above-target deployment times are entirely unavoidable (e.g. weather, routine equipment downtime for maintenance, the security requirements for equipment). Others are conditions that are ever-present but can be ameliorated to some extent (e.g. fatigue due to the manual labor required, variability in equipment required). Finally, there were a set of contributing factors which, in my estimation, could have their influence on deployment times reduced or eliminated altogether. These factors include the multi-touch / stage of travel approach to staging light equipment, heavy equipment configuration changes required day-to-day, time spent by full crew participation in arborist meetings, and outdated / non-standard communication of equipment requirements. These were the avenues I focused on in devising improvements to Middleton's crew deployment process.

I: Improvements proposed to SavATree – Middleton management

When considering improvements to SavATree – Middleton's deployment process, there are a number of important conditions to consider. The layout of their shop floor is relatively fixed. Management instituted a reorganization of the interior facility in January 2019, which involved the construction of the mechanic's cage, the installation of pallet racks along the back wall of the shop, the installation of staff lockers, and the installation of a locked gate at the entrance of the tool closet (previously, light equipment stored within had been chained to shelves or placed behind a different locked gate). Their lease forestalls major structural alterations to the facility, both interior and exterior. The shared nature of their parking lot, and the contractual terms dictating their allotted space, prevent radical changes to the storage of heavy equipment in the truck/trailer parking area.

Consideration of high-investment solutions generally resulted in costs and conditions that would prevent Middleton from moving forward with them. As an example: I evaluated the idea of Middleton creating a second loading dock extending from the back of the tool closet, with a new exterior door directly from the interior of the closet. This dock could reduce crew travel by 100 to 240 feet per day, and equipment travel by 200 to 600 feet per day. It would also reduce congestion in the current loading area, which sometimes plays host to five trucks and their attached trailers. This solution, however, would require a large capital investment into a property SavATree doesn't own. Furthermore, the hypothetical loading dock would displace Middleton's dumpsters, and require reorganization of their leased space in the lot, likely costing them already limited staff parking. Middleton would then have to lease more space in the lot, resulting in a higher monthly lease.

As one of the smallest branches within SavATree, Middleton must be vigilant in keeping its overhead low and judicious with capital investment. Thus, when searching for avenues to reduce deployment time, I sought to leverage existing systems as much as possible, and limit costs incurred to one-time events (rather than recurring costs). The following proposals feed into one another, and lean on improving the flow of information into and throughout the deployment process while being supported by a few small capital investments.

Update work order template

The review of my Ishikawa diagram with SavATree's arborists, and a discussion of topics related to the communication of job information, lead to the first in a chain of improvements. SavATree uses a standard template for the work orders generated by its arborists. These work orders describe the nature of the work to be performed on a job, both narratively and technically, as well as any obstacles or safety concerns specific to the job site. They also contain a sidebar with standard checklists of setup and breakdown tasks, along with a section titled "Equipment" (highlighted on Figure 10, below). The Equipment section is intended to act as a manifest of the light equipment needed for the job in question. This functionality is not currently being used effectively, though. Per Branch Manager Warnock, the Equipment section is out of date, with some of the items listed on the checklist now being equipped on the work trucks by default.

The section should be elaborated on to include pieces of light equipment not currently listed, and to specifically name heavy equipment required for the job. While the inclusion of heavy equipment could be seen as redundant to the crews, whose expertise allows them to easily know which items are necessary for a day's work, it would put the information in front of them earlier, allowing for more efficient staging of vehicles and equipment. Arborists should be required to complete this section for all work orders prior to the manager's final approval.

SAVATREE
Tree, Shrub & Lawn Care

Work Order

978 739-2300

Account Key:
Service Address:

Schedule Date:
Main Salesperson: 900155 Ann Bennett
Invoice #:

Map Code:
County:
Cross Street:
Directions:

Home:
Work: -- Mobile: --

Description Of Work To Be Performed

General Tree Care -3

Location of plant material is from the perspective of main entry point and targets (trees and shrubs) are oriented in a clockwise direction.

One (1) 8" DBH Pear, Common (Pyrus communis), front right - Perform natural pruning intended to maintain the tree's and shrub's characteristic growth pattern to manage/reduce size by applying:
- reduction cuts on live branches by removing 4-6 ft in length to the upper third of the crown, and 2-3 ft in length to the sides. Thin sucker growth

One (1) twin-stem Magnolia, Star (Magnolia stellata), front right foundation - Perform natural pruning intended to maintain the tree's and shrub's characteristic growth pattern to provide clearance by applying:
- branch removal cuts on branches growing into house

One (1) 10" DBH Maple, Red (Acer rubrum), back right growing in front of larger Maple - Take down tree as close to grade as possible, haul away wood and brush.

One (1) 40" DBH Beech, American (Fagus grandifolia), back center - Perform natural pruning intended to maintain the tree's and shrub's characteristic growth pattern to raise crown by removing lowest branch with rope growing into origin.

Group of sapling Black Cherry, left rear in front of Redbud - Take down as close to grade as possible.

One (1) 8" DBH Spruce, White (Picea glauca), back center foundation - Take down tree as close to grade as possible, haul away wood and brush.

Clean affected work areas and haul resulting wood, brush and branches
Identified hazards and obstacles
Hazard: Vines
Obstacle: Landscape Decor
Hazard : poison ivy

GTC Crew Leader A.M.
- ☐ GTC Crew Leader AM
- ☐ Huddle/stretch with safety ball
- ☐ Review crew sheet
- ☐ Obtain Work order
- ☐ Meet with Arborist/Designate
- ☐ Perform DOT pre-trip walk around
- ☐ inspection
- ☐ Stow wheel chocks & cones
- ☐ Depart within 15 min of start time

Crew Setup
- ☐ PPE Arborist & Crew
- ☐ Place two wheel chocks & cones
- ☐ Client notification, intro crew leader & 2nd climber
- ☐ Work zone set up by 3rd member during client intro
- ☐ Arborist & Crew Leader review scope
- ☐ 2nd climber tags trees: Red (take down) Green (prune) Blue (cable) Yellow (brace)
- ☐ Arborist leads job safety briefing during walk around
- ☐ Min 3 hazards/obstacles ID, written, and signed off on by Arborist & Crew
- ☐ Work plan considering hazards & time frame agreed upon
- ☐ Crew Leader calls Arborist to review progress mid-day/end of job
- ☐ Crew leader confirm completion with client (walk around), signed approval
- ☐ Site clear, picked up, tools & equip secure on vehicle prior to departing

GTC Crew Leader P.M.
- ☐ GTC Crew Leader PM
- ☐ Park, place two wheel chocks & cones
- ☐ Complete DOT post trip inspection & fill out inspection report
- ☐ Complete all necessary paperwork
- ☐ Debrief with Arborist: Job status, client contact, damage/incidents, crew issues, sales opportunities
- ☐ Oversee Crew PM Standard Work

Equipment:
- ☐ Log Dolly
- ☐ Orchard Ladder
- ☐ Extra Pole Pruner/Pole Saw
- ☐ Hedge Shears ☐ Treesave
- ☐ Hard Cable ☐ Arbortie
- ☐ Large Saw ☐ Alturnamats
- ☐ Tool Kit

Job Hazard Assessment Performed
1________________
2________________
3________________
Arborist Initials__________
Crew Initials____________

Please confirm we have completed the specified services.

X____________________________ Date _____ / _____ / 2019

Figure 11: Sample SavATree - Middleton work order, with customer information redacted

Enforce use of weekly schedule board

As a part of their January 2019 renovations, Middleton staff constructed a weekly schedule board for its tree crews (pictured below in Figure 11). The plan is for each tree crew to have their work orders for the entire week available for easy access. As tree crew work routes are communicated by SavATree Corporate on a weekly basis, this should provide crews most of the information they need to deploy each day and even allow them ample opportunity to prepare for a day's work the night before.

Figure 12: Photo of SavATree - Middleton weekly schedule board

Per Branch Manager Warnock, the schedule board is not presently utilized to its fullest extent. Schedules are rarely posted for the entire week, and sometimes not posted for the next day. I propose that the maintenance of the schedule board by the arborists be enforced by management. This would entail posting the work orders under the proper day and crew when they first come in, and adjusting them or updating them in the event of changes to a job or crew. Arborists function as both the treatment plan designers and operations leads on their jobs, as well as the main point of contact with the customers, so it follows that they should bear the responsibility of keeping their crews informed of and prepared for these jobs to the fullest extent possible.

The challenge of implementing and maintaining this solution is one of personnel management. The task could feel like a large batch of paperwork to the arborists, and it would be an easy one to procrastinate. Even provided high buy-in from the arborists, the schedule can change multiple times over the course of the week. If crews come to rely on the posted schedule, outdated information could lead to mistakes in both planning and execution. If the value of a superior schedule communication system (in this case, the posting board) can be demonstrated to both operations staff (the arborists) and labor (crew members), it will create the expectation that the system be used fully and maintained properly.

Stage heavy and light equipment for the next workday

If the equipment manifests on work orders are updated to be more functional, regularly completed by the arborists, and the schedule board up-to-date, tree crews should know precisely what equipment their next day’s work requires. Given those conditions are met, I propose that tree crews be required to stage their light and heavy equipment each night, to the fullest extent possible, for the next day’s work. This would entail checking the next day’s work orders to ensure that A.) the necessary pieces of towed or trailer-carried heavy equipment are hitched to the proper vehicles, and B.) the necessary pieces of light equipment are placed on a newly-constructed staging bench on the shop floor. The responsibility of ensuring this staging is complete would fall upon the crew leader, as they're the crew members whose assignments can't be shifted day-to-day.

The process of moving vehicles around and attaching the proper heavy equipment already takes place in the morning, and was considered as a part of the measured "truck preparation" interval tracked during my crew shadowing activities. A key part of truck preparation is the performance of a required pre-trip Department of Transportation-grade inspection. The DOT inspection is not a step that can be reliably shortened without risking compliance issues. However, the truck preparation period I measured was also the time when trailers/towed equipment would be switched, as one aspect of the DOT inspection is ensuring the proper configuration of the tow assembly as well as the full operation of running and signal lights. My data does not separate equipment switching from the inspection, as aspects of the inspection may take place before trailers are changed, and not every day required the reconfiguration of trucks and trailers. Still, the days when extensive equipment swapping was required resulted in the longest truck preparation times. The greatest outlier was 8 minutes 6 seconds of preparation time, 2.5 standard deviations above the mean. Meanwhile 29% of measured times were 2 minutes 14 seconds or less, indicating a reasonable time in which a truck can be prepared if less work must be

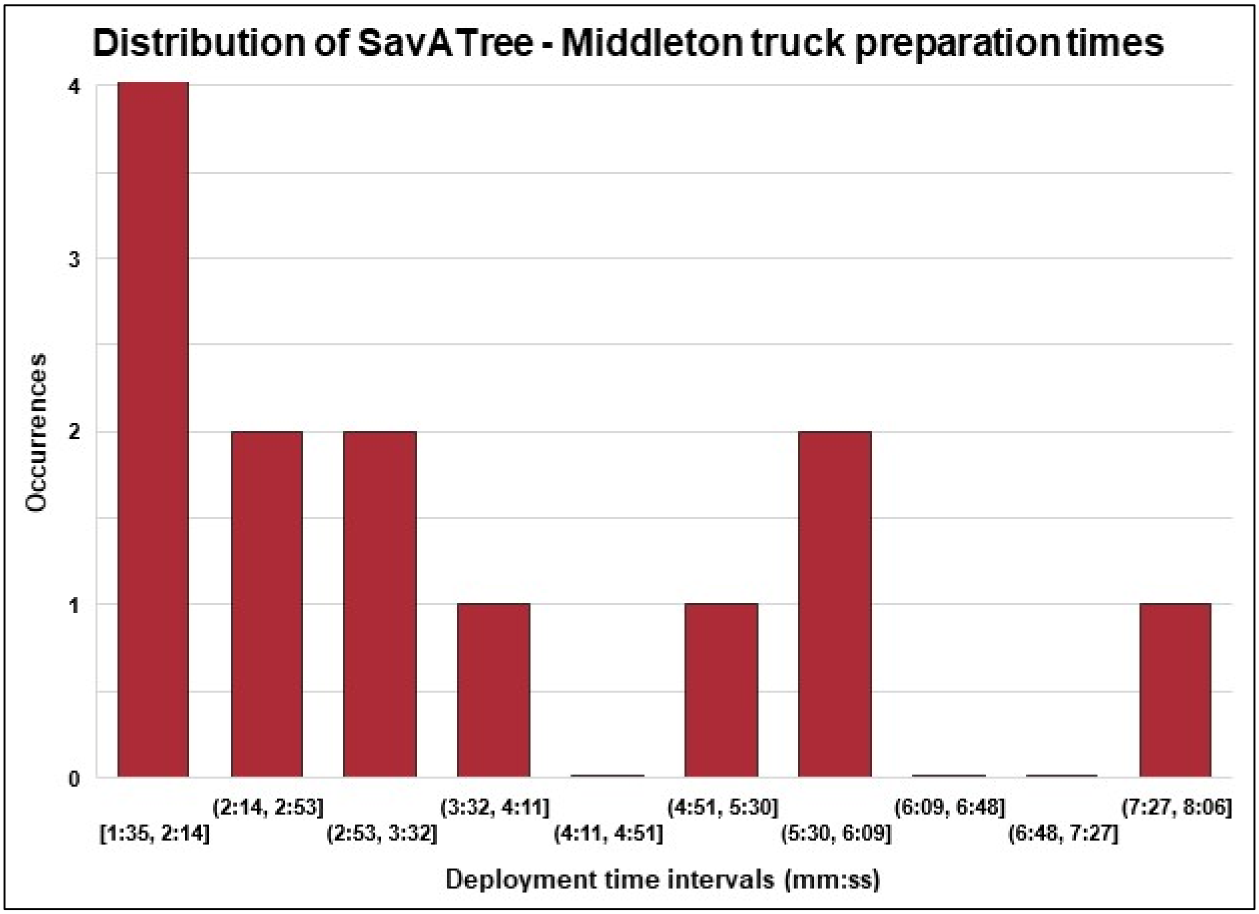

Figure 13: Distribution of measured truck preparation times at SavATree - Middleton

performed in the morning. I estimate, then, that deployment time could be consistently reduced by at least 1 minute 10 seconds if heavy equipment is staged the night before (3m24s mean less the 2m14s upper bound). The distance traveled to switch trailers varies, but might range from 60 to 120 additional feet depending on the specific switches being made. The costs of implementing this proposal are negligible, requiring two crew members a maximum of 5 minutes each on days when the switch must be made.

The second aspect of equipment staging improvement pertains to light equipment. It was the gathering and packing of this equipment (chainsaws and leaf blowers, namely) that seemed to be the most obvious area for improvement, yet proved the most intractable to solve. Carrying the equipment through the shop and all the way through the parking lot is an unenvious task. As previously discussed, light equipment is at risk for damage or loss if not stored in the locked tool closet. There is no affordable way to relocate the tool closet or other location in the shop that is both secure enough and more convenient to the rear exit. To that end, I propose the construction of a simple wooden bench upon which the next day's light equipment can be staged, as displayed in Figure 13 (below).

In my observation, each crew required anywhere from 2 to 6 chainsaws and/or leaf blowers per day. I propose that a two-tiered bench be built and placed against the outside wall of the mechanic's cage. Holes for security chains or wires could be drilled through the legs, supports, and surfaces of the bench, and then wound through loops or handles on the equipment. This same locking system was used to secure light equipment to a shelf when the tool closet entrance was not gated, and so should be acceptable for the staging bench.

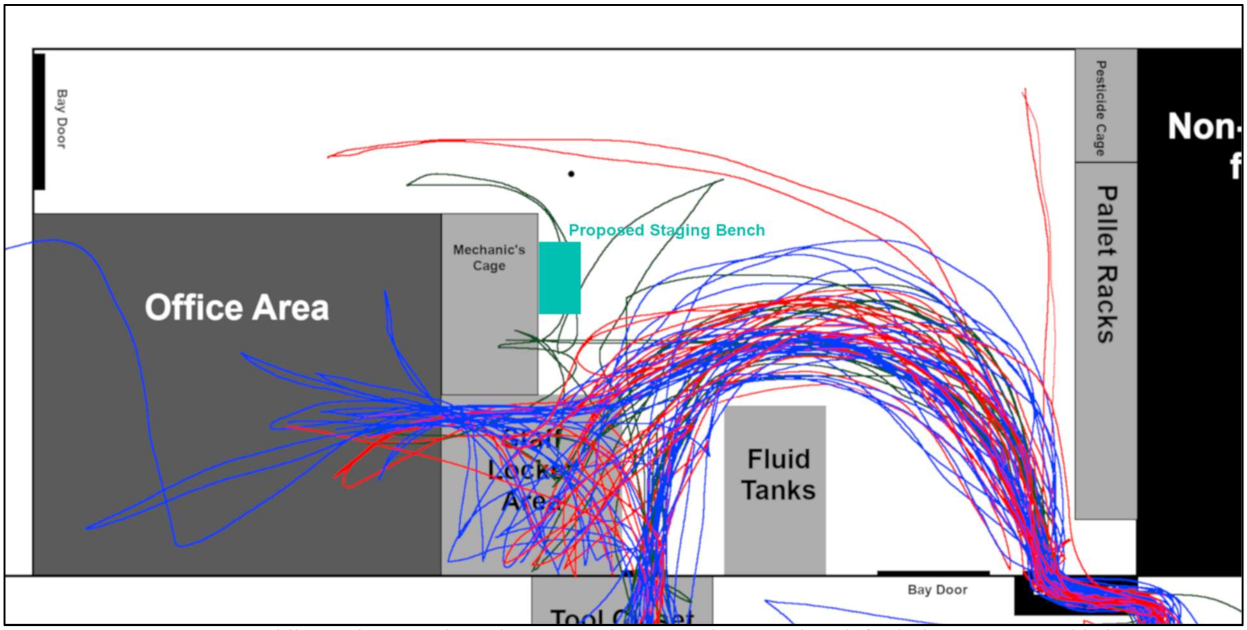

Figure 14: SavATree - Middleton shop spaghetti diagram with proposed staging bench for light equipment added

Each night, upon their return to the shop, crews will stage the chainsaws and leaf blowers required for the next day's work on the proposed staging bench, with crew leaders responsible for ensuring the staging is complete and equipment secured with locks. This proposal could be implemented for $100 in wood and hardware (generously), and a few hours of wages spent on shop time (well-received by crew members when they would otherwise be sent home on a rainy day) costing less than $100 in total compensation. The location I chose is low-traffic, and would reduce a portion of the bottleneck in the tool closet and staff locker area.

The distance saved by moving a day's worth of light equipment from the bench versus from the closet would be just 10 to 20 feet per crew member, at most. The time saved, however, could be substantial. I do not have a reliable measure of the time crew members took to sort through chainsaws or decide which leaf blower to take. I am confident in stating, however, that the streamlined process of simply operating a few combination locks and grabbing the tools off the staging bench would save considerable time when compared to the current process of searching through the closet, placing the day's tools on an area of open floor, then moving the tools to the loading area. I conservatively estimate that 30 seconds, minimum, could be shaved off daily deployment time as a result of these changes alone. The savings could be two or three times more when utilized in concert with my final proposal.

It is worth mentioning that there are factors which could complicate the application of this staging proposal. For example: Crew A could be back at the shop staging tomorrow's work while a piece of heavy equipment is still in use by Crew B. Should members of Crew A be required to wait at the shop until Crew B returns, so that they can stage their gear, incurring hourly wage costs and potentially hurting morale? Should Crew B be expected to stage Crew A's equipment, which could make Crew B feel punished or engender feelings of inequity towards Crew A? To that end: if this proposal were implemented, management should work in concert with crew leaders to communicate regarding end-of-day schedules and use their best judgment to weigh the costs (both financial and soft costs) of performing additional evening work if the crew schedules are substantially unaligned.

Reduce arborist meeting attendance

As mentioned in the Measurement section, crews generally meet with their assigned arborist during the deployment process to review the day's work. During this meeting, the arborist communicates with the crew about the nature of the job. They explain the work to be performed, any safety concerns with the job or property, the demands or eccentricities of a customer and/or their neighborhood. Not every crew member meets with an arborist every day, but most do. In fact, SavATree policy is that only crew leaders are required to meet with the arborist; non-leadership crew members should be going about their deployment processes. In my observed deployments, non-leadership crew members participated in arborist meetings 78% of the time.

Currently, this is when information regarding the nature of the job is disseminated, which tells the crew which light and heavy equipment they must gather. Pursuant to my earlier proposals to enhance job equipment manifests, better display upcoming jobs, and more efficiently stage the required equipment, there should be a much-reduced need for non-leadership crew members to participate in these meetings. Arborist meetings should be restricted to crew leaders only, except in outstanding circumstances. The crew leaders should then communicate the crucial and relevant information to their crews while completing other deployment tasks, while in-transit, or setting up the job site. There would be no tangible costs to implementing this proposal, and it could benefit in a full savings of the average arborist meeting length (2 minutes 33 seconds), which often occupies the entire crew.

Cost / Benefit Analysis

I believe that full implementation of these improvements would result in a minimum reduction in deployment time of 4 minutes 13 seconds, and distance traveled of 70 feet. My generous estimates for these improvements could reduce deployment time by a full minute more (as well as an additional 70 feet). These estimated improvements amount to a 21 to 26% reduction in deployment time, and a 5 to 13% reduction in distance traveled during deployment. Table 5, found below, details these estimates by improvement line item and summarizes the estimated benefits by both my conservative and generous estimates.

	Conservative est.		Generous estimate	
Improvement	**TDT reduction**	**CDT reduction**	**TDT reduction**	**CDT reduction**
Work order template	*support other improvements*		*support other improvements*	
Schedule board				
Heavy equipment staging	1:10 m	60 ft	1:10 m	120 ft
Light equipment staging	0:30 m	10 ft	1:30 m	20 ft
Arborist meeting	2:33 m	0 ft	2:33 m	0 ft
TOTAL:	**4:13 m**	**70 ft**	**5:13 m**	**140 ft**
Mean less reduction:	**16:03 m**	**1,043.5 ft**	**15:03 m**	**973.5 ft**
	-20.8%	***-5.4%***	***-25.7%***	***-12.6%***

Table 5: Cost / Benefit Analysis of proposed improvements, generous and conservative estimates

The tangible costs of implementing and maintaining these improvements are, by design, not extensive. Updating the equipment manifest section on Middleton's work order form would be performed by salaried staff, as would the maintenance of the job schedule board. The additional time commitment (this, personnel cost) of staging heavy and light equipment at the end of a work shift would be negligible. It may not even take additional time at all. The construction of the light equipment staging bench would be a one-time expense of no more than $250. There are no tangible costs directly associated with reduced participation of non-leadership crew members in arborist meetings

C: Control methods proposed

The final step of the DMAIC process, and the final prescription of my proposed improvement plan, is the Control step. That is, changes should be documented and responsibility for oversight and continued monitoring of the improvements assigned to parties at interest. The additional responsibilities assigned to SavATree – Middleton personnel should be communicated to them by branch management, added to their job descriptions, and evaluated as a part of their job performance. SavATree's branch structure also means that management bears the responsibility for the initiation of these proposed improvements, as well as the monitoring of compliance with them going forward. Table 6 details the parties responsible for performing the improvement tasks, as well as the frequency with which they should be undertaken.

Improvement	Responsible party	Frequency
Work order template	Arborists	Update as needed, when Middleton equipment inventory changes
Schedule board	Arborists	Update with weekly route batch, and daily as jobs are adjusted or changed
Heavy equipment staging	Crew leaders	Perform daily
Light equipment staging	Crew leaders	Perform daily
Arborist meeting	Crew leaders	Perform daily

Table 6: Parties responsible for proposed improvements

Conclusion

The goal of this project, when initially proposed, was to study the deployment process of crews belonging to each of SavATree – Middleton's three service lines (General Tree Care, Plant Health Care, and Lawn Care) and propose improvements which would reduce their deployment time and increase their deployment efficiency. The circumstances of Middleton's business cycle, and the foreseeable-but-still-disruptive influence of New England spring weather, limited my study to solely the GTC crews. Middleton's staff, at all positions, were supportive and encouraging of my study. I was able to collect a significant data set reflective of typical deployment activities at the branch, as well as gather valuable qualitative information through conversations with management, arborists, and crew members.

Middleton's tree crews were found to deploy in an average time of 20 minutes 16 seconds, 35% in excess of corporate standards. Crew member distance traveled to deploy was measured at an average of 1,113.5 feet per day. Weeks of observation provided me with the information to construct a flowchart detailing the steps required to deploy, as well as an Ishikawa diagram describing factors which lead to above-target deployment times at Middleton.

Based on those rubrics, I devised improvements to Middleton's processes and proposed them to branch management. These proposals focused on A.) improving and streamlining the flow of information from operations staff to crew leaders and members through enhanced equipment manifests and more visible display of the weekly work schedule, and B.) expediting the daily equipment gathering responsibilities of crew members by spending time at the end of the previous day staging tools.

These proposals could result in deployment time reductions of roughly 4 to 5 minutes, or 21% to 26 % off the current average. Even my conservative estimates of time savings would place Middleton's deployment time at 16 minutes and 3 seconds, or just over a minute past the corporate target.

I believe that these reductions are eminently attainable. Middleton's staff is highly motivated and open to changes in their work processes. The crew members have a high degree of expertise, and a great deal of pride in their work, but branch management has done well to frame prior improvement initiatives in a positive light and build buy-in from the labor force. Arborists work closely with the crews, and are more than capable of completing their new responsibilities. These improvements would come at minimal additional costs to Middleton, especially once the staff builds them into their routines.

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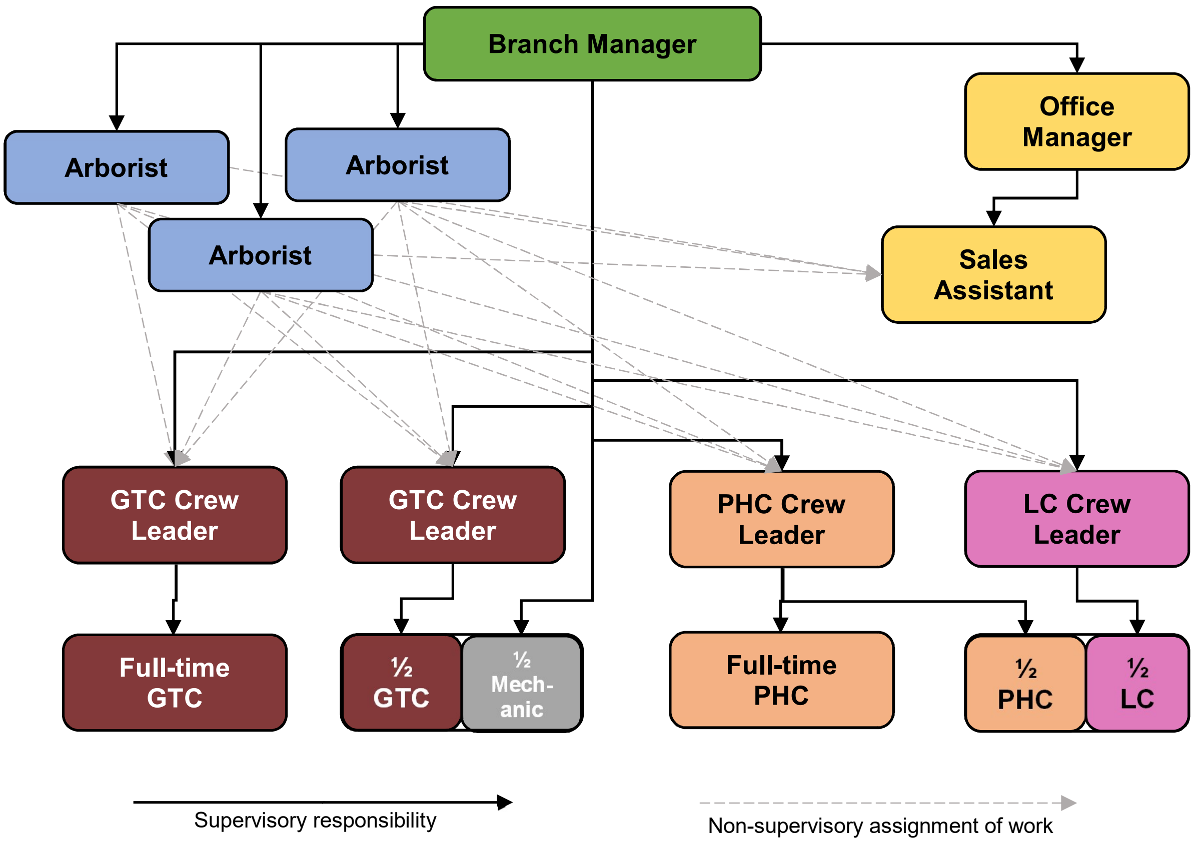
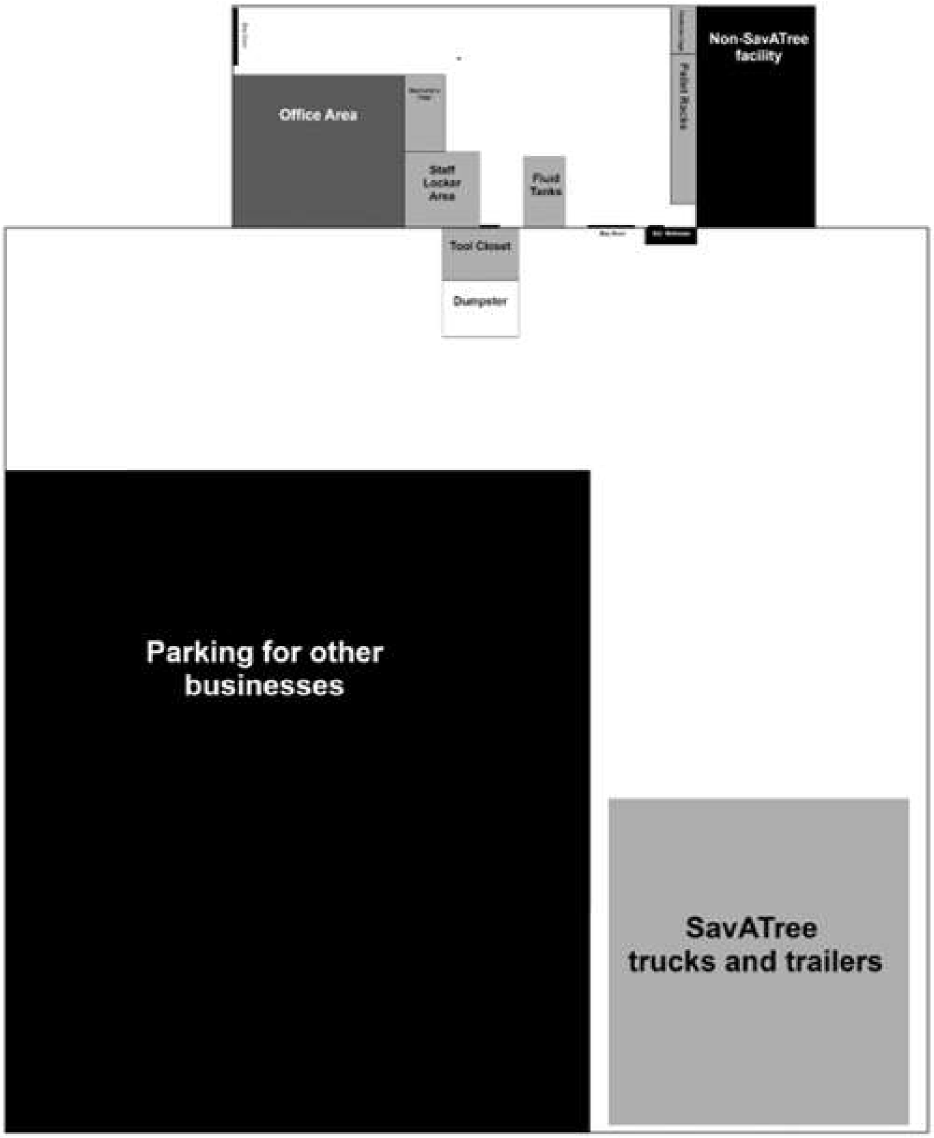
Appendices

Appendix 1: SavATree – Middleton Organization Chart

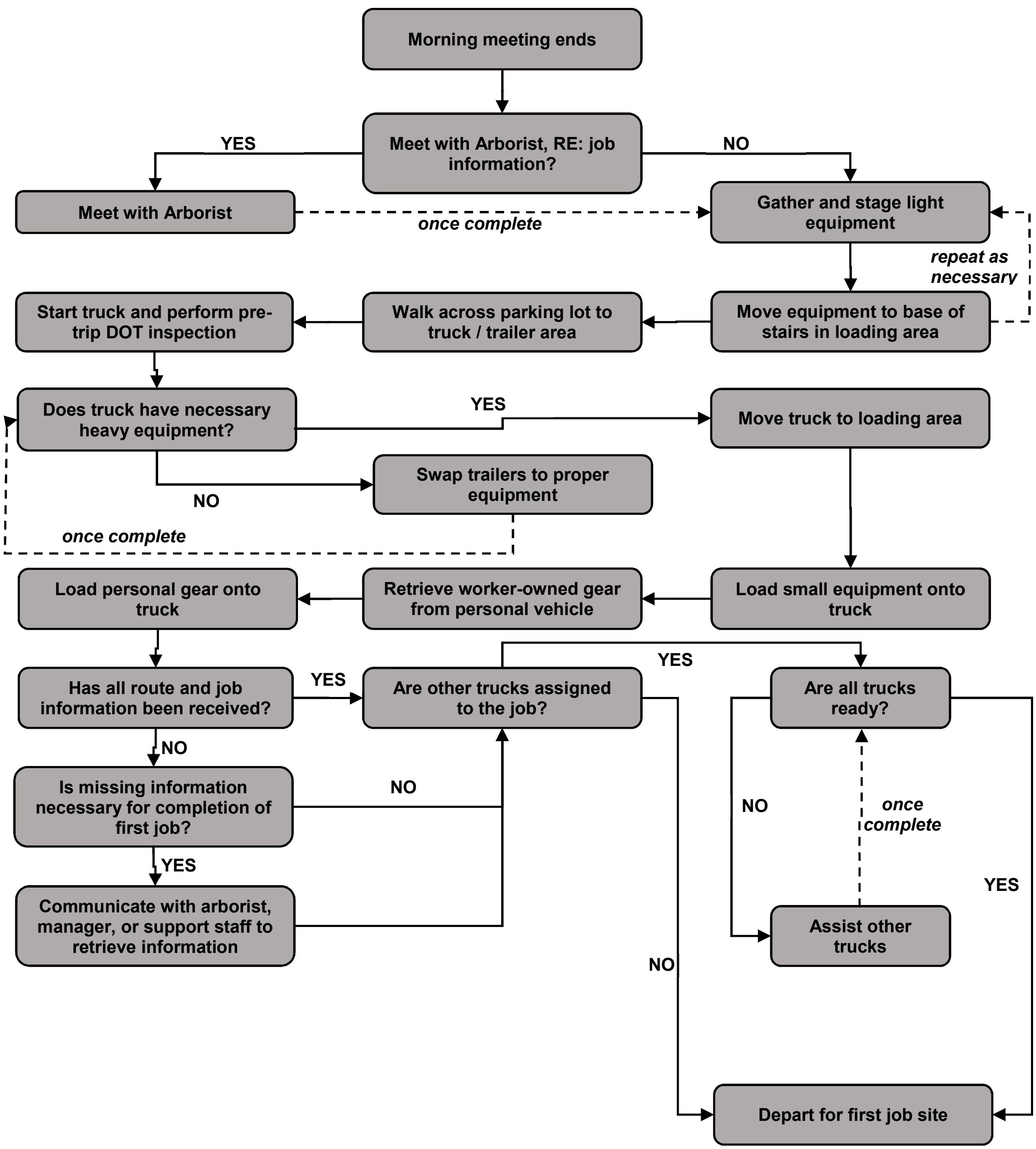


Appendix 2: Spaghetti Diagram template for study at SavATree – Middleton



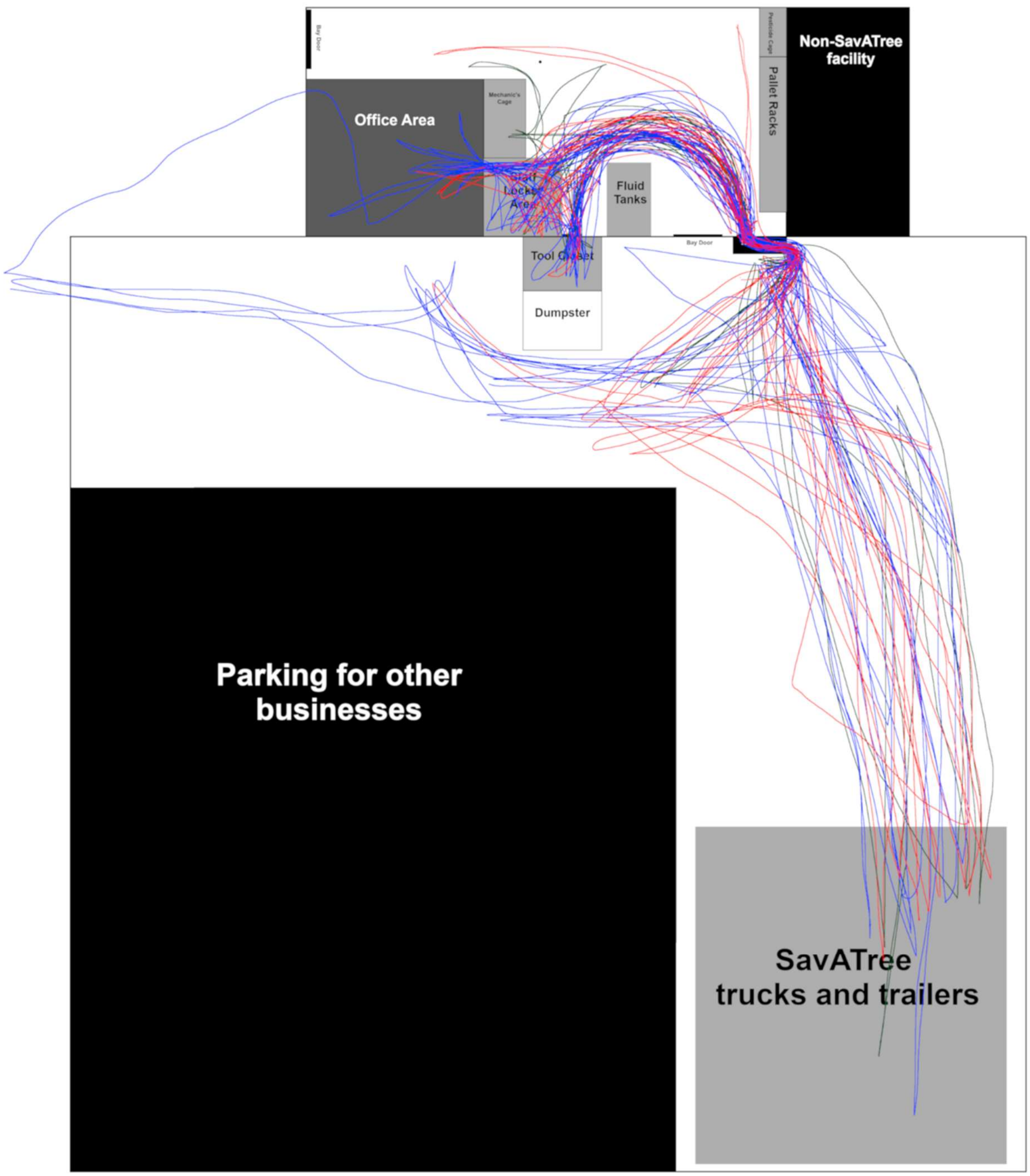
Step	Time	Dist.	Step	Time	Dist.	Step	Time	Dist.

Appendix 3: SavATree – Middleton Tree Crew Deployment Process Flowchart



Appendix 4: Spaghetti diagrams of observed crew deployments

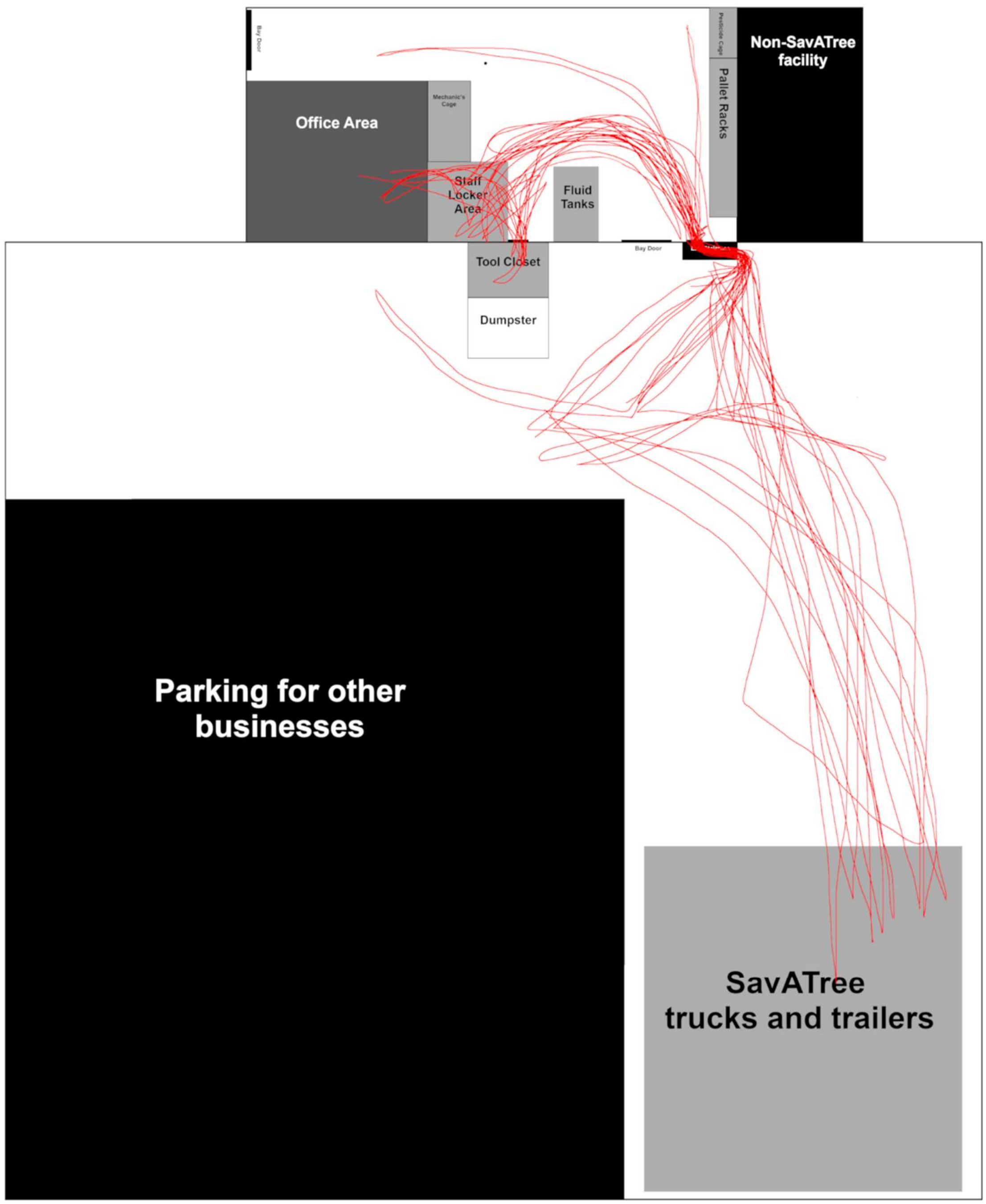
Spaghetti diagrams of SavATree - Middleton daily crew deployment
All GTC crew members combined
n = 15, collected 3/25/2019 - 4/22/2019



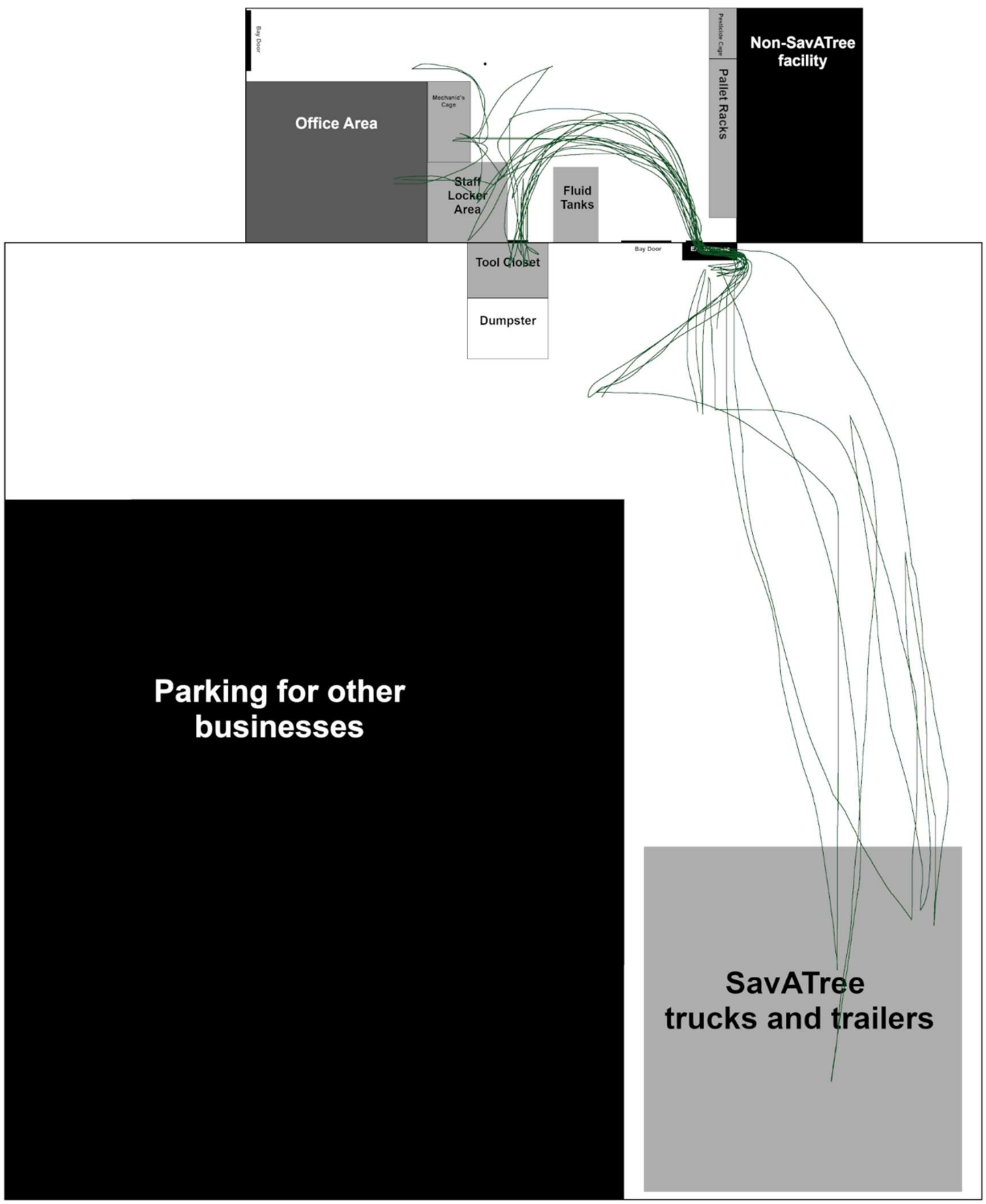
Spaghetti diagrams of SavATree - Middleton daily crew deployment

GTC crew member A

n = 6, collected 3/25, 4/3, 4/8, 4/11, 4/17, 4/22



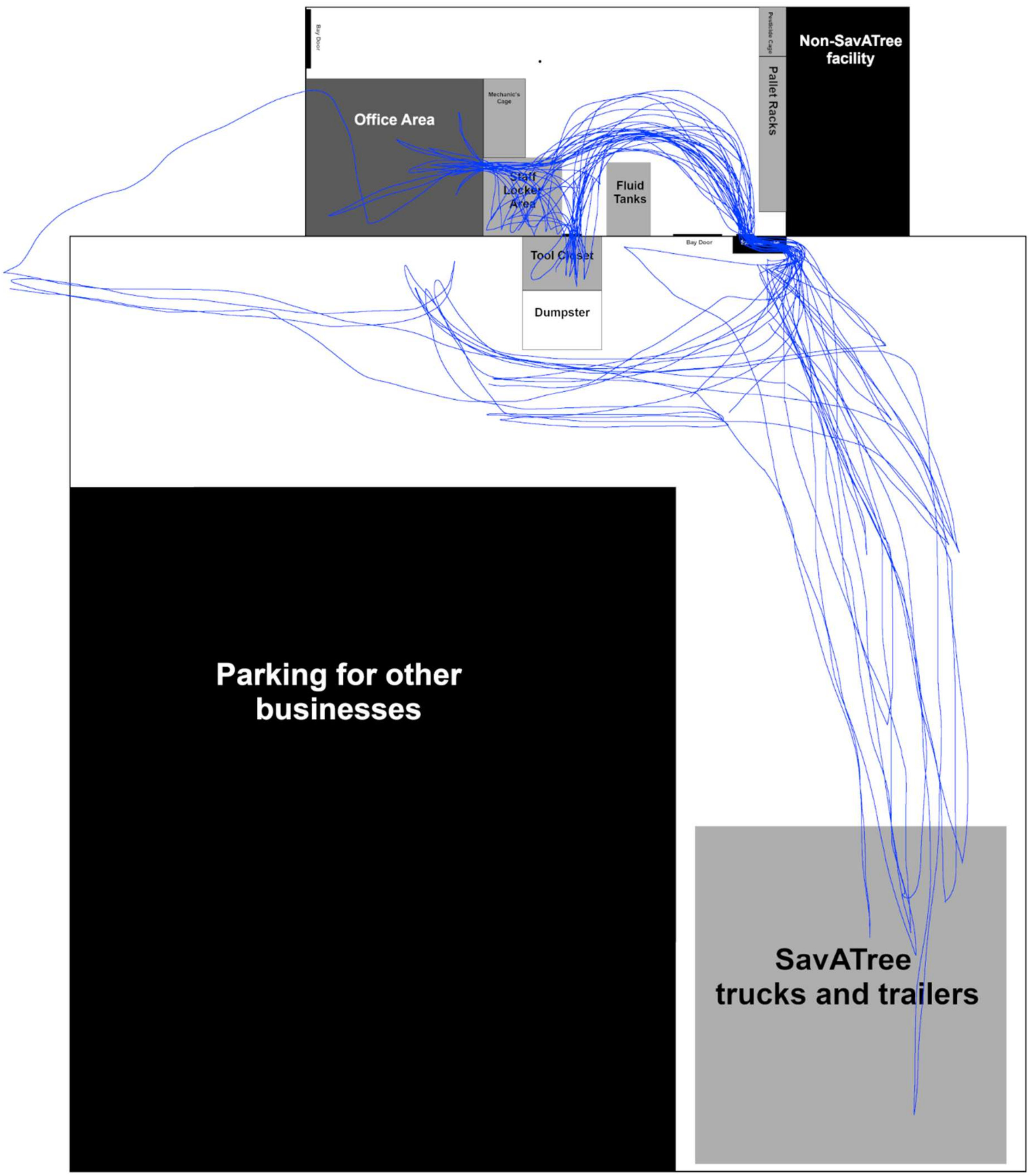
Spaghetti diagrams of SavATree - Middleton daily crew deployment
GTC crew member B
n = 3, collected 4/2, 4/4, 4/9



Spaghetti diagrams of SavATree - Middleton daily crew deployment

GTC crew member C

n = 6, collected 3/26, 3/27, 4/10, 4/12, 4/16, 4/18



Appendix 5: SavATree – Middleton Tree Crew Deployment Process Ishikawa Diagram