EFFICIENCY OF COMBINE USAGE: A STUDY OF COMBINE DATA COMPARING OPERATORS AND COMBINES TO MAXIMIZE EFFICIENCY

by

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ABSTRACT

Farming is an important industry in the United States. The custom harvesting industry plays a major role in feeding the world. Schemper Harvesting is a family-owned and operated custom harvesting service that employs 20-25 seasonal workers and understanding how to manage a custom harvesting business professionally and efficiently is the key for its success. Today, there is data available through JDLink on John Deere combine performance beginning in year 2012.

The purpose of this study is to examine the usefulness of this JDLink data to assess the efficiency of each of Schemper Harvesting's seven combines, including machine efficiency and different combine operators. The goal is to determine how the data can improve Schemper Harvesting's overall performance.

Statistical methods were used to analyze Schemper Harvesting's performance. The analysis indicated that fuel is a major expense and there are ways Schemper Harvesting can conserve fuel. This information may prove valuable in being able to operate a combine more efficiently and save money on expenses. Overall, the objective is to improve Schemper Harvesting's performance, which results in higher profit without sacrificing quality.

Precision technology is an added expense to the business. Being able to justify this expense with profit is the answer. Fuel, labor and machinery are the biggest inputs in the custom harvesting business. These costs related to production agriculture have increased the demand for precision agriculture to increase efficiency and profitability. In order to compensate for the investment in technology, it has been demonstrated that it pays for itself. Making correct use of precision technology adds to productivity. With experience,

operators improve increasing their overall efficiency. Incentive plans can be utilized through this data. With the availability of data, the costs and benefits of precision technology can be further evaluated.

Five of the seven combines are operated by family members and the other two by non-family employees. This study shows that the performance of the non-family employees was below that of family members. The initial assessment for this difference may be attributed to experience because all the family members have been operating combines for most of their lives. This implies that employing people with excellent performance experience records and/or a need to train non-family employees to help them understand the performance expectations at Schemper Harvesting. The results indicate that tracking operational output performance indicators, such as acreage and volume harvest should be completed so that they may be assessed in concert with the technical indicators such as time and fuel use. The study provides the potential benefits of using John Deere’s JDLink data service providing telematics information for its customers with the latest precision agriculture technologies.

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This thesis is dedicated to Schemper Harvesting. This business is very important in my life and I am very proud of it, always have been and always will be. I love production agriculture and have been blessed above and beyond to get to be a part of something so honest and respected. The opportunity blessed me with learning the value of time and hard work. My Dad (LaVern C. Schemper) gave me the blessed opportunity. Thank you, Dad!

CHAPTER I: INTRODUCTION

Schemper Harvesting (www.schemperharvesting.com) is a fourth-generation family custom harvesting business located in Holdrege, Nebraska. I am a third generation participant in the business, which currently is owned and operated by my Dad, two brothers, an uncle, and employs 20 to 25 seasonal workers. We operate with seven John Deere combines and supporting equipment, including trucks, semis, tractors and grain carts, etc. The combines are all 2013 or later models, making them eligible for participation in the JDLink program operated by John Deere and Company.

JDLink is a telematics system that remotely monitors machines that are enrolled in the program. It provides customers with machine location, utilization (time and fuel), maintenance status, operator alerts, diagnostic trouble codes, and security and machine hours. JDLink technology's value proposition is to reduce machine downtime by anticipating it and initiating corrective actions before such downtimes occur. Although Deere dealerships are struggling to deliver new technologies such as JDLink to customers in a way that brings value to both them as well as the end use customer. JDLink presents an opportunity for firms such as Schemper Harvesting to improve their operations and enhance performance.

JDLink is capable of providing several value added services. The first is machine/fleet utilization – a machine owner is able to monitor single or multiple machine hours including fuel consumption, utilization, engine speed, machine speed, idle time, and location. These are all related to economic aspects of the machine and all influence the economics of ownership. The second added value service is machine monitoring and performance, i.e., monitoring machine "health" and performance on a regular basis can prevent breakdowns, and importantly, stop small problems from becoming worse. Machines running onboard diagnostics are able to generate and upload 1,000 different diagnostic trouble codes and alert both the owner and dealership. The third added value with JDLink is increased trade-in value. When a machine is ready for trade-in, a full report of exactly how the machine was used and serviced is available. This type of information is a selling point for dealers, resulting in a higher trade-in value for customers. The fourth added value is enhanced machine security. A machine owner will be able to pinpoint the exact location of a machine at any given time. Additionally, a *geofence* can be set around a machine to provide instant notification when the machine is moved outside of this defined area.

1.1 Background and Motivation

I have been around the custom harvesting business my entire life and know that with my education I can add more value to the family business. It is my business to provide the strategic orientation for the family business. I have taken on the management of our participation in JDLink for a couple of reasons: (1) I am curious about how it works and its potential deployment; and (2) I believe that there are yet unknown advantages that the technology could offer that have not been adopted from a management perspective and I want to position myself and our family business to take advantage of these.

The relatively small size of our family business puts us in a position to harvest the benefits of JDLink technology for effective management of our productivity. It could provide our management team with important information about how each of the seven combines are being used and the economic value of each operator based on use. Because participation in the JDLink program is not free, it is important that the data be employed as part of the firm's management information system to develop more effective approaches to doing business, motivating employees, training and investing in supporting equipment. In a dynamic marketplace such as we find ourselves, information and its strategic deployment become critical competitiveness-enhancing tools. Participating in the JDLink program provides an opportunity to enhance the economic effectiveness of our operations as a business. However, achieving this outcome requires understanding the data provided by JDLink and organizing them into information that can be used in managing the business, its equipment and its people as its finances.

1.2 Problem Statement

A critical resource for a custom grain harvesting business are its combines. The seven combines owned by Schemper Harvesting are all enrolled in the JDLink program. This implies that they are remotely connected to diagnostic systems at John Deere that allow for the collection of information that can prevent downtime and improve machine use efficiency. Given the data collected are available to machine owners, the question that emerges is how small businesses such as Schemper Harvesting can use this new source of data to generate management information to improve operational performance and enhance competitiveness. Since many participants in the JDLink program are still developing their appreciation of its value, undertaking these analyses at Schemper Harvesting's could provide innovative strategies that may help our business to improve its market share in some of its markets by improving our overall performance.

1.3 Research Objectives

The primary reason for undertaking this research is to provide evidence-based research-driven management information for Schemper Harvesting. In the end, this research seeks to ensure that Schemper Harvesting will be here beyond the next four generations by positioning the business as one managed by excellent research-based and evidence-driven information.

Specifically, the objectives of this research are as follows:

1. Evaluate the performance of the Schemper Harvesting fleet of combines on a number of technical indicators and compare each machine in the fleet to the fleet average;
2. Develop specific efficiency metrics to assess the performance of each machine in the Schemper Harvesting fleet with the view comparing each machines efficiency metrics against the best in class;
3. Use the foregoing information to develop specific management strategies for the 2014 harvesting season.

1.4 Thesis Outline

In this chapter, we have provided a rationale for undertaking this study and provided the objectives. The next chapter develops a context for the importance of the study, describing the custom harvesting industry, which Schemper Harvesting has been a part of since the beginning. It also provides a survey of the literature on custom harvesting and emerging technologies in agriculture that influence the work of custom harvesters. The third chapter describes the data used in the analyses and the indicators that are of interest in this study. Chapter IV presents the results of the analyses to address the first and second objectives of the study. Chapter V uses the foregoing results to develop specific management strategies that we will deploy in the 2014 harvesting season. It will also identify new information that are currently not collected by JDLink that could be helpful for a business such as ours as well as other sources of data that we at Schemper Harvesting may need to collect on our machines and the operators in order to boost our effectiveness and enhance our overall competitiveness in the business.

CHAPTER II: LITERATURE REVIEW

Farm data collection is becoming popular. However, the objective for collecting these data are unclear to many farmers and others from whom the data are being collected. This has prompted the formation of organizations such as Farmobile (www.farmobile.com) attempting to organize farmers to be financially rewarded for providing data to the companies that are collecting these data from them. Monsanto, for example, is a seed company that is collecting information from farms about the performance of their seeds during planting through harvesting. John Deere and Company is also collecting data about the performance of its equipment from its customers. In fact, Deere's data collection on its machine performance extends beyond agriculture into all the sectors into which it sells machines.

In agriculture and the farm sector, suppliers, such as Monsanto and John Deere, collecting data on their customers is still a very new construct and the implications of which are not completely understood. People like Jason Tatge (2014) who writes the blog on Farmobile, argues that the collection of these data by these companies to "access, mine, analyze, and do predictive modeling with a farmer's data so they know what's happening before the farmer does." There is a feeling that farmers do not have control over these data that they produce and that the data would be analyzed and used against the very people who produce them. American Farm Bureau Federation, for example, has warned farmers to be cautious of participating in sharing their data because of privacy issues as well as giving too much power to these companies. There are also concerns that the information gathered may be used by these companies and others to manipulate the grain market (Charles 2014). The reality, though, is that data is becoming an increasingly important part of all management activities and an ability to use “Big Data” to enhance competitiveness in agricultural firms is imperative for long term profitability and survival (Sonka 2014).

It is important to recognize that the data collection is not a single way street. Some companies, Monsanto and John Deere included, offer the data to those producing them. The challenge confronting most farmers is how to use the data that these organizations have collected to their own advantage. Monsanto, for example, is experimenting with a data-sharing system with its customers, allowing the farmers to log in and view data related to their crops by field. The collected data is to help improve productivity, efficiency and yield. It is supposed to provide more value to producers and customers. Customers will be able to use the data to make choices about the use and flow of the data (Reed 2013). Farmers’ ability to use the data to their own advantage is the current gap in the emerging technology around the collection of vast volumes of on farm data and equipment data.

2.1 The Age of Precision in Agriculture

Modern technology in agriculture is expected today. Precision agriculture has become a very important tool in the farmer’s toolset. Precision agriculture involves the deployment of information technology tools to enhance the management of farming and related activities through observing, measuring and responding to inter and intra-field variability in crop performance. It is being driven by many forces that are together shaping the economics of agriculture: input price increases; output price variability; energy costs; equipment management; and expanding operations. In addition to these business reasons, precision agriculture also has social benefits. By accurately identifying how much chemicals to use in a particular area of a field and when to apply a certain amount of fertilizer to a crop, precision farmers contribute to building sustainability into their operations. In so doing, they reduce pollution of ground water or air pollution even as they reduce their operating costs in terms of time and money spent on applications and input purchases.

Precision farming is based on several separate technologies, which together form the basis for individual management systems. Precision agriculture technology has evolved in such a manner that it provides farmers with new and innovative ways to possibly improve profitability. Liquid chemicals are one input that Automatic Section Control on a sprayer has an ability to manage the input application across the spray boom. The technology utilizes GPS to locate the position of the sprayer within the field and then records the areas covered. With recording it can automatically eliminate over application. Automatic Section Control can manage chemical application in areas such as point rows, headland turns and ditches and waterways. The biggest benefit is the ability to reduce inputs in overlapped areas especially in imperfect irregular shaped fields. Overall, the purpose for adopting precision technologies in agriculture is to potentially increase profits due to being able to reduce the input costs (Bakhtiari and Abbas and Hemztian 2013).

2.2 The Custom Harvesting Industry

Custom harvesting is the business of harvesting crops for farmers. Custom harvesting is a service that relieves the farmer of having to invest in machinery and labor that both can be costly and hire a harvester to harvest the crops in a timely fashion where weather always plays a threatening concern to damaging the crop before it is harvested.

Custom harvesters typically own their own combines and supporting equipment and often travel and work for the same farmers every harvest season. A harvester has a fleet of combines and supporting equipment whereas a farmer would typically have one combine and less supporting equipment. A harvester can accomplish a harvesting job much faster than a farmer with having an entire harvesting crew. This has the advantage of increasing the operating performance of the farm by reducing or eliminating harvesting risks. The custom harvesting industry dates back to the mid-twentieth century when mechanization of agriculture started taking off and agricultural labor started getting increasingly scarce and expensive. Prior to this period, farmers generally performed all their work – from planting through harvesting – using locally available labor or importing migrant labor to help with time sensitive activities such as harvesting. The economics of grain farming today underscores the important role custom harvesting plays in agricultural production across the Midwest of America, allowing the custom harvesting industry to become an entrenched component of American agriculture.

Custom harvesters typically have their own equipment including combines, tractors and grain carts, trucks, semis and other necessary supporting equipment. They are more efficient in using these equipment than their farmer customers because they tend to use them over larger acreage than the farmers would typically be capable of using their equipment. This use rate also allows them to maintain a currency with their technology, allowing them to more efficiently deploy emerging innovations that can't be justified economically by most farmers.

2.2.1 History of Custom Harvesting in the U.S.

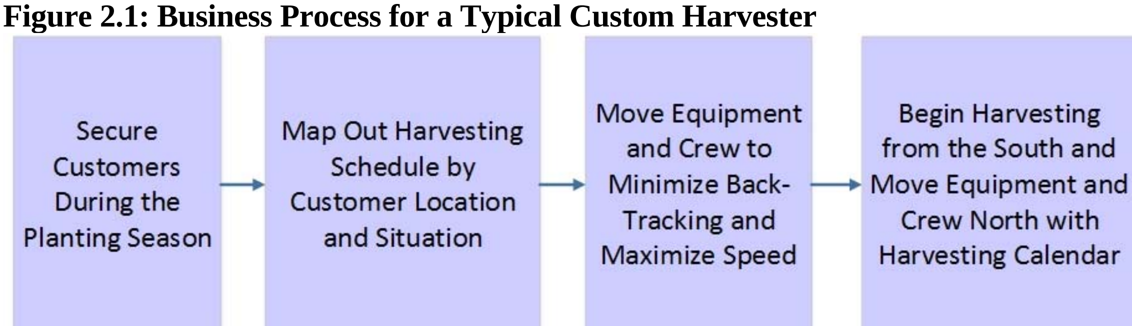
By the end of World War II (WWII), U.S. agriculture had become extensively mechanized (Sable 1987). This provided the economic foundation for the development of an industry that was focused on addressing the capital challenges that confronted many farmers in acquiring their own equipment and providing value for efficient harvesting of crops. That industry is the U.S. custom harvesting industry. However, the story of the impetus for the growth of the industry is told within the context of the stress of WWII on labor supply and steel availability. The pulled people from farming and other industries as well as natural resources such as steel to be used towards the war effort, e.g., the production of much needed war equipment – airplanes, ships, guns, etc. It is reported that the sales manager of Massey-Harris Company, USA during this period proposed the Massey-Harris Harvest Brigade as a solution to the problem posed by insufficient labor and steel supply. The proposal, accepted by the War Production Board, involved the manufacture of 500 of the #21 self-propelled combines, which were sold to combine operators (the Harvest Brigade) who guaranteed they would use each combine to harvest a minimum of 2000 acres (http://customcombinetribute.tripod.com/id13.html).

The number of custom harvesters in North America increased from about 500 in 1942 to more than 8,000 in Kansas alone by 1947 (Wishart 2004). The main operating region for custom harvesters stretched from Texas to Saskatchewan and Manitoba in Canada. The industry has grown and survived for two main reasons. The first being that it was an economical occupation in agriculture production. Also, like farming, custom harvesting became a family tradition. Beginning in the 1960s, irrigated crops began providing lucrative fall runs for harvesters in the Central Plains. By 1971, it was reported that there were 3,341 custom harvesters with nearly 7,551 combines used out on the harvest. The decline in the number of custom harvesters is a result of consolidation in agriculture, which is providing an economic foundation for larger farmers to own their own equipment. Another is the increasing competition in the industry itself as custom harvesters search for more competitive advantages through economies of scale. By having multiple machines, these companies could offer farmers better service than many single machine harvesters could offer, forcing these out of the industry over time. The interesting evolution is that many farmers have become custom harvesters to extend their agricultural way of life on the farm and make better use of their harvesting equipment by doing custom work to justify the expense of having their own equipment to harvest their own crops.

2.2.2 The Business of Custom Harvesting

The business of custom harvesting is very time sensitive. It begins with securing customers long before harvest time and planning the harvesting schedule based on these customers' due dates (Figure 2.1). As expected, then, this plan is very dependent on all assumptions about weather being accurate. Custom harvesters then move their equipment from their home base to the earliest location for harvest and begin the harvesting process. The nature of cropping and climate is such that custom harvesting begins in the southern plains – Texas and Oklahoma – and move north, through Kansas to the Dakotas. For those who undertake fall harvesting, the process is repeated as they may move back south and work their way back north again depending on where their fall harvest takes place.

Figure 2.1: Business Process for a Typical Custom Harvester



There are two principal revenue models for custom harvesters: (i) A flat per-acre rate; and (ii) A per acre rate with additional charges for high yields. Harvesters also charge for hauling the grain they harvested to the storage facility for the farmer. Farmers have become increasingly reliant on custom harvesters for their harvesting needs. The business of custom harvesting, then, has become increasingly time sensitive as crops in particular locations have to be harvested within a small window time frame. Additionally, for the custom harvester to maximize the return on time and investment, the operations have to be organized in ways that ensured minimum disruptions and speed and accuracy in the completion of each job on each acre of farm ground. This not only ensures customer (farmer) satisfaction, but also enhances the custom harvester's profitability.

Access to the latest technology is critical to the competitiveness of custom harvesters. As such, the most competitive custom harvesters change their harvesting equipment frequently, may be annually or a couple years. This ensures that they have the latest technology to enhance their effectiveness in providing all the support their customers demand as well as increase their own profitability. Warranty is also another reason.

One important technology for the modern custom harvesting business is auto steering and its attendant guidance systems technologies. GPS guidance systems reduces implement overlap during harvesting and saves labor time, and in so doing reduces combine hours and ultimately fuel usage. Overlaps can be reduced through using a guidance system, which saves about $13,000 in variable costs annually for a farm of 1,000 acres, according to USDA/NRCS (2012). Based on these estimates, a GPS guidance system provides a substantial return on investment and pays for itself within one year. Roberts (2012) also shows that in the Upper-Midwest region of the USA fuel and time savings resulting from guidance systems was about 34% and 6% while auto steering resulted in fuel and time savings of 5.33% and 5.75% respectively. Saving time implies a reduction in fatigue experienced by operators, contributing to lower risk in accidents when using these heavy equipment. Biggs and Giles (2014) also report 3% to 5% improvements in fuel efficiency.

There are two principal categories of guidance systems: guidance aides and autonomous systems. Guidance aides are what combine operators use while harvesting. They can use the GPS but it still requires an operator to fully control the machines operations just relieves the operator of steering. However, the autonomous system is used to free up the operator of not only steering but the tasks involved and the purpose is to improve the operating efficiency. Overall, the role of autonomous field machinery is designed to help the operator avoid stress and increase work efficiency (Bakhtiari and Abbas and Hemztian 2013).

Overall, in the U.S. 75% of farmers use some form of GPS during operations. The technology is expected to become more widespread sooner than most people think due to its declining cost as well as increasing evidence of its value in controlling production cost.

2.3 The JDLink Technology

FarmSight is John Deere's new global suite of advanced technologies and is designed to help optimize machinery use and overall farm operations. It integrates wireless technology and in the future, the system will connect professionals involved with the farming business, including owners, operators, dealers and agricultural consultants. Being able to do so will enhance productivity and increase efficiency and all will happen through sharing information with wireless technology. The purpose is to reduce overall input costs and increase efficiency (Moore 2012).

When fully implemented, JDLink will not only be useful for the machine's location, fuel consumption and status but JDLink Ultimate will enable remote monitoring and diagnostics, including the generation of message alerts via e-mail or mobile phone text message service whenever an equipment requires service or maintenance. This new level of service increases the efficiency of machine diagnostics, maintenance and repair, and most importantly reduces machine downtime. The purpose of JDLink access and knowing the machine's exact location reduces time in explaining directions to an operator when that operator needs to be in a particular field. It is also useful when there are needs for service and the service technician can arrive at the exact location where the machine is.

The new GreenStar 2630 in-cab display is another option of the JDLink Ultimate precision technology. With this extra option, the machine owner or the dealer can have access to seeing the display without being there physically. This allows for quicker responses and efficiency is not having to travel to the machine for codes or problems when the diagnoses can be made through this new technology (Moore 2012).

Machine Sync is a new element of the FarmSight strategy. It is the ability to exchange data on-the-move to improve the efficiency of the harvesting and unloading on-the-go, allowing the combine operator to 'guide' the tractor and grain cart alongside the combine. RTK is a service offered as well and is used for the increased, repeatable guidance positioning accuracy as precise as one inch. It is extremely useful in automatic guidance and machine automation applications. It is for customers requiring the very highest levels of accuracy for farming and harvesting guidance (Moore 2012). Being precisely straight and in the correct line when needed will reduce costs and labor time.

The foregoing suggest the benefits of participating in the JDLink program. Having alerts collected through JDLink could alert dealers with special instructions to help customers work around a possible problem. It could also help identify well-timed product improvement programs to address issues identified through the analysis of Machine Data. Another benefit includes creating tools to help reduce the setup and calibration time and complexity of a machine. It could also help John Deere in automation routines that identify changes in machine performance to allow the equipment to automatically adjust to share actionable alerts to the operator for manual adjustment. With John Deere being able to better understand the use and downtime of the equipment will help them to better identify and execute such programs and help to reduce downtime or improving performance for customers in later seasons.

While the JDLink technologies are useful, they, like all new technologies, have experienced (and are experiencing) some start up challenges. In their first years of operation, users are getting a lot of alerts that may or may not be valid concerns, leading to a lot of calls to dealerships. These calls are increasing costs at the dealerships and creating billing problems. It would seem that the company is not really set up to handle all of the alerts that are generated by the technologies, leading to customer frustrations across the board. As far as the sales departments selling the JDLink subscription are concerned, the AMS specialists are supposed to support subscribing customers but the knowledge for this support seems to be currently lacking. Service departments in dealerships are also experiencing increased customer downtime and a decrease in customer satisfaction as problems triggered by the JDLink system encourage customers to call for service. What seems to be happening is that the new technologies *are more technical* than the machines that combine harvesters and farmers are purchasing and there is a lot of work that needs to be done to exploit all the value that these technologies offer.

In summary, there needs to be better customer support for JDLink to make sure that the customer always experiences the best customer experience. The overall John Deere FarmSight strategy needs improved and JDLink should provide value for both the dealership organization and end use customer to contribute to the success of the strategy.

CHAPTER III: DATA AND METHODS

We have indicated that Schemper Harvesting updates its combines and supporting equipment frequently to ensure it has access to the most current technologies. We have a subscription to JDLink that we have experienced significant challenges with. However, our subscription to JDLink offers significant data on each of our machines that I believe will be helpful in enhancing our operations management and improving our performance.

In this chapter, I describe the data that is available from our JDLink subscription. I also describe the methods that were employed to provide the information that may be used to manage our operations in 2014. The chapter is, thus, divided into two sections. The first presents a thorough description of the data and how we receive the data at Schemper Harvesting. The second describes the analytical methods that were used and the indicators that were developed to guide managers at Schemper Harvesting.

3.1 Data Description

As indicated in the first chapter, Schemper Harvesting operates seven combines along with supporting equipment – trucks, semis, tractors and grain carts, etc. The combines are all enrolled in JDLink, so we have access to each machine’s performance on a daily basis in real-time. The machines and their operators are presented in Table 3.1. The table shows that I am the operator for combine 012-#4. I have been operating a combine since I was 13 years old. The day that school got out in May, we were headed south 480 miles to Davidson, Oklahoma to catch up to Dad and the harvest to be a part of the harvest crew for the entire summer. In August when it was time to go back home for school, we traveled the 550 miles home from Jamestown, North Dakota typically arriving the night before school began. In 2004, I graduated with my undergraduate degree. That was also the first year that I harvested the full harvest season of May through November. I enjoy following the harvest, getting to travel and supporting each unique harvest. I love operating a new John Deere combine each year. I also appreciate gaining more experience each harvest season.

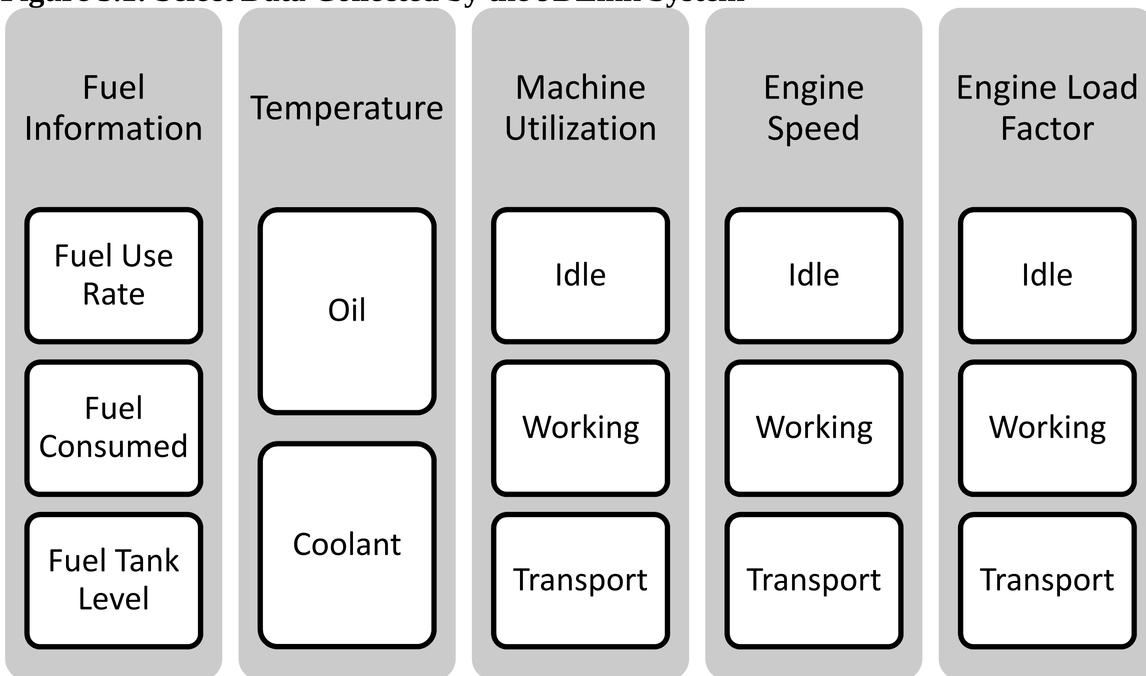
Table 3.1 Combine and Operator Description

Machine ID	Model	Operator	Operator Experience (Years)
005-#5	2013 s670	Family Member	20+
007-#1	2013 s670	Employee 1	<1
008-#3	2013 s670	Family Member	20+
010-#2	2013 s670	Family Member	50+
012-#4	2013 s670	Janel Schemper	20+
014-#7	2013 s670	Employee 2	<1
015-#6	2013 s670	Family Member	50+

The table also shows that all my family members have 20 or more years' experience operating combines. The high turnover in the custom harvesting industry has meant hiring new people each year and training them as quickly as possible to join the harvest. This has meant that our new employees often do not have the same level of experience and that has the potential to affect performance. The assumption in the industry seems to be that if the employee can drive the machine, then they are capable. This research sheds light on this assumption and provides Schemper Harvesting with potential insights into how we manage hired labor in our operations.

JDLink provides a lot of data on each machine. However, the relevant ones for this study are presented in Figure 3.1. The figure shows that fuel and machine utilization information are very important for determining the effecting use of the businesses limited resources – time and fuel. The others are indicators of machine health – engine temperature, speed and load factor.

Figure 3.1: Select Data Collected by the JDLink System



Under fuel information, fuel use rate measured in gallons per hour is available. Fuel Information encompasses the average fuel consumption, total amount of fuel consumed during time periods and fuel tank level. It is evident from the description of the data that these variables, although grouped under different headings, are not independent of each other. They, together contribute to the development of a set of management information that may be used by Schemper Harvesting to improve its operations and enhance competitiveness.

Temperature is useful because it can be used as a starting point for basic troubleshooting. Table 3.2 displays the combine temperature in four categories. Combines #5, #1 and #3 have the highest average hydraulic oil temperature however, #1 has the highest max hydraulic oil temperature. Combine #3 has the highest average coolant temperature as well as the highest max coolant temperature. Combine #3 almost overheated at one point and that could be due to having a radiator that was full of dirt and it needed blown out with an air hose. Temperatures can be related to how hard the machine was being pushed. Ground conditions can cause the temperatures to rise as the machine is worked harder in wet conditions caused by weather.

Table 3.2: Combine Temperature

Operator	Average Hydraulic Oil Temp (F)	Average Coolant Temp (F)	Max Hydraulic Oil Temp (F)	Max Coolant Temp (F)
#5	145.3	187.8	186.8	221
#1	144.3	187.7	192.2	215.6
#3	143.8	190.9	181.4	230
#2	140.3	188.1	181.4	226.4
#4	138.6	189	179.6	224.6
#7	134	186.4	176	213.8
#6	142.7	186.2	183.2	213.8
Mean	141.3	188.0	182.9	220.7
Standard Deviation	4.0	1.6	5.2	6.5

3.2 Analytical Methods

Statistical methods are the primary analytical approaches used in this study. The various data were organized by the machines and evaluated for differences between machines. Additionally, deviations from the best machine in each of the defined metric categories were estimated and discussed. It is understood that machine operator may have a significant impact on the performance indicators that were estimated. Therefore, the differences between machine performances are explained using the personal knowledge the researcher has about the operators.

A number of indicators were developed to facilitate the discussion. These are grouped into fuel efficiency indicators and machine utilization efficiency indicators. The fuel efficiency indicators develop specific performance metrics on the basis of fuel utilization. This is important because fuel is a major variable cost for Schemper Harvesting.

Machine utilization efficiency indicators cover how operators use machine hours. Time is a critical factor for custom harvesters since they are often working on very tight time constraints. Together these two groups of indicators provide insights into how Schemper Harvesting may improve its performance in the coming years and get value out of its subscription to the JDLink system.

CHAPTER IV: RESULTS AND DISCUSSION

Although there are several indicators used in this study, they may be seen as falling under two categories based on the two economic resources at play for the business: time and fuel. Therefore, the assessment of performance focuses on these two resources and how they are used by individual operators. Use of time and fuel is divided into two main activities:

1. Direct Economic Activity: These are all activities that directly generate revenue. They include harvesting and unloading of grain into grain trucks and semis. Unloading grain may be done either when the combine is idle or when harvesting is occurring. The latter is preferred if it can be done without loss of efficiency.
2. Direct Cost Activities: These are all activities that do not directly lead to revenue generation. They include all activities outside harvesting and unloading grain. These are headland turn and transportation of the combines between field locations. The less time and fuel used on these activities, the more time and fuel are available for direct economic activities. Therefore, the purpose of this division is to bring focus to time and fuel use and identify the best practices in direct cost activities that may be instructive for the business.

4.1 Summary Statistics: Operating Hours

The combines were operated in 2013 for a total of 5,777.1 hours. Table 4.1 shows the allocation of these hours across the seven machines. These hours comprised of idle, working and transportation utilization. Working is defined as when the machine is harvesting or unloading grain. The average total utilization was 825.3 hours across all seven machines, with a standard deviation of 168.7 hours. The average working hours was about 615.1 hours over the period, with a standard deviation of 127.4 hours. The average number of hours that the machines were idle was 99.8 hours with a standard deviation of 23.4 hours. This was slightly lower than the number of hours that the machines were in transit between fields, which was 110.4 hours, with a standard deviation of 22.9 hours. The coefficient of variation was the same for working and transportation hours but lower than idle hours. This suggests a slightly higher variability among machines when it comes to idle hours.

Table 4.1: Summary Utilization Hours Statistics

Operator/Estimate	Total Utilization	Machine Utilization Idle (hour)	Machine Utilization Working (hour)	Machine Utilization Transport (hour)
#5	964.1	124.7	720.7	118.7
#1	924.7	126.8	686.1	111.8
#3	986.3	113.8	744.9	127.6
#2	771.8	95.9	570.2	105.7
#4	831.9	88.1	613.3	130.5
#7	490.0	62.0	365.7	62.3
#6	808.3	87.3	604.5	116.5
Mean	825.3	99.8	615.1	110.4
Standard Deviation	168.7	23.4	127.4	22.9
CV	20.4%	23.4%	20.7%	20.7%

Machine Utilization by machine state is data that can be analyzed for machine performance efficiency comparisons including (1) fuel consumption to engine RPM, ground speed and load applied to a machine and (2) idle time to working and transport time. The Machine Utilization shows Detailed Utilization by Machine State based on total hours operated and this includes all 8 indicators as displayed in Table 4.2. The 8 Machine States are reduced to 2 indicators including Direct Economic Activity and Cost Activity.

Figure 4.1 displays the Machine Utilization comparison based on total hours. Combines #6, #2 and #4 are the leaders in Direct Economic Activity for Total Hours Operated.

Table 4.2: Activity Based on Total Hours Operated, 8 Indicators Reduced to 2

Activity Based on Total Hours Operated	**#5**	**#1**	**#3**	**#2**	**#4**	**#7**	**#6**
% Idle w/ Grain Tank Not Full	9.7%	10.9%	9.0%	11.2%	8.4%	10.2%	9.5%
% Idle w/ Grain Tank Full	2.8%	2.7%	2.5%	1.3%	1.8%	2.5%	1.1%
% Unloading not Harvesting	1.3%	1.3%	2.2%	1.4%	1.4%	1.9%	1.2%
% Harvesting and Unloading	4.7%	4.2%	5.2%	4.1%	4.5%	7.7%	3.7%
% Harvesting	64.0%	63.4%	62.5%	65.4%	64.3%	56.6%	66.2%
% Headland Turn Rotor On	5.1%	5.3%	5.6%	3.0%	3.7%	8.5%	3.9%
% Transport Below 10 mph Rotor Off	5.6%	5.5%	6.0%	6.0%	6.6%	5.8%	6.7%
% Transport Above 10 mph	6.8%	6.7%	7.0%	7.7%	9.2%	7.0%	7.8%
Direct Economic Activity	70.0%	69.0%	70.0%	70.9%	70.2%	66.2%	71.0%
Cost Activity	30.0%	31.0%	30.0%	29.1%	29.8%	33.8%	29.0%

Figure 4.1: 2013 Lifetime Machine Utilization Comparison, 2 Indicators

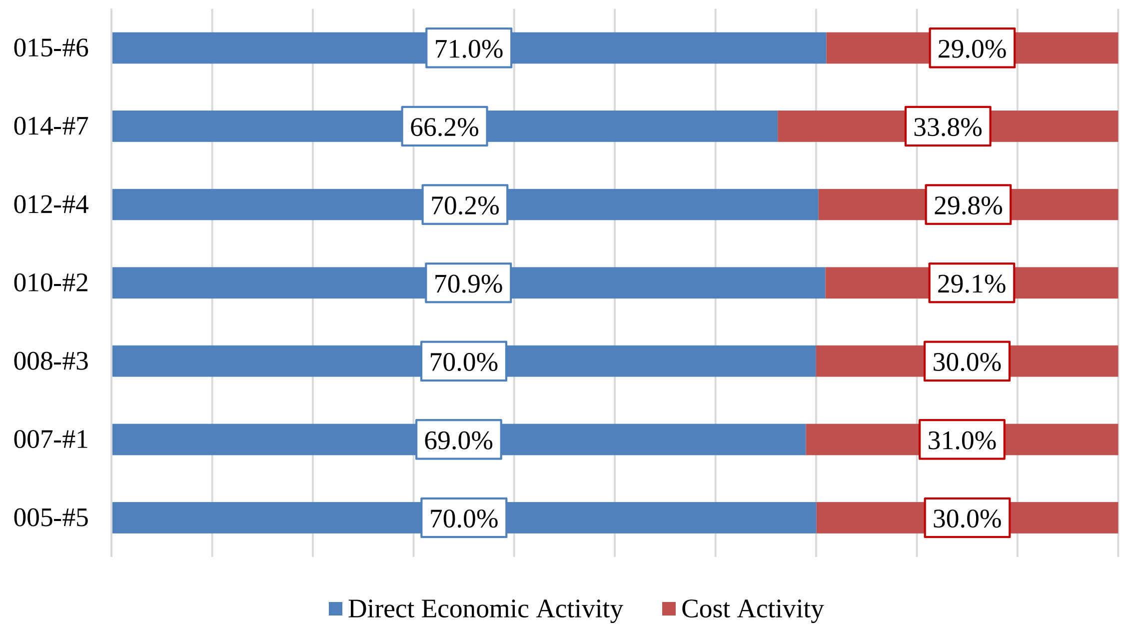


Table 4.3 displays the Averages of the Activity Based on Total Hours Operated. The average of all seven combines is the average of the entire fleet for 2013. Taking the

two employees out of the equation to assess the average of the five family members was also of interest, and that is the last column (Average of 5 Combines). The middle column (Average of 6 Combines) evaluates the average hours on the basis of all combines except Combine #7 because it had relatively very low hours of operation in 2013. Overall, the Direct Economic Activity is the highest as displayed using the average of the five family operated combines at 70.4% compared to the average of 6 combines at 70.2% and the average of 5 combines at 69.6%.

Table 4.3: Activity Based on Total Hours Operated, Averages of 7, 6, 5 Combines

Activity Based on Total Hours Operated	Average of 7 combines	Average of 6 combines	Average of 5 combines
Idle	11.9%	11.8%	11.4%
Unloading Not Harvesting	1.5%	1.3%	1.5%
Harvesting	68.1%	68.7%	68.9%
Headland Turn	5.0%	4.4%	4.3%
Transport <10mph Rotor off	6.0%	6.1%	6.2%
Transport >10mph	7.4%	7.5%	7.7%
Transport	13.5%	13.6%	13.9%
2013 Lifetime			
Direct Economic Activity	69.6%	70.2%	70.4%
Cost Activity	30.4%	29.8%	29.6%

4.2 Summary Statistics: Fuel

The total fuel used by all seven combines over the period was 70,578.6 gallons. On average, each combine used about 10,146 gallons for the season, with a standard deviation of 2,385.5 gallons. The coefficient of variation for fuel consumed over the period is 23.5%. Multiplying the average cost per gallon of fuel by the fuel consumption for each machine provides the total fuel cost associated with each machine.

Table 4.4: Summary Fuel Statistics

Operator	Average Fuel Rate (gallons/hour)	Period Fuel Consumed (total gallons)	Fuel Tank Level (%)
#5	12.7	12,223.4	13.2%
#1	12.3	11,371.3	52.0%
#3	12.9	12,692.7	38.0%
#2	12.2	9,405.7	8.8%
#4	12.5	10,364.4	18.8%
#7	11.4	5,604.2	13.2%
#6	11.6	9,359.9	54.8%
Mean	12.2	10,145.9	28.4%
Standard Deviation	0.6	2,385.5	19.5%
CV	4.5%	23.5%	68.7%

Table 4.4 displays that #3, #5 and #4 have the highest average fuel rate. This makes sense as operator #3 pushes his machine the hardest. He harvests alone occasionally during the summer harvest and most of the time during the fall harvest, and when there is only one combine in a field, the operator never has to wait on another combine to get out of the way or has to spend any time working around another one. Typically, the headland time is shorter because the combine operator has a quicker turnaround time to get the machine back in the crop.

The total fuel consumed is influenced by the number of hours the machine was operated. Therefore, the fuel consumption per hour of operation provides a more useful measure of fuel performance. The average fuel consumed per hour was 12.2 gallons, with a standard deviation of about 0.6 gallons/hour. The coefficient of variation is only about 4.5%. This shows that there is a greater similarity among the machines in the fuel use per rate than their total fuel consumption. This would indicate that the total number of hours the machines were operated exhibited higher variability.

The fuel tank level is also shown as a percentage in Table 4.4, and these results do not add any meaningful information to the current analysis. However, they have practical benefit (e.g. wanting to know specific fuel levels without having to drive to the equipment to check). Overall, fuel information data is maybe useful for rental fleet work and in order to understand periods of fuel inefficiency that could be eliminated. If the machines had been traded for new ones, our goal would have been to have the levels as close to 0% as possible at the end of the season when this data was taken. Due to the 2013 drought, the overall hours were low especially for the summer harvest. The fall harvest hours were lower than usual due to hail damaging the corn crop. The machines were not traded and will be used one more year and then more than likely be traded for new ones.

Figure 4.2 shows the percent deviation of each machine from the mean fuel rate. The figure shows that #2 is about 0.6% above the mean while #3 is just 0.2% below the mean. The #6 combine has the most efficient fuel rate, registering at 5.5% above the mean while #5 is the most inefficient in fuel rate, at 6.8% below the mean. Several reasons may contribute to the variability between operators.

A reason contributing to the variability between operators is that during the fall harvest, #5, and his employee, #1, used 8 row corn headers to harvest corn. These headers chop the corn stalks to the ground, which takes a lot more engine power and fuel. Thus, the type of crop being harvested and the header is likely part of the reason #5 and his employee, #1 are below the mean. It is also interesting to see the patterns among the machines. Schemper Harvesting typically operates in three teams including: #5 and #1 work together, #2 and #4 work together and #3 typically works with them during the summer harvest but during the fall harvest he works alone most of the time, and #7 and #6 work together and then for the fall harvest the #7 machine is leased out to a farmer and is used to harvest corn.

Figure 4.2: Percent Deviation from Mean Fuel Rate

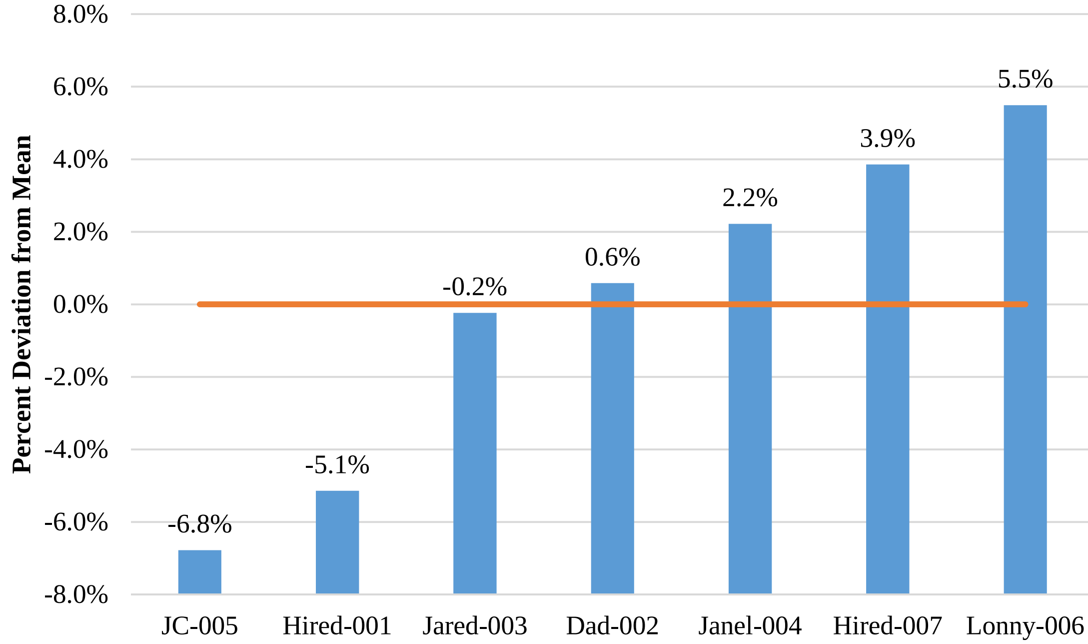


Figure 4.3 shows the percent deviation of each operator's fuel rate from the most efficient fuel rate operator. From Table 4.4 we know that the most efficient fuel rate operator is #7, with an average of 11.4 gallons per hour. The machine deviating the most from #7 is #3. Combine #6 is the closest to this operator, who works with this employee. Combines #5 and #1 work together and present very similar fuel efficiency deviations from the best operator. Combines #2 and #4 have similar fuel efficiencies but #3, who typically works with #2 and #4 during the summer harvest often works alone during the fall harvest, therefore he has a very different fuel efficiency. This difference needs to be investigated a little more deeply. It is a fact that #3 operates his machine to its full capacity and is always pushing the RPMs. However, he also harvests more corn in the fall, whereas #2 and #4 harvest more soybeans that would use less fuel. Without knowing hours by crop type it is impossible to fully disentangle the causes for the fuel rate differences.

Figure 4.3: Percent Deviations from the Most Efficient Fuel Rate (Hired-007)

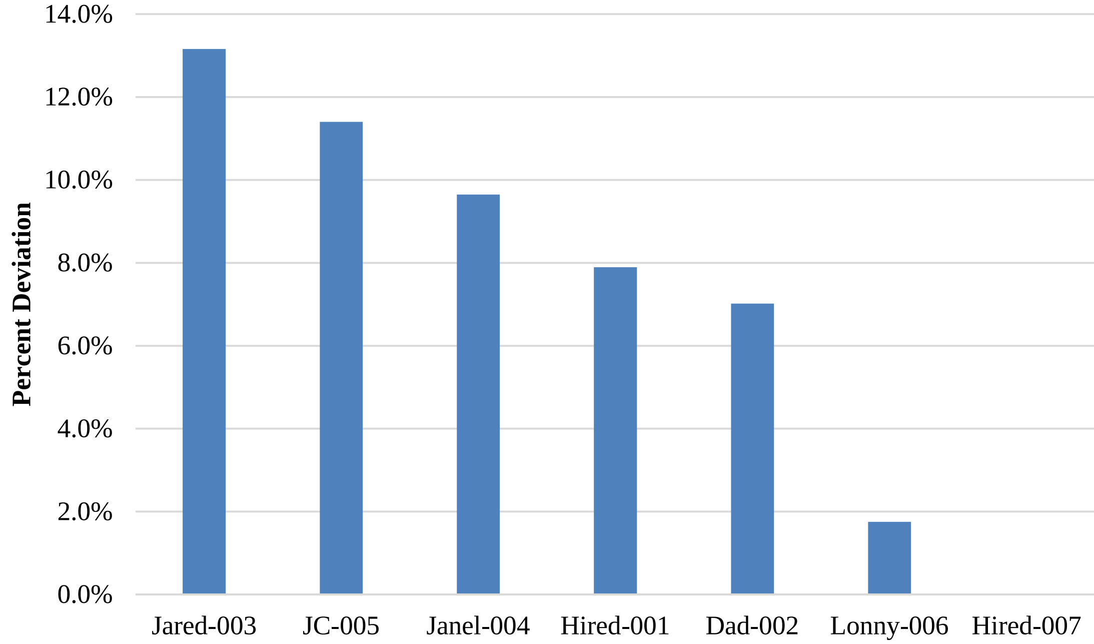


Table 4.5 shows the summary statistics for fuel use by utilization activity. For idle, the goal is to have the lowest rate possible, which indicated that the operator is keeping the RPMs low. The two employee ran combines have the highest values. This indicates an area of improvement as hired operators need more instruction about appropriate engine idle speeds. However, part of the variability could also be traceable to timing. Perhaps, hired employees are not idling the engine down soon enough.

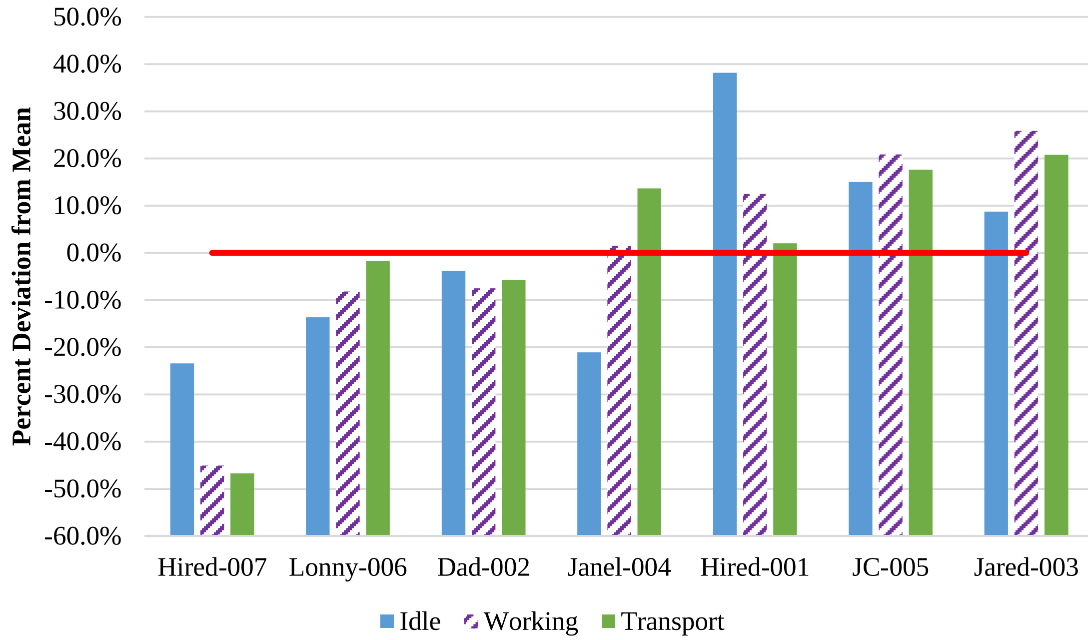
The average fuel rate during working, once again demonstrates who pushes their machine the hardest and to its full potential. Combine #3 is the leader with 15.4 gallons/hour followed by #5 and #4. The mean is 14.7 gallons/hour and four of the seven machines are above the mean. However, the average fuel rate during transport shows three of the seven machines to be above the 7.9 gallons/hour mean. Combines #5 and #3 are the leaders in this area.

Table 4.5: Summary Fuel Rate Statistics

Operator	Average Fuel Rate Idle (g/h)	Average Fuel Rate Working (g/h)	Average Fuel Rate Transport (g/h)
#5	1.7	15.2	8.7
#1	2.1	14.9	8
#3	1.8	15.4	8.3
#2	1.9	14.7	7.8
#4	1.7	15	7.6
#7	2.3	13.7	7.5
#6	1.9	13.8	7.4
Mean	1.9	14.7	7.9
Standard Deviation	0.2	0.7	0.5
CV	11.5%	4.6%	5.9%

Figure 4.4 below shows the percent deviations from the mean fuel consumed under the three utilization activities – idle, working and transport. For this indicator, the lower the percent deviation from the mean, the more efficient the machine. The data shows that while #4 is about at the mean with respect to fuel consumed while working, (with a percent deviation of only about 1.5%), #2 is about 7.5% below the mean, while the hired operator, machine #7, is 45.1% below the mean, making him the most efficient with respect to fuel consumed while working. At the other extreme is #3, with a percent deviation from the mean working fuel consumed of about 25.9%. Overall, it is clear that #3 pushes the combine the hardest and operator #7 hardly pushes the combine. Since the #7 machine was hardly pushed, that would explain why the fuel efficiency was the greatest. Those that use the machine to its fullest capacity during working have higher figures.

Figure 4.4: Percent Deviation from Mean Fuel Consumed under Alternative Utilizations



Fuel Information is useful to look back on for rental fleet work. It can be used to indicate periods of fuel inefficiencies that could be eliminated. Also selecting time periods where different crops were harvested and different headers were used would be useful to see the fuel use rate variance among crops. Table 4.6 measures the fuel usage distribution among the eight indicators listed in the table and then they are reduced to two indicators including Direct Economic Activity and Cost Activity. Figure 4.5 displays the comparison of the seven machines Fuel Usage Distribution. Combines #2, #4 and #6 are the leaders in Direct Economic Activity for Fuel Use Distribution.

Table 4.6: Activity Based on Fuel Use Distribution, 8 Indicators Reduced to 2

Fuel Use Distribution	**005-#5**	**007-#1**	**008-#3**	**010-#2**	**012-#4**	**014-#7**	**015-#6**
% Idle w/ Grain Tank Not Full	1.3%	1.9%	1.2%	1.8%	1.1%	2.0%	1.4%
% Idle w/ Grain Tank Full	0.3%	0.4%	0.3%	0.2%	0.2%	0.6%	0.2%
% Unloading not Harvesting	0.6%	0.6%	1.0%	0.7%	0.6%	1.0%	0.5%
% Harvesting and Unloading	6.5%	5.7%	6.8%	5.4%	6.1%	12.0%	5.1%
% Harvesting	78.5%	79.1%	77.7%	80.9%	79.4%	68.6%	80.2%
% Headland Turn Rotor On	4.4%	4.5%	4.7%	2.3%	3.0%	7.5%	3.3%
% Transport Below 10 mph Rotor Off	3.2%	2.9%	3.2%	3.0%	3.1%	2.9%	3.1%
% Transport Above 10 mph	5.3%	4.9%	5.1%	5.7%	6.6%	5.4%	6.1%
Direct Economic Activity	85.6%	85.4%	85.5%	87.0%	86.1%	81.6%	85.8%
Cost Activity	14.4%	14.6%	14.5%	13.0%	13.9%	18.4%	14.2%

Figure 4.5: 2013 Lifetime Fuel Distribution Comparison, 2 Indicators

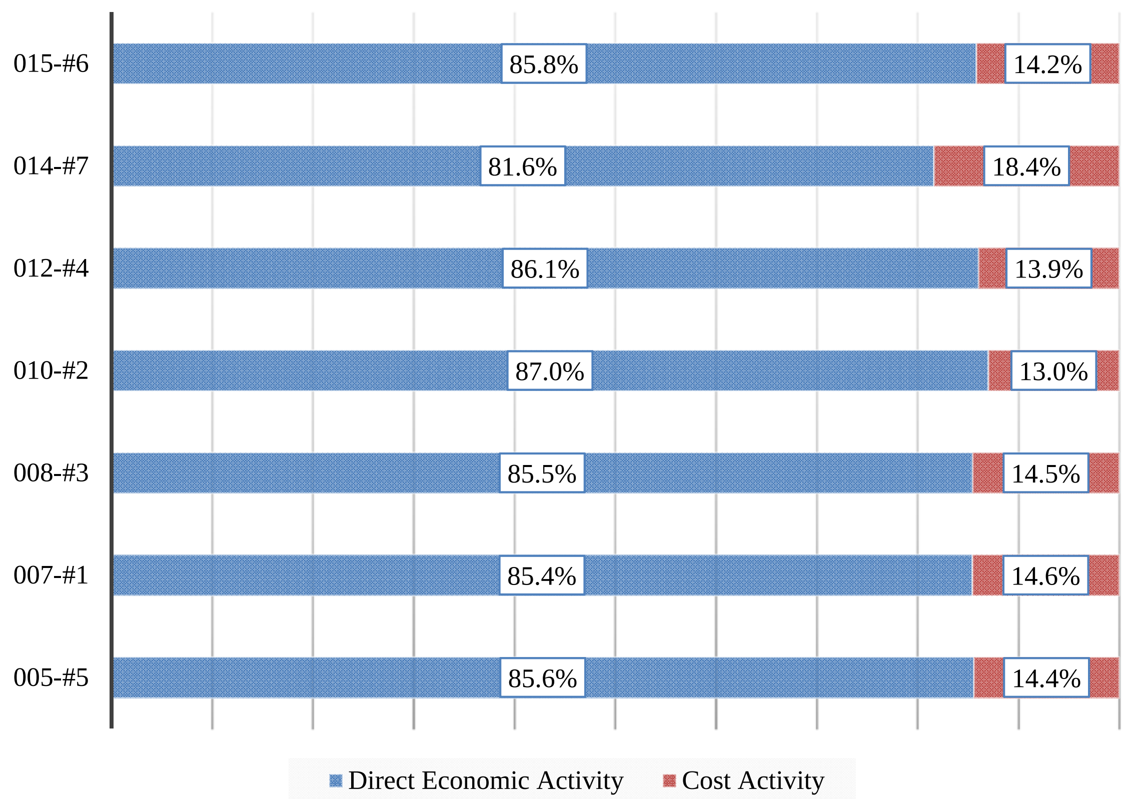


Table 4.7 displays the Averages of the Activity Based on Total Fuel Usage. The average of all seven combines is the average of the entire fleet for 2013. Taking the two

employees out of the equation to assess the average of the five family members was also of interest, and that is the last column (Average of 5 Combines). The middle column (Average of 6 Combines) evaluates the average fuel on the basis of all combines except combine #7 because it had relatively very low hours and fewer gallons used in 2013. Overall, the Direct Economic Activity is the highest as displayed using the average of the five family operated combines at 86% compared to the average of 6 combines at 85.9% and the average of 5 combines at 85.3%.

Table 4.7: Activity Based on Total Fuel Used, Averages of 7, 6, 5 Combines

Activity Based on Total Fuel Used	Average of 7 combines	Average of 6 combines	Average of 5 combines
Idle	1.8%	1.7%	1.6%
Unloading Not Harvesting	0.7%	0.7%	0.7%
Harvesting	84.6%	85.2%	85.3%
Headland Turn	4.2%	3.7%	3.5%
Transport <10mph Rotor off	3.1%	3.1%	3.1%
Transport >10mph	5.6%	5.6%	5.7%
Transport	8.6%	8.7%	8.9%
2013 Lifetime			
Direct Economic Activity	85.3%	85.9%	86.0%
Cost Activity	14.7%	14.1%	14.0%

4.3 Engine Performance and Activity

Engine Speed is important because it provides indication of how operators are running the machines under different activities. The operator controls the engine speed. There are three speeds: low (turtle), medium (turtle/rabbit), and high (rabbit). It is important to control the speeds appropriately to conserve fuel. Machine speed during harvesting at full power is 2200 RPM. Anything below this speed implies a loss of power and indicates significant pressure on the machine. It may be indicative of lack of understanding of how the machine works or reflective of other issues related to the harvesting or operation of the machine.

Table 4.8 shows the average engine speed (revolutions per minute (RPM)) under the different utilizations. Idle, working and transport are shown in the table. During idle time, combine #7 has really high RPMs. The engine is not being slowed down while idling. When the extra power is not needed then the machine should be slowed down to conserve fuel. The operator essentially does not take full advantage of the range of engine speeds, that is, they do not lower speed enough during idle but at the same time do not run as fast during work.

Also shown in the table, are working RPMs and 2200 RPMs are used when both the rotor and header are engaged at full power. As far as working RPM speeds, #3 has the lowest number at 2176.8 which shows that he pushes the combine harder than anyone else. When running at full power, the RPMs should be 2200, but when the combine is being pushed too hard an alert lets the operator know that they are too low on RPMs (i.e. the rotor is overloaded). It is common in heavy or higher moisture crops or those crops with higher yields to lose power or in some occasions have difficult ground conditions (i.e. mud). If the ground is wet, then the combine efficiency will be lower. These numbers could be informative for John Deere to compare against other models including s660s, which are smaller and s680s, which are bigger than the machines used by Schemper Harvesting. An s680 would have more power, so it would be interesting to see how the RPMs would compare when tested in similar environmental conditions.

During transport, the mean engine speed is 2159.91, but that is not significant. However, the relevance is those that start out at a lower idle would have a smaller RPM like combine #4 at 2131.6. This demonstrates that while transporting the combine, #4 idles the machine RPMs down while traveling slower due to either rough roads, traffic, or something that would cause the machine to not be used or needed at full speed therefore slowing the RPMs down helps with fuel efficiency.

Table 4.8: Summary Engine Speed Statistics

Operator	Average Engine Speed Idle (RPM)	Average Engine Speed Working (RPM)	Average Engine Speed Transport (RPM)
#5	1245.4	2184.6	2206.6
#1	1297.3	2183.6	2197.6
#3	1255.3	2176.8	2201.3
#2	1268.2	2189.6	2156
#4	1237.2	2186.7	2131.6
#7	1372.5	2190.1	2133.7
#6	1281.9	2192.8	2092.6
Mean	1279.7	2186.3	2159.9
Standard Deviation	45.9	5.3	43.5
CV	3.6%	0.2%	2.0%

Engine Load Factor provides information on how the operator is using the machine during certain times. This is figured in percentages. During idle time, the percentages should be low. During working time, the harder the machine is worked, the higher the engine load factor will be. During transport time, the engine load factor may vary due to rough roads and traffic. However, Engine Speed RPMs are affected by the Engine Load Factor.

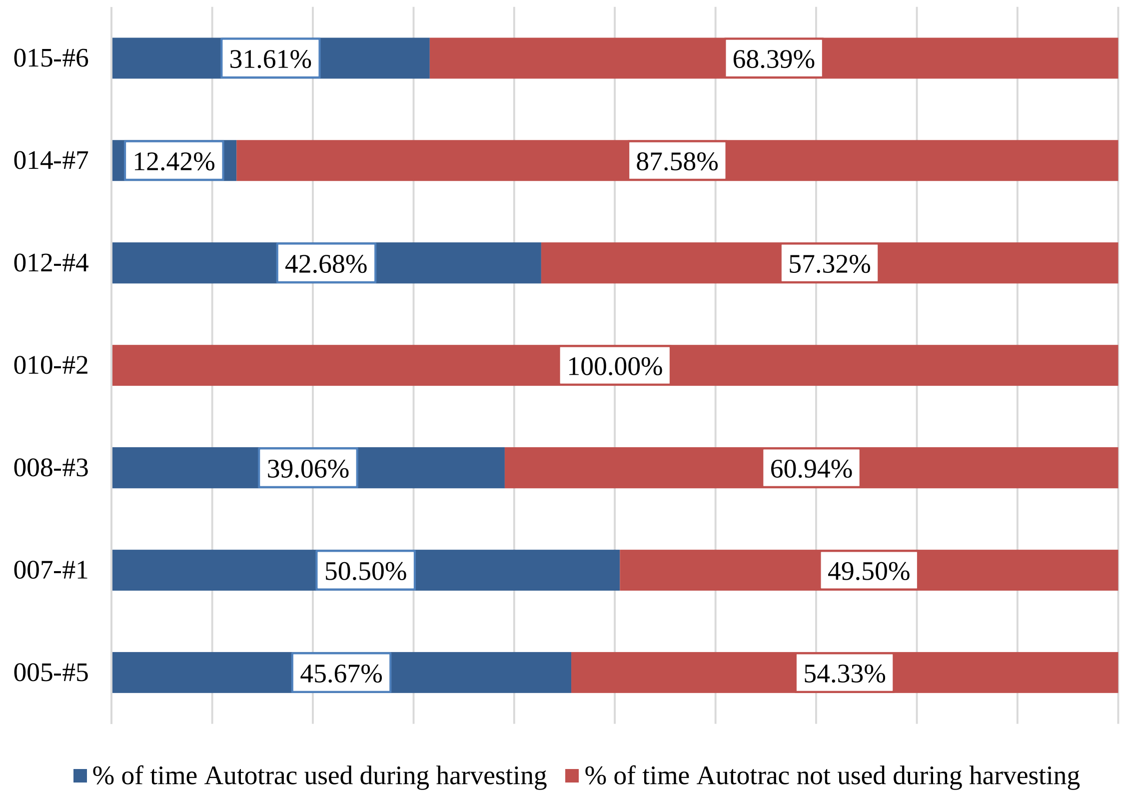
Fuel is an expense and it is necessary to know how to operate the combine correctly to be efficient. Employees often have to be told during training to idle the machine down when the power is not needed. However, it sometimes is something that is not easily learned. It takes experience to do it consistently. Table 4.9 shows the engine load factor during idle, work and transport. The higher the percentage, the harder the machine was pushed. The load factor while idle was not surprising. The two employee ran machines were the highest with 18.90% and 18.00%. Ideal load factors while idle would be about 16%. Combine #4, has the lowest at 15.8%. This demonstrates that she is operating the machine at the fullest but uses the appropriate RPMs (i.e. no more than necessary). Combine #4 also powers the machine down often during waiting times to save on fuel costs instead of letting the machine sit and idle collecting hours and using fuel. During working, the highest engine load factors were #5, #3 and #4. These combine operators are getting the absolute most out of the machine while harvesting and doing more work with the time as indicated by the table percentages. As far as transport time goes, #5 and #3 are the highest. They are likely going faster speeds quicker by pushing the hydrostat forward faster. Also, they are both most likely always in the lead when moving from field to field.

Table 4.9: Engine Load Factor

Operator	Average Engine Load Factor Idle (%)	Average Engine Load Factor Working (%)	Average Engine Load Factor Transport (%)
#5	16.40%	81.70%	53.70%
#1	18.00%	79.60%	49.60%
#3	16.40%	81.50%	51.10%
#2	17.10%	79.20%	48.70%
#4	15.80%	80.50%	47.50%
#7	18.90%	74.20%	46.80%
#6	16.50%	75.00%	46.40%
Mean	16.50%	79.60%	48.70%
Standard Deviation	1.08%	3.03%	2.60%

AutoTrac On Time is not included in Figure 3.1 but it is part of the JDLink data and is used to see how often AutoTrac was used compared to when it was unused. It shows how operators are using the guidance systems to perform their various operations in the field. Using AutoTrac has many benefits, including allowing the operator to focus on other activities that require more manual attention and relinquish the automation aspects to the AutoTrac system. It can, therefore, reduce operator tiredness. The AutoTrac signal for SF1 and SF2 alone is valued at $3,100 per machine, making understanding its value to the business important. Figure 4.6 displays how often Schemper Harvesting used AutoTrac during harvesting hours in 2013. Combine #2 does not have the AutoTrac signal.

Figure 4.6: 2013 AutoTrac Usage During Harvest Hours Comparison, 2 Indicators



Based on the findings several conclusions can be made, and also, different operators can be compared. Observing these kind of results lets the managers know where they could spend additional time training employee operators. For example, making them aware of situations in which it would be better if they turned off their machine, or to work on timing issues with tractors and grain carts, semis and trucks. Another example is engine speed. The average RPMs during idle was 1268.36. However, combine #7 was quite high at 1345.2 and combine #1 was at 1300.9. Managers need to better explain the low, medium and high idle speeds to employees to make them aware that more RPMs is equal to more fuel. Of course, fuel is a major expense for the business, and in fact, the second largest expense after the machinery, so it is just good business and environmental practice to seek as many ways as possible to reduce consumption.

One issue however, concerns the inconsistent use of some machines. Fuel efficiency can vary based on environmental factors associated with crops and also, atmospheric factors, such as air temperature and moisture. Future work will need to evaluate whether there are significant correlations between environmental factors and fuel efficiency performance. Returning to the issue of inconsistent machine use, if machines were used in different locations and across different time periods, then some part of the observed differences may not be related to operator performance.

CHAPTER V: SUMMARY AND CONCLUSIONS

Business decisions are made through knowledge. Knowledge fuels prosperity by signaling and guiding resources to higher-valued uses. Seeking, sharing, discussing or challenging ideas and plans play a crucial role inside an organization. No one ever has all the knowledge to consistently make the best decision or discoveries. I believe that exchanging thoughts and ideas with others is the best way to discover new and better ways of creating value. To be up-to-date, actively seeking knowledge and alternative points of view can be beneficial. Benchmarking is very important because it's necessary to know what the competition is doing and there may be room to learn and grow your own business. In reality, there are always ways to do things faster, cheaper, and better. Value creation includes good economic thinking, seeking and sharing knowledge, embracing the challenge process and using tools appropriately.

Schemper Harvesting is a member of the United States Custom Harvesters Incorporation and this organization allows us to benchmark other custom harvesters, and to learn and understand how others in the business succeed. More specifically, Schemper Harvesting seeks improvement by learning about (1) company internal factors (e.g. who is the best operator and why), and (2) company external factors (i.e. being competitive in the industry). Managers must focus on both aspects in order to keep moving forward. This is challenging because on the one hand you have to stay informed of what's going on in the larger market and business arena, and also, stay up to date with current technology. On the other hand, you have to stay focused maximizing efficiency within the business and this involves getting employees to align with the goals and expectations of management.

5.1 Summary

The purpose of this study was to examine the JDLink data collection to learn the efficiency of each of Schemper Harvesting's seven combines, including machine efficiency and comparing combine operators. The idea was to accomplish how to improve Schemper Harvesting's overall performance with the new available data. The future is the time to use effectiveness decisions and collect more data.

Collecting the data from JDLink and organizing the data into an excel spreadsheet was just the beginning. From there, the statistical methods were used to perform the analysis. Efficiency and productivity is the focus for Schemper Harvesting and improving it is a daily responsibility. Evaluating the performance through the data collection is on the to-do list from now on as long as the data is available. Using specific efficiency metrics to assess the performance and to make comparisons among the machines efficiency metrics against the best in class is necessary. However, taking this study and using future information and data collections will be needed to develop specific management strategies in order to boost Schemper Harvesting's productivity.

The data was collected and it was determined that time and fuel are the two economic resources at play for Schemper Harvesting. Time and fuel were both divided into two main activities including (1) Direct Economic Activity and (2) Direct Cost Activities. The highlights of the analysis are interesting. For Total Hours Operated, #6, #2 and #4 are the most efficient. For Fuel Use Distribution, #2, #4 and #6 are the most efficient. Figure 4.4 suggests that #6 has the most efficient fuel rate. Combines #3 and #5 push the hardest. Patterns could be seen between teams including #5 and #1, #2, #4 and also #3 and, #7 and #6. Again, combine #3 typically works alone in the fall and combine #7 is leased out to a farmer in the fall. The two employee combine operators are not idling the machine down while waiting. The study did show that combine #7 was the most fuel efficient while working and that suggests that the combine was not pushed to its potential. The goal is to push it to its full capacity and get the very most efficiency out of every hour possible. Having a higher fuel rate does not necessarily mean that the machine was inefficient; it is more of a possibility that it is efficient by using the machines absolute full potential and capacity.

5.2 Conclusions and Suggestions for Further Work

Schemper Harvesting has room to improve, and the way to do so is through quantitative data analysis and research. Schemper Harvesting can use the results from this study in order to improve performance and profitability. Moreover, on the basis of the findings, business strategies will be created to increase the operational efficiency of the business.

The evaluation of the JDLink data resulted in several recommendations. The following points and explanations should be considered in order to make the future data analysis even more valuable to gain better efficiency for the business.

1. Create an operator log of all non-JDLink information or data – A spreadsheet for combine operators to keep track of daily progress. Acres and bushels are necessary to collect in order to get a more precise value on combine operators and machine efficiency comparisons. Use 2013 and this study as a learning experience. Collect and analyze 2014 data, and compare and contrast performance in order to gain knowledge and create more efficiency.

2. Organize analysis to incorporate economic variables – Instead of relying on JDLink data, use price of fuel, revenue per acre and location economics in conjunction with the JDLink data (e.g. fuel efficiency and engine speed).
3. Increase cooperation and strategic alliances among combine operators – Communicate better through combine operators to handle the harvesting service in the most professional and accurate way.
4. Use JDLink data every harvest season as a strategic resource and keep records on file for future studies – All combine operators need to understand the value of increasing efficiency through this type of study. The collection of operator, fuel use, operation time, and bushels and acres will provide an additional basis on which the quantitative analysis can be conducted. This information will assist is comparing operators and also environmental factors such as geographical locations.

By implementing these four things, I believe that improvements can be made in performance and that the overall business has the potential to be more efficient. As our business grows over time, the data collection, quality and analyses can only make Schemper Harvesting more competitive, improve our value proposition to our customers and ensure this fourth generation family business is around another four generations.

If more time were allowed, several more analysis would take place including: (1) an inter-season analysis, displaying summer harvest and fall harvest statistics (2) a multiyear analysis showing statistics from year one of JDLink which was 2012. Comparisons could be made from year to year. As the data is collected over the years, multiyear analysis will take place. (3) The inclusion of total acreage and crop types harvested by each machine will be recorded so that a more efficient study and analysis can take place on the economic efficiency along time and fuel expenditures. However, one of the future goals is to record daily acres and bushels harvested. This thesis is not complete in that more data is needed and the time constraint does not allow for it at this time. Overall, patterns can be seen and operators can be compared. Fuel is a major expense for the business, so using it within reason is what is to be done. The data is new to Schemper Harvesting, so understanding a correct method to analyze the data is the future goal.

With the implementation of the plan gained from this thesis project, it is anticipated that the combine performances will be improved even further yet. Schemper Harvesting is already an elite business known for their professional combine operators. With the data and the future quality of the data improving, the conclusions, ideas and recommendations and future improved research will hopefully continue to improve Schemper Harvesting's performance evaluation overall. It would highly benefit the business to continue collecting and using the JDLink data every harvest season. More research can be done in the future based off of this study.

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