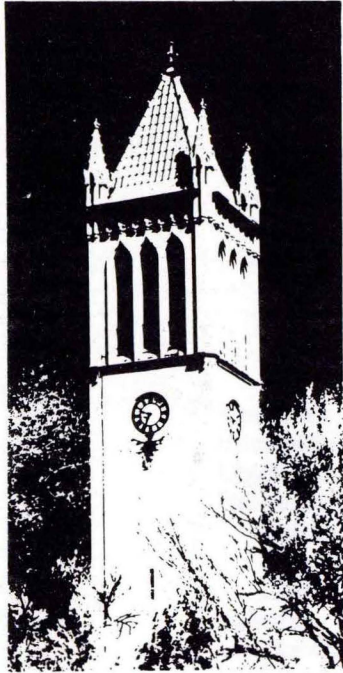


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Weight Loss of Fed Steers and Marketing-Decision Implications

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CONTENTS

Summary	4
Introduction	5
Objectives and Scope	5
Research Method	6
Cattle Marketing Arrangements in Iowa	6
Hypotheses and Experiments	6
Data	8
Results	8
Hot-Carcass Weight	9
Liveweight Shrink	10
Comparing Marketing Alternatives	11
Discussion	12
References	12
Appendix: Statistical Procedures	13

SUMMARY

Weight loss of fed steers during shipment to market adds to marketing cost. An understanding of factors influencing weight loss will aid feeders in making marketing decisions. In this study, we identified several factors that have a significant impact on percentage liveweight shrink and on hot-carcass weights of fed steers, quantified these impacts, and developed a method for predicting liveweight shrink and hot-carcass weight. Predictions of liveweight shrink and hot-carcass weight formed the basis for our development of guidelines for the evaluation and comparison of fed-steer marketing alternatives.

In this study, emphasis was placed on measuring the impact of feeding and marketing practices on weight loss of fed steers during marketing. Among the feeding practices considered were type of housing, quality and yield grades of finished steers, and weight of finished steers. Different shipping distances as well as different typical Iowa marketing arrangements also were considered.

To determine typical marketing arrangements for fed cattle in Iowa, a survey of eight Iowa packers was conducted. We found that, in Iowa, 87% of the fed cattle were purchased directly from feedlots and that terminal market purchases and a small percentage of auction purchases accounted for the remainder. Nearly half the cattle was purchased directly from feedlots on a liveweight basis. In some instances, buyers require that feed and water be withheld from cattle for a period before shipment; in other instances, cattle are held off feed and water at the plant for a period before slaughter, and, otherwise, there are no feed and water restrictions. Payweight is determined by deducting from the actual liveweight an agreed-upon percentage called pencil shrink. About 40% of all cattle were purchased directly from feedlots on a carcass-weight or carcass grade-and-weight basis. Feed and water restrictions were required on a modest percentage of these purchases.

We designed and carried out experiments that enabled us to measure differences in liveweight shrink and hot-carcass weights attributable to differences in feeding and marketing practices. The experiments were conducted over a 3-year period on 1282 steers from the Allee Research Center near Newell, Iowa.

Our results show that percentage liveweight shrink is related to feeding and marketing practices of fed steers. For instance, liveweight shrink is greater for steers fasted before slaughter than for steers not fasted, and still higher for steers withheld

from both feed and water before slaughter. Steers marketed through terminals tend to experience higher levels of shrink than those purchased directly from feedlots. Steers shipped longer distances shrink more than those shipped shorter distances. The type of housing used during feeding also has an effect on weight loss. Steers fed in unsheltered or partly sheltered facilities lose more weight than those fed in confinement buildings. And shrink is higher for steers experiencing faster rates of gain near the end of the feeding period.

Variations in hot-carcass weight are explained by a slightly different group of factors. Withholding feed before slaughter does not reduce hot-carcass weight, but withholding both feed and water does. Marketing steers through terminals also tends to reduce hot-carcass weight. As could be expected, steers with higher feedlot weights have higher hot-carcass weights. Also, higher quality and yield-grade scores are linked with higher hot-carcass weights. Hot-carcass-weight results are similar to liveweight-shrink results in that hot-carcass weights are higher for steers fed in confinement buildings than for steers fed in partly sheltered or unsheltered facilities. The two sets of results are also similar in that higher rates of gain toward the end of the feeding period are associated with lower hot-carcass weights.

By using the results from our statistical analysis, we developed a procedure that feeders can use to evaluate and compare bids from different marketing alternatives for fed steers. The unique characteristics of the feeding operation and of each marketing alternative are recognized and taken into account. The first step is to arrive at a prediction of liveweight shrink, or hot-carcass weight, or both, for each bid to be compared. Then liveweight bids, adjusted for pencil shrink, are further adjusted for predicted actual shrink. Hot-carcass-weight bids are converted to comparable liveweight bids by multiplying the hot-carcass-weight bid by the ratio of predicted hot-carcass weight to feedlot weight. Finally, the bids are adjusted for differences in transportation costs. This procedure can be used to compare liveweight bids from different outlets, liveweight and carcass-weight bids from the same or different outlets, and carcass-weight bids from different outlets. It can also be used to determine the impact on the bid of selected conditions of sale; e.g., withholding feed and water from cattle before shipment.

Weight Loss of Fed Steers and Marketing-Decision Implications¹

Ronald Raikes, Gail M. Sieck, H. L. Self, and M. Peter Hoffman²

One of the important and complicated decisions that a fed-cattle producer faces is the choice of a marketing alternative. For instance, there may be several outlets at different distances from his feedlot, and one or more buyers may submit both liveweight and carcass-weight bids. Further, different conditions of sale may be associated with different bids. To compare alternatives accurately, the feeder must be able to estimate and take into account differences in weight loss of cattle between alternatives. Weight loss may be affected by feeding practices, distance shipped, and marketing conditions. The purposes of our study were to provide information that feeders can use to predict weight loss of fed steers in a variety of marketing situations and to offer procedures that feeders can use to evaluate the marketing alternatives by comparing net effective bids that take into account differences in predicted weight loss.

In previous studies, several factors that explain some of the variation in weight loss have been identified, and impacts of some of these factors on shrink have been quantified. Liveweight shrink has been found to be less when temperature and other weather conditions are moderate (Brotherton and Tippets, 1957; Harston, 1959a), when feed and water are not withheld before shipment (Harston, 1959b), and when steers are shipped shorter distances (Abbenhaus and Penny, 1951; Henning and Thomas, 1962). Moreover, shrink increases at a decreasing rate with time elapsed during marketing and with shipping distance (Abbenhaus and Penny, 1951; Brotherton and Tippets, 1957; Henning and Thomas, 1962). Impacts of production practices and marketing conditions on hot-carcass weights are less well understood because fewer studies have been conducted. But hot-carcass weights were found to be unaffected when feed is withheld from cattle for up to 48 hours before slaughter (Carr, Allen, and Phar, 1971; Kirton, Patterson, and Duganzich, 1972). Withholding both feed and water, however, caused a sharp decrease in hot-carcass weights as examined by Raikes and Tilley (1975).

Some other factors that may affect liveweight

shrink or hot-carcass weights, or both, have not been satisfactorily explained. Raikes and Tilley (1975) provided some evidence about impacts of some feeding practices (e.g., amount of shelter provided during feeding and rate of gain) on weight loss. Also, influences of some characteristics of the finished cattle such as quality and yield grades have been investigated but not firmly established (Abbenhaus and Penny, 1951; Brotherton and Tippets, 1957; Henning and Thomas, 1962; Raikes and Tilley, 1975). But these earlier studies do not provide information about impacts of some commonly used marketing arrangements on weight loss, nor do they incorporate information about weight loss into marketing-decision guidelines.

OBJECTIVES AND SCOPE

We undertook this study with three objectives in mind. Our first objective was to identify factors that affect liveweight shrink and hot-carcass weights of fed steers during marketing and to quantify the impacts of these factors. We wanted to reexamine, and thereby provide additional evidence about, impacts of factors that had been considered in earlier studies and to consider some additional factors. The additional factors of most interest were the various feeding practices and marketing arrangements commonly used in Iowa. A second objective was to use the list of factors identified and the measures of their impacts to develop a procedure for forecasting liveweight shrink and hot-carcass weights in a wide range of marketing situations. Our third objective was to formulate guidelines that both fed-cattle producers and buyers can use in making marketing decisions. We recognized that these guidelines would be useful for comparing marketing alternatives only to the extent that accurate forecasts of weight loss are incorporated.

The results of our study are applicable to most cattle-feeding operations in Iowa. The scope of our research, however, was limited in some respects. Because only steers were used in the experiments, the results may not be applicable to fed-heifer marketing. Also, we did not attempt to determine the impact of weather conditions on weight loss, nor were we able to control for this factor by marketing all cattle in similar weather conditions. The impact on weight loss of different handling and loading procedures was not studied, but we controlled for this factor by using the same procedures for all cattle included in the experiments.

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RESEARCH METHOD

Our first step in the research was to decide which factors to consider in the analysis of weight loss. Because our ultimate objective was to develop guidelines for comparing marketing alternatives, we attempted to identify and include in the analysis the various marketing arrangements frequently practiced in Iowa.

Cattle Marketing Arrangements in Iowa

During September and October of 1974, a survey of Iowa packers was conducted to identify and determine the relative importance of alternative fed-cattle marketing arrangements. Eight Iowa packers with a total hourly slaughter capacity of 1040 head participated in the survey. The results are summarized in Table 1.

Table 1 shows that 1% of fed cattle were purchased by packers through auctions and that 12% were purchased through terminal markets. Most fed cattle, about 87%, were purchased directly from feedlots. All cattle purchased through auctions and terminals are purchased on a liveweight basis, but cattle purchased directly from feedlots may be purchased on a liveweight basis, a carcass-weight basis, or a carcass grade-and-weight basis.

According to the survey results, about 47% of all fed cattle are purchased directly from feedlots on a liveweight basis. Four different marketing arrangements have been common in Iowa. (1) About 18% of all cattle are shipped in the morning and weighed at the packing plant. A 1% to 3% pencil shrink is deducted depending upon distance from the feedlot to

the packing plant.³ (2) Nine percent of all cattle are shipped in the morning and weighed at or near the feedlot with a 3% pencil-shrink deduction. (3) About 15% of all cattle are marketed under a third arrangement whereby the cattle are held off feed and water during the afternoon and night before shipment, shipped in the morning, and weighed at the packing plant with no pencil shrink deducted. (4) Under a fourth arrangement, about 2% of all cattle are shipped in the morning, held off feed and water at the packing plant, and then weighed. No pencil shrink is deducted to determine payweight.

Carcass-weight sales are quite frequent in Iowa. According to our survey results, about 40% of all cattle are purchased directly from feedlots on a carcass-weight or carcass grade-and-weight basis. On carcass-weight or "in-the-beef" purchases, a price per cwt. of hot carcass is negotiated at the time of the purchase. Feed and water restrictions are imposed on nearly one-fourth of carcass-weight transactions. There is no pencil shrink on any carcass-weight transactions. About 9% of all cattle are sold directly from feedlots on a carcass grade-and-weight basis whereby a separate price per cwt. of hot-carcass weight is negotiated for each grade, or grade-and-weight, category at the time of sale.

The experiments described in the next section included treatments representing the fed-cattle marketing arrangements just described. Comparison of the treatments would enable us to compare weight losses between the arrangements.

Hypotheses and Experiments

We hypothesized that, in addition to marketing arrangements used, the following factors would affect liveweight shrink and hot-carcass weights of fed steers: amount of shelter provided during feeding, rate of gain at the end of the feeding period, quality and yield grades of finished cattle, final feedlot weight, and distance shipped. To test these hypotheses, data on liveweight shrink and hot-carcass weights were collected from four groups of steers fed during various intervals of a 4-year period at the Allee Research Center near Newell, Iowa. In all, 1282 steers were included in the four experimental groups.

Cattle in the experiments were housed in one of three types of facilities during feeding: confinement buildings, partly sheltered lots, and unsheltered lots. Evidence collected by Leu, Hoffman, and Self (1977) has shown that confined steers consume less, have slower average daily gains, and have less liveweight than steers fed in partly sheltered or unsheltered lots. Accordingly, we hypothesized that confined steers would have the lowest hot-carcass weights. With respect to liveweight shrink, we expected unsheltered and partly sheltered steers to experience more shrink than confined cattle; the major reason being that steers not fed in confinement tend to

Table 1. Marketing arrangements for fed cattle in Iowa: Results of a survey of eight Iowa packers conducted in the fall of 1974.

The percentage of fed cattle purchased:

Through auctions	1%
Through terminal markets	12%
Directly from feedlots	
Liveweight basis:	
A 1-3% pencil shrink deducted	18%
A 3% pencil shrink deducted	9%
Feed and water withheld at the feedlot	15%
Feed and water withheld at the packing plant	2%
Other	3%
Total liveweight purchases	47%
Carcass weight or carcass grade-and-weight basis:	
Feed and water withheld at the packing plant	9%
No feed or water restrictions	31%
Total carcass-weight purchases	40%
Total direct feedlot purchases	87%
Total purchases	100%

³ Pencil shrink is a percentage deducted from actual liveweight to arrive at payweight.

Table 2. Descriptions of marketing-arrangement treatments

Treatment number	Description
1	Cattle held at the farm without feed and water for 12 hours before shipment.
2	Cattle held at the farm without feed for 12 hours before shipment but water provided.
3	Cattle penned at the plant without feed and water for 12 hours before slaughter.
4	Cattle sold through a terminal market with no feed and water restrictions.
5	Control treatment with no feed and water restrictions.

have more debris on their hides, which may be dislodged during shipment.

Three different shipping distances were incorporated in the experiments. We hypothesized that liveweight shrink would increase and that hot-carcass weights would decrease, but at a decreasing rate, as distance shipped increases. Some of the cattle were hauled 40 miles to a packing plant at Cherokee, others went 80 miles to a packing plant at Spencer, and some loads were shipped 120 miles to a packing plant at Estherville.

The five marketing-arrangement treatments the steers were subjected to are described in Table 2. In treatment 1, steers were held at the feedlot without feed and water for 12 hours before shipment. Treatment 2 was the same as treatment 1 except that water was provided. Treatment 3 was the same as treatment 1 except that steers were held at the packing plant rather than at the feedlot. Treatment 4 was a simulated terminal-market treatment.

Steers were hauled from the feedlot to a stockyard, unloaded and held overnight, and then reloaded and hauled to the packing plant. Treatment 5 was our control. Steers were hauled directly from the feedlot to the plant and then slaughtered immediately without being subjected to feed or water restrictions. We expected that steers subjected to the control treatment would shrink less and have greater hot-carcass weights than steers subjected to the other treatments. We also expected that the rank of the other treatments would be 2, 1, 3, 4 in order of increasing shrink and decreasing hot-carcass weight. It seems likely that, if both feed and water are withheld, there will be more weight loss than if only feed is withheld, and it seems likely that steers held in unfamiliar surroundings will lose more weight than those held in more familiar surroundings. Because of the extra handling involved, we expected weight loss to be greatest for the terminal-market treatment.

We also examined the impacts of rate of gain during the final month of feeding, quality grade, and yield grade on liveweight shrink and hot-carcass weights. We expected that weight loss would be greater for faster rates of gain. We also expected that, for a given feedlot weight, hot-carcass weights would be heavier for higher yield grades and quality grades because higher grades imply fatter cattle.

Details about the application of the shipment and marketing treatments to the four groups of cattle are presented in Table 3. Referring to Table 3, there were 12 loads of cattle in the experiment con-

Table 3. Shipment and marketing treatments for each experiment

Slaughter period	Number of steers shipped											
	40 miles					80 miles					120 miles	
	Treatment					Treatment					Treatment	
	1	2	3	4	5	1	2	3	4	5	3	5
Oct. 4-5, 1972 ^{a/}												
Wed., A.M.	--	--	--	--	--	--	--	26	--	25	25	26
Wed., P.M.	--	--	26	--	26	--	--	--	--	25	--	--
Thurs., A.M.	--	--	--	--	--	--	--	26	--	26	24	25
Thurs., P.M.	--	--	25	--	24	--	--	--	--	--	--	--
May 30-31, 1973 ^{b/}												
Wed., A.M.	--	--	24	--	24	--	--	24	--	24	24	24
Thurs., A.M.	--	--	22	--	22	--	--	24	--	23	24	22
Nov. 12-13, 1974 ^{c/}												
Tues., A.M.	25	--	25	25	24	--	25	24	24	25	--	--
Wed., A.M.	--	24	24	24	24	24	--	24	24	24	--	--
Apr. 29-30, 1975 ^{d/}												
Tues., A.M.	26	--	21	--	27	27	--	27	--	27	--	--
Wed., A.M.	25	--	21	--	26	26	--	27	--	27	--	--

^{a/} During this experiment, 304 steers were marketed after 160 days on feed. The steers were selected from 16 feedlots -- seven unsheltered, five partly sheltered, and four in a confinement building.

^{b/} During this experiment, 281 steers were marketed after 180 days on feed. The steers were selected from 16 feedlots -- seven unsheltered, five partly sheltered, and four in a confinement building.

^{c/} During this experiment, 390 steers were marketed after 140 days on feed. The steers were selected from 14 feedlots -- seven unsheltered, three partly sheltered, and four in a confinement building.

^{d/} During this experiment, 307 steers were marketed after 115 or 166 days on feed. The steers were selected from 18 feedlots -- five unsheltered, three partly sheltered, and ten in a confinement building.

ducted in the fall of 1972. The first line in the table shows, for example, that 26 cattle received treatment 3 and were shipped 80 miles. That is, they were hauled 80 miles from the feedlot to the packing plant where they were penned for 12 hours without feed and water. Twelve hours after their arrival, the 25 steers that had treatment 5 (control) arrived, and both loads were slaughtered immediately. Throughout the table, steers that were slaughtered at the same time are shown on the same line. The number of steers marketed, the days on feed, and the shelter treatments applied to the cattle are in the footnotes. No more than two steers fed in the same feedlot were shipped in the same load.

During the fall 1972 and spring 1973 experiments, only two marketing-arrangement treatments (3 and 5) were applied to steers, but all three shipment-distance treatments were studied. Three additional marketing-arrangement treatments were introduced for the final two experiments, but the 120-mile distance treatment was not included. Number of days on feed ranged from 115 for some of the cattle in the spring 1975 experiment to 180 days for cattle in the experiment 2 years earlier.

Data

Each steer in the experiment was individually weighed at the feedlot before the marketing-arrangement treatment was begun and was weighed again just before slaughter at the plant. Percentage liveweight shrink was computed by subtracting feedlot weight from plant weight, dividing by the feedlot weight, and then multiplying by 100. Hot-carcass weights were recorded for each steer. Other information recorded for each steer included housing, shipment-distance, and marketing-arrangement treatments, rate of gain during the final month of feeding, yield grade, and quality grade. Quality grades were coded by using 0 for grades below Standard, 1 to 3 for the Standard grade, 4 to 6 for the Good grade, 7 to 9 for Choice, and 10 to 12 for Prime. Yield grade scores ranged from 1.0 (highest yielding) to 5.9 (lowest yielding). All grading was performed by USDA graders.

RESULTS

Average values and ranges of variables describing the animals used in the experiments are summarized in Table 4. These values indicate that steers used in the experiments were representative of fed steers typically marketed in Iowa. Final feedlot weights ranged from 770 to 1445 lb. and averaged about 1087 lb. Average liveweight shrink was 3.4%, leaving an average liveweight at the packing plant before slaughter of 1050 lb.

Averages of liveweight shrink also are detailed according to marketing treatment. Cattle with no restrictions experienced the least shrink, and those held without feed and water either at the farm or at the plant had the most shrink. Keep in mind, however, that the other variables are not identical

Table 4. Average values and ranges for selected variables of the 1,282 steers used in the experiments

Variable	Average	Range	
		Low Value	High Value
Final feedlot weight	1086.7 lb.	770	to 1445 lb.
Packing plant weight	1049.9 lb.	750	to 1404 lb.
Liveweight shrink	3.4 %	-4.9	to 9.7 %
Held at farm without feed and water	4.1 %	-0.5	to 8.8 %
Held at farm without feed	3.3 %	-1.0	to 7.3 %
Held at plant without feed and water	4.1 %	-1.1	to 9.6 %
Terminal market	4.0 %	-4.8	to 8.2 %
No restrictions	2.4 %	-4.9	to 9.7 %
Hot-carcass weight	657.5 lb.	460	to 906 lb.
Dressing percentage: hot-carcass weight over packing plant weight	62.6 %	48.6	to 83.1 %
Held at farm without feed and water	63.2 %	54.8	to 67.3 %
Held at farm without feed	63.0 %	59.6	to 67.2 %
Held at plant without feed and water	63.0 %	55.2	to 83.1 %
Terminal market	62.3 %	56.7	to 66.3 %
No restrictions	62.1 %	48.6	to 69.0 %
Dressing percentage: hot-carcass weight over final feedlot weight	60.5 %	47.3	to 77.6 %
Daily rate of gain	2.1 lb.	-3.5	to 5.8 lb.
Quality grade ^{a/}	High Good	Low Std.	to High Prime
Yield grade	3.3	0.5	to 5.5

^{a/}Quality grades were assigned by using standards in effect before the revision on July 1, 1976.

for each marketing arrangement. Consequently, differences in shrink also may be due to type of housing condition, distance hauled, or other variables. The statistical analysis that we used in presenting the final results eliminates this problem by controlling for the other variables.

The average hot-carcass weight of 658 lb. was 60.5% of the final feedlot weight and 62.6% of the liveweight at the packing plant. By marketing arrangement, the hot-carcass weight to packing plant weight dressing percentage was lowest for the cattle with no restrictions and highest for cattle held at the farm without feed and water. This seems reasonable since the cattle with intake restrictions experienced the greatest shrink and accordingly a relatively lower packing plant weight, which boosted the dressing percentage. On the other hand, the unrestricted cattle had the smallest shrink and therefore the heaviest packing plant weights, which caused a lower dressing percentage. Again, we would like to caution the reader that the other variables are not the same for each marketing arrangement and may have some impact on the relative dressing percentages.

Daily rate of gain during the final month of feeding averaged 2.1 lb. Almost all the quality and yield grades were assigned to at least some steers in the experiments, but the average yield grade was 3.3, and the average quality grade was High Good. Note that quality grades were assigned by using standards in effect before the most recent revision in 1976. The average grade likely would have been somewhat higher had the revised standards been used.

The remaining results were obtained by applying the statistical procedures discussed in the Appendix and in Raikes and Tilley (1975). In our final analysis, we examined for both hot-carcass weights and liveweight shrink effects of the explanatory fac-

tors (main effects) and of the interactions between explanatory factors. The main effects show the separate and additive effects of the various levels of the individual factors while interactions show any additional influence due to the presence of a particular combination of levels of two factors. For example, main effects may show that the terminal-market treatment increases shrink by 2% over the control treatment and that the 120-mile distance treatment increases shrink by 1% over the 40-mile distance treatment. But the interaction may show that the presence of the terminal-market treatment and the 120-mile distance treatment together may increase shrink an additional 1%. Thus, in this example, main effects alone show that shrink is 3% greater with the terminal-market and 120-mile treatments than with the control and 40-mile treatments, but if both the main effects and interactions are recognized, the difference is 4%.

Hot-Carcass Weight

Factors found to affect hot-carcass weight significantly were housing treatment, marketing-arrangement treatment, rate of gain, quality grade, yield grade, and final feedlot weight. We found that distance shipped did not significantly affect hot-carcass weights. Also, interactions did not improve the explanation of variation in hot-carcass weights.

Our hypothesis that hot-carcass weights would be lowest for steers fed in confinement was not consistent with the results. One possible explanation for our results is that, because confined steers consume less, their fill at slaughter time would be smaller, resulting in less weight loss. By holding final feedlot weight and other factors constant, hot carcasses of steers fed in confinement averaged about 12 lb. heavier than those of steers fed in partly sheltered facilities and about 11 lb. heavier than hot carcasses of steers fed in unsheltered lots. Hot-carcass weights of steers fed in partly sheltered lots were not significantly different from hot-carcass weights of steers fed in unsheltered lots, other things constant.

Results concerning the impacts of marketing-arrangement treatments on hot-carcass weights were only partly consistent with our hypothesis. Hot carcasses of steers held at the farm without feed (treatment 2) were, other things constant, more than 9 lb. heavier than hot carcasses of steers held at the farm without feed or water (treatment 1). This result supports the findings of Carr, Allen, and Phar (1971) and Kirton, Patterson, and Duganzich (1972) that withholding feed but providing water does not result in reduced hot-carcass weights. The result also suggests that withholding water before slaughter does reduce hot-carcass weights. Our results also showed that, other things constant, hot carcasses of steers held at the farm without feed were more than 11 lb. heavier than those of steers given the terminal-market treatment and nearly 13 lb. heavier than those of steers held off feed and water at the plant. A troublesome result, however, was that hot carcasses of steers given treatment 2

were significantly heavier than those of steers given the control treatment. A plausible explanation of this result escapes us.

The rest of the results, however, generally were consistent with our hypotheses. We found that steers gaining more rapidly near the end of the feeding period had slightly lower hot-carcass weights than those gaining more slowly. A 1-lb. increase in average daily rate of gain was associated with a reduction of about 3 lb. in hot-carcass weight. Other things constant, a 1-lb. increase in final feedlot weight led to a 0.63-lb. increase in hot-carcass weight. Variations in quality grade had a moderate impact on hot-carcass weight. For instance, the hot-carcass weight of a Prime steer was only 3 lb. heavier than that of a Choice steer. Yield grade variations, however, had a stronger effect. Other things constant, a steer with a yield grade of 4 had almost 7 more pounds of hot-carcass weight than a steer with a yield grade of 3.

These results can be used to forecast hot-carcass weights of steers in a variety of situations. The forecasting procedure is outlined in Table 5. First, identify the appropriate housing condition and marketing arrangement and record the corresponding impact estimators in the column entitled "Impact-estimator entries." Next, record rate of gain in pounds, final feedlot weight in pounds, quality grade score, and yield grade in the column of blanks to the left of the impact-estimator entry column. Third, multiply these values by their corresponding impact estimators and record the products in the impact-estimator entries column. Finally, sum the values in the right column to arrive at the hot-carcass weight prediction. Values for the following example situation are shown in Table 5.

The procedure for predicting hot-carcass weight can be summarized with the expression:

Table 5. Hot-carcass-weight prediction worksheet and example

Variables	Impact estimators	Impact estimator entries
Constant.....	-43.79	-43.79
Select one impact estimator each for housing condition and marketing arrangement.		
Housing condition		
No shelter.....	-3.19	
Partly sheltered.....	-4.30	-3.19
Confinement.....	7.49	
Marketing arrangement		
1 - Hold at farm without feed and water....	-0.76	
2 - Hold at farm without feed.....	8.75	
3 - Hold at plant without feed and water...	-3.85	-0.76
4 - Terminal market.....	-2.64	
5 - No restrictions.....	-1.50	
Multiply the daily rate of gain in lb., feedlot weight in lb., quality grade and yield grade by their corresponding impact estimators.		
Rate of gain.....	-2.99 X 2.1 =	-6.28
Feedlot weight.....	0.63 X 1087 =	684.81
Quality grade ^{a/}	0.84 X 6 =	5.04
Yield grade.....	6.52 X 2 =	13.04
Total the column of impact estimator entries.		
Predicted hot-carcass-weight.....		648.87

^{a/} Code quality grade as follows: Low Standard = 1, Average Standard = 2, High Standard = 3, Low Good = 4, ... High Prime = 12.

Hot-carcass weight prediction = $-43.79 +$ housing condition impact estimator + marketing-arrangement impact estimator + $(-2.99 \times \text{daily rate of gain in lb.}) + (0.63 \times \text{feedlot weight in lb.}) + (0.84 \times \text{quality grade code}) + (6.52 \times \text{yield grade})$.

Example 1. Suppose you are interested in predicting the average hot-carcass weight for steers that have been fed in an unsheltered lot, will be held at the farm without feed and water before shipment to slaughter, have had an average rate of gain of 2.1 lb. per day during the last month of feeding, have an average feedlot weight of 1087 lb., and whose quality and yield grades will average High Good and 2.0, respectively. As is shown in Table 5, the impact estimators for the housing condition and marketing arrangement are -3.19 and -0.76 , respectively. The entry for rate of gain, -6.28 , is obtained by multiplying the 2.1-lb. daily rate of gain by the corresponding impact estimator, -2.99 . The next three entries in the right column are calculated in the same manner. The sum of the column of impact-estimator entries is 648.87 lb., which is the predicted average hot-carcass weight.

Liveweight Shrink

The results for liveweight shrink suggest that amount of weight loss depends on housing condition, marketing arrangement, the interaction of housing condition and marketing arrangement, rate of gain during the final month of feeding, and shipping distance. Thus, although shipping distance does not affect hot-carcass weight, it does affect liveweight shrink. On the other hand, final feedlot weight, quality grade, and yield grade do affect hot-carcass weights but do not affect percentage of liveweight shrink.

The impacts of housing conditions during feeding on liveweight shrink were, we found, similar to their impacts on hot-carcass weights. Steers fed in confinement buildings shrank the least. Partly sheltered steers shrank the most, losing almost 0.9% more weight than steers fed in confinement buildings. But shrink losses by steers fed in unsheltered lots were almost as large. Unsheltered steers lost over 0.6% more weight than confined steers.

We anticipated that marketing-arrangement treatment would affect liveweight shrink and that the greatest weight losses would be associated with the most amount of handling and stress. The results were generally as anticipated. Shrink was least for steers in the control treatment that were shipped from the feedlot and then slaughtered immediately. Shrink for the steers held at the farm with just a feed restriction (treatment 2) was next to lowest, averaging less than 0.5% more than shrink for the control group. Steers subjected to our terminal-market treatment experienced 0.9% more shrink than control steers. It is perhaps noteworthy that steers held off both feed and water shrank more

than those given our terminal-market treatment. Steers held at the farm without feed and water shrank 1.1% more than control steers and nearly 0.7% more than steers that were held at the farm without feed but were provided water. Thus, the water restriction has a sharp impact on weight loss. Cattle held at the plant without feed and water shrank even more, 1.8% more than control steers.

We found that the total impact of a given marketing arrangement on shrink depends on the particular housing condition. That is, we found that, not only were there significant main effects for housing and marketing arrangements, but also there were significant interaction effects. Most of the interaction effects were small, but some were of moderate size. For example, the combination of partly sheltered housing and holding cattle on the farm without feed increased shrink by 0.87% over what would be indicated by the main effects alone. And shrink for the combination of confined housing with marketing treatment 2 was 0.5% less than that indicated by the main effects. When both main effects and interaction effects are considered, shrink is highest for the no-shelter, treatment 3 combination; second highest for the partly sheltered, treatment 3 combination; lowest for the confinement, treatment 2 combination; and second lowest for the partly sheltered, treatment 5 combination.

The results for rate of gain indicated that steers gaining weight more rapidly toward the end of the feeding period tend to shrink more than steers gaining less rapidly. The impact, however, is not large. For instance, a steer with a 3-lb. daily rate of gain would be expected to shrink 0.15% more than a steer with a 2-lb. daily rate of gain.

As we hypothesized, shrink increased as shipping distance increased, but at a decreasing rate. The analysis provided impact estimators for three shipping distances. Shipping steers 120 miles resulted in 0.8% more shrink than did shipping them 40 miles, but it resulted in only 0.22% more shrink than did an 80-mile haul.

Our results for liveweight shrink can be used to forecast percentage liveweight shrink of fed steers subjected to various feeding and marketing practices. The procedure is similar to the procedure used for hot-carcass weights and is outlined in Table 6. To use Table 6, select the appropriate housing condition, marketing-arrangement treatment, and interaction, and record the corresponding impact estimators in the right column. Enter the daily rate of gain in pounds, multiply it by the impact estimator, and record the product in the right column. Next, find the impact estimator for shipping distance. If distance is 39 miles or less, use -0.46 , and if it is 120 miles or more, use 0.34. If distance is between 40 and 79 miles, compute the impact estimator by using the expression:

$$-1.04 + (0.0145 \times \text{distance}) = \text{impact estimator.}$$

If distance is between 80 and 119 miles, use:

Table 6. Liveweight shrink prediction worksheet and example

Variables	Impact estimators	Impact estimator entries
Constant.....	3.06	<u>3.06</u>
Select one impact estimator each for housing condition, marketing arrangement and two-way interaction.		
Housing condition		
No shelter.....	0.14	
Partly sheltered.....	0.36	<u>0.14</u>
Confinement.....	-0.50	
Marketing arrangement		
1 - Hold at farm without feed and water	0.26	
2 - Hold at farm without feed	-0.39	
3 - Hold at plant without feed and water.....	0.93	<u>0.26</u>
4 - Terminal market	0.04	
5 - No restrictions	-0.84	
Interaction (housing condition x marketing arrangement)		
No shelter x 1	-0.08	
No shelter x 2	0.37	
No shelter x 3	0.07	
No shelter x 4	0.44	
No shelter x 5	-0.06	
Partly sheltered x 1	-0.08	
Partly sheltered x 2	0.87	
Partly sheltered x 3	-0.16	<u>-0.08</u>
Partly sheltered x 4	-0.15	
Partly sheltered x 5	-0.48	
Confinement x 1	0.16	
Confinement x 2	-0.50	
Confinement x 3	0.09	
Confinement x 4	-0.29	
Confinement x 5	0.54	
Multiply the daily rate of gain in lb. by the impact estimator:		
Rate of gain	0.15 x 2.1 =	<u>0.315</u>
Select the impact estimator for distance or enter miles and determine impact estimator.		
Shipping distance		
Less than 40 miles.....	-0.46	
40-79	-1.04 + (0.0145 x 60) =	<u>-0.17</u>
80-119 miles	-0.32 + (0.0055 x) =	
Greater than 119 miles.....	0.34	
Total the column of impact-estimator entries		
Predicted liveweight shrink percentage		<u><u>3.525</u></u>

$$-0.32 + (0.0055 \times \text{distance}) = \text{impact estimator.}$$

Finally, total the entries in the right column to arrive at the predicted percentage liveweight shrink. Table 6 illustrates a liveweight shrink prediction using the values in example 2.

The following expression summarizes the liveweight shrink prediction procedure as outlined on the worksheet.

$$\begin{aligned} \text{Liveweight shrink prediction} = & 3.06 + \\ & \text{housing condition impact estimator} + \\ & \text{marketing-arrangement impact estimator} + \\ & \text{interaction of housing conditions and} \\ & \text{marketing arrangement impact estimator} + \\ & (0.15 \times \text{daily rate of gain in lb.}) + \\ & \text{selected or calculated shipping distance im-} \\ & \text{pact estimator.} \end{aligned}$$

Example 2. Suppose that you want to forecast percentage liveweight shrink for steers to be shipped to a packer 60 miles away. Feeding practices and marketing arrangements are the same as were described in example 1. The appropriate impact estimators corresponding to housing condition, marketing arrangement, and interaction are recorded in the right column of Table 6. The rate of gain, 2.1 lb. per day, was multiplied by 0.15 to arrive at the entry of 0.315. The impact estimator for dis-

tance is $-1.04 + (0.0145 \times 60) = -0.17$. The sum of the entries in the right column and the predicted percentage liveweight shrink is 3.525%.

COMPARING MARKETING ALTERNATIVES

Information about factors affecting weight loss of fed steers during marketing, and especially forecasts of hot-carcass weights and percentage liveweight shrink, may be used by cattle feeders to compare different bids and to compare marketing arrangements. We have developed some guidelines for making these comparisons.

Comparison of bids involves much more than simply comparing numbers because some bids may be on a liveweight basis while others are on a carcass-weight basis, and marketing arrangements associated with different bids may be different. Furthermore, bids are likely to come from packers that are different distances from the feedlot. Distance is important, not only because it affects weight loss, but also because feeders in Iowa usually pay the transportation cost to the packer. To compare bids, then, it is necessary to first express bids on a comparable basis whereby adjustments have been made for differences in actual and pencil shrink and in transportation costs. To convert liveweight bids to a comparable basis, the following expression may be used:

$$\left[1.0 - \left(\frac{\text{pencil shrink} + \text{predicted shrink}}{100} \right) \right] \times [\text{liveweight bid per cwt.}] - \text{transportation costs per cwt. of liveweight} = \text{adjusted liveweight bid per cwt.}$$

To use this expression, enter the pencil shrink, if any, and add to it the predicted actual shrink. The latter may be obtained by using the worksheet in Table 6. Then, divide by 100 to convert to a decimal, subtract the decimal from 1.0, and multiply this difference by the quoted liveweight bid in dollars per cwt. This product is the net amount you receive per cwt. of liveweight at the feedlot. Finally, subtract the transportation cost per cwt. to arrive at the adjusted bid.

It often may be to the feeder's advantage to compare liveweight and carcass-weight bids. This may be accomplished by using the following expression:

$$\left[\left(\frac{\text{Predicted hot-carcass weight}}{\text{Feedlot weight}} \right) \times (\text{hot-carcass weight bid per cwt. of carcass}) \right] - \text{transportation cost per cwt. of liveweight} = \text{adjusted liveweight bid per cwt.}$$

By using this expression, the hot-carcass weight bid is converted to a net effective bid per cwt. of

liveweight that is comparable with the adjusted liveweight bid just derived. To use the expression, you need to predict the hot-carcass weight, perhaps by using the worksheet in Table 5, and to estimate the liveweight at the feedlot. Then, simply multiply the ratio of hot-carcass weight to feedlot weight by the carcass-weight. Because there usually is no pencil shrink on carcass-weight sales, it is not considered. This expression may, of course, also be used to compare different carcass-weight bids. An example will demonstrate its use in comparing liveweight and carcass-weight bids.

Example 3. In earlier examples, we predicted an average hot-carcass weight of 648.87 lb. and an average liveweight shrink of 3.525% under specified feeding and marketing conditions. Now, assume that the feeder has received a hot-carcass weight bid of \$65 per cwt. from a packer 100 miles away. Another packer, who is 60 miles away, has placed a liveweight bid of \$40.50 per cwt. with no pencil shrink. Transportation costs are \$0.30 per cwt. for a 60-mile haul and \$0.45 per cwt. for a 100-mile haul. The adjusted carcass-weight bid is

$$\left(\frac{648.87}{1087} \times \$65.00\right) - \$0.45 = \$38.35$$

and the adjusted liveweight bid is

$$\left[1.0 - \left(\frac{3.525\%}{100}\right)\right] \times \$40.50 - \$0.30 = \$38.77$$

The liveweight bid will yield the feeder greater revenue.

DISCUSSION

In addition to comparing marketing alternatives, our results form the basis for some general guidelines that cattle feeders may find useful. Because shipment distances of 120 miles or less affect percentage liveweight shrink but do not affect hot-carcass weights, it is likely that carcass-weight bids will be relatively more attractive as shipping distance increases. Keep in mind, though, that the impact of shipment distances beyond 120 miles on hot-carcass weights is not yet known. Marketing-arrangement details are quite important. For instance, if cattle are to be held off both feed and water, it is to the feeder's advantage that they be held off at the farm rather than at the plant. According to our results, it is to the feeder's advantage to withhold feed from cattle and provide water during the 12 hours before shipment on carcass-weight sales even if the buyer does not require a feed restriction. And withholding feed but providing water is to the feeder's advantage even on liveweight sales if cattle are fed in confinement. Finally, our results indicate that weight loss is a factor to be considered in selecting feeding facilities. In general, cattle fed in confinement have greater hot-carcass weights and less liveweight shrink than cattle not fed in confinement.

Specific guidelines to supplement these general ones may be obtained by using the worksheets and formulas provided. The worksheets can be used to obtain forecasts of hot-carcass weights and percentage liveweight shrink of steers fed and marketed under selected specific sets of conditions. The formulas can be used in conjunction with the forecasts to compare different liveweight bids, different carcass-weight bids, or liveweight and carcass-weight bids.

In interpreting and applying our results, feeders and other users should be mindful of some limitations of the study. Although weather may have an important influence on weight loss, we did not explicitly include weather in our list of explanatory variables, nor were we able to control for weather by marketing all loads in similar weather conditions. The cattle used in the experiments all were steers and perhaps were more accustomed to handling than typical Iowa-fed steers because they had been individually weighed several times during the feeding period. The results, therefore, may not be strictly applicable to heifers or to steers less accustomed to handling. Finally, an important and surprising finding was that steers held at the farm without feed (treatment 2) had greater hot-carcass weights than steers subjected to the control treatment. Treatment 2, however, was applied to only 49 of the 1282 steers. The impact of this treatment deserves more study.

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APPENDIX: STATISTICAL PROCEDURES

Regression procedures were used to estimate equations for our two dependent variables, hot-carcass-weight and percentage liveweight shrink. The explanatory variables were shipping distance, housing condition during feeding, marketing-arrangement treatment, rate of gain, final feedlot weight, quality grade, yield grade, year of experiment, and selected interactions.

The statistical model initially specified for both the liveweight-shrink and hot-carcass-weight equations was, in standard matrix notation,

$$Y = XB + U,$$

where the element of the vector of random errors U that corresponds to the j th steer in the i th load, u_{ij} , is given by

$$u_{ij} = v_i + e_{ij},$$

and where v_i is the random effect associated with the i th load, and where e_{ij} is the random effect associated with the j th steer in the i th load. The random errors, v_i and e_{ij} , were assumed to be independently distributed with zero means and variances σ_v^2 and σ_e^2 , respectively, where $\sigma_v^2 \geq 0$ and $\sigma_e^2 > 0$. This model is of the onefold nested-error type discussed by Fuller and Battese (1973), where the nests correspond to loads. The covariance structure of the random errors u_{ij} in this model is expressed by

$$E(u_{ij}u_{i'j'}) = \begin{cases} \sigma_v^2 + \sigma_e^2, & \text{if } i = i', j = j' \\ \sigma_v^2, & \text{if } i \neq i', j \neq j' \\ 0, & \text{if } i \neq i', j \neq j' \end{cases}$$

Table A-1 contains definitions of the dependent and independent variables considered in the analysis. The independent variables initially included in the equations explaining liveweight shrink (Y_1) and hot-carcass weight (Y_2) were X_1 through X_{15} and selected two-way interactions involving X_1 through X_8 .

Four equations for each dependent variable were estimated by applying ordinary least squares to the four data sets: fall 1972, spring 1973, fall 1974, and spring 1975. We failed to reject the null hypothesis $\sigma_v^2 = 0$ for each of the hot-carcass-weight equations, so ordinary least-squares regression was applied in further analyses involving the hot-carcass-weight dependent variable. For each of the liveweight shrink equations, however, the null hypothesis was rejected, so we used the generalized least-squares procedure suggested by Fuller and Battese (1973) for the onefold nested-error model. Their method involves using estimates of the variance components, σ_v^2 and σ_e^2 , to calculate a transformation matrix, pre-multiplying the original data by the transformation matrix, and then applying ordinary least-squares regression analysis to the transformed data to obtain the generalized least-squares estimates.

Next, we combined the data from all four experi-

Table A-1. Definitions of dependent and independent variables

Symbol	Definition
Y_1	= $(1 - PW/X_{10})(100)$ = percentage liveweight shrink, where PW = liveweight at the slaughter plant.
Y_2	= hot carcass weight.
X_0	= intercept.
X_1	= 1 if fed in unsheltered lot, -1 if fed in confinement building, 0 otherwise.
X_2	= 1 if fed in partly sheltered lot, -1 if fed in confinement building, 0 otherwise.
X_3	= 1 if shipped 40 miles, -1 if shipped 120 miles, 0 otherwise.
X_4	= 1 if shipped 80 miles, -1 if shipped 120 miles, 0 otherwise.
X_5	= 1 if held at farm without feed and water before slaughter, -1 if no restrictions, 0 otherwise.
X_6	= 1 if held at farm without feed before slaughter, -1 if no restrictions, 0 otherwise.
X_7	= 1 if held at plant without feed and water before slaughter, -1 if no restrictions, 0 otherwise.
X_8	= 1 if marketed through a terminal before slaughter, -1 if no restrictions, 0 otherwise.
X_9	= average daily rate of gain during 28 days near the end of the feeding period.
X_{10}	= liveweight at the feedlot.
X_{11}	= quality grade score, ranging from 0 for carcasses grading Low Standard to 12 for carcasses grading High Prime.
X_{12}	= yield grade score, ranging from 1.0 for high-yielding carcasses to 5.9 for low-yielding carcasses.
X_{13}	= 1 if data are from the fall 1972 experiment, -1 if data are from the spring 1975 experiment, 0 otherwise.
X_{14}	= 1 if data are from the spring 1973 experiment, -1 if data are from the spring 1975 experiment, 0 otherwise.
X_{15}	= 1 if data are from the fall 1974 experiment, -1 if data are from the spring 1975 experiment, 0 otherwise.

ments to estimate one pooled equation for each dependent variable. A set of new independent variables was added to the pooled data set to allow for the expression of differences among the four experiments. Dummy variables X_{13} through X_{15} in Table A-1 were used to distinguish the experiments. The interactions of these dummies with the variables X_1 through X_{12} also were added. The significant dummy variables and interactions with dummy variables were omitted from the prediction equations. However, because the coefficients of the dummy variables were designed to total zero, the average effects from the different experiments and interactions were reflected in the prediction equations.

A final prediction equation was obtained, then, for hot-carcass weight by using the pooled data set and ordinary least-squares regressions, and an equation for percentage liveweight shrink was estimated by using the pooled data set and the generalized least-squares procedures just discussed. A 5% level of significance was used to determine whether variables were to be left in the equations or eliminated to yield a reduced model.

The coefficient estimates and test statistics for the final hot-carcass-weight equation are presented in Table A-2. Housing conditions, marketing-arrangement, rate of gain, final weight at the feedlot, quality grade, and the interactions of final feedlot weight with the dummy for year of experiment and of quality grade with the dummy for year of experiment were the variables found to have a significant effect on the hot-carcass weight of the steers. The distance

Table A-2. Hot-carcass-weight equation: Coefficient estimates and test statistics

Variable	F-ratio	Coefficient estimates	t-ratio
Intercept X_0		-43.791	-6.222
Housing condition X_1 X_2	42.46	-3.193 -4.299	
Marketing-arrangement treatment X_5 X_6 X_7 X_8	4.25	-0.755 8.753 -3.850 -2.637	
Rate of gain X_9		-2.988	-5.740
Final feedlot weight X_{10}		0.629	89.004
Quality grade X_{11}		0.844	1.895
Yield grade X_{12}		6.524	6.817
Interactions (Final feedlot weight x year of experiment) $X_{10} \cdot X_{13}$ $X_{10} \cdot X_{14}$ $X_{10} \cdot X_{15}$	7.32	0.008 0.009 -0.016	
(Quality grade x year of experiment) $X_{11} \cdot X_{13}$ $X_{11} \cdot X_{14}$ $X_{11} \cdot X_{15}$	3.69	-0.978 -0.871 1.728	

Note: $R^2 = 0.896$

the steers were shipped, the dummy for year of experiment, and the other interaction terms were not significant.

We then tested for significant differences at the 5% level between the regression coefficients for housing conditions and for marketing arrangement treatments. To test each difference we designated $B_i - B_j = 0$ as the null hypothesis and $B_i - B_j \neq 0$ as the alternative hypothesis. The coefficients for housing conditions that were not significantly different from each other were no shelter and partial shelter. Regarding the coefficients for marketing-arrangement treatments, differences were not significant between treatments 1 and 2, 1 and 3, 2 and 4, 2 and 5, and 3 and 5.

Table A-3 contains the coefficient estimates and test statistics for the final percentage liveweight-shrink equation. The significant variables were dis-

Table A-3. Liveweight shrink equation: Coefficient estimates and test statistics

Variable	F-ratio	Coefficient estimates	t-ratio
Intercept X_0		3.058	18.408
Housing condition X_1 X_2	20.904	0.897 0.140	
Distance hauled X_3 X_4	7.222	-0.458 0.115	
Marketing-arrangement treatment X_5 X_6 X_7 X_8	21.208	0.261 -0.393 0.925 0.039	
Rate of gain X_9		0.155	4.530
Year of experiment X_{10} X_{11} X_{12}	22.146	-1.157 -0.496 0.897	
Interactions (Housing condition x marketing arrangement treatment) $X_1 \cdot X_5$ $X_1 \cdot X_6$ $X_1 \cdot X_7$ $X_1 \cdot X_8$ $X_2 \cdot X_5$ $X_2 \cdot X_6$ $X_2 \cdot X_7$ $X_2 \cdot X_8$	4.372	-0.081 -0.374 0.073 0.437 -0.081 0.869 -0.159 -0.146	

Note: $R^2 = 0.173$

tance, marketing-arrangement treatments, housing condition, rate of gain, year of the experiment, and interactions for housing and market-arrangement treatment variables. Final feedlot weight, quality grade, yield grade, and the other interaction variables were not significant.

Tests for significant differences at the 5% level between the regression coefficients for housing conditions, marketing-arrangement treatments, and distances were then performed. Considering housing conditions, we found that the "no shelter" and "partly sheltered" coefficients were not significantly different. For the marketing-arrangement treatment coefficients, differences were not significant for treatments 1 and 2, 1 and 4, 2 and 4, and 2 and 5. And lastly, the 80-mile shipping difference coefficient was not significantly different from that of the 120-mile shipping distance.



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