FLEET EXPERIENCE OF THE PROTOTYPE CONTROLLED STEERING B-DOLLY

Task Report

Arvind Mathew
C. B. Winkler
Paul Fancher
Patricia Dill

December 1987

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-87-43		

4. Title and Subtitle	5. Report Date
Fleet Experience of the Prototype Controlled Steering B-Dolly	December 1987
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
A. Mathew, C.B. Winkler, P. Fancher, P. Dill	UMTRI-87-43
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
The University of Michigan Transportation Research Institute 2901 Baxter Road, Ann Arbor, Michigan 48109	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Federal Highway Administration U.S. Department of Transportation Washington, D.C. 20590	Task Report to 11/30/87
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The purpose of this task report is to provide an assessment of the performance of the CSB-dolly throughout the field service trial program. Primary objectives of overall assessment considered fleet experiences with respect to dynamic stability, offtracking, ease of operation, coupling, loading, backing, and life-cycle costs. Actual experience with the CSB-dolly after 100,000 km has been very satisfactory as regards functional and operational considerations. An economic analysis indicates that use of the CSB-dolly represents a cost penalty within the current regulatory environment, except where operational benefits can provide a means for improved productivity and associated cost savings.

17. Key Words	18. Distribution Statement
CSB-dolly, B-dolly, Economic analysis	UNLIMITED

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
NONE	NONE	64	

TABLE OF CONTENTS

Fleet Experience of the Prototype Controlled Steering B-Dolly

1. Introduction and Background

The work reported here was performed by The University of Michigan Transportation Research Institute (UMTRI) for the Federal Highway Administration (FHWA) as part of a study entitled "Techniques for Improving the Dynamic Ability of Multi-Trailer Combination Vehicles," Contract No. DTFH61-84-C-00026. This report addresses a modification of the original study. This modification consisted of an additional task entitled "Task H - Analysis of Actual Fleet Experience."

The original study, pertaining to the dynamic performance of multi-trailer articulated vehicles, led to the development of guidelines for the design of innovative dollies that will improve the roll stability and trailing fidelity of doubles combinations [1]. The major effort of that research investigation involved identification, analysis, and further development of innovative dolly and trailer hitching hardware showing potential for the reduction of rearward amplification and prevention of rollover of the second trailer. Specifically, the project (1) reviewed the current state-of-the-art in innovative coupling mechanisms, (2) performed a parametric sensitivity study, based on computer simulation techniques, on combination vehicles using existing and proposed coupling mechanisms, (3) developed a new type of dolly believed to provide superior safety performance, (4) conducted full-scale tests of combination vehicles using various dollies, including a prototype of the new dolly, and (5) examined the potential safety and economic impacts of the use of innovative dolly hardware.

During this study, the prototype dolly, referred to as the "Controlled Steering B-dolly" or "CSB-dolly," was placed in service with TRIMAC Transportation Services of Regina, Saskatchewan, Canada. The CSB-dolly was, and is, being used in a dry bulk doubles combination vehicle.

The purpose of this task report is to provide an assessment of the performance of the CSB-dolly throughout the field service trial program. Primary objectives of the overall assessment are to consider fleet experiences with respect to dynamic stability, offtracking, ease of operation (coupling, loading, backing), and life-cycle costs.

The final section of this report contains an assessment providing a summary of the performance findings. In essence, the results of the field trial indicate that the prototype dolly performed as well as, or better than, expected with regard to stability, offtracking, backing, and maintenance requirements.

In order to provide background for the sections that follow (and for those unfamiliar with the CSB-dolly), Figures 1, 2, and 3 show the features of the CSB-dolly. The dolly has dual drawbars as shown in Figure 1. Note the additional ball connection that can be seen extending above the fifth wheel plate in Figure 1. This ball connects to the semitrailer that is connected to the fifth wheel of the dolly (see numbers 74 and 112 in Figure 2).

As shown in Figure 3, the motion of the ball (part number 74) steers the dolly wheels. This arrangement has been selected to provide good performance in low-speed offtracking, high-speed directional maneuvers, and potential rollover situations as demonstrated in analyses and proving ground tests [1].

The next section of this report describes the service environment to which the CSB-dolly was exposed. The following sections present (a) information gathered from the trip reports, (b) quarterly reviews of dolly operations, and (c) an economic analysis, based on field experience.

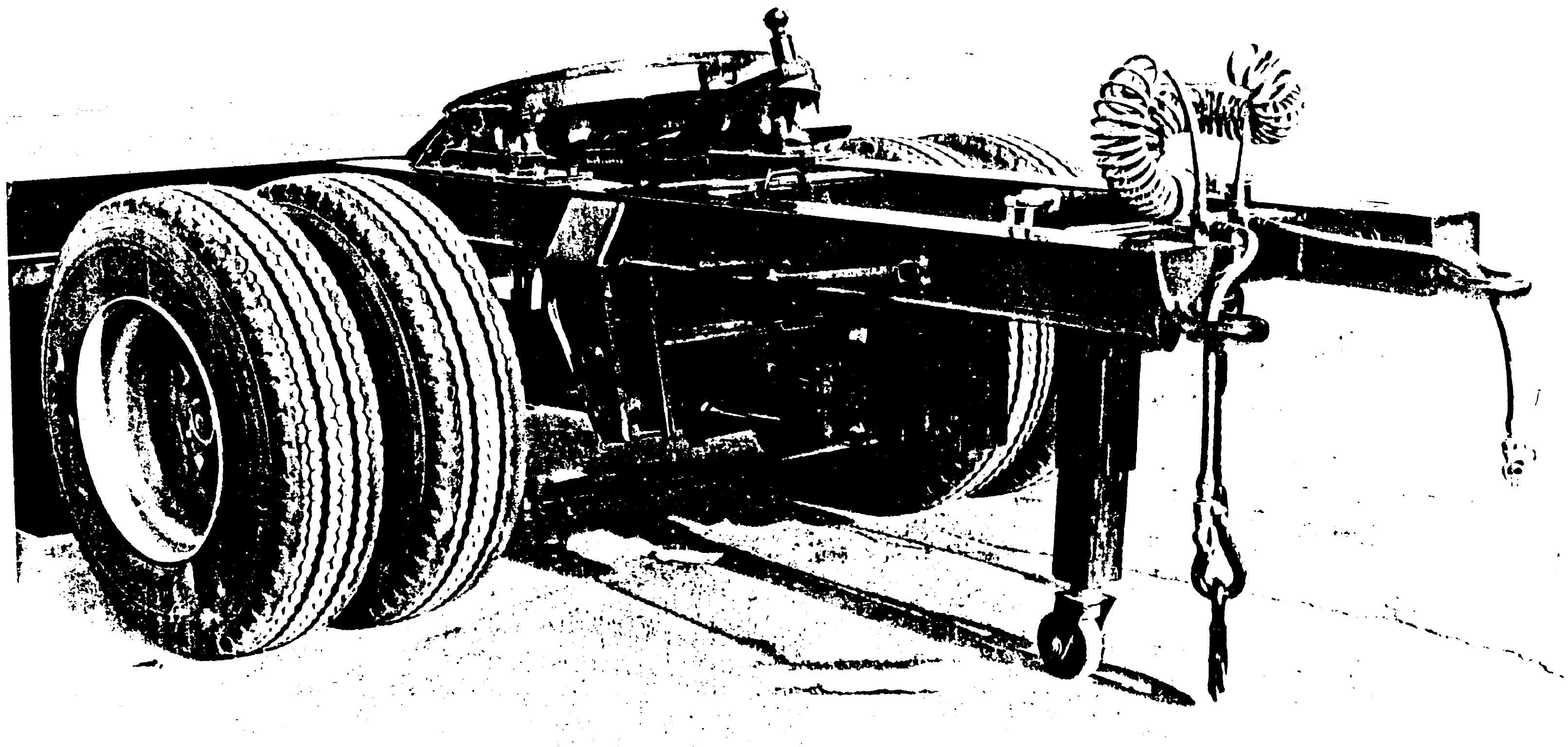


Figure 1. The controlled-steering B-dolly

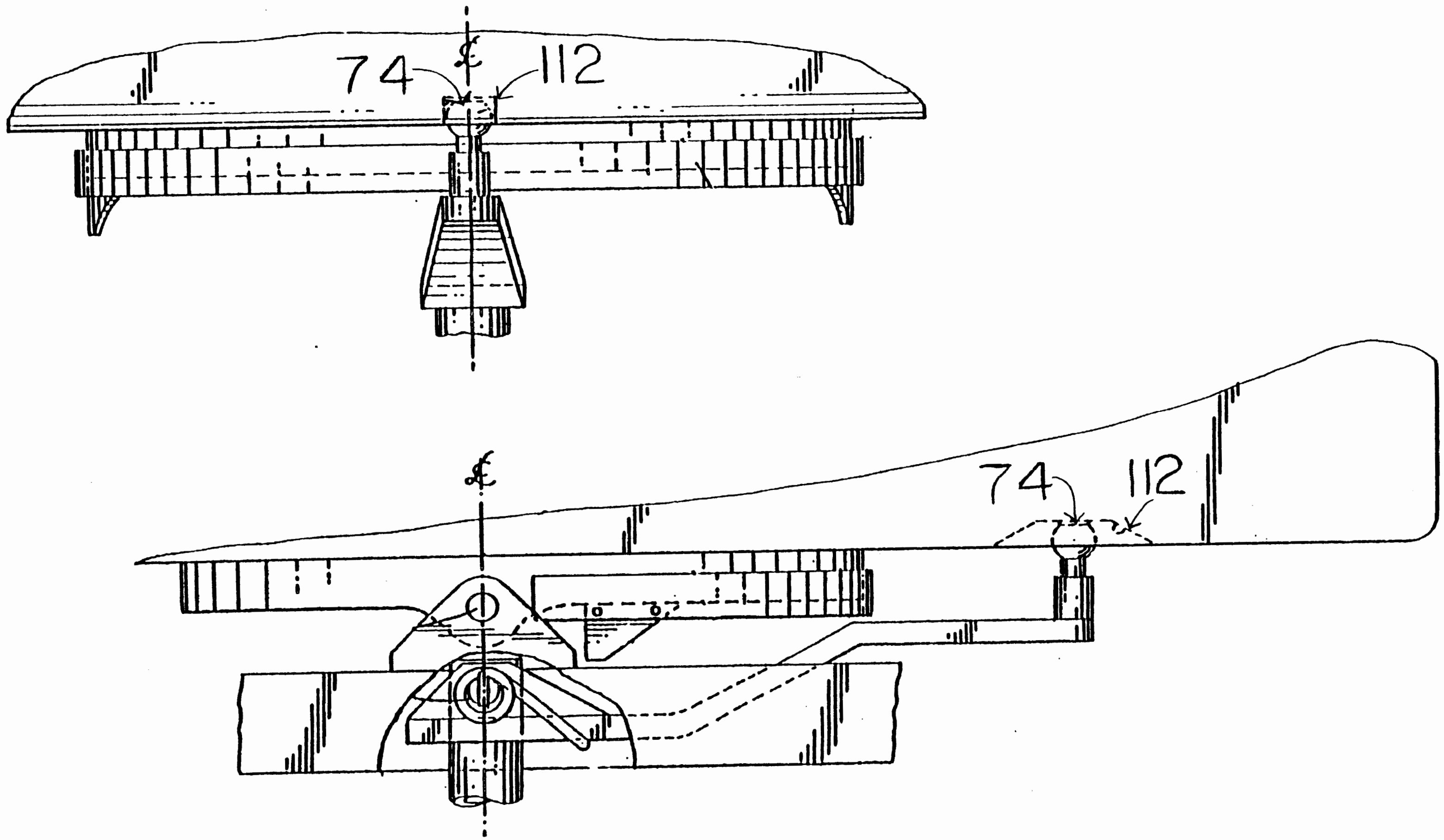


Figure 2. Schematic diagram of the CSB-dolly steering connection with its trailer

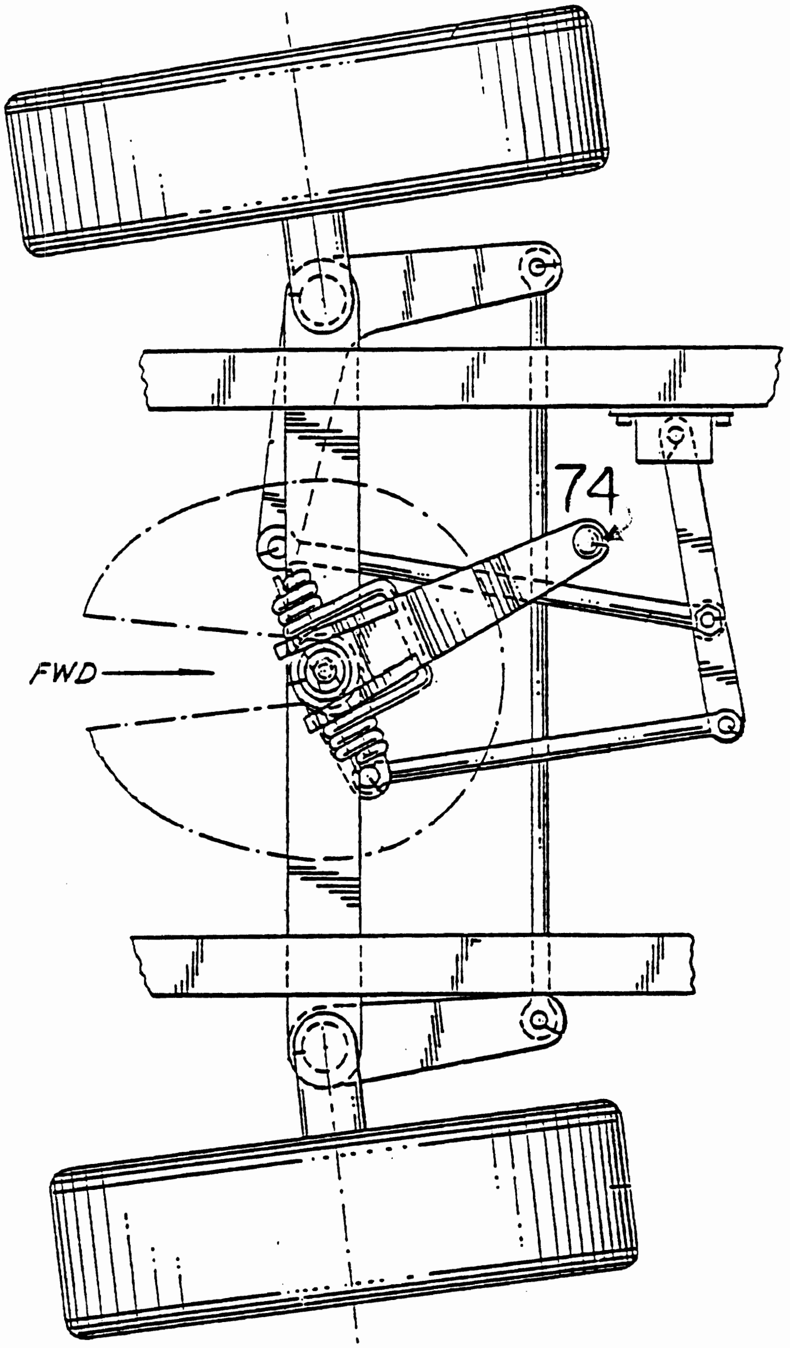


Figure 3. Schematic diagram of the CSB-dolly steering linkage

2. Service Environment of the CSB-Dolly

The in-service test of the CSB-dolly was run through TRIMAC Transportation Services of Regina, Saskatchewan, Canada.* The TRIMAC Regina fleet is an attractive environment for testing the CSB-dolly since this service environment is generally more severe than that in which most U.S. fleets operate. The results of this more rigorous testing illustrate the true capabilities of the equipment.

TRIMAC Regina is a bulk hauling operation, dealing mainly in the transport of cement and petroleum products. The area in which they operate exposes them to extremes in weather conditions. Ice, snow, rain, and high winds are all common obstacles that driver and truck must face. Many of the destinations of TRIMAC services are off the main road systems, requiring them to travel for many miles on unfinished gravel and dirt roads to pick up and deliver their payload. The bulk hauling operations in the western provinces of Canada operate, to a large extent, under a permit system that allows them a gross combination weight (GCW) of approximately 140,000 lbs when double drawbar dollies are used. TRIMAC takes advantage of this permit opportunity, creating a testing environment where the CSB-dolly was subjected to GCWs pushing 140,000 lbs, unfinished roads, and extreme weather conditions.

TRIMAC has chosen to purchase and operate a number of commercially available B-dollies (double drawbar dollies using a number of different styles of "self-steering" axles). The decision to operate B-dollies is largely due to the higher GVW allowed with their use by the permit system. The additional weight of a B-dolly over an A–dolly is of little concern because of the higher GCW allowed. TRIMAC is able to increase the GCW from approximately 100,000 lbs to 140,000 lbs. The increased stability and safety of vehicles equipped with B-dollies is an important factor in deciding to purchase them. Indeed, improved stability is a major element in the rationale of the regulating authorities which has lead to the increased weight allowances for vehicles equipped with B-dollies.

TRIMAC has been operating B-dollies since 1982, with an average of about 125,000 miles per year per dolly. As of 1986, TRIMAC Canada operated over 50 self-steering B-

* TRIMAC Transportation Inc. is a nationwide Canadian firm involved in many forms of trucking operations. TRIMAC of Regina is a branch of TRIMAC whose business is composed largely of liquid and dry bulk hauling under contract to various Saskatchewan commercial concerns. These include a dry cement facility, located immediately adjacent to the TRIMAC garages, mining concerns operating uranium mines in northern Saskatchewan, petroleum refining and distributing concerns in Regina, and other industrial and municipal transportation users.

dollies in double-vehicle combinations nationwide. TRIMAC drivers operating units with B-dollies express satisfaction with the performance of the vehicles, citing that the units are more stable, and that there is a better feel for what the rear of the unit is doing. They have been impressed with the B-dollies' performance in ice and freezing rain, conditions that force most doubles and triples off the road. Much of TRIMAC's operation of double combinations is with vehicles which are not uncoupled for loading and unloading of payload, and which traditionally (i.e., when using A-dollies) require drive–through loading areas (e.g., the bulk hauling fleet of TRIMAC Regina). Self-steering B-dollies are usually equipped with a steering lock which makes it possible to back the doubles vehicle. Given the "married vehicle" nature of the TRIMAC fleet, and the existence of drive-through loading yards geared to A-trains, the ability to back has not had a major influence in TRIMAC' s operation, but is seen as a potential benefit. In general, B-dolly-equipped vehicles draw high marks from the drivers for their performance on the road. (Appendix A includes a questionnaire completed by TRIMAC detailing the operating environment.)

The self-steering B-dollies operated by TRIMAC have experienced failures and wear that have not been observed with combinations using conventional A-dollies. The trailers connected to B-dollies experience greater wear on the kingpin. Tire wear rate on B-dollies is generally high. Some B-dollies have experienced problems with bent and broken axles and with frame failures.

This, then, is the general background of the service environment into which the CSB-dolly was introduced.

3. Summary of Information from Trip Reports

Field Trials for the CSB-Dolly

The CSB-dolly was brought into service in March, 1986, and has been undergoing field trials for approximately twenty months. It was operated under the supervision of the Saskatchewan Highways and Transportation Board and was monitored by personnel from UMTRI. As mentioned earlier, heavy vehicle loads, unpaved road surfaces, and extreme weather conditions presented a fairly rigorous testing environment. As part of the testing agreement, the truck fleet operating the CSB-dolly was required to maintain trip and maintenance records.

The actual vehicle which the CSB-dolly was used with was an eight-axle bulk tanker double composed of a three-axle tractor, two-axle lead semitrailer, the single axle CSB-dolly and a two-axle pup semitrailer. Axle weight constraints for the test were set by the Province of Saskatchewan, Department of Highways and Transportation. Initially, since the hardware was experimental, the GCVW was limited to 118,000 lbs. Later, this was lifted to 132,000 and finally to 138,000 lbs. Axle loads were limited to 11,000 lbs on the steering axle, 35,000 lbs on each of the three tandem pairs, and 20,000 lbs on the single, CSB-dolly axle. (These were the individual axle constraints, regardless of the GCVW limit.)

The vehicle was used in hauling bulk cement, potash and road salt in southern Saskatchewan and to haul lime and other bulk material to and from remote mining sites in northern Saskatchewan. In the south, typical hauls were from Regina to Saskatoon (515 kms round trip) and Regina to Estevan (400 kms round trip). Several trips were made to the northern uranium mines at Key Lake (2000 kms round trip). The majority of this route is on unimproved roads. The dolly continues to be used in this service at this time.

Trip and Maintenance Reports

In addition to periodic shop checks, the CSB-dolly was inspected prior to every road trip. The driver of the vehicle inspected the dolly for signs of wear and fatigue in structural components and in the steering system. A pre-trip inspection check list (see Figure 4) was used to identify critical areas of the dolly's structure and steering linkage. In the event of a problem, the dolly was to be removed from service until the necessary repairs were performed. The pre-trip check list was also used in the shop to record maintenance and repairs conducted on the dolly.

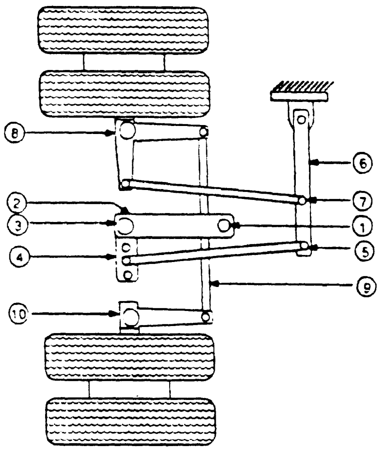
Saskatchewan Highways and Transportation

CSB - DOLLY CONVERTOR REPORT

INSPECTION

In addition to the standard pre-trip inspection, the following checks must be carried out for the CSB - Dolly Convertor.

1. Steering System:



		Normal	Wear
1	Steering Ball Hitch	(✓)	( )
2	Upper Steering Arm	(✓)	( )
3	Vertical Steering Shaft	(✓)	( )
4	Lower Steering Arm	(✓)	( )
5	1st Steering Link	(✓)	( )
6	Idler Arm	(✓)	( )
7	2nd Steering Link	(✓)	( )
8	Left Wheel Steering Arm	(✓)	( )
9	Tie Rod	(✓)	( )
10	Right Wheel Steering Arm	(✓)	( )

2. Structural Components:

	Normal	Abnormal Wear
Main frame rails	(✓)	( )
Cross members	(✓)	( )
Pintle hitches	(✓)	( )
King Pins (Shop check only)	( )	( )
Tire Wear (Shop check only)	( )	( )

If any steering or structural components show signs of wear and/or fatigue which may affect the performance of the vehicle, it is to be taken out of service immediately. The operator is to advise Trimac personnel and personnel of the Transportation Systems Branch, Department of Highways and Transportation of such action. Note defects here:

____

REPAIRS

Please note any repairs required:
REPAIR FLAT TIRE
RIGHT OUT SIDE

FOR SHOP USE ONLY

Unit No. ________________ Date Inspected Nov 5-6-7

Mechanic's Signature ____________________

Figure 4. A sample pre-trip checklist

Saskatchewan Highways and Transportation

TRIP REPORT

GENERAL

Driver [illegible] Date Nov 5-6-7 [illegible]

Unit No. [illegible] Company Trip Report # 522848

TRIP INFORMATION

FROM	TO	DEPARTURE TIME	ARRIVAL TIME	GVW
Regina	Saskatoon	4:30 pm	Nov 6 1100 pm	
Saskatoon	Regina	900 pm	130 Am	20740

Total Fuel used ~~[illegible]~~ 545 litres 35 gals. 1068 km

WEATHER

1. Temperature -5 C Clear ( ) Cloudy (✓) Rain ( ) Snow (✓)
2. Wind: Speed 40 Direction - Head ( ) Cross (✓) Tail (✓)

ROAD CONDITIONS

1. Dry (✓) Wet (✓) Ice (✓) If icy, describe operation of vehicle:

worked OK.

REPAIRS

Please note any repairs required during the trip:

FLAT TIRE IN PIPE

HOUSE AREA.

RIGHT OUTSIDE ON CONVERTER.

VEHICLE OPERATION

Please describe the general performance of the vehicle during the trip.
Include any unusual vehicle performance or traffic situations that occurred:

O.K.

Driver's Signature [signature]

One of the following is to be notified in the event of any serious problems:

Bernie Churko	Norm Burns	Peter Hurst	Road Systems Unit
787-5533 Bus.	787-5535 Bus.	787-5536 Bus.	Highways & Transportation
545-5628 Res.	586-9802 Res.	545-7750 Res.	7th Floor, 1855 Victoria Ave.
			Regina, Saskatchewan

Figure 5. A sample trip report

In addition to the pre-trip inspection, the driver was required to complete a trip report which recorded, among other things, gross vehicle weight, distance traveled, weather and road conditions, and vehicle performance. A sample trip report is shown in Figure 5. The trip reports provide some insight into the extreme operating conditions of the testing environment.

Summary of Data Gathered During the Testing Period

Over the twenty-month trial period, the CSB-dolly operated on approximately 174 trips and accumulated a total of 99,000 kms. The dolly averaged approximately 570 kms per trip and was subjected to a wide range of weather and road conditions.

Given the testing environment, the dolly performed very well, experiencing only three "shop recalls." The first occurred very early in the trial, and was found to be a "false alarm" concerning the development of lash in the steering linkage. The second recall involved wear of the steering ball (item 74 in Figures 2 and 3). Flat spots developed on the sides of the ball where it rides against the walls of the pocket in the upper fifth wheel. The ball was not replaced, and it was subsequently found that the wear rate virtually stopped once an appreciable contact area developed. There has been no need to replace the ball. These were the only items directly involving the steering mechanism which required attention in the first 99,000 kms. The third item involved the loosening of the u-bolts which attached the axle to the springs. In July of 1986, the original 3/4 inch u-bolts were replaced with 7/8 inch u-bolts and the problem did not reappear.

In early November 1987, the steering system of the CSB-dolly prototype was disassembled and examined for wear and fatigue. The bushings of the upper steering arm hinge were found to have some wear resulting in a moderate amount of steering lash. Elements of this joint (the hinge pin and the upper end of the vertical steering shaft) were magnifluxed and found to have no evidence of any fatigue damage. Some redesign of this hinge joint may be appropriate if additional CSB-dollies are constructed. However, the wear observed in the prototype was not seen as a major problem.

A summary of the testing mileage is presented in Figure 6 and in Table 1. In the figure, distance accumulated by the dolly are displayed as a function of time. Significant comments made by the driver and shop personnel have also been recorded on the chart. Table 1 supplements this information by identifying product, destination, and distance on a trip-by-trip basis.

Economic factors, such as market demands for cement and petroleum products, also affected the operation of the dolly. As can be seen in Figure 6, sluggish demand conditions

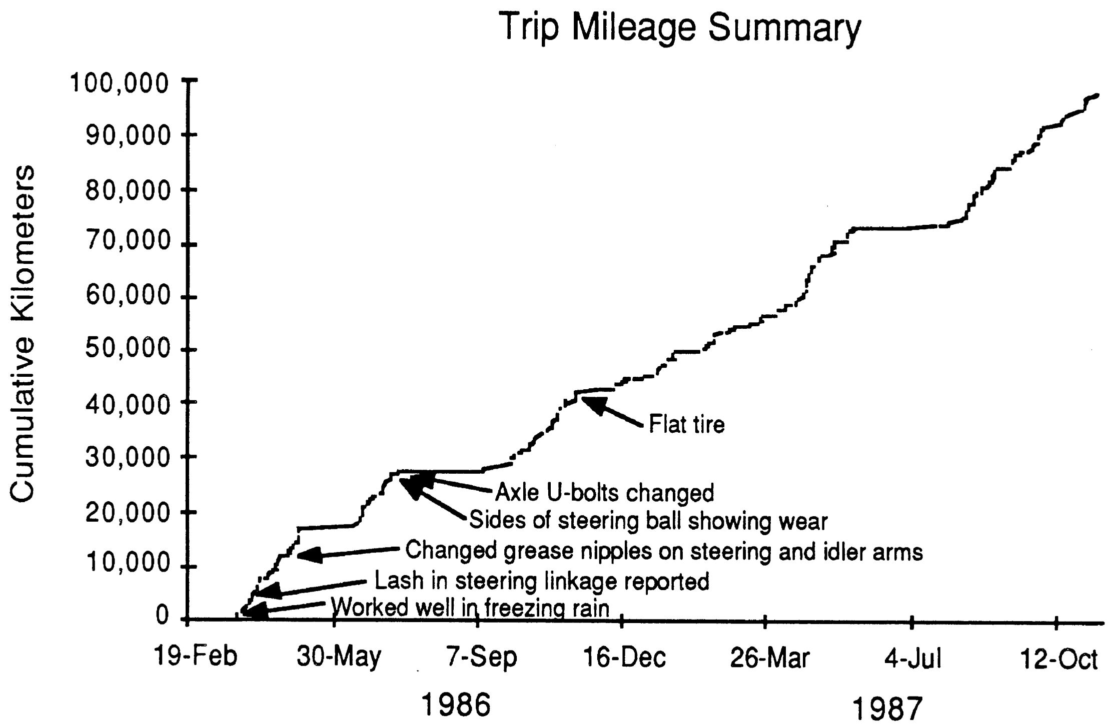


Figure 6. A chronological account of the testing period

Table 1. Prototype CSB-Dolly Trip Summary

Date	Product	Destination	Kilometers	Cumulative Km
24-Mar-86	Cement	Saskatoon	515	515
25-Mar-86	Ash	Regina/B.Dam/Regina	410	925
26-Mar-86	Ash	S.Current	499	1,424
31-Mar-86	Salt	B.Plaine/B.Dam	515	1,939
1-Apr-86	Salt	B.Plaine/B.Dam	515	2,454
2-Apr-86	Cement	Saskatoon	515	2,969
3-Apr-86	Salt/Ash	B.Plaine/B.Dam	515	3,484
4-Apr-86	Cement	Saskatoon	515	3,999
5-Apr-86	Ash	B.Dam	410	4,410
7-Apr-86	Ash	Regina/Battleford	805	5,214
8-Apr-86	Cement	Saskatoon	515	5,729
9-Apr-86	Cement	Saskatoon	515	6,244
10-Apr-86	Cement	Saskatoon	515	6,759
11-Apr-86	Cement	Saskatoon	515	7,274
14-Apr-86	Cement	Saskatoon	515	7,789
16-Apr-86	Salt	B.Dam	515	8,304
17-Apr-86	Ash	B.Dam	410	8,715
18-Apr-86	Cement	Saskatoon	515	9,230
21-Apr-86	Cement	Saskatoon	515	9,745
22-Apr-86	Cement	Saskatoon	515	10,260
23-Apr-86	Cement	Saskatoon	515	10,775
25-Apr-86	Cement	Saskatoon	515	11,290
28-Apr-86	Cement	Saskatoon	515	11,805
29-Apr-86	Ash	B.Dam	515	12,319
30-Apr-86	Cement/Ash	B.Dam/Battleford	1,159	13,478
2-May-86	Cement	Saskatoon	515	13,993
3-May-86	Ash	B.Dam	410	14,404
5-May-86	Ash	Saskatoon	515	14,919
6-May-86	Ash	B.Dam/Saskatoon	925	15,844
7-May-86	Ash	B.Dam	410	16,254
11-Jun-86	Cement/Ash	Wadena/B.Dam	774	17,028
13-Jun-86	Cement/Ash	B.Dam	410	17,439
16-Jun-86	Ash	Battleford	805	18,243
17-Jun-86	Cement	Saskatoon	515	18,758
18-Jun-86	Cement	Saskatoon	515	19,273
19-Jun-86	Cement	B.Dam/Moose Jaw	547	19,821
20-Jun-86	Ash	B.Dam/Saskatoon	925	20,746
21-Jun-86	Ash	B.Dam	410	21,156
24-Jun-86	Ash	Saskatoon	515	21,671
25-Jun-86	Cement	Estevan	402	22,074
26-Jun-86	Cement	Saskatoon	515	22,589
28-Jun-86	Cement	Saskatoon	515	23,104
30-Jun-86	Ash	B.Dam	410	23,514
2-Jul-86	Ash	Saskatoon	515	24,029
3-Jul-86	Cement	Porcupine Plain	612	24,641
5-Jul-86	Cement	Saskatoon	515	25,156
9-Jul-86	Cement	Wadena/B.Dam	772	25,928
10-Jul-86	Ash	Tisdale	724	26,652

Table 1 (continued). Prototype CSB-Dolly Trip Summary

Date	Product	Destination	Kilometers	Cumulative Km
14-Jul-86	Cement	Saskatoon	515	27,167
15-Jul-86	Cement/Ash	B.Dam	410	27,578
10-Sep-86	Ash	B.Dam	410	27,988
22-Sep-86	Ash	B.Dam/Saskatoon	925	28,913
1-Oct-86	Ash	B.Dam/Saskatoon	925	29,839
3-Oct-86	Ash	B.Dam	410	30,249
4-Oct-86	Cement	Saskatoon	515	30,764
6-Oct-86	Cement/Ash	Estevan/B.Dam	410	31,175
7-Oct-86	Cement	Saskatoon	515	31,690
13-Oct-86	Cement/Ash	Weyburn/B.Dam	410	32,100
14-Oct-86	Cement	Estevan	402	32,502
15-Oct-86	Ash	Saskatoon	515	33,017
17-Oct-86	Cement/Ash	Estevan/B.Dam	925	33,943
24-Oct-86	Potash	Richmound	933	34,876
27-Oct-86	Potash	Richmound	933	35,809
28-Oct-86	Potash	Richmound	933	36,743
31-Oct-86	Potash	Richmound	933	37,676
3-Nov-86	Cement	Saskatoon	515	38,191
4-Nov-86	Lime	Saskatoon/Key Lake	644	38,835
5-Nov-86	Lime	Enroute Key Lake	483	39,318
6-Nov-86	Lime	Inbound Key Lake	483	39,801
7-Nov-86	Lime	Inbound Key Lake	644	40,444
13-Nov-86	Salt	Lucky Lake/Emfold	724	41,169
14-Nov-86	Salt	B.Plaine/Hodgeville	483	41,651
15-Nov-86	Salt	B.Plaine/Porcupine Plain	724	42,376
2-Dec-86	Salt	B.Plaine/Rosthern	676	43,051
11-Dec-86	Cement	Estevan	402	43,454
15-Dec-86	Cement	Saskatoon	515	43,969
19-Dec-86	Ash	B.Dam	410	44,379
24-Dec-86	Cement	Saskatoon	515	44,894
30-Dec-86	Ash	B.Dam	410	45,305
6-Jan-87	Cement/Ash	Estevan/B.Dam	410	45,715
8-Jan-87	Cement/Ash	Estevan/B.Dam	410	46,125
9-Jan-87	Ash	Prince Albert	740	46,866
12-Jan-87	Ash/Cement	B.Dam/Saskatoon	925	47,791
15-Jan-87	Ash	B.Dam	410	48,201
21-Jan-87	Cement	S.Current	499	48,700
22-Jan-87	Cement	Saskatoon	515	49,215
23-Jan-87	Cement	Saskatoon	515	49,730
2-Feb-87	Cement	Estevan	402	50,133
9-Feb-87	Cement	Saskatoon	515	50,648
11-Feb-87	Cement/Ash	Estevan/B.Dam	410	51,058
13-Feb-87	Cement	Saskatoon	515	51,573
17-Feb-87	Cement	Estevan	402	51,975
18-Feb-87	Cement	Saskatoon	515	52,490
19-Feb-87	Cementy	Saskatoon	515	53,005
25-Feb-87	Cement	Saskatoon	515	53,520
27-Feb-87	Cement	Saskatoon	515	54,035

Table 1 (continued). Prototype CSB-Dolly Trip Summary

Date	Product	Destination	Kilometers	Cumulative Km
3-Mar-87	Cement/Ash	Estevan/B.Dam	410	54,446
5-Mar-87	Cement/Ash	Estevan/B.Dam	410	54,856
14-Mar-87	Cement/Ash	Estevan/B.Dam	410	55,266
19-Mar-87	Ash	B.Dam	410	55,677
20-Mar-87	Ash	B.Dam	410	56,087
23-Mar-87	Ash	B.Dam	410	56,497
24-Mar-87	Ash	S.Current	499	56,996
2-Apr-87	Empty	Saskatoon	257	57,254
6-Apr-87	Empty	Saskatoon	257	57,511
9-Apr-87	Cement	Saskatoon	515	58,026
10-Apr-87	Cement	Saskatoon	515	58,541
14-Apr-87	Ash	B.Dam	410	58,952
15-Apr-87	Ash	Prince Albert	805	59,756
16-Apr-87	Cement	Saskatoon	515	60,271
20-Apr-87	Cement	Saskatoon	515	60,786
21-Apr-87	Lime	Enroute Key Lake	644	61,430
22-Apr-87	Lime	Enroute Key Lake	483	61,913
23-Apr-87	Lime	Inbound Key Lake	805	62,718
24-Apr-87	Lime	Enroute Key Lake	644	63,361
25-Apr-87	Lime	Enroute Key Lake	483	63,844
26-Apr-87	Lime	Inbound Key Lake	966	64,810
27-Apr-87	Cement	Saskatoon	257	65,067
28-Apr-87	Cement/Lime	Saskatoon/Key Lake	644	65,711
29-Apr-87	Lime	Enroute Key Lake	644	66,355
30-Apr-87	Lime	Enroute Key Lake	483	66,837
1-May-87	Lime	Inbound Key Lake	483	67,320
2-May-87	Lime	Inbound Key Lake	483	67,803
7-May-87	Cement	Saskatoon	515	68,318
12-May-87	Lime	Enroute Key Lake	805	69,123
13-May-87	Lime	Enroute Key Lake	644	69,766
14-May-87	Lime	Inbound Key Lake	483	70,249
15-May-87	Lime	Inbound Key Lake	644	70,893
21-May-87	Cement/Ash	Estevan/B.Dam	410	71,303
22-May-87	Cement	Nipawin	789	72,092
23-May-87	Ash	B.Dam	410	72,502
26-May-87	Cement	Saskatoon	515	73,017
1-Jul-87	Ash	B.Dam	410	73,428
23-Jul-87	Salt	B.Plaine/B.Dam	515	73,943
30-Jul-87	Salt	B.Plaine/B.Dam	515	74,458
7-Aug-87	Salt	B.Plaine/B.Dam	515	74,973
10-Aug-87	Ash	B.Dam/St. Eustache/Winnepeg	644	75,616
11-Aug-87	Cement	Winnepeg	587	76,204
12-Aug-87	Cement	Enroute Edmonton	756	76,960
13-Aug-87	Cement	Inbound Edmonton	756	77,717
17-Aug-87	Salt	B.Plaine/B.Dam	515	78,232
18-Aug-87	Salt	B.Plaine/Saskatoon	547	78,779
19-Aug-87	Salt	B.Plaine/Saskatoon	547	79,326
20-Aug-87	Salt	B.Plaine/Saskatoon	547	79,873

Table 1 (continued). Prototype CSB-Dolly Trip Summary

Date	Product	Destination	Kilometers	Cumulative Km
21-Aug-87	Salt	B.Plaine/Saskatoon	547	80,420
24-Aug-87	Salt	B.Plaine/Melville	402	80,823
26-Aug-87	Salt	B.Plaine/B.Dam	515	81,338
27-Aug-87	Salt	B.Plaine/B.Dam	515	81,853
29-Aug-87	Cement	Saskatoon (twice)	1,030	82,883
1-Sep-87	Salt	B.Plaine/Outlook/B.Plaine	966	83,848
2-Sep-87	Salt	Wadena/B.Plaine/B.Dam	676	84,524
11-Sep-87	Salt	BB.Plaine/B.Dam	515	85,039
12-Sep-87	Cement	Saskatoon	515	85,554
13-Sep-87	Ash	B.Dam	410	85,965
14-Sep-87	Ash	S.Current	499	86,463
15-Sep-87	Cement	Saskatoon	515	86,978
19-Sep-87	Cement	Saskatoon	515	87,493
21-Sep-87	Cement	Saskatoon	515	88,008
26-Sep-87	Cement	Saskatoon	515	88,523
29-Sep-87	Cement	Shavnavon	708	89,231
29-Sep-87	Cement	Saskatoon	515	89,746
30-Sep-87	Cement	Saskatoon	515	90,261
2-Oct-87	Cement	Saskatoon	515	90,776
3-Oct-87	Cement	Saskatoon	515	91,291
5-Oct-87	Cement	Saskatoon	515	91,806
6-Oct-87	Cement	Saskatoon	515	92,321
17-Oct-87	Potash	Richmound	933	93,255
20-Oct-87	Cement	Saskatoon	515	93,770
29-Oct-87	Salt	Esterhazy (twice)	1,030	94,800
30-Oct-87	Salt	Esterhazy	515	95,315
31-Oct-87	Potash	Richmound (twice)	933	96,248
2-Nov-87	Salt	Esterhazy (twice)	1,030	97,278
7-Nov-87	Potash	Richmound	933	98,212
10-Nov-87	Potash	Richmound	933	99,145

idled the dolly during May of 1986 and during the summers of both 1986 and 1987. This resulted in a "staircase" effect in the cumulative mileage curve in Figure 6.

4. Quarterly Reviews of Dolly Operations

The following material provides perspectives on dolly performances as observed during the field trial.

August, September, and October of 1986

The CSB-dolly accumulated approximately 25,000 miles in dry bulk cement hauling service in and about Regina. The dolly is used in an eight-axle (1-2-2-1-2) C-train. Initially, dolly axle loads were constrained to approximately 16,000 lbs, but were raised to 20,000 lbs after the initial, successful experience.

The operators (TRIMAC Transportation Inc.) express great satisfaction with the operation of the dolly. They note that:

a) The operational stability of the train is judged by the driver to be much better than when equipped with an A-dolly and somewhat better than when equipped with self-steering B-dollies.
b) No frame-stress-related problems have been identified.
c) Tire wear is apparently very good. In particular, the excessive tire wear previously experienced with B-dollies is absent.
d) With experience, the driver has learned to back the train. Backing can be accomplished with strategies involving curved paths, not just along straight lines. This is found to be a great advantage in that it allows the use of doubles in services that previously were limited to singles by operational considerations.
e) Although the CSB-dolly requires greasing at various points of the steering system, TRIMAC indicates that the difference between "regular" maintenance costs of the CSB and other dollies are insignificant. There is not enough accumulated mileage to judge major maintenance (overhaul) costs.

November, December, and January of 1986 and 1987

During the first week of November, the CSB-dolly made its first northern trip. The train, operating at 135,000 lbs GCW was used to haul lime into (and crystalline ammonia fertilizer out of) the Key Lake uranium mine in northern Saskatchewan. The haul initiates in Saskatoon, runs north through Prince Albert, and then several hundred miles into the uninhabited north. Paved roads stop about fifty miles north of Prince Albert so that most of the trip is on dirt roads. The run is about 12 hours one way. This initial run was made in a four-vehicle convoy consisting of the CSB-dolly vehicle, a similar train using the linked-articulation hardware, a B-train (no dolly) hauling fuel oil, and a passenger van.

UMTRI personnel traveled to Saskatchewan to participate in this initial run. Others who "attended" included officials of Saskatchewan Transportation and of TRIMAC. An UMTRI staff member rode the entire northbound run in the CSB-dolly-equipped train.

The trip was certainly an unqualified success in that all three vehicles performed flawlessly.

The CSB-dolly continued in use in the Regina area through the quarter on a TRIMAC bulk tanker. During the winter quarter, the major use of that fleet is for hauling road salt. Because of the unusually mild winter weather, accumulated mileage was limited. Accumulated mileage by the end of the quarter was between 30,000 and 35,000 miles.

TRIMAC continues to declare that they are very pleased with the service of the dolly. There have been no problems of note. Maintenance costs appear to be very similar to their existing equipment. Tire wear is said to be noticeably improved over A- and self-steering B-dollies in the same service.

February, March, and April of 1987

The CSB-dolly continued in use in the Regina area through the quarter on a TRIMAC bulk tanker. It was used for hauling road salt locally, but was also returned to northern service, delivering lime to the Key Lake uranium mine.

TRIMAC is sufficiently pleased that they are considering purchasing six additional CSB-dollies. Tentatively, these would be manufactured in Regina by a local firm under licenses from the University.

The Saskatchewan Highways and Transportation is preparing to "promote" CSB-dolly use via special permits. The essential aim of this scheme would be to allow the use of vehicles in Saskatchewan now, which are anticipated to be allowed nationwide in the future as a result of the Roads and Transportation Association of Canada (RTAC) study findings.

In an additional effort, Saskatchewan is also contemplating permitting "B-C" triples. These vehicles would be composed of a B-train double (no dolly) and a third trailer with a CSB-dolly.

During May, UMTRI staff traveled to Regina and to Calgary, Alberta to interview local and regional officials of TRIMAC in connection with evaluating the CSB-dolly's economic performance. The next section presents the economic analysis.

5. Economic Analysis

INTRODUCTION

Objective. The economic analysis is designed to determine the costs and/or benefits of introducing controlled-steer B-dollies (CSB-dollies) into a fleet that uses conventional A-dollies.

Sources of Related Information. A CSB-dolly has been undergoing field trials at TRIMAC Transportation Services, Ltd. in Regina, Saskatchewan and the company has maintained trip and maintenance records specific to the dolly. To the extent that reasonable data exists for the CSB-dolly, that data were used in the analysis.

Nevertheless, the CSB-dolly is a fairly recent addition to the trucking industry and the related information is limited. With the exception of additional weight and a higher purchasing cost, CSB-dollies are similar in many respects to double-drawbar B-dollies. That is, CSB-dollies are essentially B-dollies incorporating special hardware for steering the dolly wheels. Due to the short observation period for the CSB-dolly, data from B-dolly operators are sometimes used as a surrogate for CSB-dolly data in the following economic analysis. B-dollies have been in use since 1979 and trucking fleets in Alberta and Saskatchewan operate approximately 140 B-dolly doubles with an annual mileage of approximately 20 million miles (32 million kilometers). Data from these fleets were major sources of the information used in this analysis.

Contacts with U.S. and Canadian fleet operators provided information about the costs involved in using conventional dollies. Canadian fleets have also provided information about the impacts and costs of a changeover from A- to B-dollies. These data were extrapolated to the evaluation of A- versus CSB-dollies.

Scope of Analysis. To focus the analysis on the operational/financial impact of CSB-dollies, a financial model was developed that incorporated the differences in the benefits and costs (advantages and disadvantages) between the A- and the CSB-dollies. In other words, the analysis examined issues pertinent to the type of dolly.

Method of Analysis - Sensitivity Analysis. A sensitivity analysis involves changing the values of various parameters to determine their impact on a "baseline" or reference situation. Key parameters are identified by their ability to significantly affect the results of the analysis through small variations in their values. A sensitivity analysis helps to identify the important parameters and the key issues associated with the parameters.

In this case, Canadian CSB- and B-dollies are used in bulk hauling operations and are often subjected to fairly severe loading situations. Much of the information on conventional A-dollies, however, has been obtained from U.S. trucking fleets where more stringent road-use laws create a different operating environment. Since the two dollies could not be compared directly under similar operating conditions, sensitivity analyses help to clarify the key issues with regard to the use of CSB-dollies.

THE FINANCIAL MODEL

Type of Analysis. The model determines the financial effects of using a CSB-dolly as an alternative to the conventional A-dolly. The cash flows (where costs are negative cash flows or an efflux of cash, and benefits are positive cash flows or an influx of cash) are defined as an increase or decrease in the operating cost due to the purchase of a CSB-dolly instead of an A-dolly. For example, the model projects higher annual preventive maintenance costs (see "Assumptions Concerning Economic Issues") for every CSB-dolly added to the fleet. The CSB-dolly is, therefore, *more expensive* to maintain than the conventional dolly (all cash flows are in US dollars). There is also an additional investment due to the extra cost incurred in buying a CSB-dolly instead of an A-dolly. In other words, the model analyzes the future *incremental* cash flows resulting from an *additional* investment made today.

The Investment Rule. The Net Present Value (NPV) rule is used as a basis for analyzing the investment decision. The NPV rule reduces all forecasted cash flows to current dollars (based on a given discount rate) and is reliable in ranking projects which offer different patterns of cash flow. Other investment rules such as Payback and Average Return on Book are inadequate when analyzing incremental cash flows.

Life of the Project. The life of the project - that is, the period over which the two dollies would be compared - is determined by the life of an A-dolly. Normal operation of double-trailer combinations results in relatively minor wear on the conventional dolly and some fleet operators believe that A-dollies are virtually indestructible. For this analysis, however, the life of an A-dolly is assumed to be ten years.

Assumptions Concerning Economic Issues. The following parameters, which are assumed to increase or decrease the cost of operation, are used in the financial model:

• Initial cost of the dolly. The CSB-dolly is assumed to cost $6,000 more than the A-dolly. This assumption is based on the fact that a Fruehauf single-axle A-dolly (with tires) costs $4,500 and an ASTL B-dolly (with tires) costs $8,500. The cost of manufacturing and installing the controlled-steering hardware (on the dolly and the pup trailer) is assumed to cost an additional $2,000. Differences in scrap value were taken to be negligible.

• Backing up. Assembling and disassembling double-trailer combinations is a time-consuming task. A-dolly-equipped doubles require an intermediate staging area to maneuver both trailers to their loading docks. Depending upon the distance from the loading dock to the staging area, the entire process of assembling and disassembling a set of double trailers could take up to an hour of the driver's time.

Assuming that the driver has enough space to maneuver both trailers, the CSB-dolly gives the driver the ability to back up both trailers to their loading docks without using an intermediate staging area. One variation in model parameters assumes that the driver saves twenty minutes by not having to make two trips to and from the staging area. Assuming an internal labor rate of $21 (including benefits) the fleet operator saves $7 for each double-trailer combination that is assembled and disassembled.

• Converting existing equipment. At least one semitrailer must be modified for every CSB-dolly purchased. Installing two additional pintle hooks and frame-stiffening the semitrailer's chassis is assumed to cost approximately $3,000.

• Major overhauls. Canadian operators of both A- and B-dollies believe that B-dollies must undergo a major overhaul twice as often as A-dollies. The industry standard is to overhaul an A-dolly every 500,000 mi (800,000 km) and a B-dolly every 250,000 mi (400,000 km). CSB- and B-dollies are assumed to experience similar costs and frequencies of major overhauls. As an overhaul includes, among other things, fifth wheels, drawbar eyelets, steering systems, brakes, and springs, the cost of a major overhaul is kept as a variable and is defined as a percentage of the initial cost of the dolly. This cost is assumed to include factors related to both (a) time and materials for maintenance and (b) service time lost during maintenance.

• Preventive maintenance. The cost of regular maintenance, such as inspection and lubrication, depends upon the size of the fleet and the frequency at which maintenance is done. There is, however, a general view in the Canadian trucking industry that maintenance costs of the CSB-dolly are twice that of the A-dolly. The increase in maintenance cost is attributable to the maintenance of the steering and air systems of the steerable wheels.

• Tire wear. During normal operation, the tires on conventional dollies last for 100,000-120,000 mi (160,000-193,000 km). Tire scrubbing on B-dollies tends to wear tires 10-15 percent faster. As far as tire wear is concerned, CSB-dollies are 10-15 percent better than B-dollies and tend to resemble conventional dollies. The model, therefore, eliminates tire wear from the comparative analysis.

• Scheduling costs. Scheduling varies across truck fleets, and practices are dependent on the size of the operation. Some large operations have delegated most of the scheduling exercise to computer programs which route tractors, semitrailers, and dollies according to variables such as trip length and freight being hauled. On the other hand, fleets with fewer units are more comfortable maintaining scheduling as part of the day-to-day administration of the trucking operation. Because the CSB-dolly introduces another variable into the scheduling problem, where dollies and semitrailers stop being completely interchangeable, there is bound to be an increase in scheduling costs. It is assumed, however, that there is a learning curve associated with the scheduling process, and the increase in cost will disappear over time.

A complete changeover from A- to CSB-dollies would not affect the process of scheduling. If, however, half of the total number of dollies are CSB-dollies, then the increase in scheduling costs is assumed to be at its maximum. To account for this trend, the model assumes a triangular distribution in which scheduling cost varies as a percentage of the CSB-dollies in the fleet. The model assumes a single expense to update computer programs and any scheduling-related data bases.

• Training/loss of productivity. To address the fact that drivers and yard personnel must deal with a new piece of equipment, the model accounts for training and a cost associated with a temporary loss of productivity. The increase in time required to hitch the B-dolly is a specific example of a loss of productivity. Operators of B-dollies believe that, with some exceptions (such as hitching on uneven yard surfaces), hitching B- and CSB-dollies could become as routine as hitching an A-dolly. The model uses a learning curve to account for the temporary nature of this cost.

• Loss of revenue from hauling less weight. Due to the steerable axle and a sturdier frame, the CSB-dolly weighs 1,000-1,500 lb (454-680 kg) more than the conventional dolly. Under conditions where vehicles are operated at maximum gross weight, the extra weight of the dolly displaces an equivalent amount of freight. The loss of revenue depends upon a number of factors - type of freight (freight class), trip length, etc. For example, the revenue from shipping 10,000 lb (4,535 kg) of freight from Ann Arbor, Michigan to San Diego, California (a distance of 2,373 miles (3,818 km)) is $2,125. If a vehicle is forced to forego carrying 1,000 lb (454 kg) of freight, then the loss of revenue for the trip is $212.50.

- Savings from fewer accidents. The analysis in the original study [1] predicted that the improved safety characteristics of the CSB-dolly would save the fleet operator $0.008 per mile.

- Ability to operate on secondary roads. A number of states limit the operation of double-trailer combinations on their supplemental highways. Considering a situation where both trailers in a doubles combination are headed for the same destination off the federal highway system, the combination must be disassembled and each trailer must be transported to the site independently. If such regulation were to be removed because of the improved dynamic performance of CSB-dolly-equipped doubles, there would be a cost savings associated with the elimination of two trips to and from the local drop-off site. (This is allowed by permit in Saskatchewan.)

- Permit to increase axle loads. As the loss of revenue from operating overweight dollies is so great, some provinces in Canada have allowed truck fleets to increase their gross vehicle weights on a permit basis. This assumption, very similar to the one discussed above, addresses current highway regulation and has been included to describe a possible situation.

APPLICATION OF THE FINANCIAL MODEL

To study the influence of the economic issues discussed earlier, results for three situations are presented here.

Current Operating Environment. Starting with a situation which tries to approximate the current U.S. operating and regulatory environment, the financial model is used to analyze the decision by a fleet operator to purchase six CSB-dollies. The Net Present Value (the NPV is defined as the sum of the incremental cash flows over the life of the project reduced to current dollars) of the project results in a total negative cash flow of $429,993.73. The incremental cash flows projected over ten years are as shown in Table 5 (in Appendix C). The values of the parameters used in this situation are tabulated in

Table 4 (in Appendix C). (A brief discussion of the independent parameters, their values, and their role in the financial model is also included in Appendix C.)

It is important to emphasize that this loss is an *incremental loss* due to a decision to buy CSB-dollies instead of A-dollies. For example, if there were an underlying decision (with an NPV of at least $430,000) to use twin-trailer combinations instead of tractor-semitrailers, then the decision to use CSB-dollies would reduce the profitability of the original decision. The use of conventional dollies, however, would not affect the original NPV of at least $430,000.

Assuming that the reference fleet were to raise its shipping charges to cover its incremental loss, the freight charges would have to be increased by $0.000179 per 100 lb (45 kg) per mi (1.6 km), as indicated in Table 5 (in Appendix C). The rate increase was determined for six CSB-dollies, observed over a ten year period, travelling 100,000 miles per year and carrying 40,000 lb of cargo per trip. The increase in freight charges translates into an increase of $42.48 for 100,000 lb of cargo to be shipped from Ann Arbor to San Diego - an increase of 1.96 percent.

It is often helpful to see how a project fares under various scenarios. A sensitivity analysis is helpful in determining the key variables that determine whether a project fails or succeeds. Table 2 contains a list of the reference values and variations used in the analysis. The influences of the variations listed in Table 2 are displayed in Figures 7 and 8. Figure 8 shows that reasonable increases or decreases in some of the independent variables have little influence on the operating cost. (The reference values are enclosed in square brackets for easy identification in the figures. The baseline value, indicated by a vertical dashed line, is obtained by exercising the financial model using the reference values of the independent parameters.) Examination of Figure 7 indicates that increases in (1) freight charges, (2) percentage of trips made at GVW, and (3) dolly weight have significant influences on the changes in operating cost associated with acquiring B-dollies. The "Break Even Point" (the 0.0 value on the horizontal scale in Figure 7) is the point at which the costs associated with purchasing and operating an A-dolly are equal to the costs associated with purchasing and operating a CSB-dolly. The profit side of the bar chart is reached if the owners of B-dollies are given a 2,000-lb (680-kg) weight allowance to compensate for the additional weight of the CSB-dolly. With regard to accident costs, the results presented in Figure 8 show that accident costs have only a moderate influence on the financial picture.

Table 2. Variations Used in Analyzing Operating Cost Sensitivities for a Small Fleet (see Figures 7 and 8)

Variables	Reference Values *	Sensitivity Variations	
		Minimum	Minimum
Percentage of trips at max GVW	60%	0 %	100 %
Additional dolly weight	1,500 lbs	750 lb	2250 lb
Miles per year per dolly	100,000 miles	60000 miles	140,000 miles
Charge/lb/mile for freight hauled	$0.0000894	$0.0000447	$0.0001656
Overhaul cost (percentage of initial dolly cost)	20 %	0%	40%
Preventive maintenance - per year	$500	$0	$1,000
Double assembly & disassembly (CSB-dolly backup)	0 per day	0.5	2
Accident savings per mile per CSB-dolly	$0.008	$0.000	$0.016
Annual discount rate	10 %	8.50%	11.5%
Driver/yard personnel training (first year)	$1,000	$0.00	$2,000
Local deliveries	0 per year	130	260
Overweight hauling allowance	0 lbs	1,500 lbs	2,000 lbs

* These reference values define the conditions for the baseline value of the analyses portrayed by Figures 7 and 8

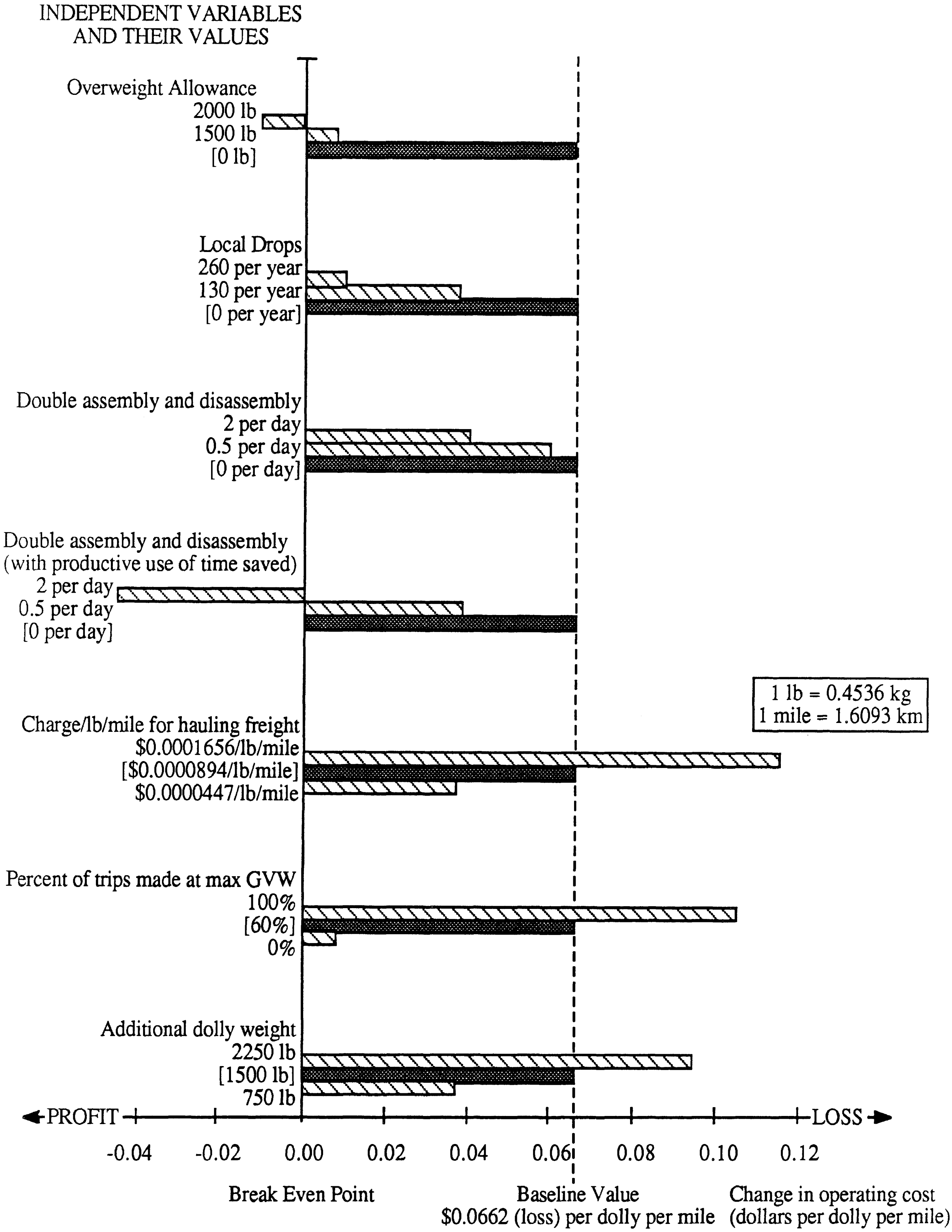


Figure 7. Operating cost sensitivites for a small fleet
(the more important variables).

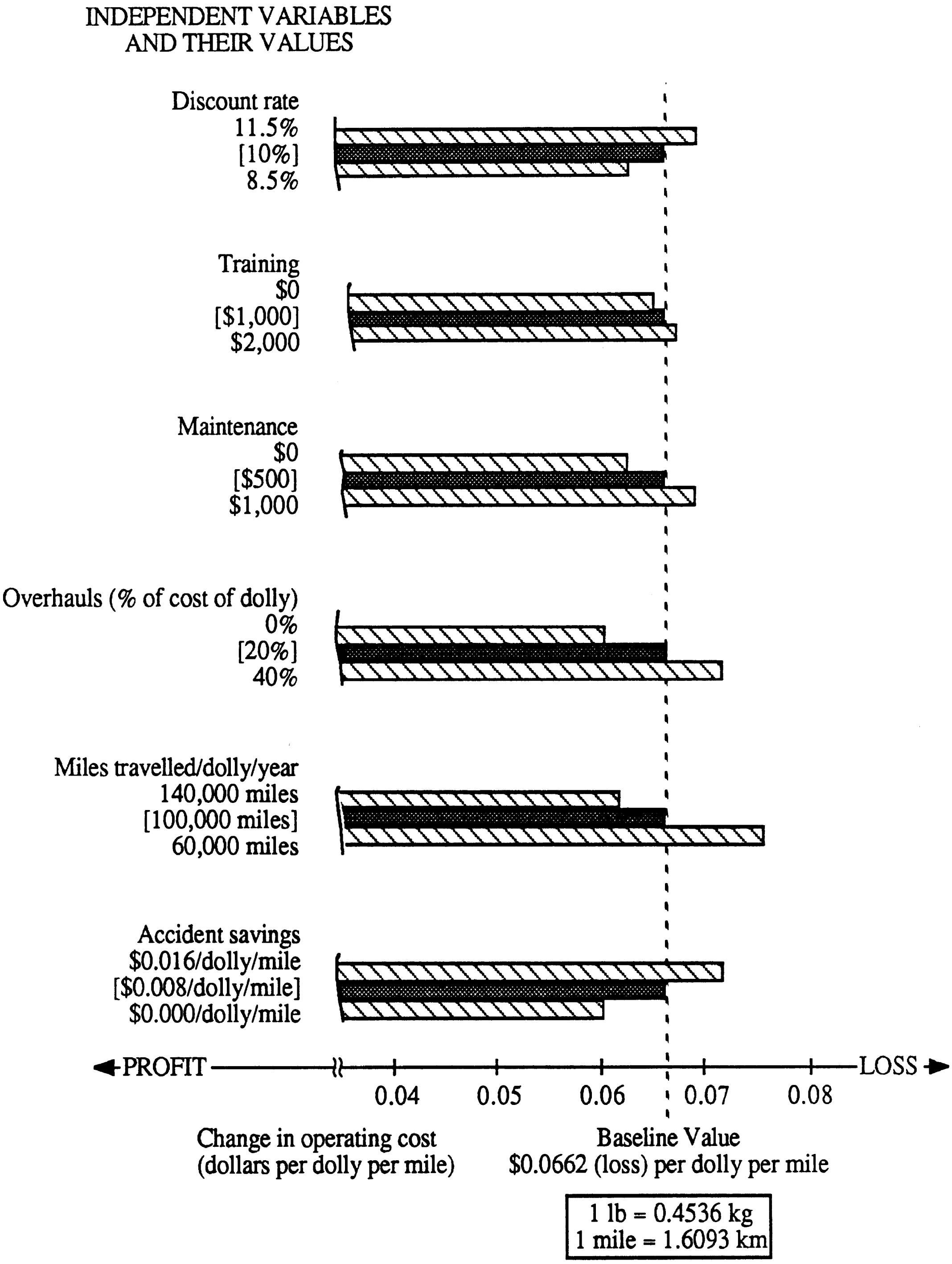


Figure 8. Operating cost sensitivites for a small fleet
(the less important variables).

The economic analysis presented in the preceding discussion has painted a picture which indicates that the introduction of CSB-dollies may not be a profitable investment decision. Additional savings might be realized by fleet operators if they were able to take full advantage of time savings allowed by the CSB-dolly. The prior financial analysis (see Table 5 in Appendix C) used conservative estimates of the benefits associated with operations such as assembling and disassembling a set of doubles. In those analyses, it was assumed that the driver saves an average of 20 minutes on this operation by being able to back up a set of doubles. With an internal labor rate of $21, the 20 minutes saved benefits the fleet operator by $7. This assumes that both the vehicle and the driver are idle for the period. However, if the time saved were accumulated and put to productive use, such as hauling freight, then the benefits would tend to overshadow the increased costs of operating a CSB-dolly.

For example, the additional benefits produced from 20 minutes of extra hauling time can be calculated in the following manner. Assuming an average transportation speed of 20 mi/h (32.2 km/h) (including stops, delays, etc.) and a freight hauling charge of $0.0000894 per lb (0.45 kg) per mi (1.6 km), then a fully loaded vehicle would earn an additional $30 per 20-minute period. When this additional productivity is introduced into the reference condition described in Table 4 and evaluated in Table 5 in Appendix C, a significant change in the results is obtained. A CSB-dolly-equipped double that is assembled and disassembled twice a day results in a net profit of $238,737 over the life of the project, as opposed to a loss of $429,993. Referring to Figure 7, the effect of the additional productivity overshadows the influences of the other key variables.

A Hypothetical Change in the Regulatory Environment. The reference condition presented earlier was designed to reflect the current regulatory environment. If, however, a hypothetical situation where heavier gross vehicle weights and the use of secondary roads were allowed (as permitted in Canada), the cash flows shown in Table 7 in Appendix C demonstrate that the decision to invest in CSB-dollies could be profitable with an NPV of approximately $82,500. (The values of the variables used in this case are displayed in Table 8 in Appendix C.) The present use of CSB-dollies is limited and, from a financial point of view, may be expected to stay that way unless highway regulations are eased in recognition of the improved dynamic ability of the CSB-dolly.

A Hypothetical Change in the Engineering of Dollies. With regard to the engineering of CSB-dollies, the economic analysis indicates that the weight of the dolly is a crucial issue. Small changes in productivity have a major influence on operating costs. It appears that reductions in dolly weight might pay for the increases in dolly purchase prices that would accompany the introduction of lighter and stronger materials. (Of course, reduced dolly weight would lead to more productive vehicles whether they employ A- or CSB-dollies.)

If a market for CSB-dollies were to develop, improved designs would probably be created. For example, assume that the weight penalty between A- and CSB-dollies was reduced to approximately 750 lb (339 kg). Under this hypothetical situation, a new reference situation, entitled "A Hypothetical Change in the Engineering Environment," has been developed (see Tables 8 and 9 in Appendix C). The baseline value of the change in operating cost for this reference condition is $0.0224/dolly/mi (which results from a negative NPV of $179,520) Table 3 lists the variations examined with respect to this reference condition. The results, displayed in Figure 9, are dominated by the influence of a large number of local deliveries. Nevertheless, fleets that operate at GVW approximately 10 percent of the time are predicted to show a small profit from purchasing CSB-dollies. This example provides an estimate of the financial situation that might evolve after several years of CSB-dolly development.

Introducing a new reference condition to address the importance of time management in the trucking industry, "efficient use of time saved" is added as a variable to the situation described in Tables 8 and 9 (see Appendix C). "Efficient use of time saved," as explained in the first situation - "the Current Operating Environment" - provides the additional benefits resulting from a productive use of the time saved from backing up a twin-trailer combination. In such an environment, a light CSB-dolly-equipped double that is assembled and disassembled once a day results in a net profit of $76,828 over the life of the project (as opposed to a loss of $179,520, which was the previous NPV). This change shifts the "Baseline Value" from a loss of $0.0224 to a profit of $0.0183 (see Figure 9). With the variations listed in Table 3, the results of the sensitivity analysis on the new reference situation are shown in Figure 10. In the new reference situation, "additional dolly weight" remains as the only variable that causes an incremental loss.

Table 3. Variations Used in Analyzing Operating Cost Sensitivities for a Lighter CSB-Dolly (see Figures 9)

Variables	Reference Values *	Sensitivity Variations	
		Minimum	Minimum
Percentage of trips at max GVW	60%	0 %	100 %
Additional dolly weight	750 lbs	0 lbs	1500 lbs
Charge/lb/mile for freight hauled	$0.0000894	$0.0000447	$0.0001341
Overhaul cost (percentage of initial dolly cost)	20 %	10%	30%
Preventive maintenance - per year	$500	$0	$1,000
Double assembly & disassembly (CSB-dolly backup)	1 per day	0	2
Accident savings per mile per CSB-dolly	$0.008	$0.000	$0.016
Local deliveries	0 per year	-	260 per year

* These reference values define the conditions for the baseline value of the analyses portrayed by Figure 9

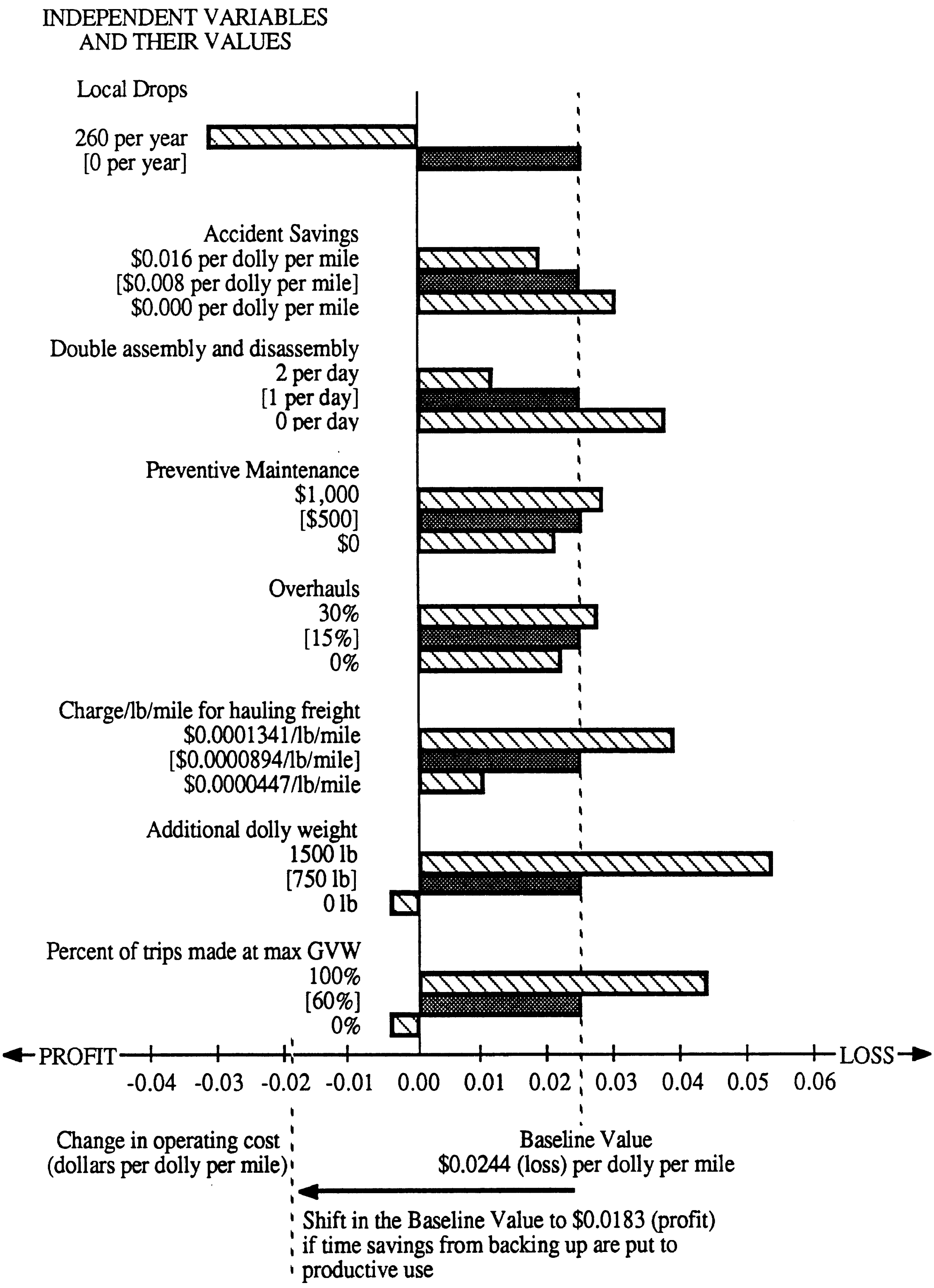


Figure 9. Operating cost sensitivites for a lighter CSB dolly.

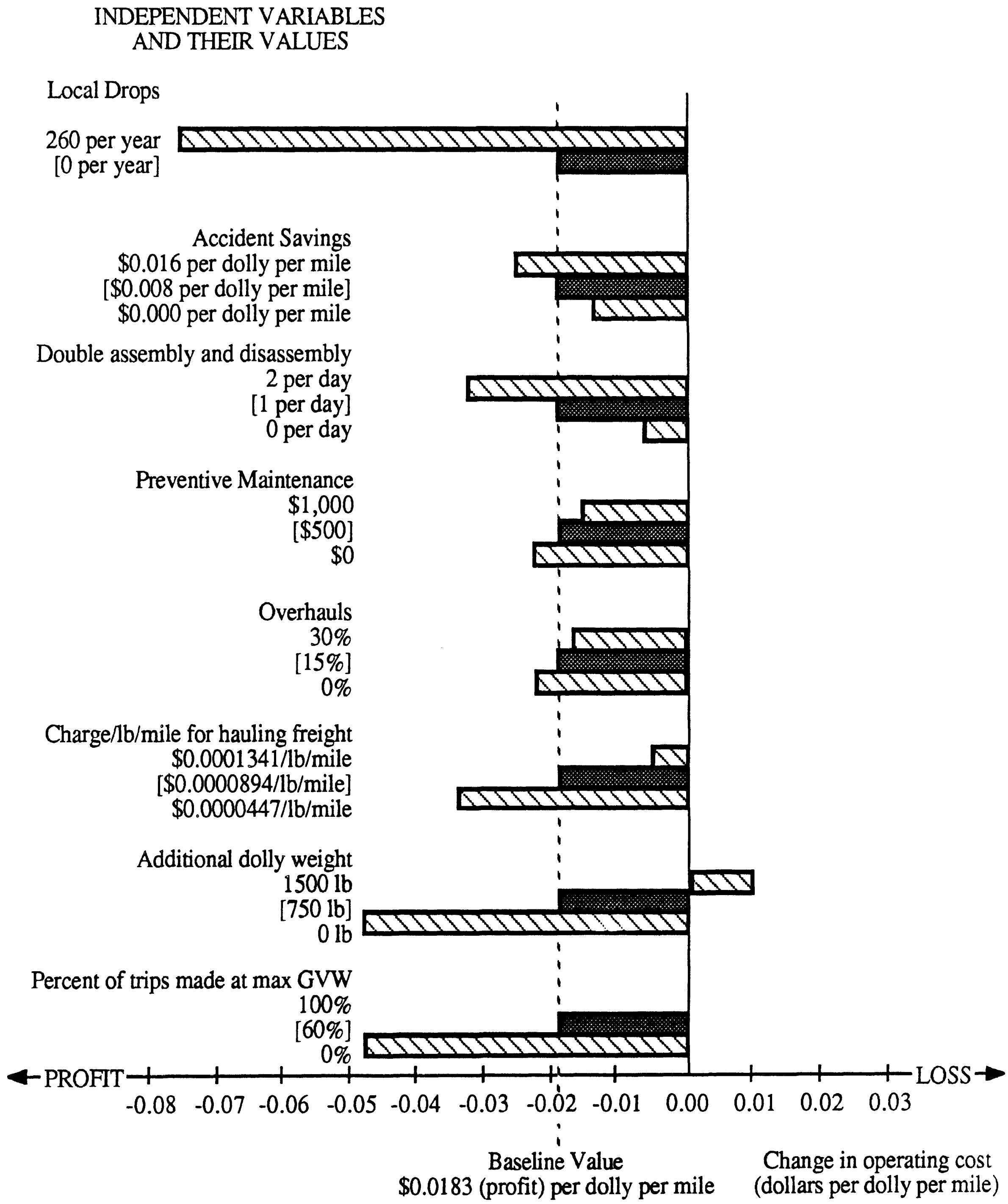


Figure 10. Operating cost sensitivites for a lighter CSB dolly (with productive use of time saved).

CONCLUDING REMARKS

As shown by the analyses presented here, the difference between profit and loss in the trucking industry depends primarily on productivity. An increase in productivity can offset increases in the costs of operating a CSB-dolly-equipped double. Time savings and the amount of weight hauled are both key factors affecting the productivity of a trucking fleet. Although the CSB-dolly causes a decrease in the amount of weight that can be carried, that loss in productivity might be compensated for if fleet operators can find ways to use features of innovative dollies (such as the ability to back up) to increase productivity.

6. Summary Assessment and Concluding Remarks

The prototype dolly has been a success in these field trials. The dynamic performance measured on the proving grounds has been reflected in the good performance observed in field operations. In fact, the field observations are generally of the "no-problem" type. The trip and maintenance reports are generally uneventful and filled with brief, positive entries such as "OK" and "works well." The driver found the stability of the vehicle to be good even in freezing rain on a windy day.

The operation at TRIMAC is set up for B-dollies. The TRIMAC operation is easier to perform when a combination is equipped with a CSB-dolly. Although backing up is not done and space is made available to avoid difficulties with offtracking, the increased maneuverability provided by the CSB-dolly is seen as a definite advantage. The ability to back up could be used in making deliveries in places that were not previously accessible.

Maintenance people find the CSB-dolly to be a large improvement over the conventional B-dolly. They have noted less tire wear with the CSB-dolly than with other dollies. Problems with axle bending and kingpin wear, that were experienced with conventional B-dollies, have not occurred with the CSB-dolly.

Initially, the CSB-dolly developed some slack and free play in its steering linkages. After this was corrected early in the field trials, the CSB-dolly performed well without a recurrence of this problem. The only maintenance factor noted lately is that some wear has started to develop on the top of the steering ball. Although the field maintenance personnel do not look on this as a major difficulty (possibly because the CSB-dolly has been much more trouble-free than other B-dollies), the wear of the ball is a matter worth investigating and design improvements are in order for the steering system. Nevertheless, the steering system has functioned very well and it has performed as intended throughout the last year.

As far as using CSB-dollies in direct competition with A-dollies, their additional weight is a major disadvantage. The economic analysis shows that this weight penalty would be very costly in situations where gross combination weight limits are not adjusted to provide an economic advantage to B-dollies.

The current CSB-dolly is approximately 1,500 lbs heavier than some A-dollies that could be used in comparable service in Canada. This additional weight is brought about by the second drawbar, an especially heavy steering axle, and the steering linkage incorporated in the CSB-dolly. With appropriate redesign and development, a lighter CSB-dolly could evolve. Nevertheless, it would seem that the simpler A-dolly will always have some weight advantage over the CSB-dolly (possibly no more than the weight of the steering system).

Although the CSB-dolly has seen extensive and demanding service, the number of miles accumulated has been less than anticipated. This was due in part to restrictions on the roads and bridges that the vehicle was permitted to use, and in part to less demand for concrete and road salt than expected. It is possible that further service could result in cracking and other problems related to fatigue; however, no fatigue-related problems have been observed so far.

Based on the field trials, further development and evaluation of the CSB-dolly is warranted. Whether the CSB-dolly is more cost effective than the A-dolly depends upon the premium placed on safety and the avoidance of rear trailer rollovers. Possibly, the improvements in performance in safety-related maneuvers merits a weight allowance making innovative dollies economically attractive.

REFERENCES

1. Winkler, C.B. Improving the Dynamic Performance of Multi-Trailer Vehicles: A Study of Innovative Dollies. Transportation Research Institute, The University of Michigan, Report No. UMTRI-86-26, July 1986.

Appendix A

TRIMAC Transportation

Questions on the Experience of the Canadian Trucking Industy in the Use of B-Dollies

1) What was the basis for your choosing to purchase and use B-dollies?

HIGHER G.V.W. FROM 108,000 lbs TO 137,000
MORE STABILITY, CRITICAL IN HIGHER GROSS UNITS.
SAFETY

2) Over what time period (and approximate total vehicle-miles) have you gained experience with B–Dollies? SINCE 1982

APPROX 125,000 Mi/YEAR.
50 DOLLIES IN USE (AUTOMATIC STEER ONLY)

3) On what types of vehicle combinations do you operate B-Dollies?

DOUBLES ONLY
(WESTERN A TRAIN)

4) In what kinds of hauling operations do you employ these vehicles?

- what kinds of roads are you on? IN SASK. BOTH PAVEMENT & GRAVEL EX SASKATOON PRIMARILY GRAVEL.

- what levels of traffic density are you operating in? LIGHT TO MODERATE.

- what are your typical axle loads? 8 AXLE UNIT.

12	35	35	20	35
STRING	DRIVE	TRL.	DOLLY	REAR TRL.

- what percentage of your loads are
  - a) cube-full 85%
  - b) max GCW 137000 lbs.
  - c) other_________

5) Are your drivers of B-Dolly rigs experienced also in operating A-trains?

YES 3 YEARS MIN EXPERI

6) What do your drivers say about their experience with the B- vs. A-Dolly hardware?

Unit is much more stable.
Driver has a Better feel for what Rear unit is Doing.

7) What has been your accident experience with A- and B-Dolly systems?

- overall accident rates ?

- types of accidents (rollover, sidewsipes, jackknife, etc.)

- weather conditions and loading

8) What unusual experiences have you had in the field operating B-Dollies that never occurred before with A-Trains? (What have been the suprises?)

Broken Axle.
greater Tire wear.

9) What is the lifespan (between major overhauls) of B- vs. A-Dollies in your experience?

Because of the extreme condition units Run in, it would be unfair to Judge ~~the~~ - Dolley on Basic Pavement operation.

10) What are the major maintenance problems with B-Dollies?

Axle Bending.
King Pin ware.

11) Have you had unusual structural failures in trailers coupled by means of a B-Dolly?

No

12) What are the differences in maintenance costs incurred with B- vs. A-Dollies?

14) Do you lose revenue because payload is replaced by the heavier B-Dolly?

No
Due to incentive of higher gross vehicle wt.

15) What is the overall cost of operating A- vs. B-Dolly vehicles in your business, ($ per ton–mile)?

?

16) In what way is the B-Dolly easier (or harder) to hitch and unhitch than the A-Dolly?

N/A in our operation.

17) Have you used so-called "automatic hitching mechanisms", with B-Dollies, instead of conventional pintle hitches? If so, do they provide any advantages?

NO

18) Is the greater ease of backing up B-Dollies important in your operation?

NO.

19) Do you need less room at your truck terminals for assembling and/or maneuvering B-Dolly-, as opposed to A-Dolly-, equipped vehicles? No

20) Have you experienced other advantages or disadvantages in the use of B-Dollies which may not have been addressed above? No.

Appendix B

A few trip and maintenance reports were selected from the sixteen month collection and are included in Appendix B. Information from some of these reports resulted in the "milestones" on the cumulative mileage chart in Figure 6.

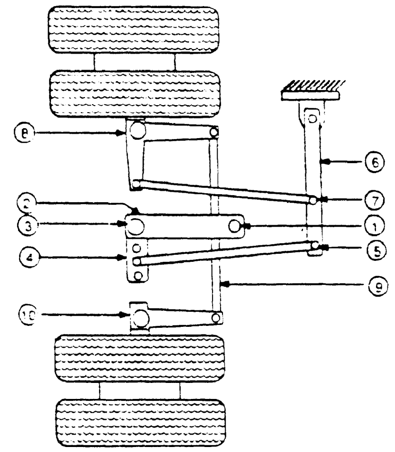
Saskatchewan Highways and Transportation

CSB - DOLLY CONVERTOR REPORT

INSPECTION

In addition to the standard pre-trip inspection, the following checks must be carried out for the CSB - Dolly Convertor.

1. Steering System:



		Normal	Wear
①	Steering Ball Hitch	(✓)	( )
②	Upper Steering Arm	(✓)	( )
③	Vertical Steering Shaft	(✓)	( )
④	Lower Steering Arm	(✓)	( )
⑤	1st Steering Link	(✓)	( )
⑥	Idler Arm	(✓)	( )
⑦	2nd Steering Link	(✓)	( )
⑧	Left Wheel Steering Arm	(✓)	( )
⑨	Tie Rod	(✓)	( )
⑩	Right Wheel Steering Arm	(✓)	( )

2. Structural Components:

	Normal	Abnormal Wear
Main frame rails	(✓)	( )
Cross members	(✓)	( )
Pintle hitches	(✓)	( )
King Pins (Shop check only)	(✓)	( )
Tire Wear (Shop check only)	(✓)	( )

If any steering or structural components show signs of wear and/or fatigue which may affect the performance of the vehicle, it is to be taken out of service immediately. The operator is to advise Trimac personnel and personnel of the Transportation Systems Branch, Department of Highways and Transportation of such action. Note defects here:

Top of Steering Ball showing a little wear.

REPAIRS

Please note any repairs required:

FOR SHOP USE ONLY

Unit No. ______ Date Inspected July 26/86

Mechanic's Signature [illegible signature]

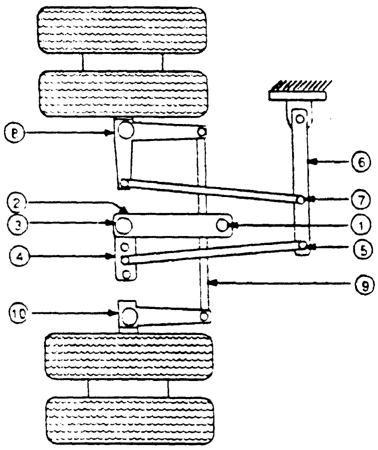
Saskatchewan Highways and Transportation

CSB - DOLLY CONVERTOR REPORT

INSPECTION

In addition to the standard pre-trip inspection, the following checks must be carried out for the CSB - Dolly Convertor.

1. Steering System:



		Normal	Wear
1	Steering Ball Hitch	(✓)	( )
2	Upper Steering Arm	(✓)	( )
3	Vertical Steering Shaft	(✓)	( )
4	Lower Steering Arm	(✓)	( )
5	1st Steering Link	(✓)	( )
6	Idler Arm	(✓)	( )
7	2nd Steering Link	(✓)	( )
8	Left Wheel Steering Arm	(✓)	( )
9	Tie Rod	(✓)	( )
10	Right Wheel Steering Arm	(✓)	( )

2. Structural Components:

	Normal	Abnormal Wear
Main frame rails	(✓)	( )
Cross members	( )	( )
Pintle hitches	(✓)	( )
King Pins (Shop check only)	(✓)	( )
Tire Wear (Shop check only)	(✓)	( )

If any steering or structural components show signs of wear and/or fatigue which may affect the performance of the vehicle, it is to be taken out of service immediately. The operator is to advise Trimac personnel and personnel of the Transportation Systems Branch, Department of Highways and Transportation of such action. Note defects here:

REPAIRS

Please note any repairs required:

Changed grease nipples on # 6, 7, 10

FOR SHOP USE ONLY

Unit No. ______________ Date Inspected April 20 86

Mechanic's Signature ______________

"SCHEDULE A"

TRIP REPORT

Driver O. Slobodian Date March 24/86

Unit No. 11348 Company Trip Report # ________

From	To	Departure Time	Arrival Time	Gross Vehicle Weight Power Unit & Lead Trailer	Gross Vehicle Weight Dolly & Rear Trailer
Regina	Stoon	9:00 AM	1:30 PM	4530 ~~14226~~	
Stoon	Regina	3:40 PM	7:40 PM	16060	53470
		Total Fuel Used	78	5790 ~~13240~~	53

Please note any repairs required during the trip.

Weather Conditons:

Temp -2°C Wind Speed 40 km Wind Direction East

Sky Clear ____ Cloudy ~~With Snow~~ ✓ To Stoon Cloudy With Rain ✓ freezing To Regina

Road Conditions:

Dry ✓ Wet ____ Ice ____

Vehicle Inspection:

The standard pre-trip inspection is required. If any items show signs of wear and/or fatigue which may affect the performance of the vehicle, it is to be taken out of service immediately. The operator is to advise Trimac personnel and personnel of the Transportation Systems Branch, Department of Highways and Transportation of such action. The Department and Trimac will jointly determine the remedial action necessary to put the vehicle back into service. Note defects here:

Trailer Self Steering Axle Assemblies:

		Loaded	Empty
Pressure on steering system:	at start of trip	_____	_____
	at completion of trip	_____	_____
Number of times axles on trailer had to be lifted:		_____	

Reasons the axle had to be lifted for:

____

Describe any occassions when steering axles did not work properly during the trip:

____

Vehicle Operation:

Please describe the general performance of the vehicle during the trip. Include any unusual vehicle performance or traffic situations that occurred during the trip. If difficulties of a serious nature occur please contact one of the people listed below for Trimac and one of the people listed below for the Department of Highways and Transportation.

Unit handled well in freezing rain conditions

Driver's Signature [illegible]

Saskatchewan Highways and Transportation

Bernie Churko	Norm Burns	Peter Hurst
787-5533 Bus.	787-5535 Bus.	787-5536 Bus.
545-5628 Res.	586-9802 Res.	545-7750 Res.

Road Systems Unit
7th Floor, 1855 Victoria Avenue
Regina, Saskatchewan

"SCHEDULE A"

TRIP REPORT

Driver O SLOBODIAN Date 4-4-86

Unit No. 11-348 Company Trip Report # ____

From	To	Departure Time	Arrival Time	Gross Vehicle Weight Power Unit & Lead Trailer	Gross Vehicle Weight Dolly & Rear Trailer
REGINA	ESTEVAN	8:00 Am	ROCHWOOD	34000	19500
ESTEVAN	REGINA	1.00 P.M	5:30 P.M	GROSS	53500

Total Fuel Used 48

404

Please note any repairs required during the trip.

Weather Conditons:

Temp -1 Wind Speed 22 Wind Direction SOUTH EAST

Sky Clear ____ Cloudy With ~~Snow~~ ✓ Cloudy With Rain ____

Road Conditions:

Dry ✓ Wet ____ Ice ____

Vehicle Inspection:

The standard pre-trip inspection is required. If any items show signs of wear and/or fatigue which may affect the performance of the vehicle, it is to be taken out of service immediately. The operator is to advise Trimac personnel and personnel of the Transportation Systems Branch, Department of Highways and Transportation of such action. The Department and Trimac will jointly determine the remedial action necessary to put the vehicle back into service. Note defects here:

OK.

Trailer Self Steering Axle Assemblies:

	Loaded	Empty
Pressure on steering system: at start of trip	____	____
at completion of trip	____	____

Number of times axles on trailer had to be lifted: ________

Reasons the axle had to be lifted for:

Describe any occassions when steering axles did not work properly during the trip:

Vehicle Operation:

Please describe the general performance of the vehicle during the trip. Include any unusual vehicle performance or traffic situations that occurred during the trip. If difficulties of a serious nature occur please contact one of the people listed below for Trimac and one of the people listed below for the Department of Highways and Transportation.

WORKED REAL WELL

NO PROBLEMS

Driver's Signature ________

Saskatchewan Highways and Transportation

Bernie Churko	Norm Burns	Peter Hurst
787-5533 Bus.	787-5535 Bus.	787-5536 Bus.
545-5628 Res.	586-9802 Res.	545-7750 Res.

Road Systems Unit
7th Floor, 1855 Victoria Avenue
Regina, Saskatchewan

03131/76-77

Appendix C

A detailed explanation of the independent variables, their values, and their role in the financial model.

APPENDIX C

THE INDEPENDENT VARIABLES AND THEIR VALUES.

1. *Influences of the excess weight of the CSB-dolly.*

a. Percent of trips at maximum gross vehicle weight (GVW). Though it is desirable to operate vehicles cube-full and at maximum axle loads, the actual loading situation is determined by the density of the freight being shipped. The reference condition assumes a hypothetical fleet operating its vehicles at maximum GVW 60 percent of the time. (This value of 60 percent corresponds to the experience of large LTL ("less than truck load") fleets in the U.S.)

b. Excess weight of the CSB-dolly. The CSB-dolly being operated in Canada weighs 1,500 lb (680 kg) more than a conventional dolly. Under more stringent road-use laws, such as in the United States, CSB-dollies, designed to operate at lower axle loads, could be 750 lb (340 kg) lighter than their Canadian counterparts.

c. Miles per year per dolly. In addition to predicting the frequency of preventive maintenance, this variable helps estimate the loss of revenue from having to carry less freight. The industry average for annual dolly-miles is 100,000 mi (161,000 km).

d. Freight charges. The freight charge has a direct bearing on the loss of revenue due to displaced cargo. Among other factors, the charge is dependent upon the distance the freight is to be shipped. For the reference condition, it is assumed that the charges are $21.21 per 100 lb (45 kg) of freight shipped from Ann Arbor, Michigan to San Diego, California. (However, the charges from Ann Arbor to Toledo, Ohio are $4.00 per 100 lbs (45 kg). On a per mile basis, the San Diego rate is $0.00894 per 100 lb (45 kg) per mi (1.6 km), and the Toledo rate is $0.08 per 100 lb (45 kg) per mi (1.6 km).)

2. *Size of the fleet.* The size of the operation and the proportion of CSB-dollies being added to the fleet determines the scheduling and training costs a company might incur. The pertinent variables are:

a. Number of CSB-dollies added to the fleet.

b. Total number of dollies owned by the fleet.

3. *Maintenance.*

a. Cost of a major overhaul. The cost of a major overhaul is defined as a percentage of the original cost of the dolly. The model assumes that a CSB-dolly undergoes a major overhaul every two years while an A-dolly has a major overhaul once every four years. The cost of a major overhaul for the hypothetical fleet is assumed to be

20 percent of the cost of the dolly - that is, $2,100 for a CSB-dolly and $900 for an A-dolly.

b. Cost of preventive maintenance. From trip and maintenance records, A-dollies have been known to cost the fleet operator $500 per year. Since CSB-dollies are twice as expensive with respect to preventive maintenance (that is, they are brought in twice as often for routine maintenance), the difference in the annual cost of preventive maintenance is estimated to be $500.

4. *Number of backups per day.* If a fleet operates over short distances where double trailer combinations must be assembled and disassembled more than once every day, then the ability to back up two trailers could have an impact on the profitability of the operation. The reference fleet, however, does not consider backing up to be a cost-saving alternative.

5. *Accident savings.* As the CSB-dolly's improved dynamic ability reduces the possibility of accidents, it is assumed to save the fleet operator $0.008 per dolly per mile (1.6 km).

6. *Discount rate.* The discount rate is used to reduce future cash flows to current amounts and is assumed to be 10 percent (after taxes) for the shipping and transportation industry.

7. *Scheduling and training.*

a. Scheduling programs and data bases. This variable attempts to address the single expense incurred by large fleets when scheduling-related computer programs and data bases are updated. A large fleet is assumed to operate at least 30 dollies.

b. Administrative training. The training of managers and administrative personnel is associated with a learning curve and is defined as the training cost per CSB-dolly during the first year of its introduction.

c. Driver/yard personnel training. The training of drivers and yard personnel is defined in a fashion similar to administrative training.

8. *Local deliveries.* (That is, the ability to operate on secondary roads.) Assuming a change in regulation, a double-trailer vehicle saves the fleet operator $30 for every local (off the federal highway system) trip it is allowed to make. This $30 represents the cost of the extra trip needed for individually towing each trailer to the local delivery site.

9. *Permit to increase gross vehicle weight.* Assuming a change in regulation, an increase in gross vehicle weight is used to offset the additional weight of the CSB-dolly.

The values of the independent variables in the first situation are tabulated in Table 4.

DISCUSSION OF THE RESULTS

The first column in Table 5 is used to label the economic issues outlined previously in this section. The following columns, titled Year 0 (the current year) through Year 9 (the tenth year), contain the annual cash flows resulting from each of the items mentioned in the first column. Negative cash flows, or expenses, are shown in parentheses.

Net Present Value: In the model, cash flows occurring in Year 0 result from operational costs and one-time expenses such as purchasing, scheduling, and equipment conversions. Cash flows in the following years result from changes in operational costs only. In the reference case, a fleet adding six B-dollies versus one adding six A-dollies would have to spend an additional $36,000 to cover the initial cost of the dollies. This cost, plus other initial investments and operational costs, results in a loss of $107,276 in the first year of the project. During the second year, the fleet operator would lose $61,577.58 due to increases in operational costs alone. The Net Present Value (NPV) of the sum of the incremental cash flows over the life of the project results in a total negative cash flow of $429,993.73.

Change in Shipping Charges. Assuming that the reference fleet were to raise its shipping charges to cover its incremental loss, the freight charges would have to be increased by $0.000179 per 100 lb (45 kg) per mi (1.6 km) as indicated in Table 5. The rate increase was determined for six CSB-dollies, observed over the ten-year period, travelling 100,000 miles per year and carrying 40,000 lb of cargo per trip.

Change in Operating Cost. The increased operating cost of a CSB-dolly - that is, the NPV of the investment less the one-time costs of scheduling, purchasing, and converting equipment - is computed (per dolly per mile (1.6 km)) in the last row of the column of Year 0. It is this value (0.0642 dollars per dolly per mi (1.6 km)) that is used as the reference value in the sensitivity analyses.

Table 4. The Variables Used in the Financial Model for Table 5

Variable Names	Values
Percentage of trips at max GVW	60 %
Additional dolly weight	1500 lbs
Miles per year per dolly	100,000 miles
Charge/lb/mile for freight hauled	$0.0000894
CSB-dollies added to the fleet	6 CSB-dollies
Total number of dollies owned	15 Dollies
Percent of tire wear increase over A-dolly	0 %
Overhaul cost (percentage of initial dolly cost)	20 %
Preventive maintenance - per year	$500.00
Double assembly & disassembly (CSB-dolly backup)	1 per day
Accident savings per mile per CSB-dolly	$0.008
Annual discount rate	10 %
Upgrading scheduling programs	$0.00
Administrative Expenses (first year)	$1,000.00
Driver/yard personnel training (first year per dolly)	$1,000.00
Local deliveries	0 per year
Overweight hauling allowance	0 lbs

Table 5. The Reference Condition—
Results Correspond to the Purchase of Six CSB-Dollies

Δ costs/benefits between A & CSB dollies	Year 0	Year 1	Year 2	Year 3	Year 4
Initial cost of dollies	($36,000.00)	$0.00	$0.00	$0.00	$0.00
Converting existing equipment	($18,000.00)	$0.00	$0.00	$0.00	$0.00
Major overhauls	$0.00	($12,600.00)	$0.00	($7,200.00)	$0.00
Tire wear	$0.00	$0.00	$0.00	$0.00	$0.00
Preventive maintenance	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)
Scheduling	($800.00)	($294.30)	($108.27)	($39.83)	($14.65)
Training	($6,000.00)	($2,207.28)	($812.01)	($298.72)	($109.89)
Ability to back up	$0.00	$0.00	$0.00	$0.00	$0.00
Less weight hauled	($48,276.00)	($48,276.00)	($48,276.00)	($48,276.00)	($48,276.00)
Fewer accidents	$4,800.00	$4,800.00	$4,800.00	$4,800.00	$4,800.00
Ability to operate on secondary roads	$0.00	$0.00	$0.00	$0.00	$0.00
Allow higher GVW	$0.00	$0.00	$0.00	$0.00	$0.00
Total	($107,276.00)	($61,577.58)	($47,396.28)	($54,014.55)	($46,600.55)
Net Present Value	($429,993.73)				
Cost increase to cover loss /100lb / mile	$1.79E-04				
Change in operating cost / dolly / mile	$0.0662				

Δ costs/benefits between A & CSB dollies	Year 5	Year 6	Year 7	Year 8	Year 9
Initial cost of dollies	$0.00	$0.00	$0.00	$0.00	$0.00
Converting existing equipment	$0.00	$0.00	$0.00	$0.00	$0.00
Major overhauls	($12,600.00)	$0.00	($7,200.00)	$0.00	($12,600.00)
Tire wear	$0.00	$0.00	$0.00	$0.00	$0.00
Preventive maintenance	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)
Scheduling	($5.39)	($1.98)	($0.73)	($0.27)	($0.10)
Training	($40.43)	($14.87)	($5.47)	($2.01)	($0.74)
Ability to back up	$0.00	$0.00	$0.00	$0.00	$0.00
Less weight hauled	($48,276.00)	($48,276.00)	($48,276.00)	($48,276.00)	($48,276.00)
Fewer accidents	$4,800.00	$4,800.00	$4,800.00	$4,800.00	$4,800.00
Ability to operate on secondary roads	$0.00	$0.00	$0.00	$0.00	$0.00
Allow higher GVW	$0.00	$0.00	$0.00	$0.00	$0.00
Total	($59,121.82)	($46,492.86)	($53,682.20)	($46,478.28)	($59,076.84)

Table 6. The Variables Used in the Financial Model for Table 7

Variable Names	Values
Percentage of trips at max GVW	60 %
Additional dolly weight	1500 lbs
Miles per year per dolly	100,000 miles
Charge/lb/mile for freight hauled	$0.0000894
CSB-dollies added to the fleet	6 CSB-dollies
Total number of dollies owned	15 Dollies
Percent of tire wear increase over A-dolly	0 %
Overhaul cost (percentage of initial dolly cost)	20 %
Preventive maintenance - per year	$500.00
Double assembly & disassembly (CSB-dolly backup)	0.5 per day
Accident savings per mile per CSB-dolly	$0.008
Annual discount rate	10 %
Upgrading scheduling programs	$0.00
Administrative Expenses (first year)	$1,000.00
Driver/yard personnel training (first year per dolly)	$1,000.00
Local deliveries	100 per year
Overweight hauling allowance	1500 lbs

Table 7. The Hypothetical Regulatory Situation

Δ costs/benefits between A & CSB dollies	Year 0	Year 1	Year 2	Year 3	Year 4
Initial cost of dollies	($36,000.00)	$0.00	$0.00	$0.00	$0.00
Converting existing equipment	($18,000.00)	$0.00	$0.00	$0.00	$0.00
Major overhauls	$0.00	($12,600.00)	$0.00	($7,200.00)	$0.00
Tire wear	$0.00	$0.00	$0.00	$0.00	$0.00
Preventive maintenance	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)
Scheduling	($800.00)	($294.30)	($108.27)	($39.83)	($14.65)
Training	($6,000.00)	($2,207.28)	($812.01)	($298.72)	($109.89)
Ability to back up	$5,460.00	$5,460.00	$5,460.00	$5,460.00	$5,460.00
Less weight hauled	$0.00	$0.00	$0.00	$0.00	$0.00
Fewer accidents	$4,800.00	$4,800.00	$4,800.00	$4,800.00	$4,800.00
Ability to operate on secondary roads	$18,000.00	$18,000.00	$18,000.00	$18,000.00	$18,000.00
Allow higher GVW	$0.00	$0.00	$0.00	$0.00	$0.00
Total	($35,540.00)	$10,158.42	$24,339.72	$17,721.45	$25,135.45
Net Present Value	$82,528.94				
Cost increase to cover loss /100lb / mile	$0.00E+00				
Change in operating cost / dolly / mile	($0.0193)				

Δ costs/benefits between A & CSB dollies	Year 5	Year 6	Year 7	Year 8	Year 9
Initial cost of dollies	$0.00	$0.00	$0.00	$0.00	$0.00
Converting existing equipment	$0.00	$0.00	$0.00	$0.00	$0.00
Major overhauls	($12,600.00)	$0.00	($7,200.00)	$0.00	($12,600.00)
Tire wear	$0.00	$0.00	$0.00	$0.00	$0.00
Preventive maintenance	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)
Scheduling	($5.39)	($1.98)	($0.73)	($0.27)	($0.10)
Training	($40.43)	($14.87)	($5.47)	($2.01)	($0.74)
Ability to back up	$5,460.00	$5,460.00	$5,460.00	$5,460.00	$5,460.00
Less weight hauled	$0.00	$0.00	$0.00	$0.00	$0.00
Fewer accidents	$4,800.00	$4,800.00	$4,800.00	$4,800.00	$4,800.00
Ability to operate on secondary roads	$18,000.00	$18,000.00	$18,000.00	$18,000.00	$18,000.00
Allow higher GVW	$0.00	$0.00	$0.00	$0.00	$0.00
Total	$12,614.18	$25,243.14	$18,053.80	$25,257.72	$12,659.16

Table 8. The Variables Used in the Financial Model for Table 9

Variable Names	Values
Percentage of trips at max GVW	60 %
Additional dolly weight	750 lbs
Miles per year per dolly	100,000 miles
Charge/lb/mile for freight hauled	$0.0000894
CSB-dollies added to the fleet	6 CSB-dollies
Total number of dollies owned	15 Dollies
Percent of tire wear increase over A-dolly	0 %
Overhaul cost (percentage of initial dolly cost)	20 %
Preventive maintenance - per year	$500.00
Double assembly & disassembly (CSB-dolly backup)	1 per day
Accident savings per mile per CSB-dolly	$0.008
Annual discount rate	10 %
Upgrading scheduling programs	$0.00
Administrative Expenses (first year)	$1,000.00
Driver/yard personnel training (first year per dolly)	$1,000.00
Local deliveries	0 per year
Overweight hauling allowance	0 lbs

Table 9. The Hypothetical Engineering Situation

Δ costs/benefits between A & CSB dollies	Year 0	Year 1	Year 2	Year 3	Year 4
Initial cost of dollies	($36,000.00)	$0.00	$0.00	$0.00	$0.00
Converting existing equipment	($18,000.00)	$0.00	$0.00	$0.00	$0.00
Major overhauls	$0.00	($12,600.00)	$0.00	($7,200.00)	$0.00
Tire wear	$0.00	$0.00	$0.00	$0.00	$0.00
Preventive maintenance	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)
Scheduling	($800.00)	($294.30)	($108.27)	($39.83)	($14.65)
Training	($6,000.00)	($2,207.28)	($812.01)	($298.72)	($109.89)
Ability to back up	$10,920.00	$10,920.00	$10,920.00	$10,920.00	$10,920.00
Less weight hauled	($24,138.00)	($24,138.00)	($24,138.00)	($24,138.00)	($24,138.00)
Fewer accidents	$4,800.00	$4,800.00	$4,800.00	$4,800.00	$4,800.00
Ability to operate on secondary roads	$0.00	$0.00	$0.00	$0.00	$0.00
Allow higher GVW	$0.00	$0.00	$0.00	$0.00	$0.00
Total	($72,218.00)	($26,519.58)	($12,338.28)	($18,956.55)	($11,542.55)
Net Present Value	($179,519.49)				
Cost increase to cover loss /100lb / mile	$7.48E-05				
Change in operating cost / dolly / mile	$0.0244				

Δ costs/benefits between A & CSB dollies	Year 5	Year 6	Year 7	Year 8	Year 9
Initial cost of dollies	$0.00	$0.00	$0.00	$0.00	$0.00
Converting existing equipment	$0.00	$0.00	$0.00	$0.00	$0.00
Major overhauls	($12,600.00)	$0.00	($7,200.00)	$0.00	($12,600.00)
Tire wear	$0.00	$0.00	$0.00	$0.00	$0.00
Preventive maintenance	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)	($3,000.00)
Scheduling	($5.39)	($1.98)	($0.73)	($0.27)	($0.10)
Training	($40.43)	($14.87)	($5.47)	($2.01)	($0.74)
Ability to back up	$10,920.00	$10,920.00	$10,920.00	$10,920.00	$10,920.00
Less weight hauled	($24,138.00)	($24,138.00)	($24,138.00)	($24,138.00)	($24,138.00)
Fewer accidents	$4,800.00	$4,800.00	$4,800.00	$4,800.00	$4,800.00
Ability to operate on secondary roads	$0.00	$0.00	$0.00	$0.00	$0.00
Allow higher GVW	$0.00	$0.00	$0.00	$0.00	$0.00
Total	($24,063.82)	($11,434.86)	($18,624.20)	($11,420.28)	($24,018.84)