Critical Control Points for Profitability in Sheep Production

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Abstract
Financial and animal performance records from sheep producers in Western North Dakota were analyzed to determine critical control points which played the largest role in determining producer profits. Records included individual animal production performance and total flock financial performance. Ninety-six sets of flock records were studied from over 30 different producers. This study found that traditionally accepted determinants of profit were not good indicators of actual profit. In fact, ewe lambing rate was not a significant determinant of profit. Pre-weaning lamb death loss played only a small role in determining profit.

Net profit was determined by Unit Cost of Production (UCOP), Gross Income (GROSS), a management measure (MANAGE), and adding value to the base flock production (FEEDLOT). Lowering UCOP increased profits. Increasing GROSS increased profits, lowering the MANAGE ratio increased profits, and increasing FEEDLOT increased profits.

Total cost and revenue curves were statistically derived for the producers in the study. This analysis suggested that flock sizes were smaller than the optimum profit size. Traditionally producers have selected replacement animals by phenotype and if the animals birth type was as a twin. Producers make little use of financial analysis tools in the sheep business. Our analysis suggests that producers use different tools and criteria for managing sheep for profit. This article is only available online at http://
Impact — This research highlights some of the critical control points responsible for profit in ewe flocks. It identifies alternative management measures for producers to use. If adopted, these management measures could increase profitability in the sheep industry.

Audience — Sheep producers, county agents, animal scientists, and economists.

Keywords
Profit, Unit-Cost, Economic, Response Surface

Introduction
Producers are faced with an array of technologies for maximizing sheep production. They do not have resources to invest in all technologies and must choose both among types and quantities of inputs used for their flocks. Economic response analyses can assist them in making profitable decisions.

Animal science research has typically focused on changing the biological production parameters of the animal to enhance production. Maximum production has been the goal, with little or no analysis of the profitability of the increased production (Heady and Dillon, 1961). Since increased physical products do not automatically generate increased total profit, this research provides an important economic component to producers' decision-making process.

In North Dakota, farm profitability is often measured through the checkbook of the producer and cash flow frequently becomes the driving force behind most producer decisions. Many farmers in the state do not analyze their individual enterprise profit centers, but rather depend on a measure of the amount of cash on hand at the end of the year to determine the success or failure of the farm or ranch total business. This frequently leads to incorrect management decisions since the profit contribution of each profit center is unknown. Furthermore, which management practice in each enterprise is most responsible for profit in each profit center is unknown.

Net profit is a function of many parameters. An almost infinite number of production practices and management decisions, as well as many external forces, affect final profit results from an enterprise. The question then becomes which factors should a producer focus his management attention on to make the best use of his limited management time.
There is speculation among researchers about the most important profit criteria. Animal scientists may focus on the production factors: lambing rate per ewe, weaning weight of lambs, and lamb death loss. Someone with an accounting background may focus on gross income, total cost of production, and net farm income. An economist may look at earned returns to labor, management, and equity capital as well as marketing decisions as crucial to the profitability of the flock. A producer however, cannot measure and analyze every possible production or financial parameter.

A producer and his/her family brings three resources to each enterprise on a farm: equity capital, unpaid family and operator labor, and management. The common factor among all three resources is that they are limited. Focusing management attention on non-critical profit parameters in the sheep profit center comes at a cost. The cost is loss in potential profits in another profit center due to limited management time.

It is important to identify the critical control points (CCP) of operating a profitable sheep enterprise so managers can focus their limited management time and skills on those factors most likely to affect the bottom line of the sheep profit center. This insures that finite management resources are allocated most efficiently for all enterprises on the farm.

This study identified the critical control points of operating a profitable sheep profit center. This was accomplished by estimating the statistical relationship of various measurable financial and production criteria to net cash profit. In this study, net cash profit was defined as the return to unpaid family labor, management, and equity capital. Cash costs of acquisition were used for all inputs measured.

**Specific Objectives of This Study**
The primary objective of this study was to identify the critical control points (CCP) for profitability in a sheep production enterprise. Knowing these CCPs allows producers to focus their management efforts on those areas most likely to affect flock profitability. This information is also available to record-keeping systems designers, allowing them to create information management systems that gather CCPs needed for profitable decision making.

The second objective of this study was to generate statistical relationships explaining each of the identified critical control points. This allows producers to understand the underlying production relationships that are critical to the CCPs.

**Materials and Methods**
**Data Used**

This study uses data from a group of North Dakota producers who were enrolled in a sheep producer education project from 1988 through 1994. The data cover 1989 through 1993. First-year data were not collected as producers had not been trained in data collection techniques. The education program terminated in 1994.

Livestock production data were collected and analyzed for each flock using the North Dakota Sheep Production Testing Program (Haugen, 1981). Producers kept production records on individual animal performance. As part of the education program, assistance was provided on weigh days for lambs and also in completing input sheets for computer processing.

Financial data were collected for the computer program SHEEPBUD (Nudell and Hughes, 1996). Client financial records ranged from shoeboxes full of receipts to computerized accounting programs. Producers were assisted in data collection, and economic data input was done on site with each client.

Not all clients who participated in the educational program agreed to maintain all records. Some kept only performance records, others kept only financial records, and still others kept both financial and performance records. Not every producer who began the program finished, and some did not start to keep records until they had been in the program for a year or two. Thus, the data set is a pooled set containing both cross-sectional and time-series data.

Data used in this study are from those producers who completed the SHEEPBUD records. Most of these producers also completed the performance testing records. Ninety-six records were used in the final analysis. Information from the North Dakota Sheep Production Testing Program and SHEEPBUD were stored in a computer database.

Flock performance data included a unique identifying number for each ewe and all of her lambs, birth date of the lambs, sex of the lambs, weaning date, and weight for each lamb. Lambs that died were recorded along with the date of death and if known, the cause of death. The data set also included optional data including sire identification for both ewes and lambs, breed information, and producer comments about the ewe or lambs. Financial data collected include approximately 150 input parameters covering both cash and opportunity costs. Measurements include variable and fixed costs, land use data, debt payments, and all revenue data.

Thirty-four production and financial factors were recorded in the database. An additional seven variables were calculated from the raw data and were included in a database. To test for non-linearity, nearly all variables were squared and cubed and
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tested for inclusion in the model.

Because of the large number of potential explanatory variables, stepwise regression was used to search for independent variables that explain the variation in profitability. The intent of this regression exercise was to determine which of the variables the stepwise regression procedure would identify as "significant" in the model and also to see which variables were "not significant" in predicting net profit.

After the stepwise equation was completed, the information gained was used to test multiple factors against net profit. Several equations were tried with a goal of increasing the model's efficiency, measured by the number of variables used, without sacrificing the predictive power of the model, measured by the calculated R-square.

Management Parameters Selected
The model identified four critical control points in the profit equation. These four CCPs were regressed against other variables in the data set to identify a subset of management factors affecting the four main critical control points. A stepwise regression procedure was again used for each parameter, and individual equations were derived for the four critical control points with a goal of finding an efficient\(^1\) equation with high predictive power.

\(^1\)Efficiency in this case is defined as an equation having fewer defining variables and still maintaining good predictive power.

Results and Discussion
This research identified four critical control points for profitable sheep production. In addition, a set of production parameters that played the largest role in predicting the CCPs for profitability were identified.

The critical success equation is:

\[
\text{NET PROFIT} = 2158 + 47.38(\text{GROSS}) - 0.215(\text{UCOP}) + 0.000015(\text{FEEDLOT})^2 - 0.089(\text{MANAGE})^2
\]

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\]

\[
(2.706) \quad (7.818) \quad (-4.754) \quad (4.634) \quad (-3.169)
\]

T values are in parenthesis below the parameters and the R-square of the equation is .764.

The identified critical control points are 1) GROSS--having a sufficient volume of production to be efficient; 2) UCOP--having a low unit cost of production; 3) FEEDLOT--adding value to the base production of the flock by feeding lambs to finish
weights; and 4) MANAGE--using the management skills necessary to efficiently utilize labor, especially at lambing.

The net profit equation suggests that producers may need to evaluate the criteria they use to measure success. Both lambing rate and market price are closely followed by producers with an assumed high correlation with financial success. This research documented no relationship between lambing rate and profitability. The data collected over several years with wide market price fluctuations and wide variations in lambing rate do not show a significant relationship between profitability and market price. The data suggest that producers should instead invest more time and effort into measuring and controlling the cost side of the operation\(^2\). As an added benefit, the cost of production is more easily controlled at the farm level than the market price.

The MANAGE factor serves as a proxy for good management of the sheep enterprise throughout the year. MANAGE is a reflection of management practices that occurred during the entire production year. Producers need to be aware that efficient use of labor (MANAGE), especially at lambing time, affects their profit potential. The sheep flock is labor intensive at lambing time. Death loss in lambs is identified in the subset of critical control points, and most death in lambs occurs in the first three days of life (Ringwall et al., 1994) when they are in the lambing barn.

Adding value to the flock's base production (FEEDLOT) is profitable. An added benefit of profit enhancement at this stage of production is that the labor requirement and death loss risk are low, relative to other times of the year, i.e., the added post-weaning weight gain returns appear to be well above post-weaning costs.

Finally, increasing size of the operation (GROSS) is positive for the profit potential of the flock. While the research project was not able to determine the optimum size for a sheep operation it did suggest that flock size increases would be positive for profits.

\(^2\)A change in Unit Cost of Production has the greatest potential to change the profit picture for producers. The elasticity of profit with respect to UCOP is the highest of all parameters studied.

Further Analysis of the Critical Control Points

In order to gain a better understanding of the critical control points, each critical control point was further analyzed to determine what variables significantly explain the critical control point.

Unit Cost of Production (UCOP)
Unit cost of production gets its analytical power from the fact that it is a ratio of total production divided by the total enterprise costs. It takes both total production and total costs into account. UCOP can be immediately compared to market price so that it constantly reminds the producer of his potential profit. Regression analysis was used to determine the measurable factors determining unit cost of production. The derived equation is shown below, with t-values of the parameter estimates in parentheses. All estimated parameters in the model are significant at the 5 percent level. R-square of the model is 0.3162.

\[
\text{UCOP} = 66.35 + 0.0064(\text{FEED}) - 0.0043(\text{WEAN}) - 0.0043(\text{FEEDLOT}) + 0.000000117(\text{FEEDLOT})^2
\]

(14.52) (4.34) (-5.27) (-3.01) (2.88)

Three factors were identified as important in determining the unit cost of production: 1) total flock feed cost (FEED), 2) total flock weaning weight (WEAN), and 3) total flock post weaning weight gain (FEEDLOT) and (FEEDLOT^2).

The feed cost parameter (.0064) implies that a $100 increase in the flock's total feed bill, with all other factors held constant, raises UCOP by 64 cents. A feed purchase as small as the purchase of three lick barrels in a flock of this size raises unit cost of production by nearly $1 a hundredweight. This analysis suggests that producers need to carefully evaluate their feed purchase decisions.

An increase in weaning weight decreases unit cost with a parameter estimate of -.0043. This implies that, at least up to a point, lamb is more cheaply produced by having the ewe feed the lamb.

Post-weaning gain (FEEDLOT), the difference between sell weight and wean weight, lowers unit cost of production. The implication of this is that starting to feed lambs earlier lowers unit cost of production. Increasing the flock's total weaned lamb weight by 100 pounds decreases unit cost of production by 43 cents. Increasing the flock's total post-weaning weight gain by 100 pounds also decreases unit cost of production, but at a slightly smaller rate. Because the squared term of FEEDLOT is in the equation and affects UCOP positively, a 100-pound increase in post-weaning weight gain decreases unit cost of production by 42.9 cents. A one thousand pound increase in the flock's total post-weaning gain decreases unit cost of production by 33 cents.

With an upper bound on acceptable size for market lambs, WEAN and FEEDLOT parameters suggest the need for further study to arrive at an economically optimum wean weight, to take advantage of the most efficiency from both pre- and post-weaning feeding times.
**Gross Revenue (GROSS)**
The statistical function for gross revenue can be represented by an equation of two parameters shown below. Parameter estimate t-values are given in parentheses. R-squared is .88 and all parameters are significant at the 5 percent level.

\[
\text{Gross} = 4003.67 + .955(\text{FEEDLOT}) - 52.28(\text{MANAGE})
\]

This equation suggests that adding value to feeder lambs is positive for gross revenue. The value-added component also is a critical success factor in the net equation. The effect of a change in the amount of post-weaning feeding of lambs (FEEDLOT) is larger than the net profit equation implies as the FEEDLOT factor also plays a positive role in increasing gross revenue.

The management parameter also is a critical control point for profitability. A positive value for MANAGE indicates that there are days during the lambing season when no ewes give birth. This is wasteful of committed labor and may lead to less rigorous attention being paid to the lambing ewes for the rest of the season. Like FEEDLOT, this factor plays a more important role in the net profit equation than its parameter estimates might suggest, since it also affects the level of gross revenue.

The combination of these two parameters suggests that more management attention should be paid to compressing the lambing season so that more of the labor and management resources can be used at the value-added (lamb fattening) phase. Both shortening the lambing season and increasing the post-weaning weight gain would have a positive effect on gross revenue, one of the critical control points for profitable sheep production.

**Management Measurement (MANAGE)**
The third critical success factor in profitable sheep production is the variable MANAGE. This variable is the length of the lambing season defined as number of days from the date the first lamb in the flock is born to the date of the birth of the last lamb minus the number of ewes in the flock. A negative number means that, on the average, there is at least one birth per day. A positive number indicates that, at least on some days during the lambing season, there are no births. A more spread out lambing season with days that have no births means that the shepherd is expending labor to check the flock and is not seeing any results.

The combination of these two parameters suggests that more management attention should be paid to compressing the lambing season so that more of the labor and management resources can be used at the value-added (lamb fattening) phase. Both shortening the lambing season and increasing the post-weaning weight gain would have a positive effect on gross revenue, one of the critical control points for profitable sheep production.

The prediction equation for MANAGE is below. T-values are in parentheses. The R-square of the model is .78 and all parameters are significant at the 5 percent level.
MANAGE = 91.71 - 21.49(MONTH) - .47(NGCWT)
          (7.76)      (-5.86)    (-16.93)

MANAGE suggests two things. First, when the lambing season is prolonged, the shepherd may get tired which leads to a reduced level of care for the flock. When few lambs are being born, it is easy to skip a night check or otherwise step down the level of management afforded the flock. Second, the lengthened lambing season is an indicator of a lower level of management during the flushing and breeding season and may be a proxy for a lower year-round management level.

MANAGE is predicted by two parameters. The first is the month the first lamb is born. This may be a biological response of the ewes to hitting their peak estrus periods. The data show a reduction in the MANAGE parameter in February, followed by a rise through March and a reduction again starting in April and continuing through June. This corresponds to data on production increases in the North Dakota Sheep Testing Program that shows an increase in lambing rate in February (Haugen, 1995). An increase in prolificacy and an increase in percentage of the flock cycling occurs when breeding is timed for the period when the ewe is most actively in estrus.

The second parameter is the total flock production (calculated without government payments) (NGCWT), suggesting that as production rises, the MANAGE number decreases. For most producers in this study, market lambs made up the bulk of the flock's production. Higher lamb production is the result of best management techniques in nutrition, reproductive management, and animal selection. Lambing season length is also affected by these best management practices.

**Value-added Component (FEEDLOT)**

Another critical control point was FEEDLOT which measures the amount of weight added to the lambs after they are weaned and before they are sold. This value-added component shows up in the equation as a squared term, implying that its impact on the net profit contribution rises exponentially.

The prediction equation for valued is below. T-values for parameter estimates are in parentheses. The FEEDLOT model has an R-square of .94 and all parameters are significant at 5 percent.

FEEDLOT =
          139.65 - 55.24(DEATH) - .83(WEAN) + 77.83(NGCWT)
          (.415)   (-2.699)   (-12.86)     (24.1)

The FEEDLOT parameter can be predicted with a three-term equation: 1) percent death loss of lambs pre-weaning (DEATH), 2) total flock weaning weight (WEAN), and
3) total flock production (calculated without government payments) (NGCWT).

As death loss rises, the critical success factor, FEEDLOT, goes down. This suggests the reluctance of a producer, who has already experienced higher death loss, to accept risk of owning the lambs for a longer time. Since the majority of lamb deaths pre-weaning occur in the first three days of life, most often in the first 24 hours, reduced management at lambing time tends to lead to sales of feeder lambs.

Total weaning weight is negatively related to FEEDLOT since average weaning weight is one of the defining terms for FEEDLOT. The upper bound for lamb weight is set by the market for slaughter lambs. As weaning weight increases, the FEEDLOT component has to be reduced. This asks the question, where are the efficiencies in lamb feeding the best? Are they gained by earlier weaning and feeding the lamb in the feedlot sooner or should lambs be weaned later to optimize the return to the producer? The data available are not sufficient to answer this question.

Finally, FEEDLOT is predicted by total non-government production (NGCWT) in the flock. Since NGCWT is positively related to FEEDLOT, the two factors will move together. The other possibility is that the manager who has the skills in all areas necessary to have a high production level also has the skills and confidence to retain ownership of his lambs through the feeding period and market at higher weights.

**Conclusions/Implications**

This research identifies critical control points for profitable sheep production. It also identifies the fallacy of some traditionally held beliefs in critical management parameters for profitable sheep production. Profits in the sheep business in the flocks studied were driven by cost control, gross production, the amount of post-weaning weight gain in lambs and a management measurement, calculated from length of lambing season and flock size.

Our study suggests that traditionally measured parameters such as lambing rate, average weaning weight and death loss are not critical control points for profitability in sheep flocks. Pre-weaning death loss did appear in the functional equation for the definition of the term feedlot, however its effect on net profit was very small. This would suggest that expensive efforts by shepherds to change the lambing rate and death loss results in their flocks may not be cost effective.

The total cost and total production functions strongly suggest that potential for size increases in sheep enterprises exists. While the available data do not cover a range large enough to be sure of the optimum size, it does set the stage for further research to determine the optimum flock size. Further work to refine the total cost curve for
this group of producers would provide them with a powerful tool for maximizing profits from their sheep enterprise. Producers who are aware of their individual cost function have a competitive advantage in agricultural production.

Producers should focus more management attention on cost of production records. While not foregoing traditional records, less emphasis should be placed on the traditional production measurements of lambing rate and pre-weaning death loss. Producers need to spend more management attention on knowing their cost of growing feeder lambs and their costs of weight gain on lambs after weaning.

Today's producer should strongly consider using a profit center analysis program to determine and monitor the profitability of his sheep flock. In addition, our study suggests that sheep producers should maintain historical records of critical control points allowing them to measure progress over time. The availability of SHEEPBUD and the SHEPHERD database to sheep producers makes this task easy and inexpensive.

Several cautions should be kept in mind when using this research. First, the analysis was done with cash cost of production data. Resources were not valued at market price. This may have allowed low cost feed producers to skew the results. The sample size is small relative to the population of sheep producers in the United States. The flocks studied represent a fairly homogenous group of producers in a small geographic area. The study group represents only part of the many different types of management, climates, marketing conditions, and other variations that exist in the sheep industry; never-the-less, it is a start. We hope that this research stimulates additional study of the critical control points for profitability in the sheep industry.

Additional/ future research needs resulting from this project
The November 1996 release of the SHEEPBUD computer program on a national basis should allow this research to be readdressed with a larger data set in the future. The SHEPHERD database has been programmed to record both cash cost and economic data from producers. In addition, if its use is more widespread, it will be possible to test the identified critical control points in other climates and marketing areas with different management systems and expanded flock sizes.

References

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### Project Background

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