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Using historical data and CMMS to track and manage preventative maintenance and emerging costs for fleet vehicles on a university campus

A Capstone Project Report

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Abstract:

Maintenance of vehicle fleets can be costly and cumbersome if done inefficiently or incorrectly. This project will look at how computerized maintenance management systems (CMMS) can be used to more efficiently manage the preventative maintenance program for a large fleet of vehicles at a university campus. Preventative maintenance programs can be difficult to implement, even more so when CMMS is being used to track and monitor the programs. It takes collaboration and buy-in between several groups to have this process go smoothly. This project will need to document all vehicular assets within the current vehicle pool and their required preventative maintenance. This data will then be used to create a maintenance program through a CMMS that is expected to decrease corrective maintenance, effectively increasing more efficient and sustainable predicative maintenance. Historical maintenance data will be used to identify failure trends in each of the vehicles that is used during snow removal at the University of Chicago. These trends will then be used to project emerging costs.

Introduction:

As university overhead costs increase and government funding decreases, it is necessary for all facets of the organization to save money where it is appropriate. Facilities services is tasked with the maintenance and general upkeep of a university's buildings, infrastructure and campus exterior as efficiently as possible to try to keep these costs in control. The vehicle pool, often managed and used predominately by facilities services, can be a major financial burden for the university. There are direct costs associated with maintenance and purchasing of vehicles as well as indirect costs such as loss of productivity for the workforce.

The costs for vehicle maintenance can be controlled by maintaining them preventatively as much as possible, rather than on a corrective basis. Preventative maintenance is often times less expensive than corrective maintenance, as it aims to reduce major maintenance by performing time, or usage based maintenance such as oil changes and tire rotations (Sullivan, G. P., Pugh, R., & Melendez, A. P., 2010). The goal of preventative maintenance is to fix small problems before they become large, expensive problems. Preventative maintenance becomes more difficult to manage and organize as the amount of assets being maintained increases. Computerized maintenance management systems (CMMS) can be used to schedule, plan and implement preventative maintenance programs for various sets of assets with vehicles being one

A vehicle can be tracked as an asset in a CMMS, allowing a preventative maintenance program to be created and managed for it. Using manufacturer's specifications or industry best practices, preventative maintenance for the vehicle can be scheduled based on the vehicle's usage or a set period of time. This maintenance can then be tracked for maintenance trends, asset depreciation and lifecycle cost of the vehicle which can then be used as a baseline for future purchases.

The biggest hurdle in creating a successful preventative maintenance program is having a reliable and capable CMMS. Once a CMMS has been chosen, the next issue is adding the assets into the system and creating a preventative maintenance program. Once the program is successfully implemented, the largest task is making sure that the maintenance is being done and assets are being managed properly in the system. The CMMS takes the administrative burden away from the staff, allowing the maintenance to be done in a timely and efficient fashion. The increase in preventative maintenance decreases corrective maintenance, allowing for a more financially sustainable vehicle pool for the university.

Historical data can be used to identify which vehicles are failing, why they are failing and when they will be expected to fail in the future. Since the University of Chicago has never had a preventative maintenance plan for vehicles, there is no historical data to use from the CMMS. There is data for the snow removal machinery since an outside vendor is used for a majority of the maintenance. Data that is collected can be used to identify trends in these vehicles which then allows for their costs for repair or replacement to be identified well in advance of when the need arises.

Problem Statement:

The University of Chicago's vehicle pool has never had a preventative maintenance program for their fleet vehicles. Very few vehicular assets are entered into Maximo, the current CMMS, with those that are entered having errors in their data. Vehicles are repaired at failure which often times requires extensive maintenance that may have been preventable, or at least minimized, had a preventative maintenance program been in place (Sullivan, et. al, 2010).

Significance:

University campuses are often times sprawling entities that require transportation for facilities staff to do their work effectively and efficiently. Losing a vehicle due to required maintenance, or complete failure, takes a vehicle out of this already limited pool of vehicles. The lack of vehicles requires staff to find alternative transportation via walking, campus transportation or riding with a coworker. All of these options decrease efficiency and productivity. The decrease in productivity has a cascading effect that can cause other areas of facilities to lose time due to downtime waiting for other work to be finished before their work can start. The reliability of a university's vehicle fleet can be improved using a preventative maintenance program. The implementation of a preventative maintenance program through CMMS can keep a vehicle fleet operating, which keeps a university's faculty, students and staff working in the best conditions possible.

Literature Review:

College tuition rates have increased steadily since 1980, with public university rates increasing over 200% and private university rates increasing slightly less at 150% (Kirshstein, 2012). The increases in tuition outpace the national inflation rate at a yearly increase of 3.2% to 4.4% in addition to inflation, dependent on the year (The College Board, 2017). In 1975 college tuition, on average, would account for 30% of a family's median income where as in 2010, the same average college tuition accounts for nearly 50% of a family's median income (Ehrenberg, 2010). While there are several reasons and theories as to why university tuition is increasing, the most definitive reason is that state funding has decreased for universities, requiring them to find financial means elsewhere. State and local funding has decreased 30% per student since 1980 which requires universities to increase tuition or decrease spending to account for the decrease in funding (Webber, 2017). Historically, state funding decreases during economic recessions when states need funding to solve immediate problems (Clelan & Kofoed, 2016). Often times, this funding is slow to return after the economy stabilizes with funding for state universities still $9 billion below its 2008 level, as of 2017 (Mitchell, Leachman & Masterson, 2017). As state funding decreases during recessions, student enrollment increases as high school graduates enter college due to the poor job market and employees that were laid off look to schooling to increase their job prospects (Mitchell, Leachman & Masterson, 2017). College enrollment was 19.8 million students in 2015, an increase of 30% from 2000 (The College Board, 2017). This leads to a situation where schools have less funding but more students on campus, requiring more use of the university's facilities and infrastructure.

The three largest expenditures for a university are financial aid, faculty and facilities (Sightlines: Staying a Step Ahead, n.d.). Seeing as how faculty and financial aid are directly tied to academics, funding for university facilities is often times the first thing to be cut, or stay stagnant, when universities need to decrease spending. A survey taken in 2011 by members of the National Council of State Directors of Community Colleges showed that 94% of the people taking the survey agreed that funding for facilities on their campuses was a major challenge (Katsinas, D'Amico & Friedel, 2011). From 2007 to 2016, the budgets for university facilities departments rose 8% as compared to inflation growing 15.5% during that same time period (Sightlines, 2017). The 7.5% gap between inflation and budget growth effectively decreases the facilities operating budget. As funding for facilities decreases, planned maintenance is frequently delayed in lieu of more pressing, immediate concerns. The delayed maintenance becomes a backlog of maintenance referred to as deferred maintenance. Deferred maintenance grew from $78 per gross square foot in 2007 to $90 per gross square foot in 2012, an increase of 13% in six years (Kadamus, 2013). Data has shown that a deferred maintenance backlog of $100 per gross square foot is the tipping point when preventative maintenance can no longer be performed due to the constant demand for curative maintenance (Kadamus, 2013). As deferred maintenance costs grow, they become compounded due to the lack of maintenance on facilities assets which causes a reduced life span, creating a situation where the life-cycle is shortened and replacement, a higher cost, is required (Sightlines: Staying a Step Ahead, n.d.).

Capital investment for university assets allows new equipment to be purchased, buildings to be renovated and new buildings to be constructed. Universities looking to save costs have decreased capital spending which creates a situation where construction of new buildings, renovations and new equipment purchases stop, or slow. This practice can potentially lead to additional deferred maintenance backlog. From 2009 to 2010, capital investments shrunk from $5.50 per gross square foot to $4.70 per gross square foot (Kadamus, 2013). In times of reduced capital spending, it becomes the facilities' leadership responsibility to decide how the funding will be split amongst the operation. Three factors need to be considered when deciding where funding should be provided: condition, function and impact of improvements to the facility asset (Sightlines: Staying a Step Ahead, n.d.). The condition and impact of improvements to the asset can be assessed using baseline metrics and historical data such as age, cost to replace vs repair and expected future costs. These metrics can be tracked by using computerized maintenance management systems (CMMS).

Computerized maintenance management systems (CMMS) are powerful software packages that can be used in small applications such as an elementary school all the way up to large military bases with tens of thousands of assets. CMMS can be used to track work orders, monitor labor, create job plans and enter and track maintenance for assets (Crain, 2003). One of the most important parts of any CMMS package is the maintenance planning, tracking and execution. There are three main types of maintenance that can be maintained through a CMMS: reactive, or corrective, maintenance, preventative maintenance and predictive maintenance.

Reactive maintenance is the least desirable of all maintenance as it is done when things break and can no longer function properly. It is the most basic of maintenance with no scheduling or planning being done since it is only done when failure occurs (Sullivan, et. al, 2010). Reactive maintenance is the cheapest method during the initial life of an asset due to the lower risk of failure on new assets (Sullivan, et. al, 2010). No money is spent on labor or parts for the asset because it is only worked on when it fails. While the initial cost for reactive maintenance may be lower, it can have catastrophic results as the asset ages (Sullivan, et. al, 2010). The lack of initial maintenance can lead to larger, more costly failures along with a shortened life span for the asset which, in the long term, proves more costly than the other three types of maintenance (Sullivan, et. al, 2010). While inefficient and costly, Studies show that reactive maintenance still accounts for over 55% of the maintenance work done in the United States (Sullivan, et. al, 2010).

Preventative maintenance as defined by Sullivan is, “ actions performed on a time or machine-run based schedule that detect, preclude or mitigate the degradation of the component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level” (Sullivan, et. al, 2010). Unlike reactive maintenance, preventative maintenance consists of scheduled maintenance that is completed before asset failure, incurring more initial costs for labor and parts than reactive maintenance (Sullivan, et. al, 2010). Properly scheduled preventive maintenance is more efficient than reactive maintenance and can save as much as 18%, on average, as compared to reactive maintenance (Sullivan, et. al, 2010). Preventative maintenance cannot completely stop failure but it can help facilitate longer asset life cycles and less downtime due to catastrophic failures (Sullivan, et. al, 2010).

Predictive maintenance is very similar to preventative maintenance in that the maintenance for an asset is done before failure. Where preventative maintenance and predictive maintenance differ is the mechanism used to initiate the maintenance. Preventative maintenance is traditionally completed at certain time or run-based schedules whereas predictive maintenance uses diagnostic equipment to determine the actual condition of an asset, allowing for maintenance to be performed when it is needed (Sullivan, et. al, 2010). Oil analysis, vibration analysis and thermal imaging are three commonly used methods for predictive maintenance that can monitor actual condition of an asset (Forsthoffer, 2017). Depending on the type of assets a facility utilizes, predictive maintenance can save upwards of 40% on maintenance over the life of the asset (Sullivan, et. al, 2010). The high up-front costs associated with the diagnostic equipment purchase, installation and staff training required to implement predictive maintenance make it the least used of the three types of maintenance (Sullivan, et. al, 2010).

Using CMMS for the execution of a preventative maintenance program can keep assets operational for a longer period of time at a lower cost (Vilarinho, Sandrina, Lopes & Oliveira, 2017). Preventative maintenance plans are often time-based plans with work being planned for set periods of time, often times set by the original manufacturer of the asset (Vilarinho,et al, 2017). Time-based maintenance (TBM) is the most basic of preventative maintenance but is the easiest to implement due to no added monitoring devices or equipment as the CMMS creates work orders when the preventative maintenance is to be completed (Vilarinho,et al, 2017). While preventative maintenance can reduce the likelihood of asset failure and costly repairs, it can also be a source for resource waste (Vilarinho,et al, 2017). Maintenance that is performed at set time intervals regardless of conditions can create a situation where an asset requires no maintenance but is having work done. There is always a risk for human error when work is being done on an asset that can cause failure after maintenance is performed. This risk is amplified when it is completed more frequently than is needed. Infant mortality, the failure of a new asset, or asset that has recently been serviced with new components, can be caused by improper installation, misdiagnosis or a faulty component (Sullivan, et. al, 2010) Time-based preventative maintenance is not the most efficient type of preventative maintenance but it can be adjusted using maintenance optimization modeling.

Rommert Dekker defines a maintenance optimization model as a mathematical model in which the costs and benefits of maintenance are quantified in order to obtain balance between them (Dekker, 1996). Maintenance optimization models can be used to bridge the gap, in a sense, between preventative and predictive maintenance by using data, rather than diagnostic equipment (Vilarinho,et al, 2017). The two main types of maintenance models are block based maintenance policy and age based maintenance policy (Barlow and Hunter, 1960). Block based preventative maintenance is done at set time intervals regardless of when previous maintenance was done, or the amount of time the asset was used (Jonge and Jakobsons, 2018). Age based preventative maintenance is similar to block based maintenance in that it is done at set time intervals but, in contrast to block based maintenance, once a part of the asset fails and is replaced, the clock is set back to zero rather than continuing on (Jonge, et al., 2018). Using historical data from age based maintenance practices of when certain assets fail can help to predict when the assets will fail in the future, allowing for funding and maintenance to be scheduled proactively (Dekker, 1996). For example, if the bearing in a certain pump has historically failed at about 1,000 hours of use, the maintenance can be budgeted and planned for when usage approached 1,000 hours. The preventative maintenance schedule for this pump's manufacturer might not even list this bearing, or if it does, might have the timing much different than what past data shows. Using optimization models for preventative maintenance can make maintenance more efficient, decreasing downtime and costs (Jonge, et al., 2018).

Along with the decreased operating and maintenance costs that can be realized through proper preventative maintenance, there is a social cost for vehicle reliability that is difficult to quantify from a cost savings, but is still very important. A university's vehicle fleet is often times responsible for transportation during hazardous weather events, such as snow, as well as the removal of this snow from the campus. The navigation of campus by students, faculty and staff during snowfall events can be very difficult when snow is being removed from building entrances and walkways in a reasonable amount of time. When vehicles begin to fail, snow removal efforts are delayed, causing a burden to campus pedestrians. Along with this unquantifiable burden is the very real risk of a monetary fine that can be levied by the city in which the university is located. For example, the city of Chicago will fine organizations up to $500 a day when snow is not removed from sidewalks within three hours of when the snow stopped falling (Chicago Department of Transportation, 2011). The negative impact from campus disruption will be reflected in client satisfaction surveys, general feedback and the possibility of a negative perception associated with the facilities group.

The main objective for a university's facilities department is ensuring that the university's assets are functioning properly, allowing for educational enrichment to take place without disruption or inconvenience to faculty, staff and student. As budgets continue to run leaner, maintaining facilities in an efficient and proactive nature becomes difficult as resources are diverted away from capital investment, maintenance and staffing. At the same time as budgets are being tightened, student enrollment is increasing, causing heavier use of campus facilities.

Purpose:

The purpose of this project is to determine how a CMMS can be used to implement and track preventative maintenance for a university's vehicle fleet, decreasing maintenance costs and increasing the accuracy of budget projections. The vehicle fleet will need to be entered into the CMMS database before any preventative maintenance program can be created. Once all of the vehicular assets are entered into the system, a preventative maintenance program will need to be created using manufacturer's specifications and industry best practices. The maintenance will be time and use based as not all of the vehicles have odometers to track mileage and even vehicles with odometers are not necessarily driven long distances.

Definitions:

CMMS (Computerized maintenance management system)- computer software that can be used to enter and manage work requests, manage preventative maintenance and schedule work tasks

CM-Corrective Maintenance- maintenance that is completed when an asset breaks or fails completely

PM-Preventative Maintenance- maintenance that is done on before an asset breaks or fails. This includes inspection, minor maintenance and testing of the asset

VIN-Vehicle ID Number- Unique number assigned to a vehicle that can be used for identification and tracking purposes

PTO- Power Take Off Shaft- shaft that connects an implement to a vehicle. For example, a snow broom or vacuum attached to the front of a utility vehicle.

Assumptions:

This project will assume the following:

1) Staff will actively monitor and follow the preventative maintenance plan that is created.
2) Vehicles with no preventative maintenance plan from the manufacturer will have one created from a similar piece of equipment.

3) Vehicles that have been decommissioned will not be included in maintenance program even if they are still owned by the university.
4) All equipment that is driven will be added to the preventative maintenance plan. Hand equipment and small machinery will not be included in the plan.

Delimitations:

The majority of the vehicles that will be entered as an asset into the CMMS are under my direct control but there are a few dozen that are outside of my responsibility. If the staff that oversee these vehicles delay their entry too long, the scope of the project's asset database could be smaller than originally planned.

When staff finish their vehicle inspection work orders, they will need to enter the use of their vehicle into the work order before they complete it. If staff fail to complete their work order, or enter the use incorrectly, it will cause data errors in the CMMS.

Methodology:

The decision was first made as to which vehicles and pieces of equipment were to be entered into the CMMS. All licensed vehicles were entered as assets along with their VIN numbers, year, model, make and mileage (hours). Asset numbers were assigned to each vehicle if they did not already have one. If a vehicle was not licensed, it needed to meet certain parameters to be entered. If the vehicle drives on the road, is over $5,000 or is a critical piece of equipment to day to day operations, it was entered as an asset with as much information as possible. In the event that a vehicle did not have a VIN, the asset number was used in place of it.

The process for which vehicles are entered into the CMMS needed to be consistent to keep data and the asset database standardized. The vehicle data was collected using a basic spreadsheet. This data was then entered into the CMMS. Once all of the assets were entered, they were checked for accuracy against the original spreadsheet.

Once the vehicles are in the CMMS, maintenance plans were created for each vehicle. Maintenance plans were created from manufacturer's maintenance schedules for each of the snow removal vehicles. The maintenance plans for the remaining facilities vehicles are still being modified as to what their frequency and scope should be. This was a higher level decision that needs to be worked through.

The preventative maintenance plans will be based upon meter time for each vehicle, be that mileage or hours. These data points are updated each time a routine vehicle check work order is created and closed. The end-user must enter the current meter time or mileage for the vehicle before it can be completed. This then alters the preventative maintenance plan frequency.

The CMMS will generate work orders automatically for preventative maintenance once the usage or time requirements are met. These work orders will then be routed to the owner of each vehicle. It is then the owner's responsibility to bring the vehicle in for the prescribed preventative maintenance. The efficacy of the preventative maintenance plan ultimately lies on the owner of each vehicle bringing in their vehicle in a timely fashion. If there is a large delay between the generation of the preventative maintenance work order and the actual execution of the work, the plan will be delayed and ineffective.

Limitations:

The University of Chicago's vehicle pool could be considered small compared to other universities. The urban campus layout does not require extensive travel which limits the amounts and types of vehicles needed. There are no shuttle buses, transportation vehicles or security vehicles in the vehicle pool. This study may be less useful for a large, land-grant university whose vehicle pool is in the 100's. A larger, more diverse vehicle pool will have more challenges than this study covers.

Findings:

This study covered the ten main pieces of equipment that are used to clear snow on the University of Chicago's Hyde Park campus. They are as follows:

- 5x Bobcat Toolcat 5600 (Four of which are active at one time. This study includes a fifth which was sold when a new one was purchased)
- 2x Bobcat 3650
- 3x Kubota RTV1100

These ten vehicles are used for the clearing of snow from the walks, entrances and docks on campus. These assets were not in our CMMS system, Maximo, and no maintenance was tracked through our CMMS. The initial step for this study is to add all of these assets into the CMMS and then create preventative maintenance plans for them. Once the assets were all in the CMMS, historical data was used to determine if an optimized maintenance model could be created to help predict, and plan for, failures.

Several pieces of Information were collected for each asset:

- Manufacturer
- Model
- Model year
- Vehicle Identification Number
- Current Mileage/Hours
- Purchase Price
- Location

This information was then entered for each asset into the CMMS using the asset entry form, Appendix A. Once the asset is entered, it receives a unique Asset ID # that will be used for its lifespan. Two of the fields, warranty and life cycle, in the asset entry page were not used as the system is currently not configured to use any of the data. Each asset then needs to have a preventative maintenance plan created for it.

Each vehicle type will have a unique preventative maintenance plan created for it. While each machine type may be similar in nature, they have different systems and uses that require different maintenance. The original equipment manufacturer of each vehicle provides maintenance plans that can be used to create preventative maintenance plans in the CMMS. Every asset used in this study monitors usage via hours rather than mileage so each preventative maintenance plan will be based on hours used. The preventative maintenance plans for each model were acquired from the original manufacturers, Kubota and Bobcat.

Every vehicular asset has a weekly, routine work order created for it that will be created automatically on Mondays. These work orders then get assigned to the operator of each vehicle where they complete the inspection list, document the meter time on the work order and close it. The tasks for each routine work order are as follows:

- Check vehicle fluids-Oil, Antifreeze and hydraulic (If applicable)
- Check tire pressure
- Check vehicle for any noticeable issues
- Check for basic vehicle cleanliness
- Check and record vehicle hour meter

After the work order is closed, the usage for the vehicle is updated in the CMMS. Once the usage for each vehicle reaches a certain hour threshold, a preventative maintenance work order is generated for that vehicle.

The basic maintenance schedules for each vehicle are provided by the manufacturer and are similar in structure. The scheduled maintenance plans for the Kubota RTV1100 (Appendix B) Bobcat Toolcat 5600 (Appendix C) and Toolcat 3650 (Appendix D) are all block based preventative maintenance plans. The plan for the Kubota starts at 50 hours and has tasks every 50 hours thereafter. Not every task is done at 50 hour intervals, with some being completed every 100, 200 or 400 hours. The Bobcat maintenance plans are similar to the Kubota plan but start at ten hours and then have variable timeframes for maintenance after the initial ten hours, ranging from every 50 hours to every 400 hours. The maintenance plans for each vehicle were loaded into the CMMS via the preventative maintenance plan entry form, Appendix E.

The plans for these vehicles are not starting at 0 since they all have been used for various amounts of time. The plans will start at the closest hour threshold to the vehicle's current hours. Maintenance will be completed as if nothing has been done to the vehicle recently. For example, a Kubota with 380 hours will have 400 hours as the next time a preventative maintenance work order. At 400 hours oil is scheduled to be changed. For the sake of consistency, and to put the maintenance in alignment with the schedule, the oil will be changed at this threshold even if it was changed recently.

The scheduled maintenance plans were all loaded into the CMMS and the expectation is that these will make up the backbone of the preventative maintenance plan for each vehicle. The issue with these maintenance plans is that they do not take into account what the vehicles are used for, the historical data for each vehicle and expected future costs. The ten vehicles selected for this project were done so because they are all used during snow removal at the University of Chicago. Due to their cost, there is no redundancy built in to the snow removal vehicle pool. If one of the Toolcat 5600's were to fail, another machine would have to do more work, slowing down the snow removal process. Snow removal is hard on a vehicle and the hour meter for the vehicle is not necessarily indicative of the wear and tear the vehicle experienced over that timeframe. A modified, optimized maintenance plan was created using historical data for each vehicle type to create a more accurate preventative maintenance plan. Along with a more accurate preventative maintenance plan, data was used to predict when major failures would occur, or vehicle replacements would be needed. The ability to project costs ensures that capital funding is available or is planned for when needed.

There was little, to no data for historical maintenance in the CMMS for each vehicle. The small amounts of data that were collected were incomplete and not useful to this project. The data that was collected for each vehicle was taken from maintenance records from the specialty vendors that service the vehicles when the in-house mechanic is not able to do so. While this data from vendors was able to present a general idea of vehicle failure trends, there are some gaps in time between maintenance events.

There are four Toolcat 5600's used during snow removal at the University of Chicago. They clear snow from the sidewalks on campus and are the main snow removal assets. Their high purchase cost, $66,000, can make them cost prohibitive especially during times when capital investment is being decreased. The yearly maintenance for the 5600's is just over $10,000, a year, Figure 1, or roughly $2,500 per unit, per year. This maintenance cost does not include costs for implements, snow broom, bucket, auger etc... According to this data, it can be assumed that each new Toolcat 5600 will cost on average $2,500 for yearly maintenance, with some years having more and some less. This allows for budgets to be adjusted if additional 5600's are purchased.

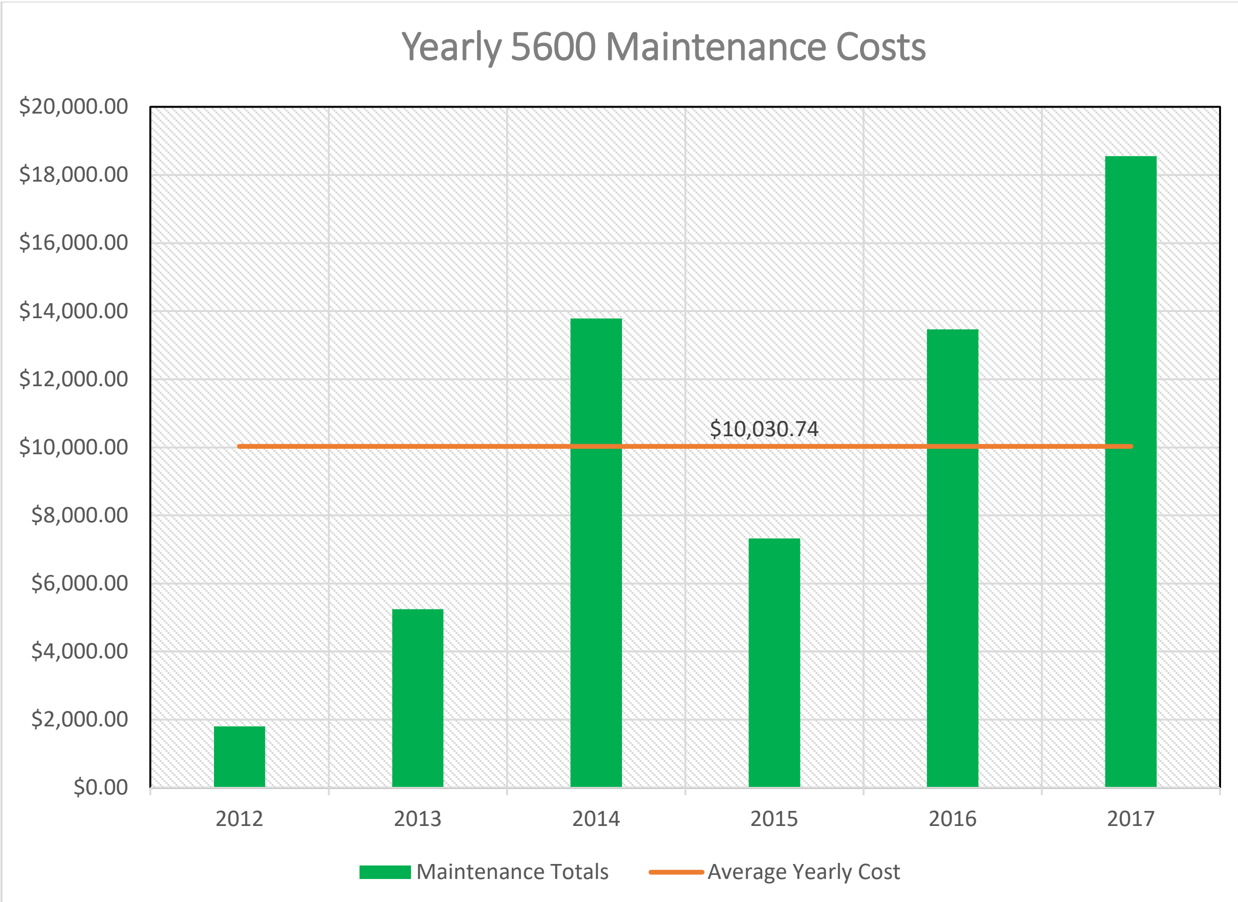

Figure 1: Bobcat Toolcat 5600 Yearly Maintenance Costs

There are peaks and valleys in the yearly maintenance costs for the 5600's, which is to be expected. Considering that the main use for these vehicles is snow removal, data was retrieved to see if there was a correlation between snowfall amounts and maintenance costs.

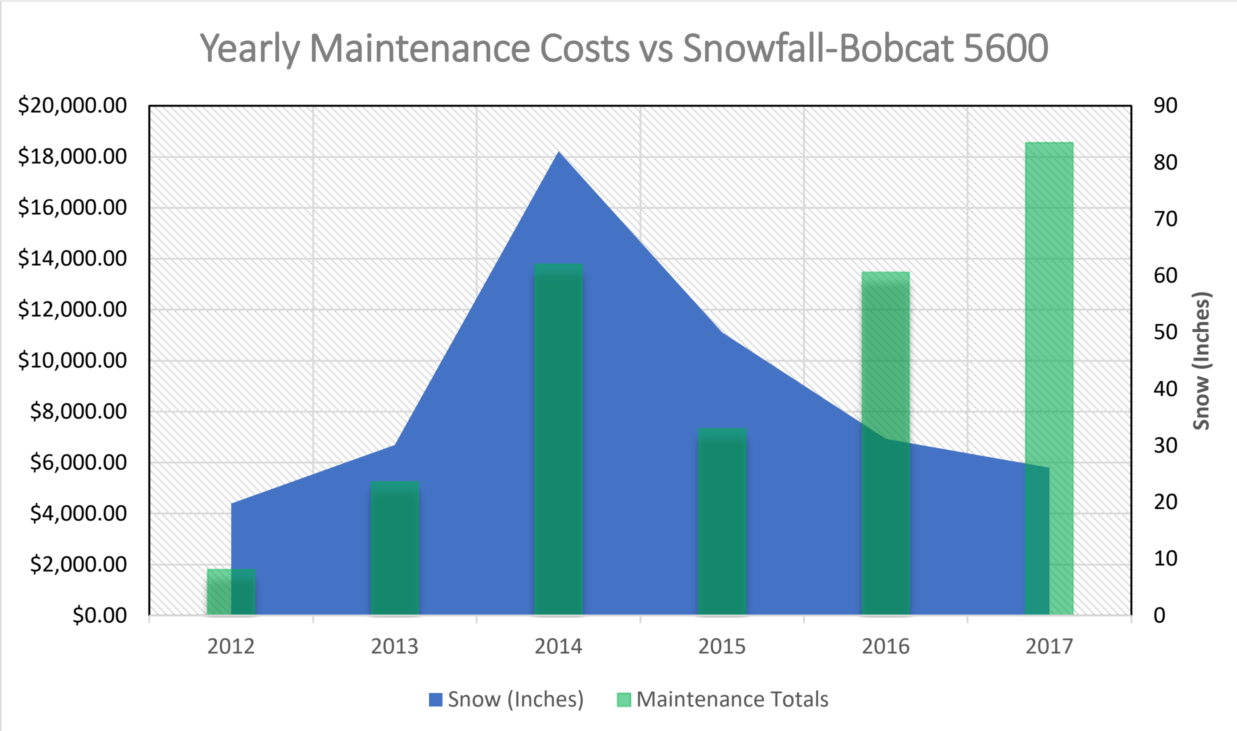

Figure 2: Bobcat Toolcat 5600 Yearly Maintenance Costs vs Yearly Snowfall

Figure 2 shows that while there was a peak in the heaviest snowfall year, 2014, there was a slight decline in the following year and a drastic increase in 2016 and 2017, which were light snowfall years as compared to the previous. This data could highlight that maintenance cost may be less tied to snow removal, and more associated with the usage of the vehicles. The average number of hours on each vehicle, Figure 3, peaks in 2016 and then slightly decreases in 2017 after an older unit was sold and a new one purchased. The trend from Figure 3 coincides with the yearly maintenance costs with 2012 and 2013 having the lowest maintenance costs and lowest amount of hours per vehicle.

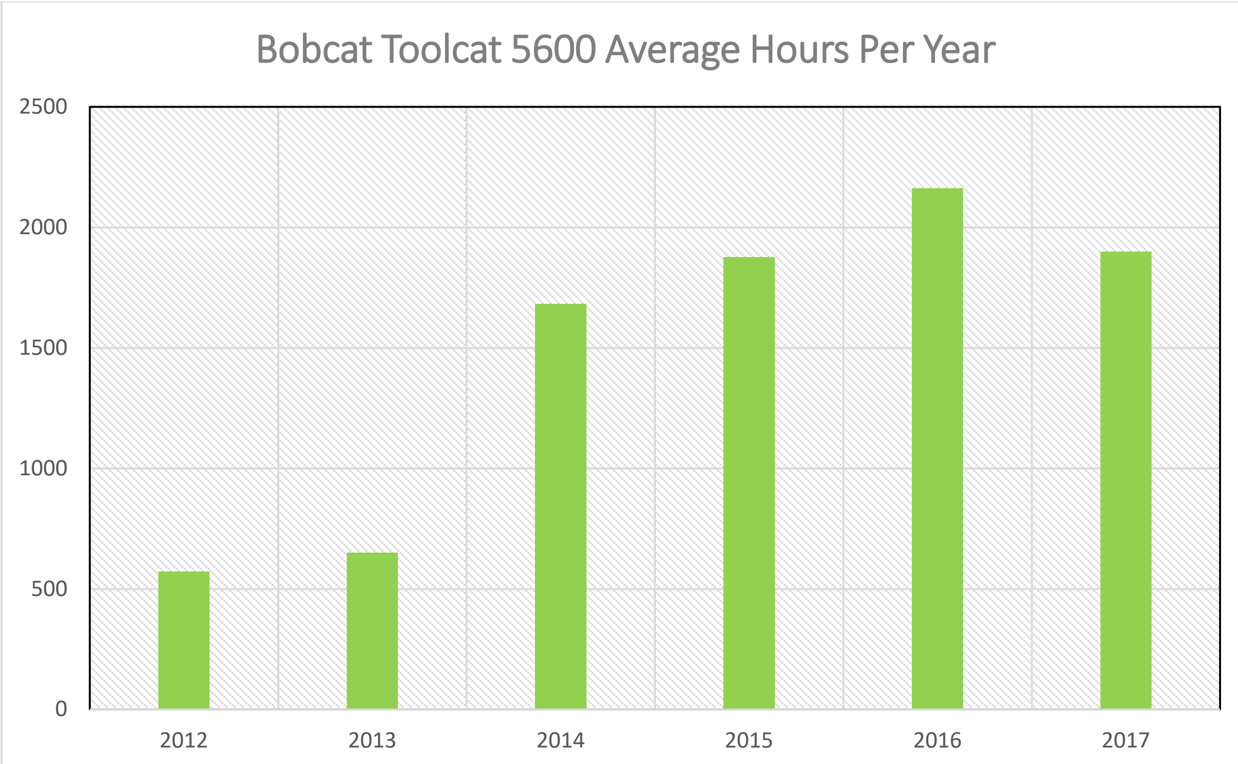

Figure 3: Bobcat Toolcat 5600 Average Hours Per Year

The amount of hours on the machine seems to correlate with the yearly maintenance cost for the vehicle. It would be advantageous for budget projections to know when the vehicle will need more maintenance and if it should be sold before these heavier costs are incurred. Figure 4 shows that the year Toolcat #11902 reached 2,500 hours of usage, maintenance costs spiked up to almost $12,000. This was also true for the other two Bobcat Toolcat 5600's, numbers 13529 and 12490, that have reached this usage milestone, Figures 5 and 6.

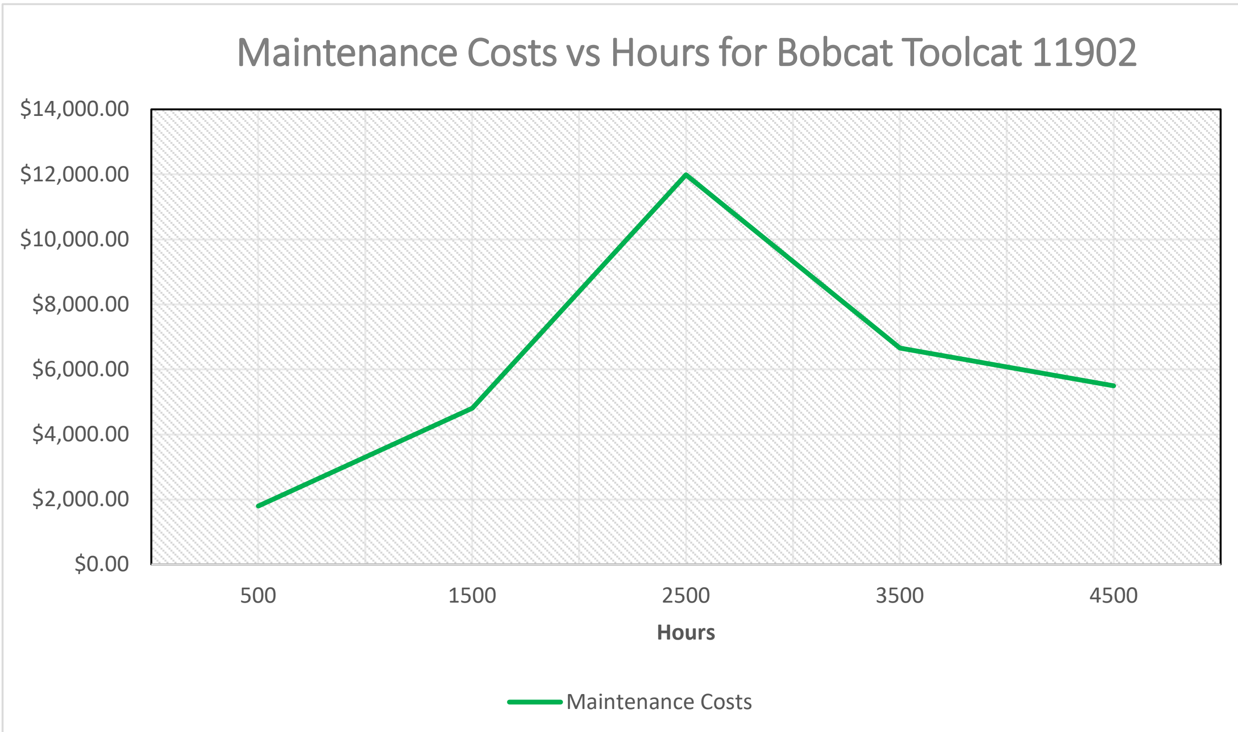

Figure 4: Maintenance Costs vs Hours for Bobcat Toolcat 11902

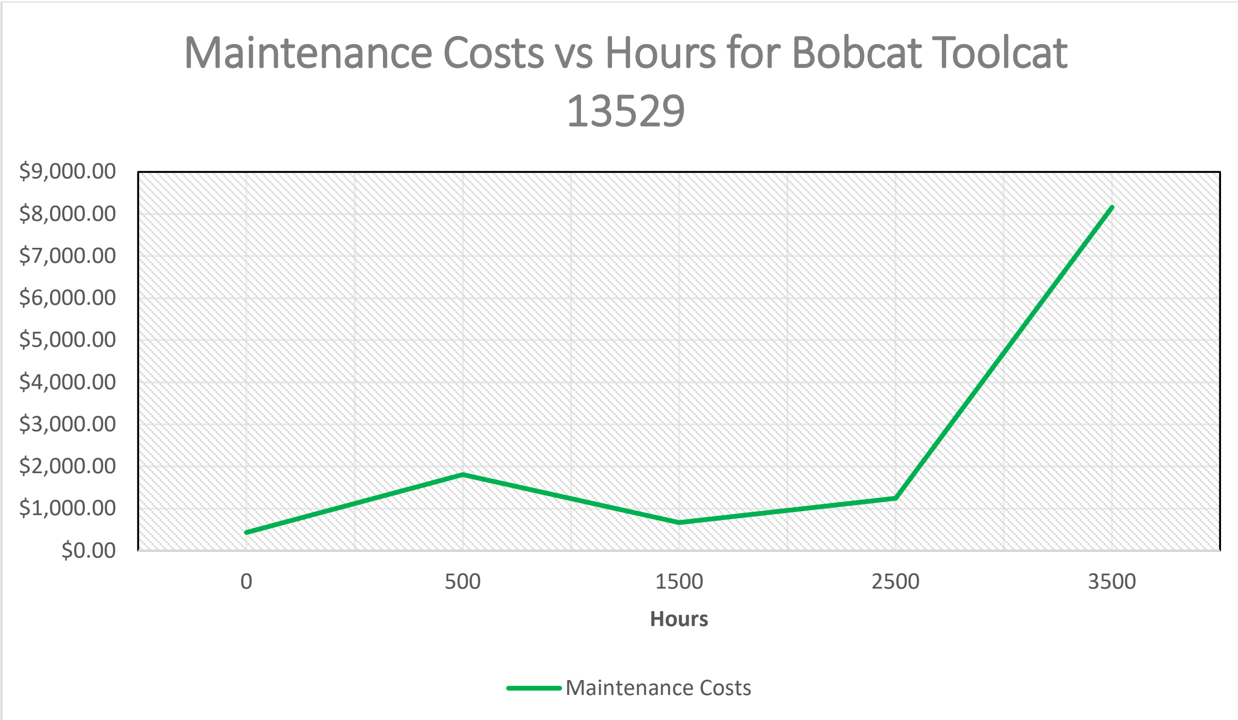

Figure 5: Maintenance Costs vs Hours for Bobcat Toolcat 13529

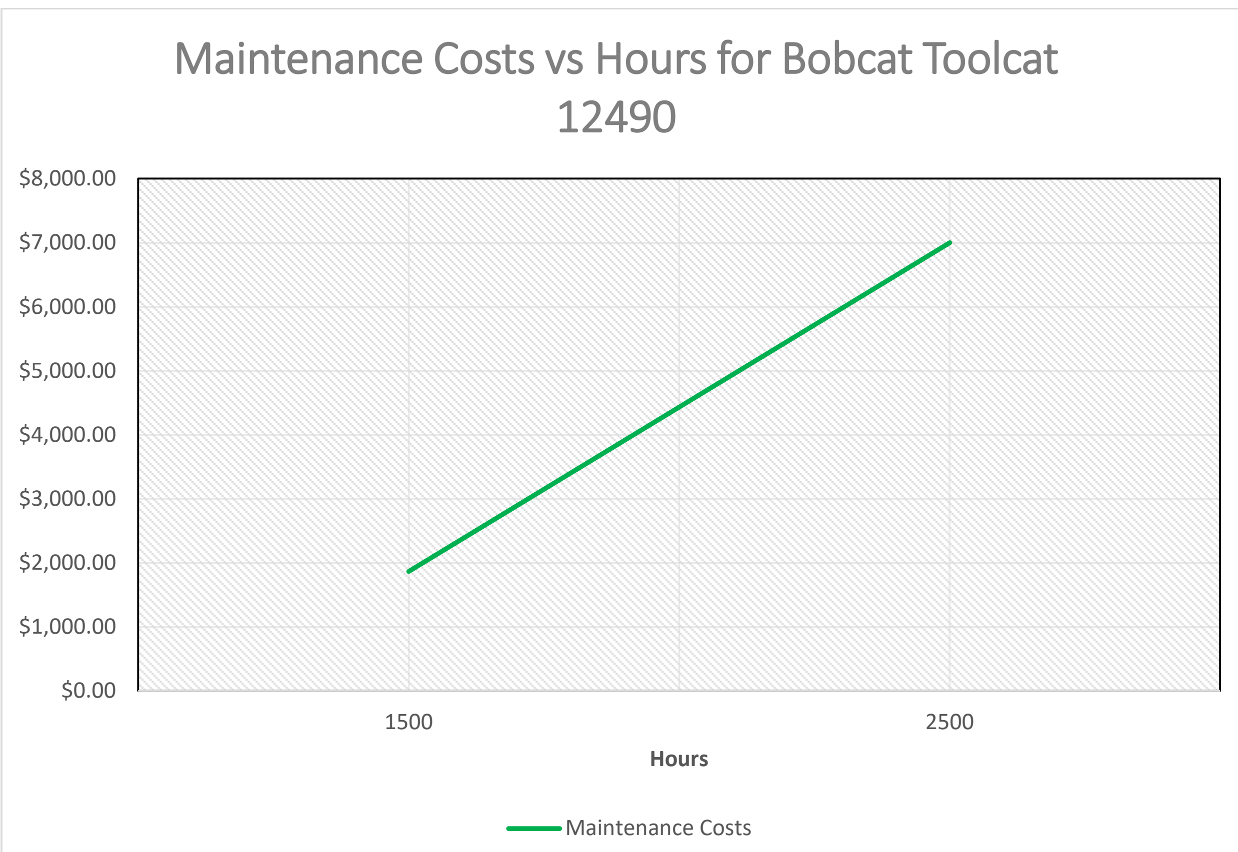

Figure 6: Maintenance Costs vs Hours for Bobcat Toolcat 12490

At 2,500 to 3,000 hours of use, maintenance costs for the year for each vehicle spike from low $1,000's to an average of almost $9,000 for the year. Considering that the average maintenance per year for the 5600's is just over $10,000, Figure 1, the bulk of the maintenance is being driven higher by older vehicles in the fleet.

Time will show if the preventative maintenance plans that are entered for each vehicle will decrease the maintenance costs or move the point at which maintenance costs increase. Over the past five years only 17%, Figure 7, of the work being done on the 5600's is preventative maintenance which is a problem in itself.

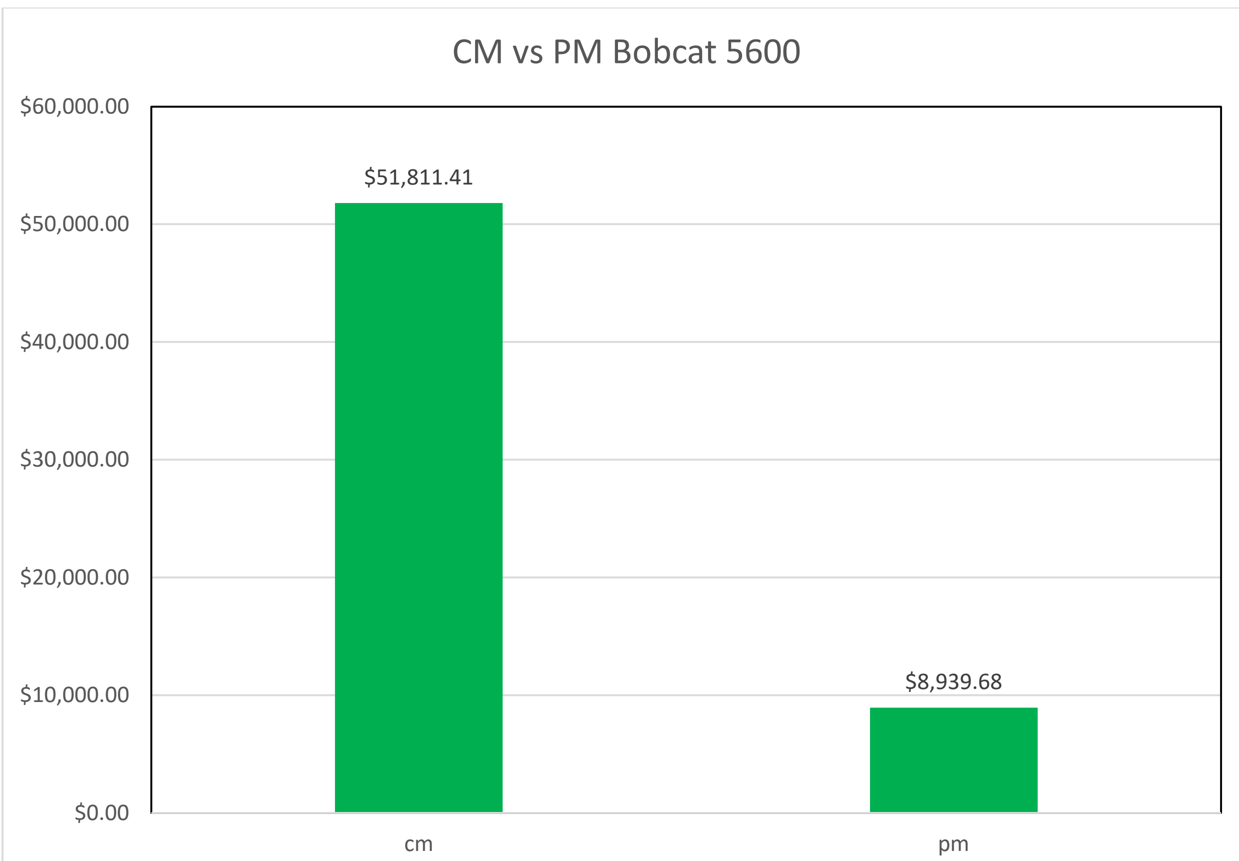

Figure 7: Corrective Maintenance vs Preventative Maintenance for Bobcat Toolcat 5600's 2012-2017

The scheduled maintenance plans from the manufacturer are certainly a good starting point but due to the nature of snow removal and other work on campus, certain areas need to be refined to meet the demands. The maintenance data was checked for any trends that may appear, which could then be highlighted for the preventative maintenance plan. Items were then added or had their frequency adjusted to meet the needs for the facility. The highest rates of failure were for tie-rods, steering cylinders and hydraulic Lines, Figure 8. The manufacturer's maintenance schedule does not have a frequency for checking tie-rods or steering cylinders. These were added to the CMMS preventative maintenance plan.

The Bobcat 3650 is similar in nature to the Bobcat Toolcat 5600 but is much smaller and less powerful. It acts as a transport vehicle and aids in removing snow from small sidewalks and entrances. The two 3650's are used extensively for snow removal on the University of Chicago campus. Again, their high cost, $35,000, is cost prohibitive to allow for redundancy within the fleet. The expectation is that

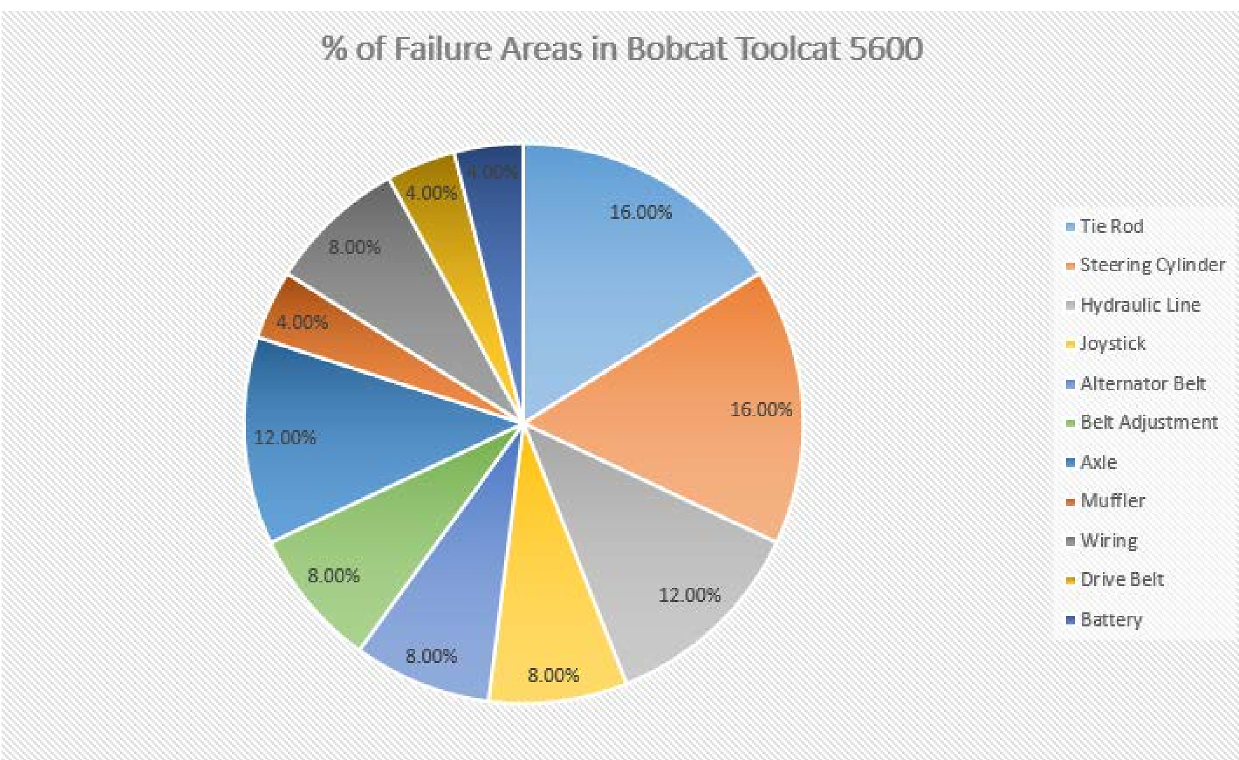

Figure 8: Failure Areas in Bobcat Toolcat 5600

they are always in operation or if they are inoperable, they will not be for long. There is less data for these two units since they are a new style of vehicle and the University of Chicago has only had two units. The yearly maintenance costs for these two vehicles is just under $2,500, which is $1,250 per unit, per year, Figure 9. These costs are half of the Toolcat 5600 but they also are not responsible for as much snow removal and maintenance on campus. There have been no years of heavy snowfall while these two units have been in operation so no conclusion can be drawn between snowfall and their maintenance costs.

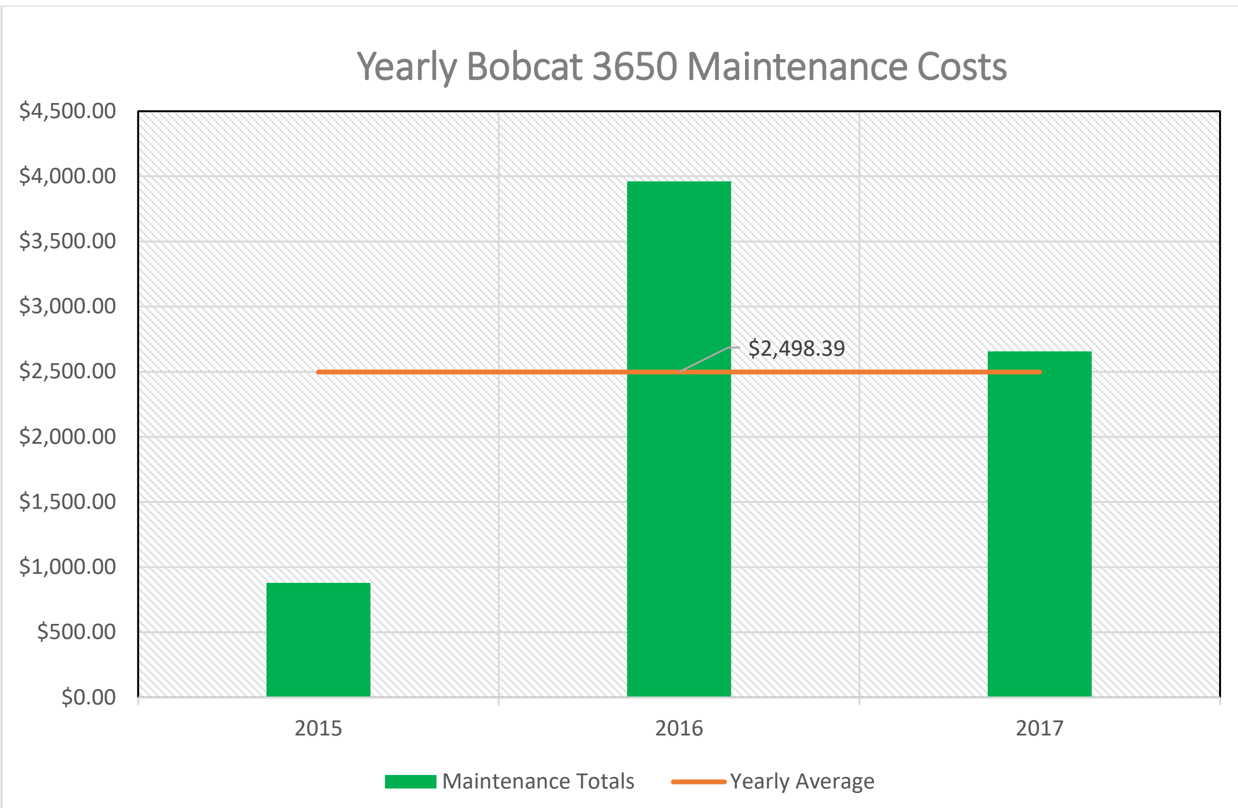

Figure 9: Yearly Bobcat 3650 Maintenance Costs

The average hours on each vehicle per year align with the increased maintenance costs from year to year. As average hours increased from 2015 to 2016, maintenance costs increased and then decreased a bit for 2017, Figure 10. The maintenance costs peaked in 2016 which is when each vehicle reached an average of almost 1,000 hours of usage. When new 3650's are purchased, budget projections will need to reflect the potential for increased maintenance costs when they start approaching this threshold of 1,000 hours.

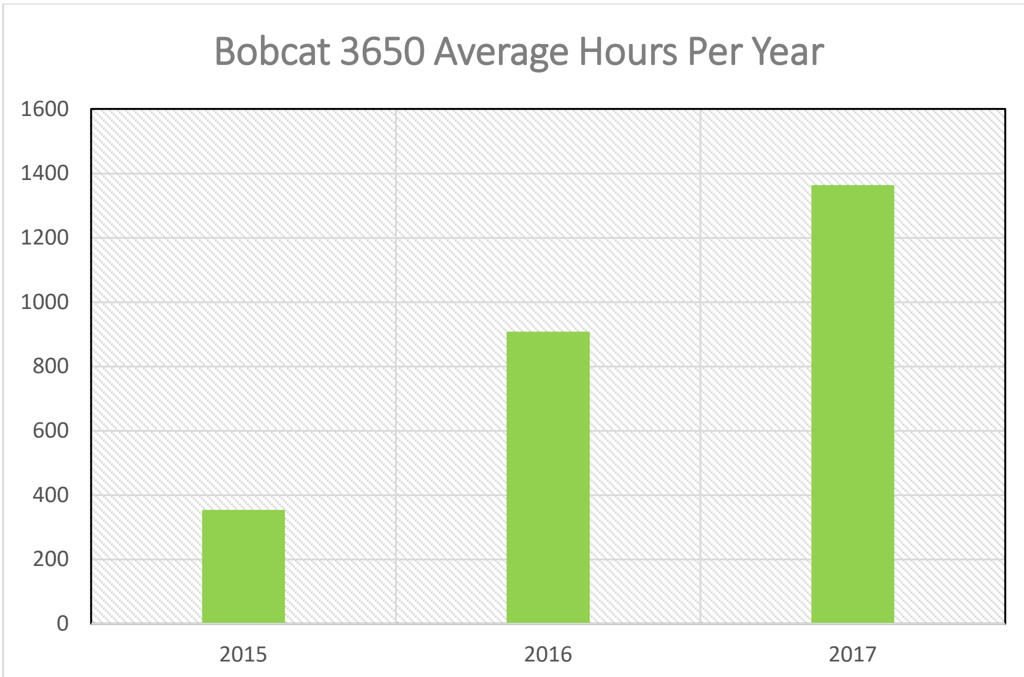

Figure 10: Bobcat 3650 Average Hours Per Year

Frequency of failures is needed for the Bobcat 3650's to be able to make a modified preventative maintenance plan in case areas were failing that were not referenced on manufacturer's maintenance schedule. Figure 11 shows that three areas were the cause of failure for the units, PTO shafts, throttle cables and rear shocks. PTO shaft inspection is listed in the maintenance schedule but at every 100 hours. This was moved to every 50 hours to try to catch failures earlier. There is no reference to throttle cables on the maintenance schedule so there was a task added at every 50 hours to check the throttle cable operation from each point of contact on the machine.

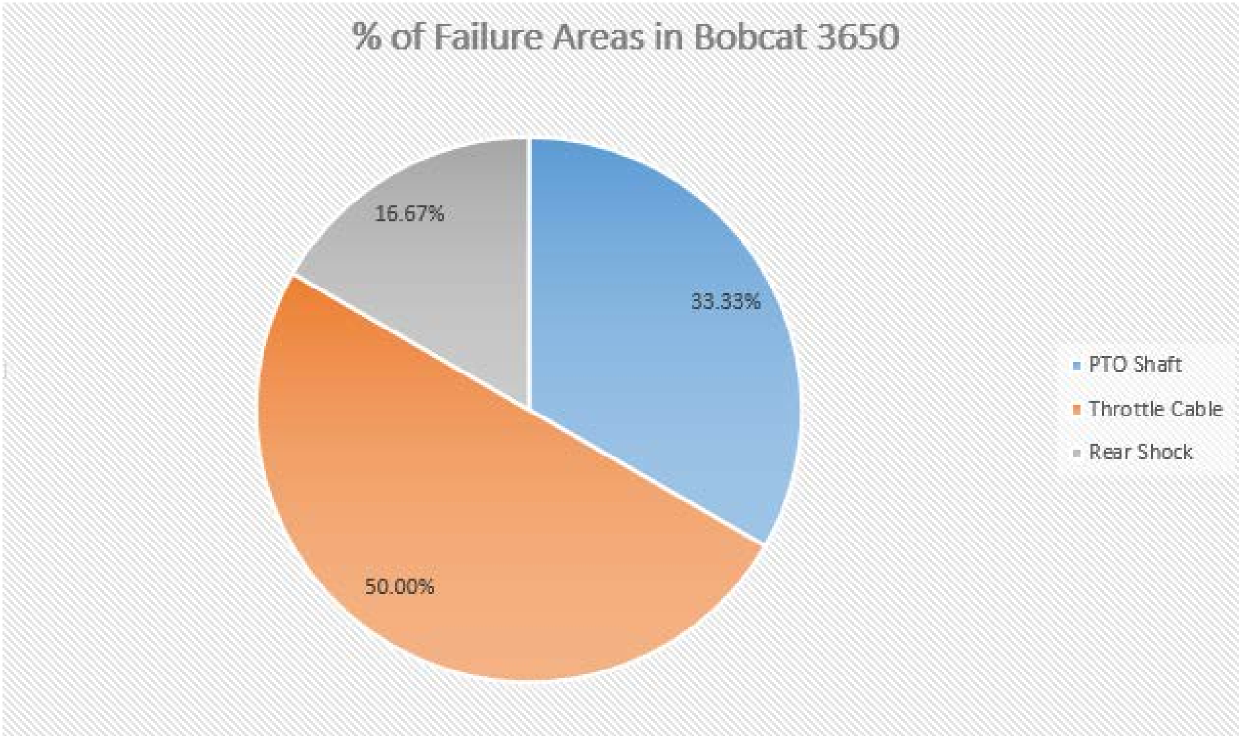

Figure 11: % of Failure Areas in Bobcat 3650

The Bobcat 3650's require half as much yearly maintenance as the Toolcat 5600's. This could be due to use but also it could be due to the increased preventative maintenance completed on these units. A bi-annual preventative maintenance plan was provided from the vendor when these two vehicles were purchased. The costs are still incurred by the University for the maintenance but the vendor schedules and completes the preventative maintenance work. Preventative maintenance accounts for 41% of the maintenance completed on the 3650's, Figure 12, compared to only 17% for the 5600's. The additional preventative maintenance on these vehicles could be the reason for the reduction in maintenance cost which, with additional preventative maintenance scheduled, should continue to trend downwards over time.

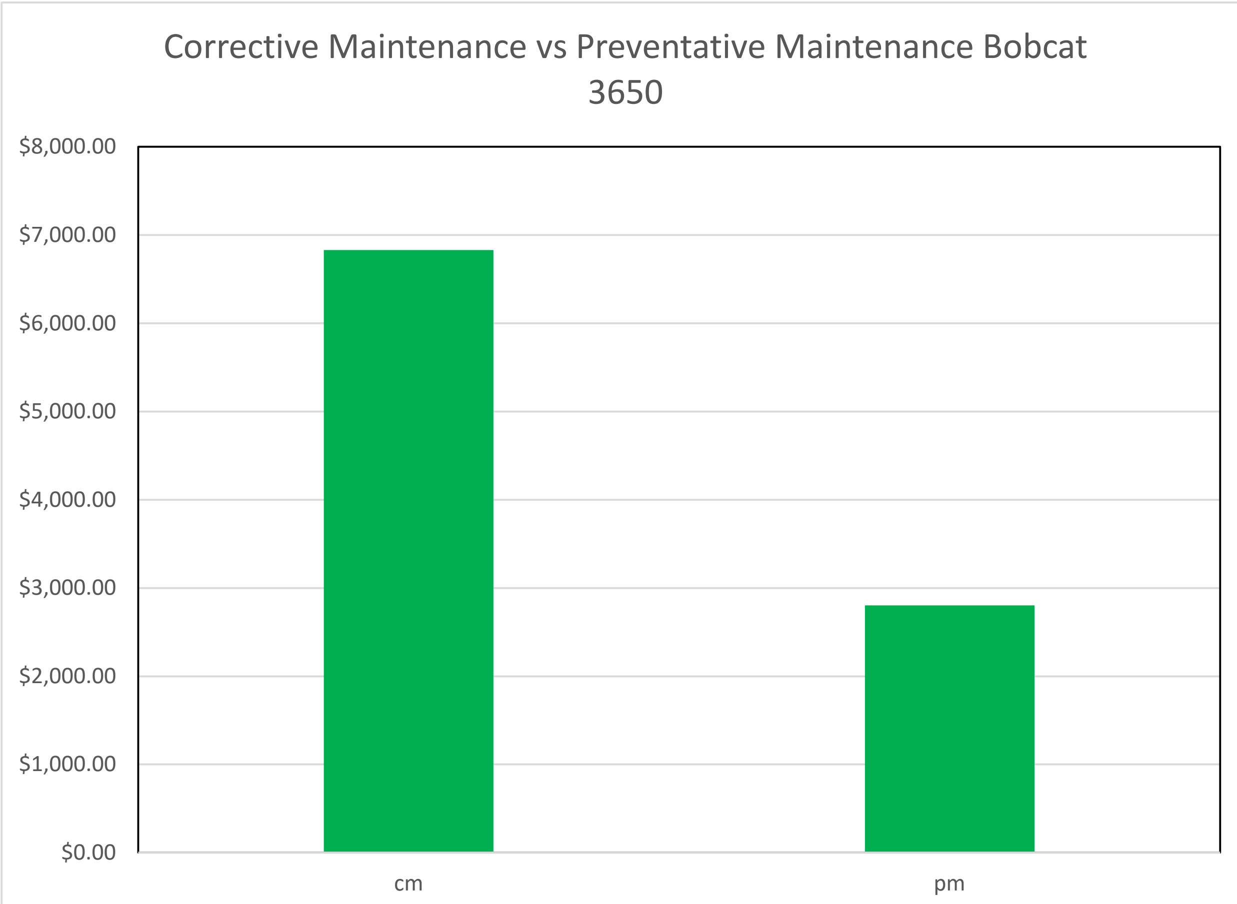

Figure 12: Corrective Maintenance vs Preventative Maintenance on Bobcat 3650

The Kubota RTV1100 is a utility vehicle that is transportation for staff during the summer and a sidewalk salter during the winter. Their use as salters causes extra wear and tear due to the weight of the product and the caustic nature of salt in general. These three vehicles are aging and will need to be replaced at some point. The average yearly maintenance costs for these three vehicles is just over $5,600 which is $1,867 per unit, per year, Figure 13. The yearly costs for these vehicles is skewed due to very above average maintenance costs in 2016 and 2017 which could be due to environmental conditions or possible the hourly threshold for maintenance on the vehicles.

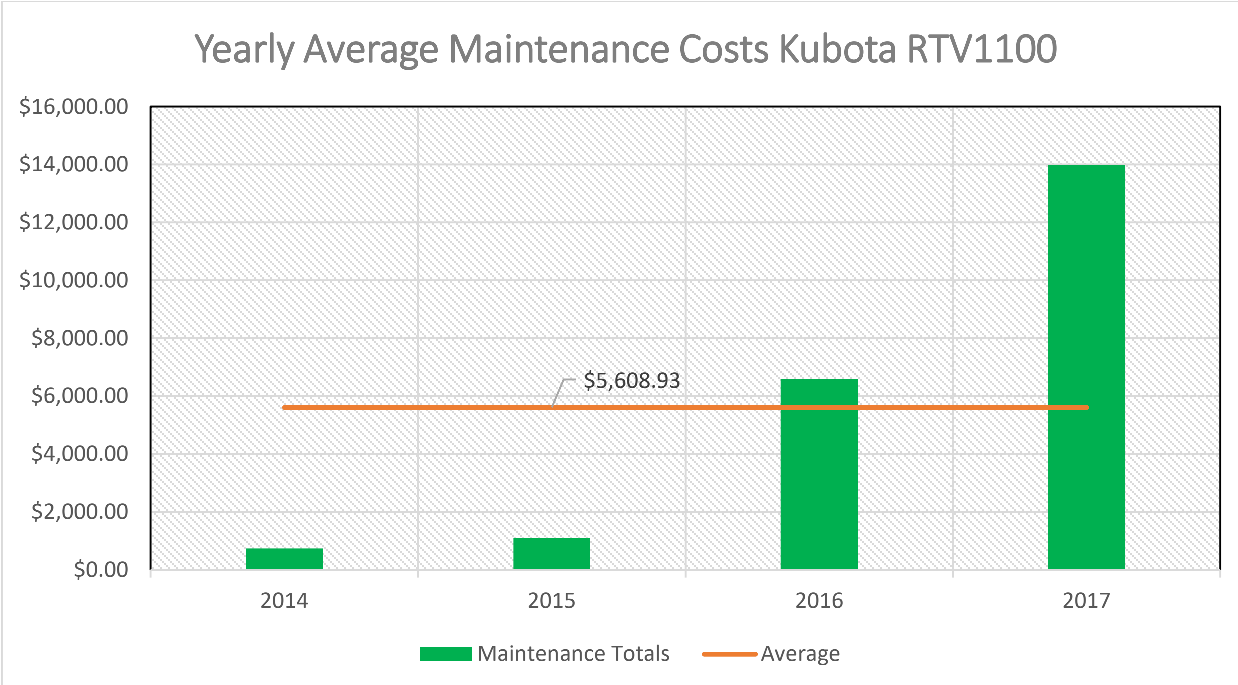

Figure 13: Yearly Average Maintenance Costs Kubota RTV1100

From 2015 into 2016, the average amount of hours on each vehicle rose from just over 1,000 to just over 2,000 hours of use, Figure 14. Maintenance for 2016 more than tripled in that same time period which makes the timeframe between 1,000 and 2,000 hours of use an important one. The decision will need to be made to keep these vehicles and incur increased maintenance costs or sell them and buy new units. Either way, the inclusion of usage tracking by hour in the preventative maintenance plan allows for cost projections to be made in anticipation of these costs.

There is no documented preventative maintenance for the Kubota RTV1100's so no conclusions can be made about whether that would have helped maintenance costs. The creation of a preventative maintenance plan for these vehicles will show if costs were decreased due to the plan.

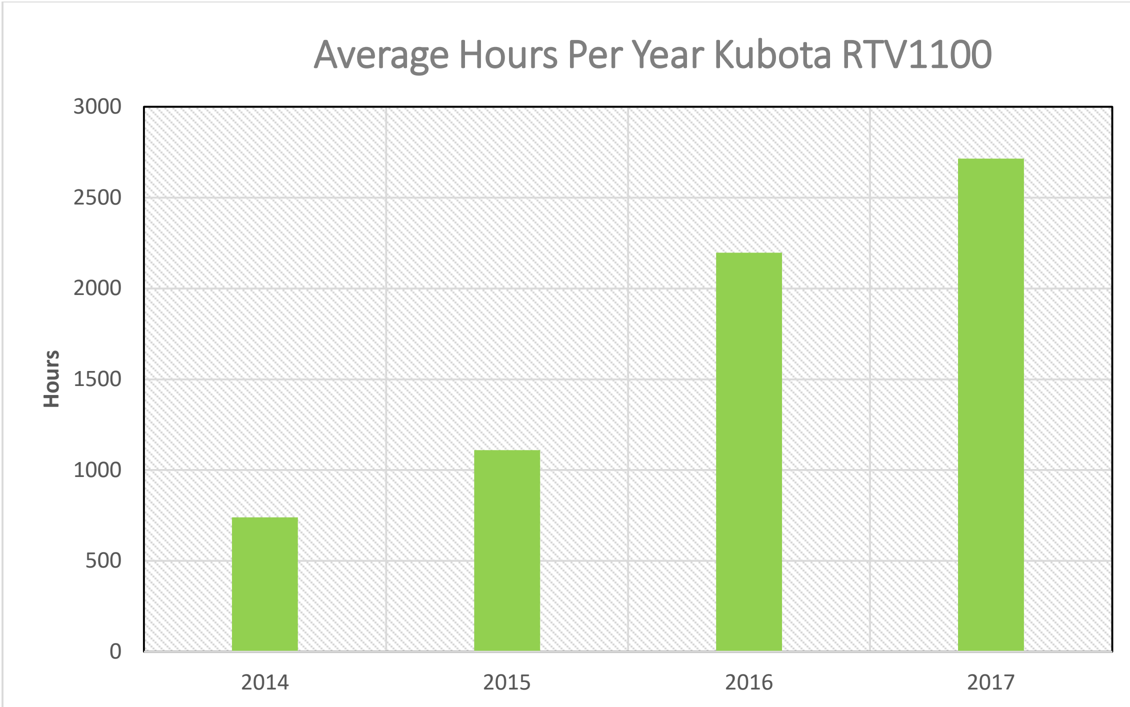

Figure 14: Average Hours Kubota RTV1100

Conclusion

There were no true preventative maintenance plans for any of the vehicles in this study. The entering of basic asset information into the CMMS was the first step in building the maintenance backbone for these assets. Using scheduled maintenance plans from the original manufacturer, preventative maintenance plans were created using the CMMS. The primary objective of this study was to determine if the preventative maintenance plans could be made more accurate, allowing for the prediction of future maintenance costs. The ability to predict costs can allow for long-term budgeting which is critical in the current financial climate of higher education.

Historical maintenance data for the ten vehicles in this study was documented and analyzed to determine if there were any trends in regards to age, usage, environmental conditions or area of failure. While the data that was used is not 100% complete, it is accurate enough to allow for trends to be noticed, and recorded. The information from these trends can be documented in the CMMS preventative maintenance plans for each vehicle so that as thresholds are met, or are approaching, the CMMS generates a notice. The trends for each vehicle are as follows:

- Bobcat Toolcat 5600
    - Average maintenance of $2,500 per year
    - Snowfall does not seem to have a major effect on maintenance costs
    - Increased preventative maintenance from 17% could slow the rise in maintenance costs as the vehicle ages
    - Tie-rods and steering cylinders are a major point of failure and should be checked routinely via the preventative maintenance program
    - Hours of use has a major effect on maintenance costs
        - 2,500 hours of use is when major maintenance has historically been occurring

The purchase price for a Bobcat Toolcat 5600 is $66,000 with all fees. The average maintenance per year for the lifetime of a 5600 is $2,500 but the bulk of this maintenance takes place after 2,500 hours. As shown in Figure 15, average maintenance costs climb from below $2,000 per year at 500 hours to just over $3,000 at 2,500 hours. Once the vehicles progress past 2,500 hours of use, maintenance costs climb to over double, on average. The resale value for a Toolcat 5600 with 2,500 hours of use is $15,000, decreasing to $10,000 after 3,000 hours and $8,000 at 3,500 hours of use. The University of Chicago puts about 700 hours of use on a

Toolcat 5600 per year which would make 3.5 years the time at which the vehicle reaches 2,500 hours of use.

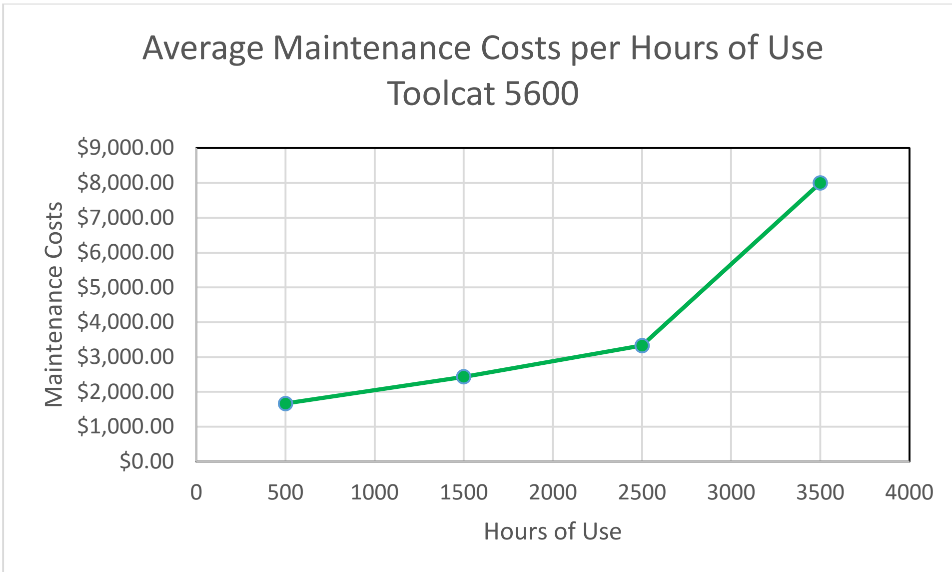

Figure 15 Average Maintenance Costs per Hours of Use

Budget requests should be made under the assumption that Toolcat 5600's will need to be traded in every 3.5 years. If these vehicles are not traded in at that time, additional maintenance costs will be incurred. If the vehicles were to be kept until 3,500 hours rather than selling at 2,500 hours, there would be an additional $14,000 in maintenance over the 1,000 hours of use. Along with the maintenance costs would be a decrease in the resale value by $7,000. Figure 16, a simplified life cycle calculation that excludes depreciation and fuel consumption, shows that the difference in costs from selling at 2,500 hours compared to 3,500 hours is just over $21,000. This data can be used as a base for budget justifications for the

Vehicle	Purchase Price	Maintenance Costs	Resale Price	Total Cost ((Purchase Price + Maintenance Costs)-Resale Price)
Bobcat Toolcat 5600 Sold at 2,500 Hours	$66,000.00	$7,400.00	$15,000.00	$58,400.00
Bobcat Toolcat 5600 Sold at 3,500 Hours	$66,000.00	$21,433.00	$8,000.00	$79,433.00

Figure 16 Maintenance and Resale Costs for Toolcat 5600

purchase of new Toolcat 5600’s.

- Bobcat 3650
    - Average Maintenance cost is $1,250 per year
    - Throttle cables and PTO shafts are a major point of failure and should be checked routinely via the preventative maintenance program
    - Hours of use has a major effect on maintenance costs
        - 1,000 hours of use is when major maintenance has historically been occurring

The Bobcat 3650 is a newer piece of equipment that does not have a large amount of maintenance data or resale data. Once there is more data, conclusions can be made in regards to when to trade in vehicles and purchase new.

- Kubota RTV1100
    - Average Maintenance cost is $1,867 per year
    - Nature of work could be amplifying maintenance costs as the vehicle ages
    - Hours of use has a major effect on maintenance costs
        - Between 1,000 and 2,000 hours of use is when major maintenance has historically been occurring

The purchase price for a Kubota RTV1100 is $22,000. The majority of maintenance on this vehicle takes place after 1,000 hours of use, which is at four years of use since they are currently used for 250 hours a year. As shown in Figure 17, maintenance costs rise from $500 at 500 hours of use to $4,500 at 2,000 hours of use. The resale price for a Kubota RTV1100 is $2,000 at 1,500 hours of use and $1,500 at 2,00 hours of use which is not a huge swing in price. The maintenance costs, however, rise significantly during the same period of use.

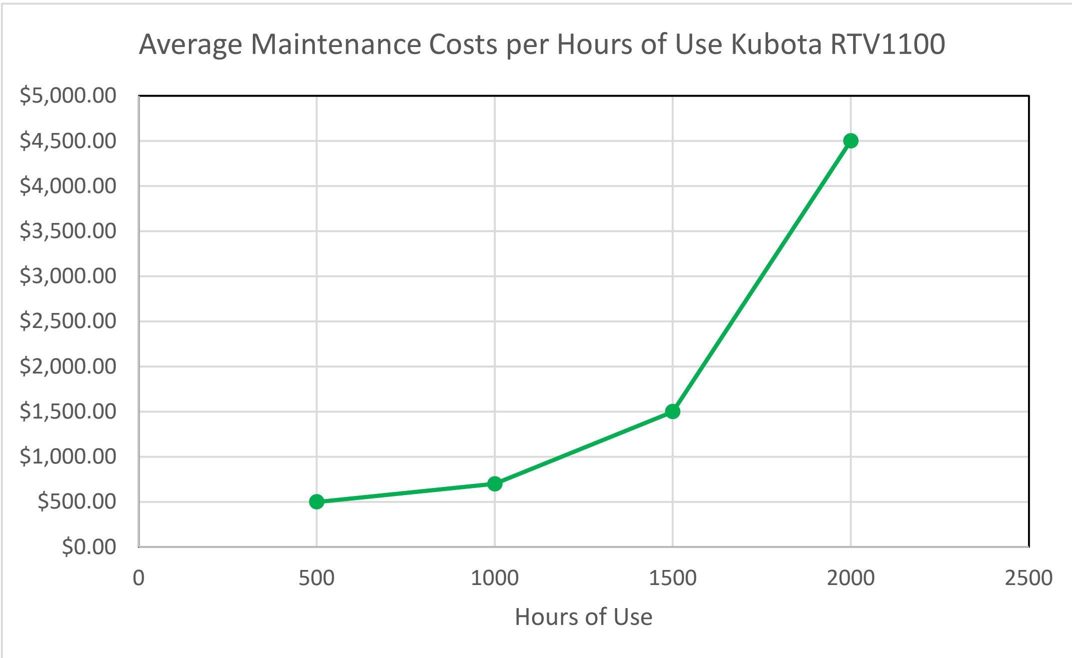

Figure 17: Average Maintenance Costs per Hours of Use Kubota RTV1100

New Kubota RTV1100's should be requested in the budget when they approach six years of use, which is 1500 hours of use, on average. Figure 18 shows the difference in costs when a Kubota would be sold at 2,500 hours instead of 1,500 hours. If three new Kubotas were to be purchased, the cost savings from all three, $15,000, would be enough to offset the maintenance for all three vehicles over their lifespan.

Vehicle	Purchase Price	Maintenance Costs	Resale Price	Total Cost ((Purchase Price + Maintenance Costs)-Resale Price)
Kubota RTV1100 Sold at 1,500 Hours	$ 22,000.00	$ 2,700.00	$ 2,000.00	$ 22,700.00
Kubota RTV1100 Sold at 2,000 Hours	$ 22,000.00	$ 7,200.00	$ 1,500.00	$ 27,700.00

Figure 18 Maintenance and Resale Costs for Kubota RTV1100

With a more robust data set, this project could have identified trends for every vehicle within the facilities portfolio. The data that was found for the snow removal vehicles was good, but there are not complete maintenance records for the entire lifespan of each vehicle. The implementation of the routine work order for maintenance will allow for increased reliable data that will be able to be used for future use.

The trends for each vehicle in this study can be used as a basis for need when it comes time for capital investment. While the trends may change, they can now be more accurately tracked by using the preventative maintenance plan that was implemented using the CMMS. As vehicles, environmental conditions and budgets change, so will the need to change the preventative maintenance approach. The data collected during the lifespan of a vehicle can be used to identify and project financial needs.

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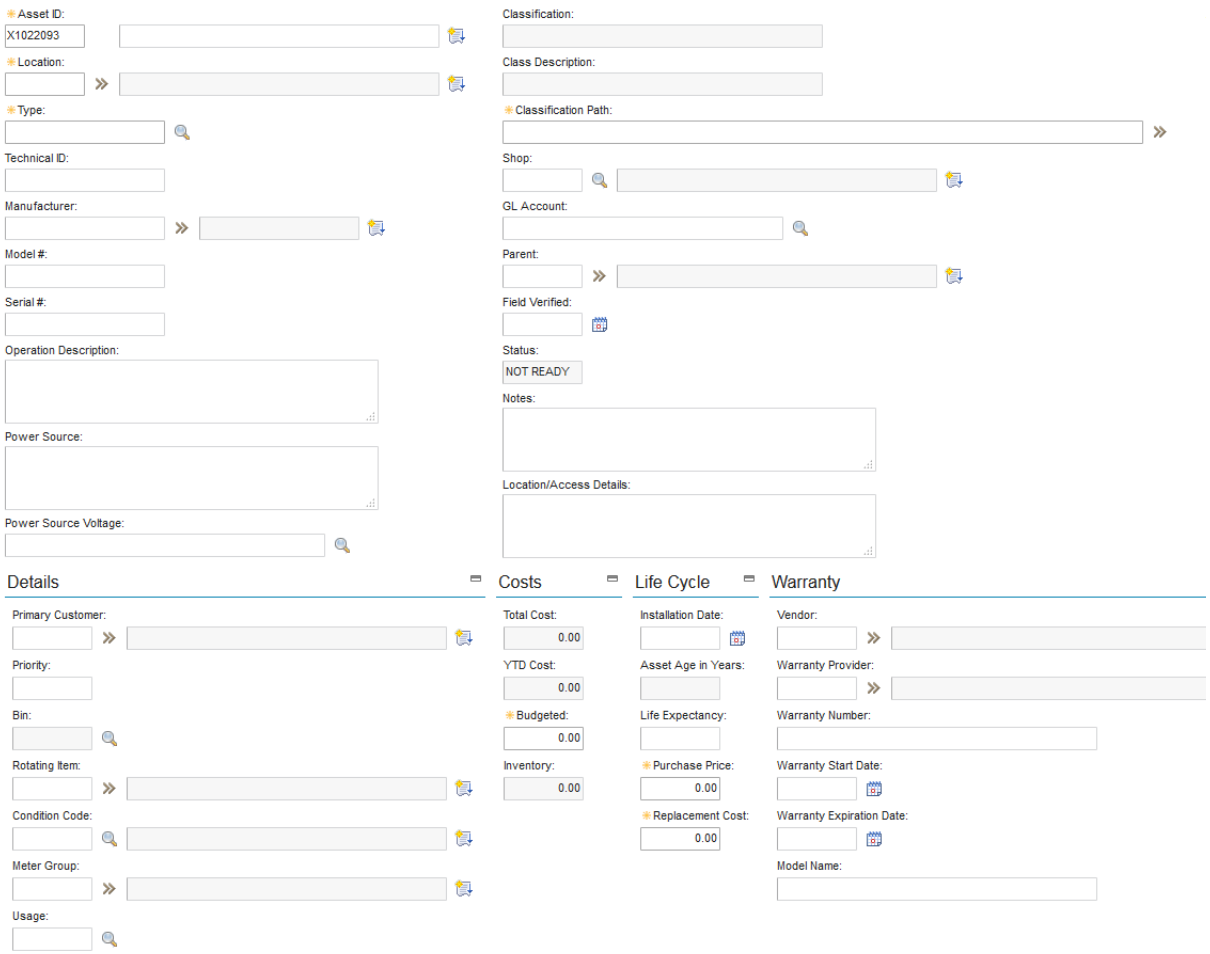
Appendix

Appendix A- CMMS Vehicle Asset Entry Form



Appendix B- Kubota RTV1100 Maintenance Schedule

MAINTENANCE

WARNING

To avoid serious injury, death or vehicle damage:

- **Be sure you have sufficient knowledge, experience, the proper replacement parts and tools before you attempt any vehicle maintenance task.**
- **If you don't have the knowledge and equipment which are necessary to perform the maintenance task, consult your local KUBOTA Dealer.**
- **Have your local KUBOTA Dealer perform inspection items which are marked *6 in the chart below.**

SERVICE INTERVALS

IMPORTANT :

- The jobs indicated by ◎ must be done after the first 50 hours of operation.

*1 The initial 50 hours should not be a replacement cycle.
*2 Air cleaner should be cleaned more often in dusty conditions than in normal conditions.
*3 Every 1000 hours or every 1 year whichever comes faster.
*4 Replace if any deterioration (crack, hardening, scar, or deformation) or damage occurred.
*5 Every 2000 hours or every 2 years whichever comes faster.
*6 Consult your local KUBOTA Dealer for this service.
*7 When the battery is used for less than 100 hours per year, check the battery condition by reading the indicator annually.

- The items listed below (@marked) are registered as emission related critical parts by KUBOTA in the U.S.EPA non road emission regulation. As the engine owner, you are responsible for the performance of the required maintenance on the engine according to the below instruction. Please see Warranty Statement in detail.

No.	Items		Indication of Hour Meter														After 700 hrs	Ref. Page		
			50	100	150	200	250	300	350	400	450	500	550	600	650	700				
1	Engine start system	Check	○	○	○	○	○	○	○	○	○	○	○	○	○	○	every 50 hrs	60		
2	Greasing	Apply	○	○	○	○	○	○	○	○	○	○	○	○	○	○	every 50 hrs	59		
3	Muffler [Spark arrester]	Clean		○		○		○		○		○		○		○	every 100 hrs	67		
4	Wheel fastener torque	Check	◎	○		○		○		○		○		○		○	every 100 hrs	62	*1	
5	Battery condition	Check		○		○		○		○		○		○		○	every 100 hrs	64	*7	
6	Alternator belt	Adjust		○		○		○		○		○		○		○	every 100 hrs	63		
7	VHT neutral spring	Check		○		○		○		○		○		○		○	every 100 hrs	61	*6	
8	VHT pressure release	Check		○		○		○		○		○		○		○	every 100 hrs	61	*6	
9	Toe-in	Adjust		○		○		○		○		○		○		○	every 100 hrs	66		
10	Fuel filter element	Check		○		○		○		○		○		○		○	every 100 hrs	63		@
		Replace								○							every 400 hrs	76	*6	

No.	Items		Indication of Hour Meter														After 700 hrs	Ref. Page		
			50	100	150	200	250	300	350	400	450	500	550	600	650	700				
11	Air cleaner element	Clean		○		○		○		○		○		○		○	every 100 hrs	62	*2	@
		Replace															every 1000 hrs or 1 year	76	*3	
12	Engine oil filter	Replace	◎			○				○				○			every 200 hrs	69	*1	
13	Engine oil	Change	◎			○				○				○			every 200 hrs	69	*1	
14	Transmission oil filter (VHT) (Yellow color)	Replace	◎			○				○				○			every 200 hrs	70	*1	
15	Transmission oil filter (Suction) (Black color)	Replace	◎			○				○				○			every 200 hrs	71	*1	
16	Brake pedal	Check	◎			○				○				○			every 200 hrs	72	*1 *6	
17	Parking brake	Adjust	◎			○				○				○			every 200 hrs	68	*1	
18	Brake light switch	Check	◎			○				○				○			every 200 hrs	73	*1	
19	Front brake case	Check	◎			○				○				○			every 200 hrs	73	*1	
20	Hydraulic tank oil	Change				○				○				○			every 200 hrs	71		
21	Tire wear	Check	◎					○						○			every 300 hrs	74	*1	
22	Transmission fluid	Change								○							every 400 hrs	75		
23	Front axle case oil	Change								○							every 400 hrs	76		
24	Front knuckle case oil	Change								○							every 400 hrs	74		
25	Engine valve clearance	Adjust															every 800 hrs	76	*6	
26	Fuel injection nozzle Injection pressure	Check															every 1500 hrs	76	*6	@
27	Cooling system	Flush															every 2000 hrs or 2 years	76	*5	
28	Coolant	Change															every 2000 hrs or 2 years	76	*5	
29	Injection pump	Check															every 3000 hrs	78	*6	@
30	Fuel line	Check															every 1 year	78	*4	@
		Replace															every 4 years	82		

No.	Items		Indication of Hour Meter														After 700 hrs	Ref. Page		
			50	100	150	200	250	300	350	400	450	500	550	600	650	700				
31	Hydraulic oil line	Check															every 1 year	78	*4	
		Replace															every 4 years	82	*6	
32	Radiator hose, pipe and clamp	Check															every 1 year	79	*4	
		Replace															every 4 years	82	*6	
33	Intake air line	Check															every 1 year	80	*4	@
		Replace															every 4 years	82	*6	
34	Engine breather hose	Check															every 1 year	81	*4	
		Replace															every 4 years	82	*6	
35	Brake hose & pipe	Check															every 1 year	81	*4	
		Replace															every 4 years	82	*6	
36	Brake fluid	Change															every 2 years	82	*6	
37	Brake master cylinder [inner parts]	Replace															every 4 years	82	*6	
38	Rear brake cylinder seal	Replace															every 4 years	82	*6	
39	Front brake seal	Replace															every 4 years	82	*6	
40	Fuel system	Bleed															Service as required	83		
41	Fuse	Replace																83		
42	Light bulb	Replace																85		
43	Hydraulic tank	Check																85		

LUBRICANTS, FUEL AND COOLANT

No.	Locations		Capacity RTV-X900	Capacity RTV-X1120D	Lubricants, fuel and coolant	
1	Fuel		30 L (7.9 U.S.gals.)		No. 2-D diesel fuel No. 1-D diesel fuel if temperature is below -10℃(14℉)	
2	Coolant (with reserve tank)		6.1 L (6.4 U.S.qts.)		Fresh clean water with anti-freeze	
3	Engine crankcase	Filter exchanged	3.1 L (3.3 U.S.qts.)	4.1 L (4.3 U.S.qts.)	● Engine oil: API Service Classification CF or higher	
					Above 25℃(77℉)	SAE30, SAE10W-30 or 15W-40
		Filter non-exchanged	2.7 L (2.9 U.S.qts.)	3.8 L (4.0 U.S.qts.)	0 to 25℃(32 to 77℉)	SAE20, SAE10W-30 or 15W-40
					Below 0℃(32℉)	SAE10W, SAE10W-30
4	Transmission case		7.0 L (1.8 U.S.gals.)		For U.S.A. market: KUBOTA SUPER UDT2 fluid* For Canada market: Premium UDT fluid* For other than the above: KUBOTA UDT or SUPER UDT fluid*	
5	Front axle case		0.6 L (0.6 U.S.qts.)			
6	Front knuckle case		Ref. 0.25 L (0.26 U.S.qts.)			
7	Hydraulic tank oil		18.0 L (19.0 U.S.qts.)			
8	Brake fluid (reservoir and lines)		0.4 L (0.4 U.S.qts.)		KUBOTA DOT3 GENUINE BRAKE FLUID	

Greasing	No. of greasing points	Capacity	Type of grease
Parking brake lever	2	moderate amount	Multipurpose EP2 Grease (NLGI Grade No. 2)
Battery terminal	2		
Cargo lift cylinder pivot	1	Until grease overflows	
Cargo bed pivot	2	moderate amount	
VHT link	2	Until grease overflows	
	1	moderate amount	
Valve lever link	1		
4WD lever link	1		
Range gear shift link	1		
Unload link	1		
Differential lock pedal	2		
Front A-ARM	6	Until grease overflows	
Rear A-ARM	8		
Parking brake link	1	moderate amount	
Hand throttle cable [if equipped]	—		Antirust silicone grease

NOTE :

* The product name of KUBOTA genuine UDT fluid may be different from that in the Operator's Manual depending on countries or territories. Consult your local KUBOTA Dealer for further detail.

Appendix C- Bobcat Toolcat 5600 Maintenance Schedule

⚠ WARNING

Instructions are necessary before operating or servicing machine. Read and understand the Operation & Maintenance Manual, Operator's Handbook and signs (decals) on machine. Follow warnings and instructions in the manuals when making repairs, adjustments or servicing. Check for correct function after adjustments, repairs or service. Untrained operators and failure to follow instructions can cause injury or death.

W-2003-0807

SERVICE SCHEDULE		HOURS					
ITEM	**SERVICE REQUIRED**	**8-10**	**50**	**100**	**[7] 250**	**[7] 500**	**[7] 1000**
Engine Oil	Check the oil level and add as needed. Do not overfill.						
Hydraulic Fluid	Check level and add as needed.						
Engine Air Filter and Air System	Check condition indicator or display. Service only when required. Check for leaks and damaged components. Do not use compressed air to clean elements.						
Engine Cooling System	Clean debris from oil cooler and radiator. Check coolant level cold, add premixed coolant as needed.						
Seat Belt, Toolcat™ Interlock Control System (TICS™) (operator's arm rest)	Check the condition of seat belts. Check for correct operation of the TICS™. Clean dirt and debris from moving parts.						
Lift Arm, Cylinders, Bob-Tach, Pivot Pins and Wedges	Lubricate with multi-purpose lithium based grease. Check Bob-Tach for proper function.						
Tires	Check for damaged tires and correct air pressure. Inflate tires to MAXIMUM pressure shown on the sidewall.						
Safety Signs and Safety Treads	Check for damaged signs (decals) and safety treads. Replace any signs or safety treads that are damaged or worn.						
Operator Cab	Check the condition of the cab.						
Indicators and Lights	Check for correct operation of all indicators and lights.						
Fuel Filter	Remove the trapped water.						
Heater / Air Conditioning Filter (If Equipped)	Clean or replace filter as needed during heating and cooling seasons.						
Parking Brake	Check function.						
Wheel Nuts	Check for loose wheel nuts and tighten to correct torque. See TIRE MAINTENANCE in this Manual.	[1]					
Hydraulic Fluid, Hoses and Tubelines	Check fluid level and add as needed. Check for damage and leaks. Repair or replace as needed.						
Spark Arrestor Muffler	Empty Spark Chamber.						
Battery	Check cables, connections and electrolyte level. Add distilled water as needed.						
Transaxle Lubricant	Check lubricant level; add as needed.						
Fuel Filter	Replace filter element.						
Alternator, A/C Belt	Check for damage and correct tension. Adjust or replace as needed.						
Engine Oil and Filter	Replace oil and filter. Use CF / CG4 or better grade oil and Bobcat filter.		[2]				
Engine / Hydrostatic Belt	Check for wear or damage. Check idler arm stop.		[4]				
Hydraulic / Hydrostatic Filter	Replace the filter element.		[3]				
Hydraulic Reservoir Breather Cap	Replace the reservoir breather cap.						
Engine Valves	Adjust the engine valves. See your Bobcat dealer for this service.						
Hydraulic Reservoir	Replace the fluid.			[5]			
Transaxle Lubricant	Replace the lubricant.				[6]		
Coolant	Replace the coolant	Every 2 years					

[1] Check every 8-10 hours for the first 24 hours; then as scheduled.
[2] First oil and filter change must occur at 50 hours; then as scheduled.
[3] Replace the hydraulic / hydrostatic filter element after the first 50 hours; and thereafter when the transmission warning light comes ON while operating or as scheduled.
[4] Check belt tension at the first 50 hours; then as scheduled.
[5] Replace the hydraulic / hydrostatic fluid after the first 100 hours; then as scheduled.
[6] First transaxle lubricant change must occur at 300 hours; then as scheduled.
[7] Or every 12 months.

Appendix D- Bobcat 3650 Maintenance Schedule

SERVICE SCHEDULE

Maintenance Intervals

Maintenance work must be done at regular intervals. Failure to do so will result in excessive wear and early failures.

The service schedule is a guide for correct maintenance of the Bobcat product.

WARNING

AVOID INJURY OR DEATH

Instructions are necessary before operating or servicing machine. Read and understand the Operation & Maintenance Manual, Operator's Handbook and signs (decals) on machine. Follow warnings and instructions in the manuals when making repairs, adjustments or servicing. Check for correct function after adjustments, repairs or service. Untrained operators and failure to follow instructions can cause injury or death.

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Daily (Before Starting The Utility Vehicle)

- **Engine Oil** - Check level and add as needed. (NOTE: The engine oil should be checked cold or allow time for the oil to drain back into the pan before checking.) (See NOTE [2])
- **Hydraulic Fluid** - Check level and add as needed. (See NOTE [2])
- **Brake Fluid** - Check level and add as needed. (See NOTE [2])
- **Fuel** - Check level and add as needed.
- **Cooling System** - Inspect oil cooler, radiator, Air Conditioning Condenser (if equipped). Inspect oil cooler, radiator, air condition condenser (if equipped) and grilles for debris. Remove debris if needed. Check coolant level COLD and add premixed coolant as needed. (See NOTE [2])
- **Brake System and Pedal Travel -** Insure proper operation. (See NOTE [2])
- **Engine Speed Control Lever** - Insure proper operation.
- **Travel Control Pedal** - Insure proper operation.
- **Tires** - Check for wear, damage and correct tire pressure. (See NOTE [2])
- **ROPS / OPS and Seat Belt** - Check the condition of the ROPS / OPS and mounting hardware. Check the condition of seat belts. Clean or replace seat belt retractors as needed.
- **Front and Rear Suspension and Steering** - Inspect for broken parts, loose hardware and free operation. (See NOTE [2])
- **Safety Signs (Decals)** - Check for damaged or missing signs (decals). Replace any signs that are damaged or missing.
- **Frame Fasteners** - Inspect and ensure tightness.
- **Head Lights, Tail Lights, Indicator Lights and Switches** - Check for proper operation and apply dielectric grease when a lamp is replaced.
- **Wheel Nuts** - Check for loose wheel nuts and tighten to correct torque. See TIRE MAINTENANCE in this Manual. (See NOTE [4])
- **Engine Air Filter and Prefilter Screen** - Inspect, clean screen and replace filter as needed. Check for leaks and damaged components. (See NOTE [2])
- **PTO (if equipped)** - Inspect the splines, guards, shields and mounting hardware. Tighten loose hardware and replace damaged parts.
- **Heater / Air Conditioning Filter (if equipped) -** Clean and replace filter as needed during the heating and cooling seasons. (See NOTE 2)

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SERVICE SCHEDULE (CONT'D)

Maintenance Intervals (Cont'd)

Every 25 Hours

- **Battery** - Check cables, connections, clean and test.
- **Attachment Interface Mounting Hardware** - Check or adjust after the first 25 hours of operation; then as scheduled.
- **Front Differential Lubricant** - Service at first 25 hours, then as scheduled. Check lubricant level; add as needed.
- **Transmission Lubricant** - Service at first 25 hours, then as scheduled. Check lubricant level; add as needed.

Every 50 Hours

- **Engine Oil and Filter** - Service at first 50 hours, then as scheduled. Replace oil and filter. See SPECIFICATION section for proper oil requirements. (See NOTE [2])
- **Fuel Filter** - Remove trapped water. Poor fuel quality may require more frequent draining.
- **Prop Shaft Yoke, Steering and Suspension Components** - Locate the fitting(s) and grease. (See NOTE [2])
- **Air Intake System** - Inspect all air intake lines for leaks and repair or replace components as necessary. Drain water drain valve.
- **Alternator / Fan / Water Pump Belt** - Service at first 50 hours, then as scheduled. Check belt tension and adjust or replace as needed.
- **Air Conditioning Belt (if equipped)** - Check belt tension and adjust or replace as needed.
- **Hydraulic Fluid, Filter and Breather Cap** - Perform first service at 50 hours; then as scheduled. (Change hydraulic filter only; fluid change not required at initial change.)

Every 100 Hours

- **Engine Oil and Filter** - Replace oil and filter. See SPECIFICATION section for proper oil requirements. (See NOTE [2])
- **Attachment Interface Mounting Hardware** - Retorque the two lower bolts to 129 N•m (95 ft-lb).
- **Travel Direction Control And Engine Speed Control System** - Ensure proper operation and adjust as necessary.
- **Brake Pad Wear** - Inspect. Replace if necessary. (See NOTE [2])
- **Shift Linkage** - Inspect, lubricate and adjust.
- **Front Differential Lubricant** - Check lubricant level; add as needed. (See NOTE [1 and 2])
- **Transmission Lubricant** - Check lubricant level; add as needed. (See NOTE [1 and 2])
- **Fuel System** - Check for leaks at tank cap, lines and fuel pump. (See NOTE [3])
- **Radiator** - Check for leaks and clean external surfaces. (See NOTE [2])
- **Cooling Hoses, Engine Mounts, Exhaust Pipe, Muffler and Hydraulic Hoses** - Inspect for damage or leaks (if applicable). Replace components if necessary. (See NOTE [3])
- **Wiring** - Inspect for wear and routing. Apply dielectric grease to connectors subjected to water, mud, etc.
- **Front and Rear Suspension and Steering** - Inspect for steering freeplay and suspension wear. Replace components as necessary. (See NOTE [2])
- **Front Wheel Bearings** - Inspect. Replace as needed.
- **PTO Gearbox** - Inspect for leaks.
- **Alternator / Fan / Water Pump Belt** - Check belt tension and adjust or replace as needed.
- **Air Conditioning Belt (if equipped)** - Check belt tension and adjust or replace as needed.

Every 150 Hours

- **Engine Air Filter** - Replace filter element.
- **Fuel Filter** - Replace filter element.

Every 200 Hours

- **PTO Belt (if equipped)** – Inspect belt. Replace as needed.
- **Toe Adjust** – Inspect front axle toe adjustment. Adjust if necessary and when parts are replaced. (See NOTE [2])
- **Brake Fluid** - Replace the fluid. (Change every 200 hours or two years, whichever comes first)

SERVICE SCHEDULE (CONT'D)

Maintenance Intervals (Cont'd)

Every 400 Hours

- **Hydraulic Fluid, Filter and Breather Cap** - Replace the fluid and filter.
- **PTO Gearbox Lubricant** - Replace the fluid.
- **PTO Shaft Universal Joints** - Inspect for wear. Replace as needed.
- **PTO Clutch Brake** - Adjust tension.

Every 12 Months

- **Cooling System** - Test coolant strength and pressure test system.
- **PTO Gearbox Lubricant** - Replace the fluid.
- **PTO Shaft Universal Joints** - Inspect for wear. Replace as needed.
- **PTO Clutch Brake** - Adjust tension.

Every 24 Months

- **Coolant** - Replace the coolant.

Every 300 Hours or 36 Months

- **Spark Arrestor Muffler** - Empty the spark chamber.

Every 1000 Hours

- **Engine Valves** - Adjust engine valves. See your Bobcat dealer for service.

Every 1500 Hours

- **Engine Breather System** - Inspect the cranckcase breather system. See your Bobcat dealer for service.

[1] Change yearly.
[2] Perform these procedures more often for vehicles subject to severe use.
[3] Replace lines every two years.
[4] The wheel nuts must be checked and torqued after the first eight hours of operation of a new machine and after the first eight hours of operation when the wheel(s) have been removed for service.

Appendix E- CMMS Preventative Maintenance Plan Template