NATIONAL
WEIGH IN MOTION
CONFERENCE

July 11-15, 1983
Stapleton Plaza Hotel
Denver, Colorado

Conference Conducted by the:
Colorado Department of Highways
Division of Transportation Planning

Project Coordinator:
Tom Talmadge 303-757-9261
Technical Coordinator:
Bob Tenney 303-757-9488

in cooperation with the:
U.S. Department of Transportation
Federal Highway Administration
Project Coordinators:
John Hooks 703-285-2362
Perry Kent 202-426-0160

STATE OF COLORADO

DEPARTMENT OF HIGHWAYS

4201 East Arkansas Ave.
Denver, Colorado 80222
(303) 757-9011

CONFERENCE CRITIQUE

1. WHY WERE YOU HERE AND WHAT WAS YOUR PRIMARY INTEREST?

2. HOW SOON DO YOU FEEL ANOTHER CONFERENCE SHOULD BE HELD?

3. WHERE SHOULD THIS CONFERENCE BE HELD?

4. WOULD YOUR STATE AGREE TO BE THE HOST?

5. IF NO FEDERAL FUNDS FOR THE CONFERENCE ARE AVAILABLE, WOULD YOUR STATE AGREE TO BE THE HOST?

PLEASE MAIL YOUR RESPONSE TO:

MR. PERRY M. KENT
U.S. DEPT. OF TRANSPORTATION
FHWA
400 SEVENTH ST., S.W.
WASHINGTON, D.C. 20590

TABLE OF CONTENTS

NATIONAL WORKSHOP ON WIM TECHNOLOGY & APPLICATIONS

I. Opening Session

Welcome: Mr. Dwight Bower, Deputy Director
Colorado Department of Highways
Denver, Colorado

Welcome: Mr. M. C. Reinhardt
Regional Federal Highway Administrator
FHWA
Region 8
Denver, Colorado

Overview of Truck Weight Data Needs --
Mr. Kevin Heanue, Director
Office of Highway Planning
FHWA
Washington, D.C.

Why Size & Weight Enforcement --
Mr. Harry Skinner, Chief
Traffic Engineering Division
FHWA
Washington, D.C.

Overview of State Programs:

Truck Weight Studies --
Mr. Jerry Legg
West Virginia Department of Highways
Charleston, West Virginia

Size & Weight Enforcement --
Mr. Allan Childers
Director of Operations
Georgia Department of Transportation
Atlanta, Georgia

Combined Size & Weight Enforcement --
Mr. Spence Garret and Mr. Adam Uhrich
Wyoming Highway Department
Cheyenne, Wyoming

Guest Dinner Speaker
Mr. Robin Moore
TRRL
Ministry of Transport
United Kingdom

II. Collection and Use of Truck Characteristics Data

Truck Weight Data (Federal & State Programs for Collection and Use of Truck Weight Data) --

Mr. P. M. Kent
Office of Highway Planning
FHWA
Washington, D.C.

Mr. George Novenski
Wisconsin Department of Transportation
Madison, Wisconsin

Mr. Stephen Fregger
Florida Department of Transportation
Tallahasse, Florida

Size and Weight Enforcement (Federal & State Programs for Enforcement of Size and Weight Regulations) --

Mr. Harold J. Brown
FHWA
Washington, D.C.

Mr. John Balcom
Washington Highway Patrol

Mr. J. R. Doughty
Pennsylvania Department of Transportation
Harrisburg, Pennsylvania

Lunch Guest Speaker

Jack Winder
Department of Transportation
United Kingdom

Handbook 44 --

Mr. Otto Warnloff
National Bureau of Standards
Gathersburg, Maryland

III. WIM Technology

Concepts, Advantages, & Applications of WIM System --

Dr. Clyde Lee
University of Texas
Austin, Texas

Experiences with WIM Systems --

Minnesota (IRD):
Mr. William Ebert
Minnesota Department of Transportation
St. Paul, Minnesota

Idaho (PAT):
Mr. John Hamrick
Idaho Department of Transportation
Boise, Idaho

Nevada (Radian):
Mr. Donald Pray
Nevada Department of Transportation
Carson City, Nevada

Georgia (Streeter Amet):
Mr. Kenneth Copeland
Georgia Department of Transportation
Atlanta, Georgia

Ohio (Bridge WIM):
Mr. Anthony Manch
Ohio Department of Transportation
Columbus, Ohio

Maine (Bridge WIM):
Mr. John Wyman
Maine Department of Transportation
Augusta, Maine

Arizona (Golden River):
Mr. Louis Schmitt
Arizona Department of Transportation
Phoenix, Arizona

IV. Design and Operation of WIM Equipment

Design and Operation of WIM Sites

Ed Rugenstein
Office of Traffic Operations
FHWA
Washington, D.C.

Mr. Larry Symones
Kansas Department of Revenue
Topeka, Kansas

V. RTAP Demonstration

RTAP Demonstrations of Coordinated Program for Trucks Weight Studies and Size & Weight Enforcement --

Texas
Mr. Otto Wehring
State Department of Highways and
  Public Transportation
Austin, Texas

Arizona
Mr. Edward Green
Arizona Department of Transportation
Phoenix, Arizona

Wisconsin
Mr. William Gardner
Division of Planning and Budget
Madison, Wisconsin

VI. Summary of Conference

Future Advances in WIM Technology --

Dr. Arthur T. Bergan
Assistant Dean of Engineering
University of Saskatchewan
Saskatoon, Canada

Workshops

WORKSHOP A - RECOMMENDATIONS FOR IMPROVING THE FHWA TRUCK WEIGHT STUDY

Panel:

<u>Iowa</u>
(Chairperson)
Mr. Patrick Cain
Iowa Department of Transportation
Ames, Iowa

<u>Alaska</u>
Ms. Karen Morehouse
Alaska Department of Transportation
Juneau, Alaska

<u>Arkansas</u>
Mr. Paul Simms
Arkansas State Highway & Transportation Department
Little Rock, Arkansas

WORKSHOP B - USE OF WIM EQUIPMENT IN AN EFFECTIVE SIZE & WEIGHT ENFORCEMENT PROGRAM

Panel:

<u>Pennsylvania</u>
(Chairperson)
Mr. J. R. Doughty
Pennsylvania Department of Transportation
Harrisburg, Pennsylvania

<u>Alabama</u>
Mr. Paul Bowlin
Alabama Highway Department
Montgomery, Alabama

<u>Illinois</u>
Mr. Larry Shoudel
Illinois Department of Transportation
Springfield, Illinois

WORKSHOP C - COORDINATED WEIGHT MOITORING & ENFORCEMENT PROGRAM USING WIM EQUIPMENT

Panel:

<u>Nevada</u>
(Chairperson)
Mr. Donald Pray
Nevada Department of Transportation
Carson City, Nevada

Oregon
Mr. Loyd Henion
Oregon Department of Transportation
Salem, Oregon

Caltrans
Mr. Wallace Ames
California Department of Transportation
Sacramento, California

Chief E. E. Kynaston
California Highway Patrol
Sacramento, California

WORKSHOP D - USES OF WIM EQUIPMENT FOR BRIDGE LOAD HISTORIES, PAVEMENT LOADING DATA, ETC.

Panel:

Washington
(Chairperson)
Mr. Kris Gupta
Washington Department of Transportation
Tallahassee, Florida

Florida
Mr. William Lofroos
Florida Department of Transportation
Tallahassee, Florida

Kentucky
Mr. R. A. Walsburger
Kentucky Transportation Cabinet
Frankfort, Kentucky

Louisiana
Mr. Steve Bokun
Louisiana Department of Transportation
Baton Rouge, Louisiana

CONFERENCE ATTENDEES

WIM CONFERENCE ATTENDEES
Denver, Colorado
July 11-15, 1983

Aldridge, Wright B.	Federal Highway Admin.	801 Broadway	Nashville, TN 37027	615-251-5396
Ames Wallace H.	California Dept of Transp	1120 N. Street	Sacramento, CA 95814	916-445-8487
Antilley, Bob	Texas Dept Hwys& Public Tran	P.O. Box 5051	Austin, TX 78763	512-465-7437
Atchison, Harvey R.	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	303-757-9525
Balcon, John	Washington State Patrol	515 15th - KA 12	Olympia, WA 98504	206-753-6554
Balshaw, John	FHWA, Region 9,	2 Embarcadero Center Suite 530	San Francisco, CA 94111	415-556-2940
Barrett, Dean	Texas State Dept. of Hwys.		Austin, TX	512-465-7345
Barrows, William	Illinois Dept. of Transp.	2300 S. Dirksen Pkwy.	Springfield, IL 62764	217-785-2998
Barton, Tom	FHWA - Illinois	320 W. Washington	Springfield, IL 62701	217-492-4637
Batson, Don T.	Radian Corp.	P.O. Box 9948	Austin, TX 78766	512-454-4797
Beard, Ken	Oklahoma Dept of Transp.		Oklahoma City, OK	405-521-2575
Bedard, R. R.	Streeter Amet,Div of Mangood	155 Wick St.	Grayslake, IL 60030	312-223-4801
Bergan, Dr. Arthur	Univ of Sashatchewan		Saskatoon, Canada	343-3795
Beutler, A. G.	Systron Donner	2750 Systron Dr.	Concord, CA 94518	415-671-6770

Biggs, Elmer	Fed. Hwy. Adm., Region 3	1633 Fed Bldg	31 Hopkins Plaza Baltimore, MD 21201	301-962-0080
Bitz, Jim	Texas Dept of Public Safety	Box 4087	Austin, TX	512-465-2053
Blackwood, Dan	West Virginia Dept. of Hwys.	1900 Washington St.	Charleston, WV	304-348-3723
Bochenek, Dave	Maryland State Hwy Authority Bureau of Hwy Statistics	707 N. Calvert St.	Baltimore, MD 21202	301-659-1148
Bokun, Steve	Louisiana Dept of Transp	1048 Seyburn Dr.	Baton Rouge, LA	504-766-0311
Bowlin, Paul	Alabama Hwy. Dept.	11 South Union St.	Montgomery, AL 36130	205-832-5402
Brady, Charles N.	American Automobile Assoc			
Brown, Hal J.	FHWA - Washington, D.C.			202-426-1993
Brown, Larry R.	Michigan Dept. of Transp.	P.O. Box 30050	Lansing, MI 48909	513-373-2249
Cain, Patrick R.	Iowa Dept. of Transp.	800 Lincoln Way	Ames, Iowa 50010	515-239-1073
Chaney, Robert A.	Utah Dept of Transp.			
Cheatham, James A.	FHWA, Region 5, Chicago, IL	18209 Dixie Hwy.	Homewood, IL 60430	312-799-6300 x138
Childers, Allan	Georgia Dept. of Transp.	Atlanta, GA		
Chocol, Barbara	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	
Christianson, Paul J.	Wisconsin Dept. of Transp.	4802 Sheboygan Ave.	Madison, WI	608-266-8665
Conger, John E.	Colorado Dept. of Highways	4201 E. Arkansas	Denver, CO 80222	303-757-9527
Connor, Billy	Alaska Dept of Transp. PF	2301 Peger Rd.	Fairbanks, AK 99701	907-479-2241

Cooke, Michael B.	Greenhorne & O'Mara Inc			
Copeland, Ken	Georgia Dept. of Transp.	Atlanta, GA		
Cunagin, Wiley D.	Texas Transportation Insti.	500 Cherry St.	College Station, TX 77840	409-846-1915
Dahlin, Curtis	Minnesota Dept. of Transp.	John Iveland Blvd.	St. Paul, MN 55155	612-296-6846
	Transp. Bldg.			
Davies, Jeff	CMI - Dearborn Inc	Exeter Rd.	Hampton Falls, NH	603-772-9791
Davis, Bryan	Arkansas State Hwy Dept			
Davis, Ed	Texas Dept. of	11th & Brazos	Austin, TX 78701	512-475-4198
	Hwys & Public Trans.			
Davis, John H.	Colt Ind.	St. Johnsbury, UT		802-748-5111
Davisson, Sgt. Bruce	Colorado State Patrol			
DeGraftenreid, Don R.	Fed Hwy Admin - Montana			
DeSautel, Curtis L.	FHWA, Hawaii	1145 Olawalu Way	Honolulu, HI 96825	808-546-5150
Deschamp, Don	Bridge Design	Colorado Dept of Hwys	Denver, CO	303-757-9640
Dickey, David I.	Colorado Dept of Hwys.	4201 E. Arkansas Ave.	Denver, CO 80222	
Doebert, H.	Siemens-Allis			
Donnelly, Denis E.	Colorado Highway Dept.	4201 E. Arkansas	Denver, CO 80222	303-757-9506
Doughty, J. R.	Pennsylvania Dept of Trans.	Trans. Safety Bldg.	Harrisburg, PA 17120	717-787-3620
Driskill, Roger J.	FHWA - Oklahoma	Oklahoma City, OK		231-4624

Duke, Carl J.	Streeter Amet	1227 Walnut St.	Allentown, PA 18102	215-434-4371
Dummermuth, Heinz	Siemens A.G.	7500 Karlsruhe	W. Germany, Dept. E677	011-49-721-59
	Rheinbrueckenstr.50			x2762
Duncan, William T.	Utah Highway Patrol	4501 So. 2700 W.	S.L.C., Utah 84119	801-965-4235
Ebert, William G.	Minnesota Dept. of Trans.	State Trans. Bldg.	St. Paul, MN 55125	612-296-1670
Engleby, Mal	CMI-Dearborn	5353 Wilcox	Montague, MI	616-894-9051
Erickson, Ray C. Jr.	Colorado Dept of Hwys.	Staff Traffic		
Esterson, David	Golden River Corp.	3930 Knowles Ave	Kensington, MD 20895	301-942-9022
Evans, D. F. J.	Saratoga Automation Inc.	1500 N. Washington Bldg.	Saratoga, FL	813-366-8770
Figal, Joe	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	303-757-9488
Finn, Edward	FHWA - Iowa	5th and Duff	Ames, Iowa	515-233-1664
Finnell, Norm W.	Wyoming Dept. of Rev.	2200 Carey Ave.	Cheyenne WY 82002	777-7961
Ford, Robert A.	FHWA - Wash. D.C. Design	8012 Carbondale Way	Springfield, VA 22153	703-455-4877
Frank, Thomas L.	FHWA - Wisconsin	6905 Colony Dr.	Madison, WI 53717	608-833-1139
Fregger, Stephan	Florida Dept of Transp.	605 Suwannee St.	Tallahassee, FL 32301	904-488-4111
Gable, George	Bridge Weighing Systems	4423 Emery Rnd. Pkwy.	Warrensville Hts, OH	216-831-6131
Galambos, Charles F.	FHWA - Washington, D.C.	Research		703-285-2060
Gardner, William D.	Wisconsin Dept. of Transp	Room 901	Madison, WI	608-266-2961
	Hill Farms State Off Bldg			

Garrett, Spence	Wyoming Highway Department	P.O. Box 1708	Cheyenne, WY 82002-9019	307-777-7552
Gassner, Siegfriedt	PAT	Hertzstr. 32-34 D 7505	Ettlingen, W. Germany	011-49-7243-709(
Glee, Harold	Leupold & Stevens	P.O. Box 688	Beaverton, OR 97070	503-646-9171
Goble, Dr. George G.	University of Colorado	Boulder, CO		303-492-7315
Gorman, Len F.	Weighwrite Ltd	49 West Street	Farnham, Surrey ENGLAND GU97DX	0252-711011
Grauberger, Randy	Colorado Dept. of Highways	4201 E. Arkansas Ave.	Denver, CO 80222	303-757-9281
Green, Edward K.	Arizona Dept. of Transp.	1651 W. Jackson (120F)	Phoenix, AZ 85007	602-255-7893
Gregory, Bill	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	303-757-9488
Griffin, Rich	Colorado Highway Department	4201 E. Arkansas	Denver, CO 80222	303-757-9506
Gupta, Kris	Washington Dept of Transp.	Trans. Bldg.	Olympia, WA 98502	206-753-6167
Hallenbeck, Mark E.	Peat, Marwick, Mitchell & Co	1990 K St., N.W.	Washington, DC 20006	202-223-9525
Hamilton, Edward R.	Rainhart Co.	Austin, TX		452-8848
Hamrick, John L.	Idaho Dept. of Transp.	3311 State Street	Boise, Idaho	208-334-2578
Hanscom, Fred R.	Transportation Research Corp		Haymarket, VA 22069	703-754-7236
Harrington, Richard	Mortec Industries Inc.	Box 977	Brush, CO	303-842-5063
Hawley, Frank E. (Ted)	Western Highway Institute	San Francisco, CA		415-952-4900
Hay, P.	Siemens-AG	Rheinbrueckenstr.50	7500 Karlsruhe, W Germany	011-49-721-59527
Hayden, Bob	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	
Heanue, Kevin E.	Fed Hwy Admin.	U.S. Dept of Transp.	Washington, D.C.	202-426-2951

Henion, Loyd	Oregon Dept. of Transp.	ODOT Bldg.	Salem, OR 97310	503-378-4081
Henry, James D.	Oklahoma Dept of Transp.	Oklahoma City, OK		521-2927
Hickman, Robert E.	FHWA - Region 8	Denver, CO		303-234-4218
Hood, Robin F.	Utah Dept. of Trans.			
Hooks, John M.	FHWA Turner-Fairbank HRC (HRT-10)	6300 Georgetown Pike	McLean, VA 22101	703-285-2362
Huft, David L.	S Dakota Dept of Transp.	Research SD Dept Trans.	Piere, SD 57501	605-773-3871
Hutter, Werner	Colorado Dept. of Highways	4201 E. Arkansas	Denver, CO 80222	303-757-9506
Ibanez, Dr. Paul	ANCO Engineers, Inc.			
Jackson, Nawton	Washington Dept of Transp.	2714 Hibiscis et	Olympic, WN 98503	206-253-7110
Jones, G. W.	Streeter Amet	155 Wick St.	Grayslake, IL 60030	312-223-4801
Johnson, Bernard	Streeteramet	155 Wick St.	Grayslake, IL	312-223-4801
Jones, Michael G.	Electromatic Pty. Limited P.O. Box 1252	Petermariteburg 3200	South Africa	0331-53339
Juba, Frederick R.	Pennsylvania Dept. of Trans	Rm 1014B T & S Bldg	Harrisburg, PA 17120	717-787-6322
Kasinskas, Michael M.	Connecticut Dept. of Transp.	280 West Street	Rocky Hill, CT 06067	203-529-7741
Kent, Perry M.	US Dept. of Trans., FHWA	400 Seventh St., SW	Washington, DC 20590	202-426-0160
Kidy, Charles	California Highway Patrol	2555 1st Ave.	Sacramento, CA 95818	916-445-1865
King, Capt. C. E.	California Hwy Patrol			

King, Sgt. Guy	Colorado State Patrol			
Kohles, Derald S.	Nebraska Dept. of Roads	P.O. Box 94759	Lincoln, NB 68512	402-473-4519
Koucherik, Judy	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	303-757-9525
Kraemer, Douglas L.	Idaho Transportation Dept.			
Kral, Joe Jr.	Mortec Industries Inc.	Box 977	Brush, CO	303-842-5063
Kreutzer, Terry	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	303-757-9527
Krukar, Milan	Oregon Dept. of Transp.	513 Transp. Bldg.	Salem, OR 97310	503-378-4082
	Economics-Planning			
Kuhl, William N.	Maryland State Hwy Admin	2323 West Joppa Rd	Brooklandville, MD 21022	301-321-3531
Leary, Michael T.	Fed. Hwy. Administration	Box 1915	Sacramento, CA	916-440-3246
Lee, Clyde E.	The Univ. of Texas at Austin	ECJ Hall, Room 4.2	Austin, TX 78712	512-471-4379
	Dept. of Civil Engr.			
Lee, Harold	Leupold & Stevens	P. O. Box 688	Beaverton, OR 97070	503-646-9171
Legg, Jerry L.	West Virginia Dept. of Hwys.	1900 Wash, S & E	Charleston, WV 25305	304-348-2864
Lofroos, W. N.	Florida Dept. of Trans.	605 Suwanee St.	Tallahassee, FL	904-487-1700
Long, Jim B.	Federal Hwy. Administration	819 Taylor St.	Ft. Worth, TX 76102	817-334-4359
Loucks, Insp. Peter J.	Michigan State Police	300 N Clippert, Suite 10	Lansing, MI	517-337-6196
	Motor Carrier Division			
Lowe, John B.	Govt. of Alberta, Transp.	10405 Jasper Ave.	Edmonton, Alberta Canada	403-422-2750

Manch, Anthony J.	Ohio Dept. of Transp.	25 S. Front Street	Columbus, OH 43216	614-466-4224
Marshall, Ron	FHWA - N.D.	P.O. Box 1755	N. D. 58502	715-255-4011 #3
McBeth, Wilson P.	Oregon Dept. of Transp. Highway Division	Box 14030	Salem, OR 97310	503-373-1550
McElhaney, Dave	US Dept. of Trans., FHWA	400 Seventh St., SW	Washington, DC 20590	202-426-0180
Merle-Smitif, G.	Industrial System Engineers			
Miles, David	Utah Dept. of Trans.	4501 So. 2700 West	Salt Lake City, UT 84119	801-965-4324
Miller, Theodore L.	Fed Hwy Admin. - Texas	826 Fed Bldg.	Austin, TX	512-482-5917
Miskuff, Richard	Golden River Corp			
Mitchell, Maurice L.	FHWA	Denver, CO		303-234-4438
Miyazono, Kenneth M.	Hawaii Dept. of Transp.	600 Kapiolani Blvd.	Honolulu, HI 96813	808-548-3228
Moore, Robin C.	Transport & Road	Research Laboratory U.K.	Crowthorne, U.K.	0346-77-3131
Morehouse, Karen	Alaska Dept of Transp.	Pouch Z MS 2504	Juneau, AK 99811	907-364-4331
Morris, J. Weldon	Colo Port of Entry Division	140 W. 6th Ave.	Denver, CO	303-866-3734
Moses, Dr. Fred	Case Western Reserve Univ.	Cleveland, OH 44106		216-368-2922
Myers, Larry	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	303-757-9488
Neely, Gerald L.	Radian Corporation	P.O. Box 9948	Austin, TX 78766	512-454-4797
Nelson Thane I.	Okla. Dept. of Transp.	200 NE 21st St.	Oklahoma City, OK 73105	405-521-2671
Novenski, George J.	Wisconsin Dept of Transp.	4802 Sheboygan Ave.	Madison, WI 53707	

Oliver, Jeff	Golden River Co Ltd.	Bicester, Oxon, England OX67XT (U.K.)		8692-44551
	Churchill Road			
Orr, F. Donald	Radian Corp.	Austin, TX		512-454-4797
Petersen, Charles	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	303-757-9488
Phang, William A.	Ontario Ministry/Transp&Comm	Downsview, Ontario	CANADA M3M IJ8	416-248-3355
	1201 Wilson Ave.			
Phillips, Jack D.	Pennsylvania Dept of Transp	Trans. Safety Bldg.	HBG, PA	717-787-6171
Phillips, Rick	Washington State Patrol	Gen Admin Bldg AX-12	Olympia, WA 98504	206-753-4451
Picher, Gedeon G.	Maine Dept of Transp.	Station 16, State House	Augusta, ME 04364	207-289-3131
Pipan, James J.	Fed Hwy Admin. - Nebraska	100 Centennial Mall N.	Lincoln NE 68508	402-471-5521
Pondleton, John R.	Utah Highway Patrol	4501 So. 2700 W.	S.L.C., Utah 84119	801-965-4235
Potter, Donald H.	Federal Highway Admin.	708 SW 3rd Ave.	Portland, OR	503-221-2061
Pray, Don	Nevada Dept. of Transp.	1263 S. Stewart	Carson City, NV 89712	702-885-3452
Price, John	Fed Hwy Admin. - Oregon	530 Center Street NE	Salem, OR 97301	503-378-3845
Putzier, Evelyn M	S Dakota Dept of Transp.	RR2 Box 46	Blunt, SD 57522	773-3335
Quinn, Michael	Kansas Dept of Transp	State Office Bldg	Topeka, KS 66612	913-296-7452
	Bureau of Plan.			
Reagan, C. D.(Dan)	FHWA Region 1	729 O'Brien Building	Albany, NY 12207	518-472-4271
Reche, Gedion G.	Maine Dept. of Transp.	Station 16,State House	Augusta, ME	207-289-3131

Reinhardt, Morris	FHWA - Denver	Denver, Colorado		303-234-4051
Robert, Marc	Quebec Dept of Transp.	200 Dorchester, SUD 3 F	Quebec, CANADA GIK 5Z1	418-643-6808
	Service des Releves Tech			
Roth, Tom	D.C. Dept. of Transp.	613 G St. N.W. 22151	Washington, D.C. 22151	202-727-5605
Rugenstein, Ed	Fed. Hwy. Administration	400 7th St., S.W.	Washington, D.C. 20590	202-426-1993
Sakaguchi, Robert	Colorado Dept. of Highways	4201 E. Arkansas	Denver, CO 80222	303-757-9261
Sauer, Cliff	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	303-757-9261
Schmidt, James A.	Oklahoma Dept. of Transp.	200 N.E. 21st St.	Oklahoma City, OK 73105	405-521-2671
Schmidt, Robert D..	Illinois Dept of Transp.	2300 S. Park	Springfield, IL	217-782-4503
Schmitt, Louis A.	Arizona Dept of Transp.	206 S. 17th Avenue	Phoenix, AZ	602-261-7433
Schoenhard, Larry	S Dakota Dept of Transp.	Pierre, SD		605-773-3278
Sells, Jim	CO Roady Mix Concrete Assoc			
Shanteau, Robert	Purdue University	Civil Engr. Bldg.,Purdue	W Lafayette, IN 47907	317-494-2212
Shepley, J. R.	Trans-Tech Assoc.	Edgemout Br. Box 10633	Golden, CO	303-526-0869
Shoudel, Larry	Illinois Dept. of Transp.	2300 South Dirksen	Rm. 117 Springfield, IL 62563	217-782-7984
Sime, James M.	Connecticut Dept. of Transp.	280 West Street	Rocky Hill, CT 06067	203-529-7741
Simms, Paul E.	Arkansas Hwy & Transp. Dept.	Little Rock, Arkansas		501-569-2207
Skinner, Harry G.	FHWA - Washington	HTO-30	Washington, DC 20590	202-426-1993
Smith, J. M.	Industrial System Engineers			

Smith, Susan	Streeter Amet,Div of Mangood	155 Wick St.	Grayslake, IL 60030	312-223-4801
Snyder, Richard E.	Bridge Weighing Systems, Inc	4423 Emery Rnd. Pkwy.	Warrensville Hts, OH	216-831-6131
Sofokidis, H.	FHWA Region 4, Atlanta	1720 Peachtree Rd., N.W.	Atlanta, GA	404-881-4499
Speckmann, Robert	North Dakota State Hwy Dept	Bismarck, ND		701-224-4395
Stadlbauer, H.	Siemens-Allis Inc.	186 Wood Ave. South	Iselin, NJ	201-321-8826
Stein, Howard	Insurance Institute for Highway Safety	Watergate Six Hundred	Washington, DC 20037	202-333-0770
Stevens, Sgt. Edward	Colorado State Patrol	4201 East Arkansas Ave.	Denver, CO 80222	303-757-9465
Stoessel, John C.	ANCO Engineers, Inc.			
Studer, Bob	Iowa Dept of Transp.	Ames, Iowa		515-239-1306
Sullivan, David D.	FHWA - Wyoming	P.O. Box 1127	Cheyenne, WY 82001	307-772-2101
Sweitzer, Gordon A.	Iowa Motor Vehicle Div.	5268 NW 2nd Ave.	Des Moines, Iowa 50313	515-281-6465
Symonds, Larry K.	Kansas Dept. of Revenue Motor Carrier Inspec.	3rd Floor S.O.B.	Topeka, KS 66612	913-296-3316
Talmadge, Tom	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	303-757-9261
Tenney, Bob	Colorado Dept of Hwys.	4201 E. Arkansas	Denver, CO 80222	303-757-9488
Todd, Robert J.	Utah Dept. of Transp.	5232 S. Gravenstein	Murray, UT	801-965-4321
Tonies, L. A.	StreeterAmer, Div of Mangood			
Townley, K. C.	Missouri Hwy. & Transp Dept.	P.O. Box 270	Jefferson City, MO 65102	314-787-2785

Uhrich, Adam L.	Wyoming Highway Department	P.O. Box 1708	Cheyenne, WY 82002-9019	307-777-7552
Vasquez, Philip A.	Colo. Port of Entry			866-3734
Vieth, Peggy J.	FHWA - Region 7, Kansis City	P.O. Box 19715	Kansas City, MO 64141	813-926-5236
Vrohe, Michael B.	Greenhorne & O'Mara Inc.	1325 South Colorado	Suite 405 Denver, CO 80222	303-758-5250
Vruereu, Roy	Idaho Transp. Dept. POE	3311 Wistale	Boise, Idaho	208-334-2994
Walden, R. L.	FHWA - Kentucky	P.O. Box 536	Frankfort, KY 40602	502-277-7321
Walsburger, Bob	Kentucky Dept. of Highways	Frankfort, Kentucky		502-564-3730
Warnloff, O. K.	National Bureau of Standards	OWM	Washington, DC 20234	301-921-2401
Warpoole, Richard D.	Tennessee Dept. of Transp.	James K. Polk Bldg.	Nashville, TN 37219	615-741-6741
	Suite 1000			
Weeks, Michael K.	Sarasota Automation In			
Wehring, Otto	Texas State Dept. of Hwys.	P.O. Box 5051	Austin, TX 78745	512-465-7321
Wels, Kurt	Siemens-Allis	635 Montrose Ave.	South Plainfield, NJ	201-756-8660
Welter, Nic	Siemens AG, 7500 Karlsruhe	W. Germany	EMA Field Engineering	011-49-721-595
				x2339
	Borsigstreetr.3			
Whitlow, Lt. Donald L.	Ill. State Police	401 Armory Bldg.	Springfield, Ill. 62706	217-782-6267
Winder, Jack	London Dept. of Transp.	DTp, Marshamst, London		01-212-8739
Wollin, Bud	Weigh-Tronix, Inc.			

Wood, Joe	New Mexico Highway Dept.	Santa Fe, NM	Illinois State Police	505-983-0593
	Box 1149			
Workman, Charles	Delaware Dept of Transp	P.O. Box 778	Dover, Delaware	301-736-4346
Wyman, John H.	Bridge Weigh in Motion	Box 4970	Pittsfield, ME 04967	207-487-5086
	Maine Dept. of Trans.			
Young, Richard	Siemens-Allis	1 Computer Drive	Cherry Hill, NJ	609-424-9210
Zegar, John	Streeter Amet,Div of Mangood	155 Wick St.	Grayslake, IL 60030	312-223-4801

WELCOME

MR. DWIGHT BOWER
DEPUTY DIRECTOR
COLORADO DEPARTMENT OF HIGHWAYS
DENVER, COLORADO

Dwight Bower
Deputy Director
Colorado Department of Highways

On behalf of the Department of Highways and certainly the State of Colorado, I would like to welcome all of you here. It occurred to me from looking at the program that it has been well thought out. There are a number of activities that I myself would like to participate in and would like to stay for the entire conference. Unfortunately, I will not be able to. I am going to leave town as soon as I leave here. But I am certainly expecting that our people from the Department will bring back a lot of good information that we will be able to use that will be helpful to us and to other agencies in the State of Colorado in our weighing and truck activities throughout the state.

There are a number of important things that I think will come out of this conference. Certainly weighing vehicles with the limited funds we have is one of the important things that you will be looking at. The availability of these types of scales, accuracies, all of the things that I am sure you will be learning, are important to the entire industry both private and public. One of the things in the Colorado Department of Highways that we hope to be improving on is our allocation formulas as they relate to the trucking industry. I would think that with these types of devices we ought to be able to develop more information at a lower price and certainly have it more reliable. This past year we experienced the pleasant opportunity to go to the Legislature trying to get an increase in our fuel tax as well as our distribution of the burden to the trucking industry as well as the motorist. One of the things that we were hard pressed to do was to really come up with a good allocation formula of costs which are attributable to trucks.

So with all of that, I wish all of you a good session. I hope you enjoy your stay in Colorado and that you all will take advantage of the trips that have been put together as part of this conference. I want to congratulate all of you on what is obviously going to be a very successful conference.

WELCOME

MR. M. C. REINHARDT
REGINAL FEDERAL HIGHWAY ADMINISTRATOR
FHWA
REGION 8
DENVER, COLORADO

Morris Reinhardt
Regional Federal Highway Administration
Region 8
Federal Highway Administration

On behalf of the Federal Highway Administration it is a real pleasure for me to welcome you to Denver because this is the home of our regional office and one of our division offices. We do welcome you to Denver, and on behalf of the regional office, if you see anything that comes up during your stay this week that we can do to make not only the business part of your trip but also the personal situation more enjoyable, if possible we will try to accommocate you. Give us a call.

Since we are having a Weigh-in-Motion Conference I would be remiss on the part of representing the Federal Highway Administration if I didn't say a few words about the conference. We are here today primarily because of a special appropriation act by Congress in the form of a real technical assistance program that has its intent and purposes of providing assistance to state and local governments in their efforts to resolve state and local transportation problems. So financially that is why we are here.

Over and above that, I think I can safely say the Federal Highway Administration for several years and certainly today has a very strong interest in weigh-in-motion technology development and advancement and hopefully ultimate full utilization. So we see this conference as a part of a means to that end. We do have a vested interest. When you start talking about weigh-in-motion technology equipment procedures and so forth, you say, "why do you need that?" Probably all of you in your own spectrum of work environment know this better than I, it comes quick to the mind the era of data collection, also the potential for truck weight enforcement. Data collection for your overall general highway needs and what you may or may not be doing. Hopefully all of you are doing something in long term pavement monitoring. We just recently got enacted the new Highway Transportation Act of 1982 that permits longer and heavier trucks on our highways. We see all these things together and independently as possible areas where we need to look much closer.

So weigh-in-motion has a potential to give us the capability to get the data we need to make our future decisions from the standpoint of all these things I mentioned. If you read the media presentations that have come out both from the industry in some cases, but more primarily from the investigative types such as the Inspector General Office and the General Accounting Office, they have been very critical in the past of some states' weigh-in-motion program. I think that is just two examples of where FHWA sees some potential use for this conference to develop a data collection process or procedures system and help you in a hopefully more effective and efficient truck weight program, whether it be research or law enforcement. You say, "why this conference?" I don't know of a better way. We see this as a real opportunity to explore, not only what has been done, but the potentials down the road in the area of just the technology procedures and concerns and so forth. We are faced with it as a group today trying to work out some of our transportation concerns. I see a golden opportunity for you if you will participate fully to provide data information not only to this conference but to all the individuals here that they might take back home and share in their state with those people who need to be involved. We sometimes sort of get to the point of being isolationists in the little things that we do, we don't see the big picture. This is one of the areas that we are in today that it takes all kinds of disciplines, and if we are ever going to make this a successful part of our planning tools and enforcement tools in regards to the highway operations, we need the engineer, we need the traffic engineer, we need enforcement personnel, researchers, we need not only our structural but our pavement designers, we need all these people. We are trying to get a general overview of what the needs are, how we are going to solve these needs. No one is going to do this by himself. Again, that just gives another reinforcement as to why we at FHWA see a need and a very strong potential for positive results coming out of a conference of this nature. I looked at the agenda and it is very comprehensive. There is going to be a world of information exchanged. So all I can do at this point of time is say I totally endorse strong participation by each one whether you are giving a paper or receiving information. Digest what is heard and take it back home and put it to some use. I think collectively then we all can come up with a much better, more efficient method of doing some of the things we need to do in the area of total highway planning, which is the basic tool for developing implementation. Weigh-in-motion today has that potential. It has been a very important vital tool. With that, I wish you folks success in the conference. And I briefly restate, welcome to Colorado. At the Highway Administration, if our staff can be of assistance to you while you are out here, feel free to call. Have a good conference.

OVERVIEW OF TRUCK WEIGHT DATA NEEDS

MR. KEVIN HEANUE, DIRECTOR
OFFICE OF HIGHWAY PLANNING
FHWA
WASHINGTON, D.C.

OVERVIEW OF TRUCK WEIGHT DATA NEEDS

by Kevin E. Heanue

It would not have been possible 3 or 4 years ago for the Federal Highway Administration (FHWA) to have sponsored this conference. The interest was not there at the technical level or at the policy level. For many years, FHWA involvement in truck weight issues meant "loadometer" surveys and, more recently, the enforcement certification program. The "loadometer" surveys could be characterized as involving only one issue--how to get the States to continue the studies. Many defined them as surveys conducted by reluctant States under Federal mandate. We often heard that the surveys were of "no use" to the States because the results were not used within the States. When the studies were completed and the results sent to FHWA, that was the end of it. The surveys did have inherent problems such as seasonal bias (usually conducted only in summer), locational bias (limited to truck routes where there was room to get the trucks off the through-traffic lanes), and bias caused by a high probability of scale evasion.

State enforcement officials are weighing an increasing number of trucks in recent years, but because of policies and beliefs dating back to the 1930's, it is almost universally believed that you cannot mix enforcement weighing and planning survey weighing. In fact, the current Truck Weight Study Manual still contains a statement that "It is necessary to suspend enforcement during the period planning data are being collected in order to obtain unbiased data" if the highway planning data is collected in conjunction with the enforcement function. Weighing-in-motion will likely change this notion.

Where do we stand today? A revolution has occurred in recent times, particularly during the last 3 years! The influences are coming from a number of directions. For a number of years, Congress has been focusing increasing attention on truck size and weight issues. Of most importance is the visibility that has been given to the costs occasioned (i.e., damage caused) by heavy vehicles through the Federal cost allocation studies and the followup debate in the Congress.

The cost allocation study demonstrated to us that in spite of the many vehicles weighed each year, we would have liked to have obtained a lot better weight information, particularly relationships and correlations of vehicle types, load applications, and pavement conditions. That is not to say that I think our cost allocation results and recommendations are not well-founded, but perhaps we would not have had, and continue to have, so much debate on the issue of cost allocation if we had more data.

The second thing that has impacted truck weight studies is the approaching completion of the Interstate System and the well-noted pavement deterioration on many of the older sections of the Interstate. We in FHWA, and most of the States, are recognizing the need for better pavement management programs. The Congress has responded to this situation by significantly increasing funds available for 3R-type work.

- o But do we really understand what is happening to pavements?
- o Are they reaching the end of their design life and failing?
- o Are traffic volumes exceeding estimates and causing premature failure?
- o Are vehicle weights increasing faster than projected?
- o Are pavements failing prematurely due to poor design?

Experience indicates that some of these theories may be happening, but unfortunately we are weak at quantifying the contribution of the specific causes. We are now updating the AASHTO Pavement Design Guide, and unfortunately, there are too many questions and not enough answers. Judgment of experts will have to substitute for facts!

The next and final influence heightening the interest in truck weighing comes from the Congressional mandate to establish national uniformity of vehicle weight, length, and width limits. The issue on vehicle lengths seems to be the major consideration. Nationally, uniform limits will affect the practices of 38

States. As we have traveled to various States, David Oliver, a colleague and lawyer who has worked with size and weight issues for 10 years, is appalled by some States that are outraged on length issues and yet virtually ignore vehicle weights. There are no records of weight enforcement and only a minimal fine structure. In addition, many States seem almost paranoid about the operation of double trailer combinations, yet almost totally ignore the loading characteristics of the single semitrailer combination.

Let me try to quickly pull things together.

In 1981, we decided, for many of the reasons noted above, that our truck weight manual was outdated and we established a task force to decide what to do. This task force was staffed with members from different FHWA offices, including planning, design, and research, as well as representatives from field offices. In addition, the States provided numerous and extensive comments on the draft report.

In brief, the recommendations of the task force were:

1. The Truck Weight Study should be completely redesigned to: (a) establish a statistically representative network of weigh-in-motion scale sites for the collection of noninterview data on a continuing basis and (b) collect interview

data either at static scale sites every 5 years or on a case study basis.

2. To maximize the effectiveness of the first recommendation, FHWA should adopt a set of standard vehicle class definitions and promote their use by the States.

3. Legislation should be developed that would set aside special Federal-aid funds or create new funds for purchasing and installing weigh-in-motion equipment and for conducting interview type truck surveys.

4. A subset of the weigh-in-motion sites should be selected as a national continuing panel of truck data sites.

5. Improved procedures should be developed by FHWA to estimate projected traffic loadings for pavement performance studies and for the design of highway sections.

6. The Office of Highway Planning should assess truck weight study analysis procedures to reaffirm that maximum use is made of truck weight study data.

The Rural Transportation Assistance Program (RTAP), which was funded through the last two congressional highway bills, will provide additional information regarding coordinated weight monitoring for planning and enforcement. The Weighing-in-Motion Demonstration Project portion of the program will assist the efforts of eight States that have been selected for the 2-year program with some specific objectives: (a) The States will evaluate current programs and compare those separate activities to a coordinated program using weighing-in-motion; (b) They will evaluate and report on the adequacy of weigh-in-motion systems currently on the market; (c) They will test alternative monitoring and enforcement strategies; and (d) They will document the results for distribution to all of the States.

Are we - the Federal Highway Administration - endorsing weighing-in-motion?

Yes, we encourage States to initiate weigh-in-motion programs and to experiment, but mistakes will be made. We must get the bugs out, we must determine which equipment works and at what accuracy, and we must make maximum use of new technology. I am convinced that the only way to accelerate development is through trials. Accuracy will improve and cost will be reduced. Weighing-in-motion to me means weight and vehicle classification as well. A weight without a vehicle type is of limited value. If we pick up total count and speed, so much the better. I ask you to focus on this in the workshops.

Additionally, there is the relationship between pavement design and vehicle weights. My friends in the Office of Engineering are fond of saying that there is a data problem, and by implication or directly, they ask what we planners are going to do about it. But in reality, the combined current resources of planning and enforcement of truck weighing data probably would allow us sufficient data if it were all retained and correlated. What is lacking is the necessary performance relationships among design standards, materials, quality of construction and load applications. We have to work together to develop broader use of the various data bases to quantify these relationships. For example, if we had monitored pavements adjacent to permanent weighing stations and had permanent automatic traffic recorders at the same points over the last 20 years, such pavement life relationships might now exist.

In conclusion, I am convinced that the weigh-in-motion capability is the key to solving our data collection problems. Monitoring the compression or deflection of devices in or on our pavements and interpreting the responses with microcomputers will provide new approaches to planning, design, research, and enforcement. Through the use of telemetry, it can all be accomplished more efficiently. For example, in planning, regardless of the method of collection, we may be able to obtain higher quality products with fewer automated monitoring points. New theories in design are emerging, and by understanding the dynamic response to loads rather than approximating static loads it will be possible to develop the wear relationship, resulting in significant breakthroughs. As we have done with bridges, we may be able to consolidate pavement design functions into specific categories, for example, by volume and truck weight categories.

In the research area, better long-term monitoring data and dynamic response will lead to new approaches to pavement design, more emphasis on targeting 3R activities to optimize overall pavement cost. New emphasis will be directed toward vehicle suspension systems and axle configurations.

In enforcement, there may be much less emphasis on conventional weighing station operations and more emphasis in the area of weighing-in-motion. For example, for key routes in States, and even the not so key routes, the percent of overweight trucks by hour of the day may be determined. The enforcement program can better be targeted where the problems are the worst and with the same flexibility that radar now provides for speed enforcement.

Finally, do not sell this conference short. I urge you to join in the workshops and make sure that your perspective is represented and made known. In this way, the conference as a whole will be much greater than the sum of its parts.

WHY SIZE AND WEIGHT ENFORCEMENT

MR. HARRY SKINNER, CHIEF
DIVISION OF TRAFFIC ENGINEERING
FHWA
WASHINGTON, D.C.

Why Size and Weight Legislation
Harry B. Skinner
July 11, 1983

Legislation

- Federal-aid Highway Act of 1956
    - Maximum allowable weight and width on Interstate system
- Federal-aid Highway Amendments of 1974
    - Increased allowable weights on Interstate system
- Surface Transportation Assistance Act of 1982
    - Maximum allowable weights made mandatory
    - Maximum allowable widths increased and made mandatory

Regulations related to State certification of enforcement

- Until 1976: Telegramed certification
- 1976-1980: Supplemental data required
- 1980-present: Enforcement plan required
- Future: Sampling plans similar to 55 M.P.H. monitoring plan

Recent program monitoring

- General Accounting Office (GAO)
    - 1979, EXCESSIVE TRUCK WEIGHT: An Expensive Burden we Can no Longer Support
- Office of Inspector General (OIG)
    - 1981, FHWA Region 6, Fort Worth
    - 1983, FHWA Regions 1, Albany, New York and 9, San Francisco and Headquarters

-Observations

-Twenty five percent of all loaded 5 axle trucks are overweight,

-One 5 axle truck loaded to 80,000 pounds does equivalent damage to the pavement as 9,600 two thousand pound cars,

-One 20,000 pound axle does equivalent damage as 4,000 cars but, one 26,000 pound axle does equivalent damage as 12,000 cars-a 30 percent increase in productivity but, a 200 percent increase in damage,

-States spend $98,000,000 annually on enforcement and do not know if that enforcement reduces damage due to overweight,

-Overweight trucks cause $562,000,000 incremental damage to the Interstate system each year,

-Recommendations of GAO and OIG

-Extend Federal Truck Size and Weight Requirements to all Federal-aid systems,

-Eliminate all grandfather rights

-Eliminate permitting all divisible loads

-Assure that fines and penalities sufficient to deter violations

-Assure that repeat violators are sufficiently penalized

-Get answers to 2 questions:

-What is the magnitude of the National Overweight Problem?

-Is the Overweight Problem getting better or worse each year?

STATE TRUCK WEIGHT STUDIES

MR. JERRY LEGG
WEST VIRGINIA DEPARTMENT OF HIGHWAYS
CHARLESTON, WEST VIRGINIA

TRUCK WEIGHT STUDIES

Objectives and Methods From a State's Viewpoint

Submitted by Jerry L. Legg
West Virginia Department
of Highways

TRUCK WEIGHT STUDIES - OBJECTIVES AND METHODS FROM A STATE'S VIEWPOINT

Truck weight studies are conducted as part of the engineering investigations designated in Section 307 (c), Title 23 of the US Code. The study is conducted in West Virginia in accordance with the Highway Planning Program Manual, Volume 4, Chapter III and the Guide for Truck Weight Study Manual. The W.Va. Department of Highways' Statewide Planning Division conscientiously collects, processes and transmits to the Federal Highway Administration each data item as required.[1] But should states carry out truck weight studies solely to meet FHWA obligations? Recently there has been considerable resistance by states to carry on the study for this single need. What are the objectives from a state's viewpoint and what methods would most effectively accomplish these objectives?

West Virginia is primarily interested in collecting data which will be useful in developing the following:

1. Trends in vehicle (truck) characteristics such as body type, size, weight, and axle configuration.

2. Data for pavement design.

3. Information for revenue estimates, vehicle tax rate calculations (including weight/mile), etc.

4. Information for cost allocation.

5. Input into recently created pavement monitoring and management programs.

---

1 In 1982 W.Va. did not conduct weighing activities as scheduled due to financial and manpower limitations.

Currently the data is mainly used as input into items 1 and 2. However, with the prevalent highway financial situation, necessitating research of alternate revenue sources, it is seen that a greater input into revenue estimating and cost allocation is imminent. Truck weights and other characteristics obtained from the truck weight study are the primary source of these types of data at the present.

While the current truck weight study program provides sufficient data to meet the Highway Department's needs, it requires the collection of many more items than are used by the department. Such items as engine type, basis of registration, model year, operation class and registered weight are of marginal interest. Yet these items require the majority of the data collection personnel's time due to the fact that the driver of the vehicle must be interviewed to obtain them. Forthcoming revisions to the Truck Weight Study Manual may provide for optional collection of certain items as desired by the individual states. This would be a considerble improvement in West Virginia's opinion. For West Virginia's needs it would suffice to collect axle weights, vehicle type, body type and perhaps, load status (loaded or empty). This would enable analysts to calculate the necessary data to meet the Highway Department's objectives. Collecting only this information would speed up the data collection process markedly and perhaps reduce the number of data collection personnel required. The decrease in time spent on each vehicle would result in a capability to sample a greater number of vehicles during each survey period. In addition, minimizing traffic interruption could enable stations to be conducted at locations currently unsuitable for data collection.

Obviously Weigh-In-Motion (WIM) equipment would facilitate truck weight data collection tremendously. As would be the case with eliminating the collection of data items requiring driver interviews, WIM would result in increased data collection capabilities. WIM could also allow data collection on lower classification roads where a serious lack of data currently exists. In West Virginia and similar states with large mining industries a great deal of heavy truck movement, overloaded trucks in particular, occurs on secondary roads between mines and various transfer points. The nature of these roads (narrow pavement, minimal shoulders and poor geometrics) is incongruent to weighing using static equipment. Enforcement weighing of very brief periods is carried out, but weighing for extended periods for data collection purposes is impractical, if not impossible. Even if static equipment could be used, overweight vehicles simply avoid weighing operations or, if sites cannot be avoided, simply cease operations. This situation has decreased somewhat for data collection, not enforcement, weighing activities with the advent of the Citizen's Band radio. Once it is determined that no enforcement is taking place, the truck drivers inform one another via the CB and "normal" movement resumes. However, it is felt that many overloaded vehicles still cautiously avoid any type weighting operations. WIM equipment, particularly if no interruption of traffic flow occurred, could eliminate, or subdue, the truckers' awareness that weighing was being done. This would result in more complete data and increases statistical reliability with respect to representing true truck weights.

Presently W.Va. collects data at seventeen sites. These sites for the most part were hand selected at the time the Truck Weight Study originated. A few stations have been replaced with sites located on the completed Interstate system. Given the constantly changing traffic flow pattern and development along highways, it is almost a certainty that the current locations are not a statistically representative sampling of the state's truck travel and weights. A restructuring of the study based on mileage or truck travel by highway functional classification would give a much more complete base from which to sample data. Perhaps a restructuring based on a statistical design similar to the 55 mile per hour speed monitoring program would be adequate. Statistically sound samples could be obtained for all functional classes; including all urban classes and lower class rural routes which are not being adequately sampled at the present.

An alternate to possibly eliminating some existing stations through statistical realignment might be to simply add more stations located so as to "fill-in" the gaps. The added expense may be prohibitive but this might be more evenly distributed by conducting portions of the stations each year rather than conducting all stations on the same biennial cycle. Or, research may reveal that a greater cycle than two years could be utilized with little, or no loss in data precision. If this latter procedure could be implemented no additional costs would be involved if stations could be sampled at four year intervals. This way the same number of stations presently surveyed could be sampled every two years with a doubling of the total number of stations' data in each four year cycle.

In line with the possible relocation or expansion of stations, it is also contemplated that a variation of the hours of the day sampled might be beneficial. Currently weighing operation takes place for either eight or sixteen hours during the periods 6 AM - 2 PM and 2 PM - 10 PM. No comparison of truck weights occurring during non-survey hours with data collected during the survey has been made due to the added expense of collecting more information, the added safety hazards of night weighing to Department personnel and motorists, and the hesitance to suggest changes in the FHWA's program. Perhaps some spot checks of non-standard survey hours could indicate whether any advantage could be realized by varying data collection hours. Similar spot checks might indicate a day-of-the-week variation exists and similarly, seasonal variation as well. Weekend surveying might give very different data than weekday. Comparable variation might be found in seasonal data. Obviously weighing activities would be restricted during periods of bad weather but the fall and spring months could be sampled effectively.

Obvious difficulties lie in making any of the aforementioned modifications to the existing survey methods, schedules or equipment. The most beneficial change would be the conversion to WIM equipment. Unfortunately the expense is currently prohibitive. Some research has been conducted into utilizing portable WIM equipment. However, portable WIM equipment sacrifices many of the advantages gained. The presence of weighing activity cannot be concealed, traffic interruption is magnified, and personnel needs may be increased.

Altering weighing schedules for different months, day-of-the-week, or hours of survey could create problems such as: greater chance for interruption of activities due to inclement weather if non-summer months were surveyed, increased traffic flow delays if weekend weighing activities occurred on recreational or other heavily traveled routes, increased safety hazards and additional personnel management requirements during nighttime surveys, etc.

In an attempt to circumvent some of our data need shortcomings West Virginia is attempting to develop a "truck weight profile" to enable the Departments' traffic analysts to analyze truck characteristics on routes having little or no weight survey data. This "profile" will be an endeavor to statistically correlate truck types and body styles with axle weights. This will allow the analyst to estimate axle loadings for pavement design, etc. on routes where only vehicle classification data is obtainable. Hopefully these correlations will prove reliable enough to allow such profiles to be developed. Such an analytical tool would be extremely useful until such time as the financial situation recovers sufficiently to allow the conversion to WIM equipment, or the advancements in WIM technology create more economical equipment.

In summary, West Virginia feels that the current FHWA's Truck Weight Study could be improved by:

1. Reducing the number of data items collected; particularly those requiring driver interviewing.

2. Statistically realigning the study to provide more complete data coverage for all highway systems.

3. Possibly introducing variations in hours, days-of-week, and seasons of the year for data collection.

4. Converting to WIM equipment to increase volume and reliability of study data.

It is felt that if truck weight study data is absolutely needed by all states, or by the FHWA for all states, that these modifications could be implemented to varying degrees by most states and would result in improved data collection efforts.

STATE SIZE AND WEIGHT ENFORCEMENT

MR. ALLAN CHILDERS
DIRECTOR OF OPERATIONS
GEORGIA DEPARTMENT OF TRANSPORTATION
ATLANTA, GEORGIA

OVERVIEW OF GEORGIA'S

SIZE AND WEIGHT ENFORCEMENT PROGRAM

In 1956 when the interstate system was born, Georgia's weight laws were very simple - 73,280 pounds gross and 18,000 pounds plus a 13% tolerance on each individual axle, or in other words, 20,340 pounds per axle or 73,280 pounds gross.

This remained basically the same up until 1975, when many states increased their gross weights to 80,000 pounds, but implemented, at least in theory, the "Bridge Formula". At this time, Georgia included the "Bridge Formula", which was required by the Federal Highway Administration, only for vehicles weighing between 73,280 and 80,000 pounds. Even after this, Georgia was like many or most other states, and did not completely enforce the "Bridge Formula", even for the vehicles weighing between 73,280 and 80,000 pounds. Until recently, we enforced only the exterior axle gross weights in accordance with the "Bridge Formula", and not the inner axle groupings.

After much urging from the Federal Highway Administration, during this past legislative session - the first of 1983, Georgia changed the laws to be in accordance with the new weight laws passed by the Federal government this past December and January. Our new law does not differentiate between the interstate system and state highway and local road systems, with respect to the "Bridge Formula". We are presently enforcing the "Bridge Formula" completely on the interstate system. The mining industry in Georgia obtained an injunction through the courts to stop us from enforcement of the "Bridge Formula" on routes other than the interstate. During this past week, however, the judge lifted the temporary restraining order and we are beginning today, July 11, 1983, to enforce the "Bridge Formula" on all routes throughout the state of Georgia. The Federal government allowed Georgia to grandfather our 40,680 pound tandem weight for vehicles weighing less than 73,280 pounds. However, the 34,000 pound tandem weight applies for vehicles above 73,280. The "Bridge Formula" applies in all instances.

In Georgia, we were allowed to permit vehicles weighing less than 73,280 pounds, to be exempt from the "Bridge Formula" for a three or five year period, providing they were registered with our Department of Revenue prior to April 1, 1983. I understand many or most other states were allowed this same exemption. This was one concession which helped to pass our new law in Georgia during our past legislative session. This allows those vehicles that were in use as of April 1, 1983, to be depreciated out over the next three to five years.

Georgia's height law is 13 feet 6 inches, as is most states, and our widths on the interstate are in accordance with the new Federal law, a maximum of 102 inches. Our state law on routes other than interstates and designated routes, which are very limited in Georgia, remains at 96 inches. Twin trailers and the 102 inch widths are allowed, primarily, on our interstate system, only as of today. Forty-eight foot semi-trailers are allowed on all routes in Georgia.

Vehicles that are <u>overdimension</u> are cited for <u>criminal violations</u> and the citations are processed through the local courts. As I am sure you are well aware, the fines vary considerably for these types of violations because the local courts set the fines.

Vehicles that are <u>overweight</u> are guilty of a <u>civil violation</u> and are issued an overweight assessment. The amount of the assessment is based on a specific amount per pound overweight, which varies from .8¢ per pound to as much as 5¢ per pound. Individuals receiving an overweight citation are required to off-load any excess weight of more than 6,000 pounds. This off-loading does not reduce the amount of the assessment, which often exceeds $1,000. The violator must pay the assessment within fifteen days, or he may apply for a hearing within this time frame. Failure to pay or request a hearing within the fifteen days causes an automatic lien on the vehicle and a tag suspension.

I think the reasons for weight and dimension limitations are very obvious. For instance, if you consider an 18,000 pound single axle equivalent load factor for pavement damage, considering 18,000 pounds as 1.0, an increase of 2,340 pounds or up to 20,340 pounds will increase the equivalent load factor, from the standpoint of road damage, by 69%. If a vehicle is hauling 23,000 pounds on an axle, then the factor would increase by 189%. This would be for a pavement section with a servicability index of 2.0 and a structural number of 3.0. The net result would be that the pavement, if it was designed, for instance, for a ten year life with 20,340 pounds single axle weight and you went to 23,000 pounds, the service life, in lieu of ten years,would be reduced to approximately six and one-half years. Considering tandem weights and, again based on 18,000 pound single axle equivalent load factors, a 34,000 pound tandem would be only an 8% increase over what an 18,000 pound single axle equivalent load would be. If you go to the 40,680 pound tandem loading, which is what our law is, this would be increased to 132% over the 18,000 pound equivalent load factor. If you went then to a 46,000 pound tandem the equivalent factor would be increased by 292%.

Again, going from a ten year design, based on 34,000 pounds, to a 40,680 pound tandem limit, the service life would be reduced from ten years to approximately five and one-half years. As we all know, bridges are designed for carrying certain loads and if they are overstressed it certainly is going to reduce the life of the structure.

From a safety standpoint, it is very obvious that the wider a vehicle is the more chance you have of having a collision with either another vehicle or an obstacle along the side of the roadway, particularly on state and local routes. The interstate system is not nearly so critical. Our interstate systems in this country are certainly designed to better handle all types of traffic than our other highway systems such as the state routes and local roads. I think our safety statistics bear this out. In Georgia, based on our 1980 accident data, tractor-trailer type trucks are at least ten times more safe on the interstates than on other state routes and local roads, and fatality rates involving trucks are only approximately 10% as high on the interstate systems as on other roads. In comparison with all vehicles, including trucks, accident and fatality rates on other routes versus the interstate system are only about four times as great. To me this means that large trucks should be limited as much as practical to the interstate systems and certainly movements of those vehicles that are overwidth and overlength should be carefully controlled if at all possible.

The responsibility of monitoring the weights and dimensions in Georgia rests with our Permit and Enforcement Office. All of our officers are D.O.T. personnel. We consider this as a plus, since these officers are under the control of the Department of Transportation and devote full-time to our enforcement program; unlike many states whose officers perform, not only this function, but have many other functions as well. We have a Chief of our Permit and Enforcement functions, who is in the room here, as I pointed out earlier. We have seven Districts which are each comprised of a captain and other officers, to monitor the program. We have a total of 206 certified police officers in our overall program.

We have 41 two-man patrolling teams who operate from station wagons, each of which are equipped with six MD 500 scales and measuring devices. Each vehicle is equipped with a two-way radio on the State Patrol frequency, as well as, an additional two-way radio that is on our Maintenance frequency.

This assures us of rapid contact with our teams, and allows for close coordination between our D.O.T. personnel who spot problems, and our enforcement officers. All of our officers are certified Peace Officers who have attended the Mandate Schools as required of all police officers. Each of these patrolling teams covers from three to five counties. In Georgia, we have a total of 159 counties. Each team operates five days a week, eight hours a day. However, the days and hours are staggered as necessary.

At the present time, we have 11 permanent weigh stations along our interstate system, most of which are reasonably close to the state lines. We will have two more of these stations to come on line within the next month. Each station is operated with two officers per shift and are generally open seven days a week, 24 hours a day. Studies indicate that this is necessary because violators are moving at all hours of the day and night.

At our permanent weigh stations along the interstate system, there is sufficient space on the grounds, as well as, in the building to accommodate other agencies such as the Public Service Commission, both federal and state safety inspectors and other enforcement units which may need to check trucks. Each station is equipped with three platform scales which are 2 feet by 11 feet, for weighing separate axles statically. Each station also has a weigh-in-motion system for sorting purposes. Georgia was the first state to utilize weigh-in-motion for sorting, having installed a system in Monroe County, Georgia in 1978. Our plans are to have a total of 18 of these stations in operation within the next three years.

As you can imagine I am sure, there is a problem of trucks bypassing these permanent scales by using other routes. We have addressed this by assigning a one-man patrol to each pair of stations to monitor likely bypass routes and require suspected violators to return to the permanent stations for weighing.

In addition to our 11 permanent weigh stations on the interstate system and our roving patrol teams, we have what we call a semi-portable scale that is also used by a number of teams. These particular scales are Lodec, split wheel weighers capable of weighing three axles at one time. We have nine of these scales that are transported by vans to prepared locations. We have prepared 22 locations along the interstate system in areas where we do not have permanent stations. In addition, we have more than 50 prepared locations on other routes for use with these scales, and are still preparing additional locations. Five of these scales are surface-type and four are transported and placed in prepared pits. We have an additional seven of these surface-type scales, one assigned to each of our Districts, which can be transported by a roving team to any location which is determined to be a problem area with a relatively high traffic volume.

Within the past several months we have trained a number of our personnel to handle the maintenance problems with our scales. We presently have two men equipped with mobile units and the necessary equipment and tools to maintain scales. To aid them in this work we are utilizing the Agriculture

Department's weigh truck, as well as our own D.O.T. weigh truck, assigned to the Department of Transportation's Laboratory, in order to calibrate our pit scales.

We have found that overweight vehicles operate 24 hours a day, seven days a week throughout our highway system, which consists of 1,171 miles of interstate highways; 16,937 miles of state highways and 86,684 miles of local roads, for a total of 104,792 miles. To assist with enforcement on all roads we have, within the past several months, issued portable scales to 28 of our 159 counties, for use by the county police or sheriffs offices. We issued each of these counties four of our portable wheel weighers. This method has helped our program and caused the counties to become more involved. As an incentive, the counties receive 50% of all overweight assessments within their respective counties, except for violations written on the interstate system. In which case, the D.O.T. retains 100% of the assessment.

During the past ten years we feel that we have made considerable progress with our enforcement program. At that time we had a total of 16 portable teams working statewide and were weighing approximately 250,000 vehicles per year. At the present time we are weighing approximately four and one-half million vehicles per year. We are looking forward to the time in Georgia when we can make overweight citations based on in-motion scale weights, which, of course, we could do much faster, thus allowing us to weigh many more vehicles than we do at this time. However, to my knowledge there is not on the market at this time a weigh-in-motion scale that is considered accurate enough at high speeds from which the courts would accept the weights for enforcement purposes. We hope to learn something this week that will assist us in this area.

STATE COMBINED SIZE AND WEIGHT ENFORCEMENT PROGRAM

MR. SPENCE GARRET AND MR. ADAM UHRICH
WYOMING HIGHWAY DEPARTMENT
CHEYENNE, WYOMING

COMBINED TRUCK WEIGHT STUDY

AND SIZE AND WEIGHT

ENFORCEMENT PROGRAM

PRESENTED AT

THE NATIONAL WEIGH IN MOTION CONFERENCE
JULY 11-15, 1983
DENVER, COLORADO

GOOD AFTERNOON, I HAVE BEEN ASKED TO ADDRESS THE TOPIC OF WYOMING'S COMBINED TRUCK WEIGHT STUDY AND SIZE AND WEIGHT ENFORCEMENT PROGRAM.

TO MY KNOWLEDGE, WYOMING IS THE ONLY STATE WHICH PRESENTLY OPERATES A COMBINED DESIGN/ENFORCEMENT TRUCK WEIGHING PROGRAM.

OUR PROGRAM EVOLVED AND WAS GIVEN ADDITIONAL IMPETUS WHEN THE FHWA THOUGHT WYOMING WAS NOT WEIGHING ENOUGH TRUCKS FOR ENFORCEMENT.

I FEEL THAT A BRIEF HISTORY OF OUR WEIGHING EFFORTS IS IN ORDER. IN THE MID 1930's THE HIGHWAY DEPARTMENT, USING PORTABLE SCALES, BEGAN WEIGHING TRUCKS FOR PLANNING PURPOSES. THE WEIGHING WAS COORDINATED WITH POLICIES ESTABLISHED BY THE FEDERAL GOVERNMENT.

WE UTILIZED THE BLACK & DECKER "LOADOMETER" PORTABLE SCALES UNTIL 1978 AT WHICH TIME WE PURCHASED A SET OF SEMI-PORTABLE SCALES. THE SEMI-PORTABLE SCALES, FOR ACCURACY, ARE MUCH BETTER THAN THE OLD "BATHROOM SCALE." PRIOR TO 1978 THE PATROLS WEIGHING EFFORTS WERE MAINLY CONCENTRATED AT THE PORTS-OF-ENTRY AND OTHER FIXED

TYPE FACILITIES. SOME WORK BY THE PATROL WITH PORTABLE SCALES WAS ATTEMPTED BUT MET WITH LIMITED SUCCESS. THE SUCCESS RATE WAS MINIMAL BECAUSE OF THE INACCURACY OF THE SCALES AND THE WEIGHTS WOULD NOT HOLD UP IN COURTS-OF-LAW.

OUR STATE, FOR YEARS, HAS MAINTAINED NUMEROUS PORT-OF-ENTRY STATIONS AND PERMANENT SCALES FOR THE PURPOSES OF REGULATING TRUCK TRAFFIC AND ENFORCING LAWS MANDATED BY LEGISLATION. THROUGH THE USE OF OUR SEMI-PORTABLE SCALES THE PLANNING BRANCH ALSO HAS BIENNIALLY CONDUCTED A TRUCK WEIGHT STUDY AT VARIOUS SITES TO SUPPLY NEEDED ROAD USE/DESIGN INFORMATION AND TO SATISFY THE REQUIREMENT OF THE FEDERAL TRUCK WEIGHT STUDY. SEVERAL YEARS AGO WE SUSPECTED THAT VARIOUS INTRASTATE TRUCKING OPERATIONS WERE GOING UNCHECKED DUE TO THE LACK OF CONVENIENT WEIGHING LOCATIONS. THEREFORE, WE ESTABLISHED AS OUR GOAL THE DEVELOPMENT OF A PROGRAM THAT WOULD PROVIDE FOR A SET OF SEMI-PORTABLE SCALES TO BE SET UP AT RANDOM LOCATIONS THROUGHOUT THE STATE. THE PURPOSE OF THIS ROVING SCALE PROGRAM WOULD BE TWOFOLD: FIRST, TO PROVIDE DATA ON ROAD USE AND VEHICULAR CHARACTERISTICS, SUCH AS LENGTH, WIDTH, AND KIP FACTOR,

FOR DESIGN PURPOSES, AND SECONDLY, FOR TRUCK WEIGHT LIMIT ENFORCEMENT PURPOSES. ABOUT THE TIME OUR PLANS FOR THE DEVELOPMENT OF A SEMI-PORTABLE SCALE PROGRAM BEGAN TO SOLIDIFY, ANOTHER EVENT TRANSPIRED WHICH INTRODUCED SOME COMPLICATIONS FOR US. IN OCTOBER OF 1979, THE FEDERAL HIGHWAY ADMINISTRATION NOTIFIED THE STATE THAT A SIGNIFICANT PORTION OF OUR FEDERAL HIGHWAY ALLOCATIONS WOULD BE WITHHELD UNLESS WE COMPLIED WITH A MORE COMPREHENSIVE TRUCK WEIGHT LIMIT ENFORCEMENT PROGRAM. WE WERE GIVEN 60 DAYS TO SHOW CAUSE WHY THE SANCTION, WHICH AMOUNTED TO 10% OF ALL THE STATE'S FEDERAL HIGHWAY FUNDING, SHOULD NOT BE IMPOSED.

DURING THE 60 DAY PERIOD A MEETING WAS HELD IN WASHINGTON D.C. BETWEEN OFFICIALS OF THE FEDERAL HIGHWAY ADMINISTRATION AND THE STATE HIGHWAY DEPARTMENT. AN AGREEMENT WAS REACHED IN RESOLVING THE IMPOSED SANCTION. THE AGREEMENT INCLUDED A PROPOSAL TO SUPPLEMENT THE STAFF OF THE HIGHWAY PATROL MOTOR CARRIER DIVISION WITH ADDITIONAL OFFICERS AND TO IMPLEMENT TWO SETS OF SEMI-PORTABLE SCALES IN CONTINUOUS OPERATION THROUGHOUT THE STATE.

THIS BRINGS US UP TO WHERE WE INITIATED THE COMBINED PROGRAM INVOLVING THE PLANNING BRANCH AND THE HIGHWAY PATROL. SINCE THE PLANNING BRANCH HAD SEVERAL YEARS OF EXPERIENCE UTILIZING PORTABLE AND SEMI-PORTABLE SCALES, THE SUPERINTENDENT AND CHIEF ENGINEER SUGGESTED THAT THE PATROL AND PLANNING COMBINE THEIR EFFORTS AND TO DEVELOP A PILOT PROGRAM. UNDER THE TERMS OF THE PILOT PROGRAM, PLANNING WOULD OPERATE THE SEMI-PORTABLE SCALES AND THE PATROL WOULD ENFORCE WEIGHT VIOLATIONS FOUND WITH THE USE OF THE SCALES. THE PILOT PROGRAM WAS INITIATED IN MARCH OF 1980, AND MET WITH VARIOUS DEGREES OF SUCCESS. THE PROGRAM WAS DETERMINED TO BE EFFECTIVE AND WE WERE INSTRUCTED TO CONTINUE THE PROGRAM INDEFINITELY. THE BIGGEST PROBLEM WE CONFRONTED DURING THE INITIAL PHASES OF THE PROGRAM WAS SCALE CERTIFICATION. SCALE CERTIFICATION IS CONDUCTED BY THE STATE DEPARTMENT OF AGRICULTURE. WE FOUND THAT TO HAVE THE INTEGRITY OF A PROGRAM WHICH WAS DEFENDABLE IN A COURT, THAT CERTIFICATION WAS IMPERATIVE. AFTER A COUPLE OF YEARS OF STRUGGLING TO OBTAIN CERTIFICATION WE FINALLY MET WITH SUCCESS. IN SEPTEMBER OF 1982 THE SCALES WERE CERTIFIED. ONE ITEM

CONTINGENT FOR SCALE CERTIFICATION WAS THAT WE HAVE APPROXIMATELY 24 FEET OF APPROACH PLATFORMS, 12 FEET FORE AND 12 FEET AFT OF THE SCALES. THE APPROACHES HAVE BEEN A SLIGHT PROBLEM IN SETTING THE SCALES UP AND DISASSEMBLING THEM, HOWEVER, THEY ARE MANAGEABLE.

WE HAVE EXPERIENCED A VERY AMIABLE WORKING RELATIONSHIP BETWEEN THE PLANNING AND PATROL PERSONNEL. THIS, POSSIBLY, COULD BE ATTRIBUTED SOMEWHAT TO THE FACT THAT BOTH THE PATROL AND PLANNING REPORT TO ONE ADMINSTRATOR, THE SUPERINTENDENT AND CHIEF ENGINEER.

PLANNING, UTILIZING THE TRADITIONAL FEDERAL TRUCK WEIGHT STUDY WOULD USUALLY WEIGH APPROXIMATELY 1,000 TRUCKS EVERY TWO YEARS. THIS TRUCK WEIGHT DATA WAS USED TO DETERMINE THE HIGHWAY LOADINGS FOR DESIGN. WE REALIZED THAT THE INFORMATION FROM THE BIENNIAL TRUCK WEIGHING AT BEST WAS INADEQUATE BECAUSE OF THE SMALL SAMPLE SIZE. CONSEQUENTLY, WE KNEW SOMETHING HAD TO BE DONE TO OBTAIN MORE REPRESENTATIVE INFORMATION. THE PATROL'S WEIGHING EFFORTS APPARENTLY WERE CONSIDERED INSUFFICIENT BY THE FHWA BECAUSE OF THE IMPOSED SANCTION.

THE PROGRAM AS WE ARE PRESENTLY OPERATING HAS BEEN VERY BENEFICIAL TO BOTH GROUPS. WHEN I BECAME UNIT SUPERVISOR IN 1977 WE WERE USING AN 18 KIP EQUIVALENT FACTOR, FOR FLEXIBLE PAVEMENT, OF 706.36 FOR A 3S2. THIS FACTOR WAS A STATEWIDE FACTOR AND WAS TAKEN FROM THE 1975 TRUCK WEIGHT STUDY. SINCE WE STARTED OUR COMBINED DESIGN/-ENFORCEMENT WEIGHING EFFORT THE FACTOR HAS RISEN TO 1,311.54. IN MY OPINION THE INCREASE IN THE MAGNITUDE OF THIS FACTOR HAS ARISEN MAINLY FROM THE LARGER SAMPLE SIZE AND THE ELIMINATION OF THE "BATHROOM SCALES." AT THIS POINT I WOULD LIKE TO STATE THAT WE DO NOT USE SELECTIVE WEIGHING AS WE WEIGH ALL TRUCKS WHETHER EMPTY OR LOADED. WE ALSO WEIGH BOTH DIRECTIONS ON TWO LANES, AND WE ALTERNATE DIRECTIONS ON 4-LANE FACILITIES.

WE HAVE FOUND THAT KIP EQUIVALENT FACTORS FOR ONE OF OUR WEIGHING SITES VARY FOR DIFFERENT PERIODS OF THE DAY. THE FACTORS ARE SHOWN ON THE ATTACHED TABLES. EACH TABLE REPRESENTS 72 HOURS OF CONTIN-UOUS WEIGHING AND THE FACTORS ARE COMPUTED FOR EACH PERIOD OF THE DAY AND ARE SHOWN BY DIRECTION OF TRAVEL. EACH TABLE REPRESENTS

A DIFFERENT YEAR, ONE TABLE IS FOR AUGUST, 1982 AND THE OTHER IS FOR MAY, 1983.

ONE SPECIFIC QUESTION ASKED OF OUR WEIGHING PROGRAM IS THERE A DUPLICATION OF WEIGHING. THE ANSWER IS "NO" BECAUSE WE ARE THE ONLY GROUP WITHIN THE STATE USING SEMI-PORTABLE SCALES. ALL SCHEDULING OF LOCATIONS IS COORDINATED BETWEEN THE PATROL MOTOR CARRIER SUPERVISOR AND THE TRAFFIC UNIT SUPERVISOR. IF SPECIAL AREAS NEED TO BE WEIGHED A PATROLMAN ASSIGNED TO THE MOTOR CARRIER DIVISION, OF WHICH THERE ARE 16 ASSIGNED TO 13 DIFFERENT TOWNS, WILL SELECT A SITE WHERE WEIGHING CAN BE ACCOMPLISHED IN THEIR RESPECTIVE AREAS.

THE ADVANTAGES OF THE COMBINED PROGRAM FAR OUTWEIGH THE DISADVANTAGES. HAVING THE PATROL WITH PLANNING HAS ELIMINATED THE TRUCKS FROM RUNNING OUR WEIGHING SITES. WITHOUT THE PATROL, MANY TRUCKS WOULD REFUSE TO BE WEIGHED, THEREFORE, THE 18 KIP EQUIVALENT FACTORS WOULD SUFFER. AN ADVANTAGE FOR THE PATROL IS THAT THEY HAVE A <u>CAPTIVE</u> AUDIENCE AND CAN SIMULTANEOUSLY CHECK TRUCKS FOR VARIOUS

ITEMS E.G., LOG BOOKS, SAFETY VIOLATIONS, REGISTRATIONS, ROUTINGS, AS WELL AS OVERWEIGHTS. ONE EFFECT THAT IS IMMEASURABLE FROM THE PROGRAM IS THE NUMBER OF TRUCKING COMPANIES THAT BRING THEIR PAPER WORK UP TO DATE BECAUSE THE SCALES ARE BEING OPERATED IN THEIR AREA. WE HAVE BEEN TOLD BY VARIOUS REVENUE AND HIGHWAY DEPARTMENT CLERKS THAT THEY CAN TELL WHEN THE SCALES ARE BEING OPERATED NEAR THEIR TOWNS AS THEIR WORK LOAD INCREASES DUE TO TRUCK COMPANIES OBTAINING PERMITS, ETC.

IN 1982 THE PATROL CITED APPROXIMATELY 4% OF THE TRUCKS WEIGHED FOR OVERWEIGHTS. ANOTHER 3% OF THE TRUCKERS RECEIVED WARNINGS FOR OVERWEIGHTS, WHICH IN EFFECT CONSTITUTES APPROXIMATELY 7% OF THE TRUCKS AS VIOLATORS OF THE WEIGHT LAWS. OTHER VIOLATIONS AMOUNT TO 7% CITATIONS, THEREFORE, THE PROGRAM IS RESPONSIBLE FOR APPROXIMATELY 14% OF THE TRUCKS BEING WEIGHED HAVING A VIOLATION OF SOME TYPE.

I BELIEVE THE SINGLE MOST IMPORTANT ITEM IN A COOPERATIVE PROGRAM SUCH AS THIS IS THAT THERE IS ONE ADMINISTRATOR IN OVERALL CHARGE THUS ELIMINATING ANY SORT OF DUPLICATED EFFORTS.

I WOULD LIKE TO THANK YOU FOR YOUR TIME AND IF YOU HAVE ANY QUESTIONS I WILL BE GLAD TO TRY TO ANSWER THEM. IF THERE ARE NO QUESTIONS, AGAIN THANK YOU.

18 KIP EQUIVALENT FACTORS BY PERIODS OF THE DAY

US 20 & WYO 789 SOUTH OF THERMOPOLIS

3S2

DATE	DIRECTION	12 AM - 8 AM	8 AM - 4 PM	4 PM - 12 AM	DIRECTIONAL DAILY AVERAGE	DAILY AVERAGE
August 31, 1982	NB		(32) 763.56	(24) 884.83	(56) 815.53	(184)
Tuesday	SB		(67) 1,296.60	(61) 1,506.82	(128) 1,396.78	1,219.88
September 1, 1982	NB	(26) 645.08	(44) 1,038.30	(16) 637.31	(86) 844.82	(252)
Wednesday	SB	(40) 1,600.95	(59) 1,175.27	(67) 1,362.87	(166) 1,353.56	1,179.94
September 2, 1982	NB	(18) 882.83	(53) 714.85	(21) 640.57	(92) 730.76	(233)
Thursday	SB	(22) 1,285.64	(51) 1,174.61	(68) 1,510.16	(141) 1,353.76	1,107.77
September 3, 1982	NB	(29) 377.03			(29) 377.03	(48)
Friday	SB	(19) 1,695.11			(19) 1,695.11	898.77
TOTAL	**NB**	**(73) 597.22**	**(129) 837.26**	**(61) 735.82**	**(263) 747.11**	**(717)**
	SB	**(81) 1,537.40**	**(177) 1,221.01**	**(196) 1,458.77**	**(454) 1,380.10**	**1,147.92**
AVERAGE	**BOTH DIRECTIONS**	**(154) 1,091.73**	**(306) 1,059.23**	**(257) 1,287.18**	**(717) 1,147.92**	

EXAMPLE: **# Trucks (27)**
Factor 1,200.00

18 KIP EQUIVALENT FACTORS BY PERIODS OF THE DAY

US 20 & WYO 789 SOUTH OF THERMOPOLIS

3S2

DATE	DIRECTION	12 AM - 8 AM	8 AM - 4 PM	4 PM - 12 AM	DIRECTIONAL DAILY AVERAGE	DAILY AVERAGE
May 24, 1983	NB		(39) 963.74	(25) 603.92	(64) 823.19	(172)
Tuesday	SB		(55) 1,453.82	(53) 1,769.75	(108) 1,608.86	1,316.55
May 25, 1983	NB	(23) 871.22	(48) 740.94	(40) 867.98	(111) 813.72	(234)
Wednesday	SB	(18) 1,336.11	(60) 1,291.07	(45) 1,613.31	(123) 1,415.55	1,130.07
May 26, 1983	NB	(27) 830.00	(56) 739.75	(32) 728.78	(115) 757.89	(228)
Thursday	SB	(27) 1,225.00	(58) 1,592.81	(28) 1,377.36	(113) 1,451.54	1,101.67
May 27, 1983	NB	(17) 937.59			(17) 937.59	(29)
Friday	SB	(12) 1,467.33			(12) 1,467.33	1,156.79
TOTAL	**NB**	**(67) 871.45**	**(143) 801.24**	**(97) 754.00**	**(307) 801.64**	**(663)**
	SB	**(57) 1,311.10**	**(173) 1,443.97**	**(126) 1,626.68**	**(356) 1,487.36**	**1,169.84**
AVERAGE	**BOTH DIRECTIONS**	**(124) 1,073.55**	**(316) 1,153.11**	**(223) 1,247.08**	**(663) 1,169.84**	

EXAMPLE: **# Trucks (27)**
Factor 1,200.00

ROBIN MOORE
TRRL
MINISTRY OF TRANSPORT
UNITED KINGDOM

Robin Moore

TRRL

Ministry of Transport

United Kingdom

It is a real honor and privilege for me to be invited to be here this evening. I really welcome the opportunity.

One might ask us what is an Englishman doing here tonight talking to you at your National Weigh-In-Motion Conference? I think that is a pretty good question. I wish I had a good answer. I've got an answer, but perhaps not too good of one. However, following my visit to your country last year the FHWA and our host here tonight, the Colorado Department of Highways were kind, or perhaps foolish enough to ask me to come along and talk.

First of all, I think we should deal with the 5Ws. You don't know what those are? I was told by my boss many years ago that if he didn't find the 5Ws in the first paragraph of any of the reports that I might read he would just throw it in the trash can. Over the years I found that was pretty sound advise. Because the 5Ws are the key things, who, why, when, where and what. I think if you know that you know most of what is going on.

So let's start with the first W. I am a principle scientist attached to the Department of Transport, working for the Transport and Road Laboratory in the United Kingdom. My research interests are automatic vehicle classification systems (AVCS), and weigh-in-motion, the WIM systems.

The second W, why. I hope that current policy of WIM systems in U.K. in Europe and the technology employed will be of interest to all the delegates here tonight. I very much hope we can produce a useful information exchange between the U.S.A. and Europe on this subject during the next few days.

The second and third W, when and where. That is obvious tonight.

The fifth and last W. Current Application and Future Developments of WIM Technology in the U.K. and Europe. So this is my topic.

I think perhaps we will start with policy. It is the right place to start. Weigh-In-Motion policy. Winston Churchill once said, "policy should only consist of three words, "We shall win," and then you apply it to everything." However, with regard to the heavy vehicle size and weight issue, we may well win but at what cost to our community. What mistakes in predicting future truck growth in terms volume, vehicle design, and road damage over the next 10 to 40 years will we make? We have great responsibilities in shielding future generations from increasing financial burdens without bridge and road maintenance. None of us can pretend that future forecasting of truck damage to the road infrastructure is an easy task. It is a very complicated problem. The factors such as economic growth and financial investment, energy supply, trucking industry regulations and economics, environmental impact, transfer of cargo from one transport mode to another, all need full, complete and proper assessment. To those of you who study this problem, I would recommend starting with a paper written by Mr. C. Shippey, Officer of Research, FHWA, Washington, D.C., entitled "Technical and Policy Factors in the Heavy Vehicle Size and Weight Issue." I was reading that paper again recently and was somewhat horrified to find that it was written and presented at an OECD Seminar in Paris in 1977. When you read that paper you wonder what steps we have really made since then. It demonstrates very well the nature of the problem. Because of the problem complexity, many of us I suspect would like to think about a lesser problem or even change careers.

We have heard in some detail this afternoon from the FHWA, the states of Virginia, Georgia, Wyoming. We should hear more on the collection and use of such data. At the risk of repeating what has already been said, the needs for traffic data are first to provide the trend data in traffic growth, axle loads and spacings by vehicle category. Such trends are necessary to provide the data source from which estimates for the future can be made. Specific highway sections will also produce input for updating, road design standards for both new road construction and existing road maintenance projects.

Second, the trend data should be obtained for each separate regional state. This provides for interstate variations and enables a critical distribution in central finance for road construction and maintenance.

Last, but not least, a truck enforcement program, to ensure truck operators keep to the regulations and to safeguard the road infrastructure. In my view, the policies adopted the truck data collection must reflect these three needs. I would not suggest that once you have obtained all of this information, all national policies with regard to the trucking industry, pavement design could easily be made. It would tell us nothing about predicted energy shortfalls. We must also remember the climactic damage as well as truck damage that cause our highways to fail. However, an unbiased indication of traffic growth, vehicle time, axle weights and spacings would be a valuable to future planning of our road structure.

So how are America and Europe going to obtain this information? We have mentioned policies are being or about to be taken. Policy has of course existed for many years in both Europe and America with regard to both enforcement and the collection of axle load spectrum on selected sections of highway. In the U.K. enforcement of truck regulations is conducted by the Department of Transport, the Trading Standards Association and the police. The U.K. Department of Transport checked about 200,000 trucks in 1982. From those opted to weigh 55,000. From those 20% were found to be overweight. Due to the additional activities of the Trading Standards authorities and the police, a total of about 130,000 trucks are check weighed in the U.K. every year on static or slow speed dynamic axle weighs. By slow speed, I mean the type of weigher that can weigh a vehicle moving up to 2 1/2 mph.

The Weighrite Company's product is used extensively for this purpose in the U.K. A total of 41 installations exist and an increase is planned. However, this enforcement data obtained will not satisfy the needs that I previously mentioned. We are not satisfied because it is biased data. The enforcement checks are conducted on vehicles principally which appear to the police or whoever is conducting the survey to be overweight. There is no doubt about it, some overweight vehicles undoubtedly take alternative routes. The sample size in the U.K. although it is small is respectable because 130,000 trucks weighed every year represents 7 1/2% of our trucking population.

The enforcement effort in other European countries is similar in scale. France, for example, has 46 locations and a similar number of mobile units.

In France, I was talking about a year ago to one of the enforcement authorities on one of the highways 40 or 50 miles west of Paris. There they have built on the side of the road structure, static, continuously in position scales.

One of the main problems they have is due to vehicles very quickly knowing, that they are opening up enforcement static weighing stations. What happens is that the information gets back down the road, and has for the last 10 years, before the CB was ever around in Europe. What happened is when they opened up the station on this side of the road, then all of the drivers with heavy goods vehicles just picked up a copy of the daily paper and stuck in the window and all the trucks coming down would see the paper there and know that there was an enforcement program going on. They took surveys on this and they found that within 1/2 an hour of opening up an enforcement scales about 20 to 25% of the heavy goods vehicles had either stopped upstream or were on the feeder roads around the side. Of course, Europe has a much bigger problem than you in this regard because it has so many parallel feeder roads. It is very easy for drivers to divert and it really takes them only five or six miles out of their way. This has very serious implications for enforcement in Europe, because from the cost benefit point of view, you may be catching one or two of these and fining them, but you are putting all these heavies, particularly the ones who think they are overweight onto the roads that aren't built for that traffic, so you are knocking those roads to pieces.

In Europe the major effort for enforcement is conducted at sea ports and borders between countries. The trucking regulations vary a bit within countries. Most European countries have a maximum rate limit of 44 tons. In the U.K. the maximum total weight limit was raised this year from 32 to 38 tons. To obtain axle weight data, many of the European countries install high speed weighing systems. In the U.K. we have WIM scales at 30 locations, producing sample data and axle weight inspection. Axle numbers are collected in weight bounds, and are recorded at 16 or 24 hour intervals. However, these WIM systems in the U.K. have been installed mainly on experimental sections of highway where evaluations of operation are being conducted. Pavement history is also collected at these sites from the accumulating equipment axle weighings.

The U.K. WIM system commenced operations in 1968. The design is based on three modules, each one 2' by 2, strain gauge, low cells with traditional design. It weighs one set of wheels from the axle, takes that weight and doubles it , which is axle weight. Now these sites need to be regularly maintained to give reliable axle weight data. By that I mean they need to be looked at and calibrated about once every four to six months. We have found that this measurement system with a recently smooth road profile, the ratio of the dynamic load to the static load has a value between 0.7 and 1.3 for a single axle measurement. In the study of road pavement damage, however, when the effects of large numbers of vehicles are considered, variations of vehicle speeds, vehicle suspension systems introduce a randomness into the dynamic loads so the average dynamic factors, the average ones are much closer to unity. On our scales we record average dynamic factors between 0.1 and 1.1. In the rest of Europe the most popular WIM system arrived at the German BAST (bonding plate). These bending plates have been used in West Germany. They've got about 80 or 100 installations. Denmark 7. Netherlands around 20. Sweden and Switzerland have a few. In the U.K., we've got three installations of this design I heard that this design has been used in several states and it will be interesting to see if the experiences of the Idaho Transportation Department are similar to the U.K. experience.,
In addition to truck data from static enforcement and WIM weighing systems, most European countries obtain truck data from annual censuses from the truck populators and owners. In the U.K. for example, a continuous survey of rail goods transport commenced in 1970. Each year details on some 15,000 trucks and what they do are collected by a weekly postal questionnaire. Information obtained contains vehicle details rigid or articulated number of axles, unladen weight, etc., details like one week's activity, payload weight, and commodity carrier. Unfortunately, axle weight is not recorded. And again, this information, although very useful does not shed light on truck overloading. According to the returns, no overloaded trucks ever run on the U.K. road network.

So in Europe at present, truck data is obtained as a by-product from enforcement weighing, by annual census methods, by specialized case study and by axle road data from high speed WIM systems. All of these methods, apart from the WIM techniques, produce a collection bias in the data. Now the critics of the WIM system, and there are some of course, are quite correctly concerned with the question, don't high speed WIM techniques also produce bias data. I have no doubt that several contributors of this conference would attempt to answer this question. From measurements taken in the U.K. at a number of high speed WIM sites, it is my view that periodic measurements of road profile at least 100 yards prior to each weigh bridge should be made. This road section profile should meet an approved specification. Furthermore, prior to data collection, when data is continuously collected at regular intervals, in impact factors for rigid and articulated test trucks should be obtained. These impact factors should also be within approved specifications. These two procedures will insure that data collecting is a meaningful accuracy. Variations due to road profile change and equipment performance were overcome. The TRR apparently is investigating variations of impact road factors with known road profiles.

So in Europe I have outlined the current situation and what new policies, new equipment are emerging. Now I know that a popular view of Europe, particularly from this side of the Atlantic is that the EAC appears to be a boxing club European nations. There they are busy fighting, arguing, cutting each other's economic throats, all of this activity happening simultaneously in at least 10 languages. There is some truth in that. It will be some years yet before the countries in Europe become a fully integrated set of nations with full econoomic financial and political economic partnership. However progress is being made. Where there is a will, there is a way. Sometimes, of course, Murphy's way. I believe that Murphy's law, if something can go wrong, it will, is as well known to you over here as it is in Europe.

The European economic community does try to pull things together. It requests and obtains from member states every 4 years statistical returns of traffic data. This data is in the form of vehicle kilometers by vehicle country, category and weight data. It is used to assess road utilization by member countries and to provide a base for future allocation, central finance, road construction and maintenance. At the current time, most of this classified flow and weight data are collected using manual counts and special surveys.

In the U.K. research at the TRRL produced an effective and accurate automatic vehicle classification system. This system can classify road vehicles into separate categories and provide strict detail by vehicle category. Other details such as vehicle wheel base, length and lane occupancy can also be obtained. In the U.K. vehicle classification requirements are for 20 separate categories and their road classification accuracy by the ABSC is 95%. This system has been demonstrated to the FHWA using facilities provided by the Maine Department of Transportation last year. The TRRL designed the software to suit the FHWA performance which at the time was for 13 vehicle categories. The Department of Transport Maine carried out the collection analysis and the data and it produced accuracies of around 98%. Now this is as good as or even better than manual observers can do. Of course, the mathematic system can be carrying on while doing something else. The AVCS micro-computer equipment has now through the research stage, specifications have been written and contracts let for the U.K. Company to produce that equipment. A policy decision has also been made in the U.K. to equip 120 sites with this equipment to enable the collection of continuous classified vehicle data. This automatic traffic census is expected to commence operation in early 1987.

In addition to the data mentioned, the census is also planned to collect axle weight information. My recent research activity in the U.K. is to link the ASCS with our existing WIM systems. We did this last October. The TRRL collected four weeks of continuous data for traffic crossing on one of our largest bridges, the Sudden Bridge, which carries the traffic from England to Wales. This bridge is 10 years old. It is one of Britain's first and biggest box girder suspension bridges. It carries four lanes of traffic. On a typical week day 17,500 vehicles cross over this bridge, 17% of them are trucks. The total bridge span length is just under a mile and the bridge deck is 170 feet above the river. Now in the U.K. that is a big bridge. I'm not sure with what is over here, it is a medium bridge. But traffic data has been collected and analyzed to provide details on average complete traffic loadings on the bridge structure. It has also been possible to calculate maximum traffic load which would occur if there was an accident on the bridge and the traffic plane was closed. Accidents occur on this bridge quite frequently, about once a week. Also the time interval between an accident occuring and a stationary traffic queue occupying at a defined length of this bridge structure, can be calculated from the data. The records show that a maximum traffic load that could exist in a typical month's data was just under 5,000 tons on the main bridge span, the length is quite a bit less, it is just over 3,000 feet. The period of most risk is early in the morning between 4 a.m. and 7 a.m. when the truck traffic is heavy and the car volume is small. During late morning and early afternoon there are peak loads of 3,700 tons queue can form and a formation time on our bridge with less than 18 minutes. So the data collected by this combined AVCS WIM system can be very useful for the road, or in this case, the bridge design engineer. It enables, not only on bridge structural design to be made, but also it provides an insight into requirements for any traffic control scheme to detect incidents and prevent traffic queuing on the structure.

Of course, traffic data in   with other data can be interpreted in several ways. I always like the story of three scientists travelling from London to the conference in Edenborough. They just passed over the border when they saw a black sheep. "How interesting the astronometer said, "all sheep in Scotland are black." "That's an unwarranted assumption," the physist replied. "All we know is that some sheep in Scotland are black." "All we can really disclose," said the statistician, "is that at least one sheep in Scotland is black, on at least one side."

I see from the conference time table, our guest speaker will be talking about future developments of WIM technology. Along with most of you, I will be extremely interested in that presentation.

In Europe at present, efforts are being made to produce low cost and portable WIM systems. The Pezzo electric pavement sensor is manufactured in France and is the subject of considerable studies in Europe. It shows great promise as a relatively low cost sensor, but at the present time the variation by the TRL indicates that future research is needed to produce results which will be comparible with existing WIM systems. I would expect to see the remaining problems associated with this sensor overcome within the next two years, provided research funds are forthcoming. In the U.K. the TRL have installed the Pezzo electric sensors in the approach roads of one of our oldest bridges. It was built in 1819. The bridge is now restricted to a single traffic lane in each direction. We have a system which weighs the weight of vehicles approaching and if the vehicle is over the 2 ton limit, sign saying to the driver, "overweight, turn back." The system is supported by occasional enforcement to add some bite to this warning. The complete cost of such a system amounted to about $8,000 for each approach and I think that is a pretty low cost to protect a valuable bridge structure.

The capacity of Weighmat has received some attention in Europe. I know that the Arizona Department of Transportation will be describing their experiences with an weighmat connected to the Golden River weigh analyzer. I think it best if I left Arizona to provide you with the relevant details on this portable WIM system.

COLLECTION AND USE OF TRUCK CHARACTERISTICS DATA

MR. GEORGE NOVENSKI
DIVISION OF PLANNING AND BUDGET
WISCONSIN DEPARTMENT OF TRANSPORTATION
MADISON, WISCONSIN

WISCONSIN

TRUCK WEIGHT & CHARACTERISTICS

PROGRAM

George J. Novenski, P.E.
Wisconsin Department of Transportation
Division of Planning and Budget

For Presentation at the
National Weigh-In-Motion Conference
Denver, Colorado
July, 1983

Wisconsin

Truck Weight and Characteristics

Program

The Truck Weight and Characteristics Program for Wisconsin was completely redesigned in 1982. The impetus for the study was with our ability to respond positively to several key questions. Does the data satisfy the needs of the various users? Is the program comprehensive and statistically defendable? Is there a valid data base? A cursory examination provided a resounding "No" to the questions, with only a slightly qualified "No" to the first question. With these consistent responses the choices were to drop the entire Truck Weight Program or to develop a new one. Here the direction was split. Those individuals interested in personnel positions and budget reductions favored program elimination. However, the data users, those needing the information for satisfactory accomplishment of their studies, projects, and programs were unified and prevailed for a new program.

The development of the new program took into consideration previous program activities plus additional current conditions. The latter also served as prerequisites for the future. The remainder of this paper will address this development.

Previous Programs

An analysis of historical activities provided insight to how, when, where, and especially why these programs were conducted. This is not to say there was a total explanation or justification ... some queries still remain unanswered. However, rationalized answers started the framework to develop a new program.

The major attributes for each of the programs are summarized in Table 1 by time periods. The initial program in 1936 and 1937 was unique, since its principle purpose was to obtain factual data and not having to rely on personal feelings. After that, it is interesting to note that annual activities usually remained constant for seven year periods. From 1942 through 1973 the Truck Weight Programs grew in size, coverage, and sophistication. Then from 1974 to 1981 the bottom dropped out. Portable operations were nearly eliminated as unsafe for the travelling public, as well as, the state personnel conducting the program. Further budgetary cuts were imposed, since the requirements for a valid data base could not be firmly defined. The remainder was a fragment of a program, limited to some coverage of the rural Interstate and State Trunk Highway systems.

The geographic distribution of locations for the collection of field data was responsive to shifts in the extent of the program, and as a minimum, always included the southern half of the state. That area has the highest population density, heavy industry, and agricultural activity. However, with a de-emphasis of rail service in the northern portion of the state the movement of forest products has been shifting to trucking.

Temporal coverage has been relatively stable throughout the years. It is believed this was a result of operational criteria and not data validity. Weekend data were not collected prior to 1980-81. As a part of the Highway Performance Monitoring System (HPMS) Truck Weights Case Study it was found that truck weights do not vary significantly between weekdays and weekend days and across seasons in Wisconsin. This can be partially attributed to Wisconsin's flexible motor carrier enforcement program.

TABLE 1

TRUCK WEIGHT & CHARACTERISTICS PROGRAMS

Program Attribute	-Time Period- 1936 - 1937	1938 - 1941	1942 - 1949	1950 - 1957	1958 - 1973	1974 - 1981
Station Distribution:		NO PROGRAM				
Number	75		12	20	40	11
System Coverage	64(R) STH 11(R) CTH		12(R) STH	20(R) STH	4(R)-1(u) IH 21(R)-8(u) STH 4(R)-2(u) Local	5(R) IH 6(R) STH
Type of Operations	3 Pit - 72 Port.		2 Pit - 10 Port.	3 Pit - 17 Port.	14 Pit - 26 Port.	8 Pit - 3 Port.
Graphic Distribution:	(?) Important Intersections		Southern Half Of State	Statewide Excl. Extreme North	Statewide	Southern Half Of State
Temporal Coverage:						
Hours	Most 16 - Few 24		All 8	Most 16 - Few 24	Most 16 - Few 24	Most 16 - Few 24
Days of Week	Weekdays		Weekdays	Weekdays	Weekdays	Weekdays
Seasons	All		Summer	All	Summer	Summer
No. of Samples:	83,731		1,600	4,500	10,200	6,200
Data Extent:						
Truck Weights	GVW & Axle		GVW & Axle	GVW & Axle	GVW & Axle	GVW & Axle
Truck Types	6		11	12	18	27
Truck Characteristic Items	8		9	22	16	14
Vehicle Classification:	Yes		Yes	Yes	Yes	Yes
Data Use/Need:	-Improvement Program Priority -Type of Highway Design -Discover Truck Characteristics -Obtain Factual Data		-Improvement Program Priority -Type of Highway Design -Trend Data	-Improvement Program Priority -Type of Highway Design -Trend Data -Special Problems	-Improvement Program Priority -Type of Highway Design -Trend Data -Pavement Design -Traffic Engr. -Admin. Concerns -Cost Alloc. Study	-Improvement Program Priority -Trend Data -Pavement Design -Traffic Engr. -Admin. Concerns -Cost Alloc. Study -Pavement Research -Bridge Design -Highway Maintenance -Enf. Facility Design -Motor Carrier Enf. Program -Oversize/Overweight Permits -Traffic Forecasting -Accident Analysis -Energy Consumption Forecasting -Air Quality and Noise Analysis -Socioeconomic Analysis -Freight Flow Analysis -State Rail Plan -Railroad Abandonments -TOFC Studies -Harbor Studies -Policy Studies -Legislative Issues

The number of samples obtained per year are shown in Table 1 for informational purposes and a common base for relative comparison does not exist. In addition, in 1963 a 10-minute random sampling procedure was initiated to reduce the delay on truckers, thus further complicating a comparison.

The sole basis for the program, obtaining information about gross vehicle weights and the weights of individual axles, remained throughout all of the years. The growth in truck types was a contributing factor to the program demise by increasing complexity and sophistication. Temporal sampling rules caused shortages in the number of samples by truck type, resulting in limited value for much of the data.

The number of truck characteristic items collected fluctuated in response to changes in needs and issues of concern. Some of the usual items were axle spacings, truck dimensions, commodities, trip origin-destination, and more, but at times included tire size, special dimensions, fuel consumption, annual miles of travel and others.

All vehicles of the entire traffic stream were manually classified every year the program was conducted. This was especially important as an operational control when the trucks were random sampled for weighing.

The listed uses/needs of truck weight and characteristics data are for state purposes. Although the surveyed data was transmitted to the Federal Highway Administration (FHWA) for many years, no attempt was made here to list FHWA's uses. Several areas of data use were repeated for each year the program was conducted. Others were added as highway engineering and administrative practices intensified. Of particular importance is the ballooning of needs and uses during the past ten years. Comparing these desired uses to the program's other attributes leads one to conclude that many could not be supported at all. For those that could use the data it had to be used as a general indicator, recognizing a lack of statistical reliability. In addition to the lack of responsiveness to specific application areas, there was a much larger concern, namely, developing a data base to satisfy all of the needs.

Program Prerequisites

The examination of previous program experiences in conjunction with other current factors influenced the design of the new program. These factors, described below, made it possible to satisfy the program's primary objective of creating a valid data base.

- A prioritization of data items for each data application area allowed for the program to be divided into two components. One component consisted of axle and gross weights by truck type and the other addressed truck characteristic items.

- Variances in operating gross weights of trucks on different highway systems, based on the HPMS Case Study, directed an increase in system coverage. The extent of increase should also be guided by changes in facility design class and proportion of truck VMT.

- The extent of different trucking practices on the sections of a highway system are highly variable. Until more information is available, a random selection technique should be used for geographic distribution of station locations.

- Some people express concern that truck data collected at pit scales is biased. Pit scales should not be utilized for the Truck Weight Program if adequate alternative technology exists.

- A method must be developed to relate sample size to statistical levels of accuracy for user acceptance.

- A consolidation of truck types to a reduced number of categories, as suggested by FHWA, should enhance our ability to satisfy sampling requirements within reasonable periods of field operations.

- The needed degree of data precision will determine program cycles.

- Selected monitor stations will facilitate the measuring of stability or change in trucking practices between weekdays and weekend days and across seasons.

- Technological advances in weighing equipment should reduce total operating expenditures and costs per sample.

- For increased understandability and ease of use, improvements must be made in the format and timeliness of data presentation.

- The new program should be developed on a concept of progressive satisfaction of present and changing user needs.

New Program

The program being implemented has two distinct components. The component emphasizing truck weights is further divided into two parts, a base and a monitor, for operational purposes. The second component emphasizes truck characteristics through driver interviews, with secondary importance placed on truck weights. This separation is used in Table 2 to describe the program's major attributes.

The base and monitor parts that together make up the truck weight component are repeated every other year for a two year program cycle. This portion of the program is suspended during the fifth year and replaced with the truck characteristics component. The cycling is based on operational balancing and data users accuracy suggestions.

The base part requires the collection of data at twenty-one stations statewide to realize an 80%/10% level of accuracy (80% confidence/10% precision). Other accuracy levels, such as 90%/10% requiring 33 stations or 95%/5% requiring 188 stations could have been chosen, but were precluded by cost considerations. The twenty-one bidirectional stations are distributed across seven jurisdictional and functional road systems by proportionate share of truck vehicle miles of travel (VMT). These seven road types serve 83% of the truck VMT. The remaining road types, rural Town Roads, urban City/Village Streets and Other Roads will be selectively sampled on a spot basis as the need arises.

The monitor part is, as the title suggests, a sampling of data at one station for each road system to track temporal variations.

TABLE 2

NEW TRUCK WEIGHT & CHARACTERISTICS PROGRAMS

Program Attribute	Truck Weight Component: Base Part, Years 1 & 3	Base Part, Years 2 & 4	Monitor Part[1/], Years 1 & 3	Monitor Part[1/], Years 2 & 4	Truck Characteristics Component, Year 5
Station Distribution:					
Number	11	10	3	4	6
System Coverage	2(U) IH - PA 4(R) IH - PA 5(R) STH - PA	3(U) STH - PA 1(U) STH - MA 4(R) STH - MA 2(R) CTH - Maj. Coll.	1(U) IH - PA 1(R) IH - PA 1(R) STH - PA	1(U) STH - PA 1(U) STH - MA 1(R) STH - MA 1(R) CTH - Maj. Coll.	4(R) IH - PA 2(R) STH - PA
Type of Operations	WIM		WIM		Pit
Geographic Distribution:	Statewide		Selected		Major Corridors
Temporal Coverage:[2/]					
Hours	6A to 6P		6P to 6A / 6A to 6P	6A to 6P	6A to 6P
Days of Week	Weekdays		Weekdays / Weekends	Weekdays	Weekdays
Seasons	Summer		Summer / Summer	Fa-Wi-Sp	Summer
No. of Samples:					
95% Confidence/5% Precision	13,615	12,897	18,115	25,415	7,246 (min.)
95% Confidence/10% Precision	4,123	4,227	5,435	8,585	1,518 (min.)
Data Extent:					
Truck Weights	GVW & Axle Weights & Axle Spacings		GVW & Axle Weights & Axle Spacings		GVW & Axle Weights
Truck Types	9		9		9
Truck Characteristic Items	0		0		6
Vehicle Classification:	No		No		Yes
Data Use & Need:	ibid, 1974-1981 list plus data user survey data elements.[3/]				

1/ The monitor part is a supplement to the basic part for the total Truck Weight Component.

2/ Temporal values are general guidelines for scheduling. Actual operations are based on minimum samples for each truck category for each station.

3/ Data elements listed in Wisconsin Truck Weight Study, Data User Needs, Working Paper #1, February, 1982.

The bridge Weighing-In-Motion (WIM) system is to be used to collect truck weight information. A few of its most significant attributes are:

- The system is not particularly sensitive to approach pavement conditions, thus initial or installation capital expenditures are less than for permanent sites.

- The field crew size is reduced from 6 or 8 to 2.

- After calibration, station set-up and tear-down can be accomplished by the operating crew and does not require added personnel, equipment, or materials.

- The system can obtain the total load of multi-vehicles, as well as single vehicle loads on a bridge.

- Data accuracy is adequate for planning purposes.

- Individual gross vehicle weights, axle weights, vehicle type, and vehicle speed are collected and recorded automatically without human intervention, thus improving data quality.

- The rate of sampling is expected to be at least twice the rate of manual operations, thus increasing data quantity while reducing cost per sample.

- Weighing operations are virtually undetectable by truckers, thus reducing bias.

- Weighing operations are conducted at all vehicle speeds so traffic flow is not impeded.

- The system can be operated at night and under most weather conditions.

- The system is highly portable so highway system coverage can include any system that has adequate bridges.

Of course, the bridge WIM system is not everything to everybody. Some of the major shortcomings are:

- Bridges must exist on the highway system and in the area for which data is needed.

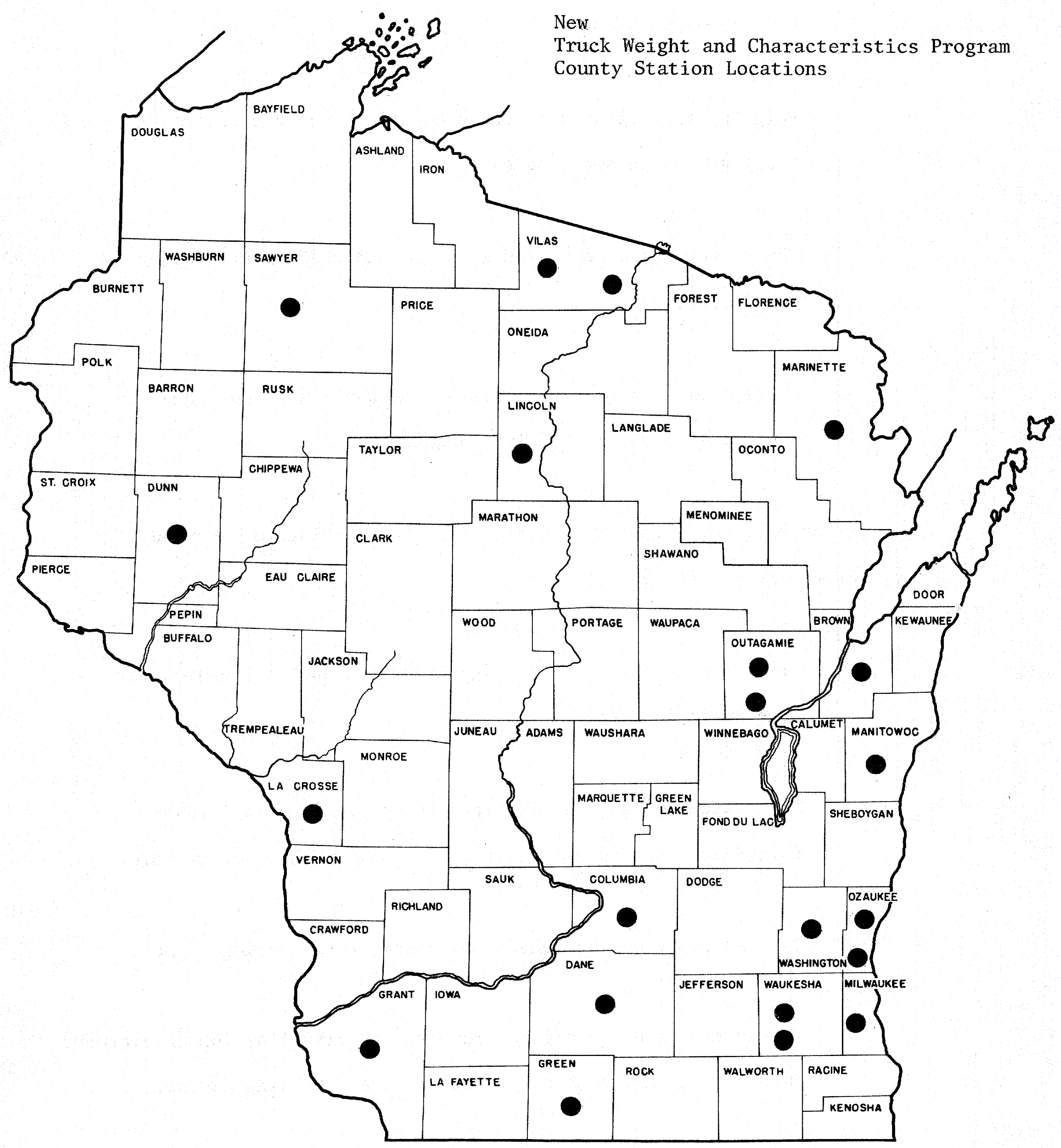
- The system may not be efficient for collecting individual truck data on bridges carrying very high volumes of traffic.

- Data accuracy may be reduced by using certain bridge types.

- The system is not certified for issuing citations for enforcement purposes, although it can function as a screening devise.

The twenty-one stations, shown on Map 1, are located in seventeen of Wisconsin's seventy-two counties. This random distribution gives comprehensive geographic coverage.

MAP 1


New
Truck Weight and Characteristics Program
County Station Locations
DOUGLAS
BAYFIELD
ASHLAND
IRON
VILAS
WASHBURN
SAWYER
BURNETT
PRICE
FOREST
FLORENCE
ONEIDA
POLK
MARINETTE
BARRON
RUSK
LINCOLN
LANGLADE
TAYLOR
OCONTO
CHIPPEWA
ST. CROIX
DUNN
MARATHON
MENOMINEE
CLARK
SHAWANO
PIERCE
EAU CLAIRE
DOOR
PEPIN
WOOD
PORTAGE
WAUPACA
BROWN
KEWAUNEE
BUFFALO
OUTAGAMIE
JACKSON
TREMPEALEAU
JUNEAU
ADAMS
WAUSHARA
WINNEBAGO
CALUMET
MANITOWOC
MONROE
LA CROSSE
MARQUETTE
GREEN LAKE
FOND DU LAC
SHEBOYGAN
VERNON
SAUK
COLUMBIA
DODGE
OZAUKEE
RICHLAND
CRAWFORD
WASHINGTON
DANE
GRANT
IOWA
JEFFERSON
WAUKESHA
MILWAUKEE
GREEN
ROCK
WALWORTH
RACINE
LA FAYETTE
KENOSHA

Because it is necessary to re-establish a sound data base in a reasonable amount of time, initially extensive temporal levels of detail are not being attempted. Statistically valid data will not be available for each hour of the day nor for each day of the week. If the "need-to-know" intensifies, the program can be refined or adjusted to the appropriate level. Therefore, the temporal coverage shown in Table 2 is used as a general guideline for scheduling of field operations. A minimum sample size by truck category for the time period is the governing criteria. On a summer weekday, data may be collected for only six hours of the 6A to 6P period to attain the minimum sample. Conversely, several 6A to 6P periods may be required at low volume stations to satisfy the number of needed observations. This same concept applies to the monitor part which supplements the basic part to make the truck weight component complete.

The sample size is different for each truck category for each jurisdictional and functional class of a highway system. As an example, 60 single unit 3 axle (and plus) truck samples are required at a rural Interstate station, while a rural State Trunk Highway principal arterial requires 100 samples for a 95%/10% accuracy. The number of samples shown in Table 2 are an aggregation of the minimum required for an annual program. The program is based on a 95%/10% accuracy level (95% confidence/10% precision). To achieve a 95%/5% accuracy would require more than a tripling of effort and was considered unnecessary for an initial program.

For the truck weight component of the program the following planning data items will be obtained: 1) truck type; 2) gross vehicle weight; 3) axle weights; and 4) axle spacings. For other purposes vehicle speed and bridge strain information will be available. The truck types will be compressed into nine truck categories and for practical purposes little truck characteristic data will be collected. Limited body type data will be collected during selected operations.

The entire traffic stream will not be classified during WIM operations, since it is not necessary as a control of random sampling. In addition the past supply of such information has led to misuse. Some individuals accepted the 24 hours of summer weekday classification data to represent annual values.

The purpose of the truck characteristics component of the program is to monitor changes in trucking practices. These characteristics tend to be more stable than truck loading operations, since they are influenced by much broader factors. Several of the factors are: 1) changes in truck size and weight legislation; 2) updating of licensing and registration practices; 3) trucking deregulation; 4) major shifts for distribution of commodities; 5) scrappage and replacement rates of trucks; and, of course, 6) economic well-being. Therefore, a five year data update cycle is considered adequate to measure these characteristic variances.

The majority of the characteristics are indicative of the trucking industry as a whole and are not road system or site specific dependent. To optimize data collection activities the stations are located in high volume trucking corridors on rural Interstate and State Trunk highways.

Permanent-site pit-scale locations will be used to collect the driver interview data. These provide the greatest safety for the truckers and the survey crew.

Again the temporal coverage shown represents a time period, the same as for the truck weight component, with the governing criteria being sample size. The minimum sample shown is predicated on variations in truck weights. Based on the truck characteristic with the most severe variation, 20,736 samples are required for a 95%/5% accuracy and 5,184 are needed for a 95%/10% accuracy. Since there is a significant difference in the sampling requirements for characteristics and weights, these preliminary values will be confirmed before actual operations.

Truck characteristic data items are emphasized for this component of the program. These are: 1) registered weight; 2) load status, i.e., loaded, empty, permitted overload; 3) commodity type; 4) origin/destination; 5) fuel type; and 6) annual miles of travel. Gross vehicle weight and axle weights are of secondary importance and will be collected only for possible correlation of data to the weight component of the program. It is not necessary to collect axle spacings, since they are obtained in the other program component and would increase costs significantly to duplicate.

Manual vehicle classification of the highway traffic stream will be conducted only for the period of field operations as a verification of random sampling.

The needs for both truck weight and characteristics data continues to grow in number of application areas and in data items required. This is obvious from Table 1 and is expected to continue in the future. The intent of the program is to be able to convert the needs to actual uses by providing valid data. The initial program focuses on the most important data elements by jurisdictional and functional highway systems. This base can be supplemented later with less important data elements and expanded to sub-highway systems or to a site specific level.

Summary

The Truck Weight Programs from 1936 to 1973 were adequate to support the identified planning and administrative needs of the users. From 1974 to date, needs increased dramatically for policy, planning, programming, design, operations, research, administrative, and legislative purposes. At the same time the Truck Weight Program was being reduced so that less and less of the data needs could be satisfied. The fragment of a program remaining in 1981 was suspended until a new program could be developed.

The goal to develop a program that would contain a statistically valid data base was predicated on past experiences, prioritization of user needs, availability of weighing equipment and costs. The most significant factor that aided in developing a viable program was the splitting of the program into two components, one addressing truck weights and the other truck characteristics. The initial capital expenditures will be amortized in less than six years through reduced operational costs, while road system coverage and data integrity will be greatly enhanced. In summary, so to go from a good program to an extremely bad one can be beneficial, providing it can be the impetus to design a new improved program.

Special Note

The development of the new Truck Weight and Characteristics program is described in more detail in the following reports:

Truck Weight Study Prospectus, WISDOT, Division of Planning and Budget, November, 1981.

Wisconsin Truck Weight Study: Data User Needs, Working Paper #1, WISDOT, Division of Planning and Budget, February, 1982.

Wisconsin Truck Weight Study: Sampling Plan, Working Paper #2, WISDOT, Division of Planning and Budget June, 1982.

Wisconsin Truck Weight Study: Weighing Equipment Options, Working Paper #3, WISDOT, Division of Planning and Budget, June, 1982.

Wisconsin Truck Weight Study: Final Report, WISDOT, Division of Planning and Budget, July, 1982.

Any one or all of these reports are available, upon request from:

William D. Gardner
Wisconsin Department of Transportation
Division of Planning and Budget - Room 901
P. O. Box 7913
Madison, WI 53707

COLLECTION AND USE OF TRUCK CHARACTERISTICS DATA

MR. STEPHAN FREGGER, CHIEF
BUREAU OF SYSTEMS STATISTICS
FLORIDA DEPARTMENT OF TRANSPORTATION

FLORIDA'S COLLECTION AND USE OF TRUCK CHARACTERISTIC DATA

By

Stephan Fregger, P.E.
Chief, Bureau of System Statistics
Florida Department of Transportation

At this stage in the conference, I believe it would be somewhat redundant for me to spend much time to tell you why Florida collects truck weight data. Suffice it to say that we are principally a "Planning Survey" State.

Our mission has been twofold: First, to determine statewide truck weight averages by truck classification; and, second, to develop long term trends in loading configurations and truck classification usage. All of our collection of weight data, and classifications, and averages, and trends was strictly for highway design purposes.

Over the past nine years our weigh-in-motion system has weighed several million vehicles, including over five hundred thousand trucks. I dare say that no state has as much experience as Florida. In fact I suspect that we may surpass the combined experience of the rest of you here today.

Let me spend the next few minutes sharing with you the experiences of our method of operation. Following that, before your very eyes, I will bare my soul with a confession that may re-direct the future of weigh-in-motion.

Ten years ago we collected all of our truck weight data by Loadometer Survey. Our surveys were conducted during the summer months only (student labor was cheap and plentiful then); during daylight hours only (night surveys were unsafe for the students); and during sunshine only (rain dampened the student's spirits).

In 1973 it occurred to us that data collected in such a manner was probably severely biased. We were missing truck data for the three other seasons, including all of the fall, winter, and spring agricultural movements. We were also missing all of the night truck movements.

Clearly, a better statistical sampling system was necessary. Our staff began a technology analysis to identify alternative procedures for collecting truck weight data. After participating in a weigh-in-motion conference in Austin, Texas in 1973, we became firmly convinced that weigh-in-motion was the solution to our data collection problems.

The next year, 1974, we acquired a WIM I-A weigh-in-motion system from Unitech (the predecessor of Radian). I believe that our system was the second or third unit delivered in the country. Upon delivery of the WIM System we abandoned our Loadometer Surveys and switched to exclusive WIM operation.

The WIM System collects weight data by individual wheel, it sums the wheel weights by axle; and it totals the axle weights for a total vehicle weight. The system provides vehicle configuration data by counting the number of axles and computing the distance between axles. The system also measures vehicle speed, a feature which we have used extensively in our 55 mph speed certification program.

Operationally, the system consists of two wheelpath transducer pads placed in a single roadway lane. Also installed in the roadway lane are inductance loops for vehicle speed and presence detection. In our system, the electronic data is transmitted by wire to our mobile housing unit which is an Argosy Travel Trailer. Inside the trailer are located all of the electronic input/output, processing, and storage devices. In the WIM I-A, those devices were an ASR 33 teletype, a Data General Nova minicomputer/controller, and a Wang magnetic tape drive.

By 1980, our six year old system had become obsolete. That year we entered into negotiations to conduct an HPMS Truck Weight Case Study for the Federal Highway Administration, for which we subsequently acquired a new WIM I-D System. This new system collects essentially the same data as the previous system, although it does have multi-lane data collection capability. With the exceptions of the nine year old Argosy trailer and the transducer pads, all of the system components have been replaced and upgraded. The new system utilizes a video display/keyboard, floppy diskette storage and a high speed printer.

Florida has 19 operational WIM sites. Within this year we expect to complete our system with the installation of two more sites. Our sites are geographically distributed throughout the state on Interstate routes, and other principal and minor arterials. They cover rural and urban locations.

As noted earlier, we have recorded a tremendous number of samples -- literally millions of vehicles, including hundreds of thousand trucks. At our high point in 1981 we weighed over 1/2 million vehicles. That "Guiness Record" was made during the period when we were conducting 4-day surveys at each site.

We have subsequently altered the program to permit better system management and equipment maintenance. Our current program provides for a 48-hour survey at each site.

During a typical week, the three man WIM crew is in the headquarters on Monday morning, attending to administrative details and completing any required system maintenance. Monday afternoon the crew begins its travel to the scheduled survey site. The dormant site is activated and the survey commences at noon on Tuesday. The survey proceeds for 48 straight hours, concluding at noon on Thursday. The site is de-activated and the crew returns to the headquarters. Friday is reserved for data processing and system maintenance. Periodically, time is allowed in the schedule for major repairs, new construction and vacations.

As a consequence of our new 48-hour survey program, the WIM System is maintained in a better state of repair; personnel management is substantially improved; and, the overall program operates more smoothly. Of course, with the reduced survey period, there is a reduction in the number of weight samples. Last year we only weighed 1/4 million vehicles!

Output from the WIM System is routine and automatic. The survey data stored on diskettes is brought back to headquarters where it is converted to magnetic tape. The data is then processed on the Department's IBM mainframe where the output is in FHWA card format on tape.

Originally the tapes were forwarded to the FHWA for processing into W-Tables. However our procedure now performs the W-Table conversion inhouse. The W-Tables are then converted to 18 KIP equivalency factors. That data, combined with ADT, T, D and Lane Factor, yields the equivalent 18 KIP axle loads necessary for pavement design purposes.

Our overall experience with the WIM System has been absolutely favorable. Unitech/Radian and their transducer supplier (Rainhart) have been consistently cooperative and helpful. Certainly our system has had its share of the operational problems that all pioneering programs experience. But, with our own ingenuity and some advice from Radian, we have been able to resolve them all. I will be glad to address specific problem issues in the question session following this presentation.

The WIM program is beset with one major difficulty. It is a difficulty that has avoided a solution for several years, although we expect to solve it next year. The difficulty is that the system is super efficient!

We operate the WIM System with a three man crew. Each of the crew members is a highly specialized expert on system operation and electronic repair. The WIM Unit itself is a highly specialized electronic device which requires environmental conditioning and frequent exercising.

When you buy into such a specialized operation, you can never "pull the plug." Have you seen the TV commercial for Ryder trucks where Ed and his wife run a rabbit business? I must frankly tell you that we are up to our axles in truck weight data, and we can't stop the flow.

For years we have been searching for some compatible program to merge with the WIM resources. Our hope was to be able to divert the personnel and/or equipment to the other program on alternate weeks, or months or years. Last year we identified a proposed video log system as the long-sought program. Fortunately we have now been given authorization to acquire the video system. We hope that this compatible program will resolve our surplus weight data difficulty.

Now it is confessional time!

A funny thing happened on the way to this conference. About a month ago we came to the realization that the truck data element of the pavement design procedure had a serious conceptual flaw. This finding was the out growth of the creation of a new Pavement Management System in our Department.

The conceptual flaw: For decades we have been creating historical files of generalized or average truck traffic data for the usage of the pavement designers. Yet, the designers have been producing specific project pavement designs which require project-specific truck data.

Thus, the designers have had to rely on extrapolated or synthesized estimations of truck traffic data to design their specific projects. Unfortunately, in many instances the estimations of current truck traffic have been poor and the design truck traffic projections have been terrible. As a result some roads have experienced substantial over-design, while other roads have prematurely disintegrated.

The new Pavement Management System is going to require responsible design based on accurate project-specific traffic data and reliable design truck traffic projections. More over, to complete the accountability loop, long term project-specific traffic data monitoring will be required to validate the truck traffic projection procedures that were utilized in the design of the project.

So, I'm here to confess to you that while we have gotten high grades for our WIM operation and our historical generalized weight data files, we have failed the course in developing accurate useful data for the pavement designs.

What does all this mean? Well in Florida it does not mean that we are going to abandon our WIM System. We will continue to need the baseline weight and classification data developed by that program. However, I see the WIM program assuming a role similar to the role of the Automatic Traffic Recorder (ATR) in the traffic counting program.

We are now preparing to develop a truck weight and classification data collection program which will fulfill the needs of the Pavement Management System. As presently envisioned the program will assure that every pavement project in the Work Program has been provided project-specific truck data sufficient for responsible and accurate pavement design. In addition, the program will provide long term monitoring of constructed projects to validate the design loading projections.

We have begun the investigation of portable automatic vehicle classification equipment. Six units have already been purchased and are now being field proved. Funds for ten additional units have just been appropriated for this year and I expect more for next year.

This conference signals the start of our investigation of portable automatic weighing equipment. If there are any equipment manufacturers who are willing to join us in this exciting new phase in truck weight data collection, I urge you to contact us.

On that blatant note of solicitation I will close these comments and respond to any questions you may have.

SIZE AND WEIGHT ENFORCEMENT PROGRAMS

MR. HAROLD J.BROWN, CHIEF
TRAFFIC REGULATION BRANCH
FHWA
WASHINGTON, D.C.

Size and Weight Enforcement

As has been previously stated, the authority for the federal government to be involved in size and weight enforcement stems from Title 23 of the U. S. Code. This authority was strengthened with the issuance of Section 123 of the Surface Transportation Assistance Act of 1978.

In capsulated form, the STAA of 1978 required the States to make an initial submission and annual revision of a plan for enforcement, and an annual certification of compliance. Failure to do either could result in a reduction of apportioned Federal-aid highway funds.

It is FHWA policy that each State enforce vehicle size and weight laws to assure that violations are discouraged and that vehicles traversing the highway system do not exceed the limits specified by law.

As I have previously stated, each State is required to develop an enforcement plan. The plan should cover:

1. Facilities and equipment, that is, the location and type of scales fixed, weigh-in-motion, semiportable, portable. No program can be approved which utilizes less than two of these type scales.
2. Resources or staff
3. Actual plan of operation, that is,
   a. Hours of operation

b. Geographical coverage

c. Off-loading requirements

d. Penalties

e. Special permits

FHWA is to annually evaluate the plan (delegated to Division office), and the state must have an approved plan in effect by October 1 of each year. Although we ask for "numbers"; consistent, vigorous enforcement activities, together with the certainty of penalty assessment for overload, are greater deterrents.

Each state shall certify to the Federal Highway Administrator before January 1 of each year that they are, in effect, following their approved plans. The actual certification includes:

1. A statement by the Governor (or his designee) that laws and regulations governing the use of the Interstate System conform to 23 U. S. C. 127.
2. A similar statement to the effect that all state size and weight laws are being enforced on all Federal-aid systems.
3. A copy of new state size and weight regulations.
4. And a comparison of the state's actual effort to that proposed.

This certification is reviewed by FHWA's Division Office, Regional Office, Office of Traffic Operations in Washington, and the Office of the Chief Counsel.

We're a little late this year, due to the new STAA of 1982 (and resulting difficulties we got ourselves into), but expect to get a response back to our Regional Office by the end of this week. We will then prepare a report to Congress. This is known as the "123 Report", and should be available in draft form by mid October.

If a State fails to certify, or the Secretary determines that the certification is not adequate, the Federal-aid funds apportioned to the State for the next fiscal year will be reduced, of course, there is a procedure to be followed and we're looking for informal resolutions.

In summary then, it is our policy that the States develop and adhere to an enforcement plan to assure that vehicles traversing the highway system do not exceed the limits specified by law. If we tend to forget what our policy is, GAO or the Office of the Inspector General will remind us!

STATE AND WEIGHT ENFORCEMENT PROGRAMS

OFFICER JOHN BALCOM
FIELD OPERATIONS COORDINATOR
COMMERCIAL VEHICLE ENFORCEMENT SECTION
WASHINGTON STATE PATROL

TOPIC: Washington State Size and Weight Enforcement

SPEAKER: Officer John Balcom, Field Operations Coordinator
Commercial Vehicle Enforcement Section
Washington State Patrol

THEME: Commercial Vehicle Enforcement Program

Size and Weight Regulations: Overview of State's Interpretation of Federal Size and Weight Standards

Enforcement Responsibility:

The Commercial Vehicle Enforcement Section of the Washington State Patrol is solely responsible for size and weight enforcement throughout the state. Some counties and cities have part-time weight enforcement programs in their respective jurisdictions.

There are presently 63 Commercial Vehicle Enforcement Officers and we are in the process of hiring approximately 30 more officers to bring us closer to our authorized strength of 93 officers.

Geography:

Washington State is divided by the Cascade Mountain Range, home of the legendary volcano, Mount St. Helens, in the southwest corner of the state. As a result, there are two different climatic regions. Western Washington borders the Pacific Ocean and is covered with the Evergreen forests that the state is famous for, hence the name "Evergreen State". Sixty percent of the state's population lives in the Puget Sound region in Western Washington. The major north-south freeway is Interstate 5 which enters the state at the Oregon border near Portland and runs to the Canadian border near Vancouver, British Columbia. The state operates a port-of-entry at Ridgefield near the Oregon border and another port is planned near the Canadian border.

Eastern Washington is a dry arid climate and is known for dry land wheat farming. Mammoth irrigation projects pumping water from the Columbia and Snake Rivers have turned it into highly productive farm land. The Wenatchee and Yakima Valleys near the Cascades are world famous for their apple production. The primary East-West corridor through the state is Interstate 90, which originates in Seattle and crosses the state to the Idaho border. We operate two Ports-of-Entry in Eastern Washington, located at Plymouth (Oregon border) and Spokane (Idaho border).

Enforcement Plan:

Washington State's enforcement plan is tailored to the needs of the state and goes beyond traditional size and weight enforcement. It also includes enforcement of the state's licensing and equipment laws. Our truck inspection program is also an intregal part of the State Patrol's Accident Prevention Plan. Through these coordinated programs, the State Patrol is able to promote commercial vehicle safety throughout the state.

In an effort to obtain the maximum benefit of our limited resources, the State Patrol has implemented a Selective Enforcement Program. This program uses computerized management information to assign our officers where they will be most effective.

The State Patrol maintains and operates 64 permanent scale sites located throughout the state's 39 counties. A number of fixed scales have markings at the 36 foot length to aid in the enforcement of bridge formula violations. We also have approximately 35 vehicles equipped with two sets of portable wheel load weighers and are attempting to purchase eight portable axle scales.

Our enforcement plan requires 24-hour operation of the state's ports-of-entry. Other weigh stations are manned on a peak traffic basis by day of week and/or season. District supervisors prepare monthly duty rosters ensuring variations in operating times of both fixed and portable scales. Officers have the responsibility and latitude to adjust their schedules according to seasonal movements within their geographical areas such as harvests, timber sales, construction projects, etc.

The department has been reevaluating the need for some of our remote weigh stations due to the increasing cost of maintenance and extensive vandalism damage; however, the trucking industry is opposed to this. Our state, has traditionally left the scales operational even when not occupied by our personnel. This practice allows the trucking industry to check weigh their loads before traveling on the highways. The department has even received offers of reimbursement for these expenses from local trucking associations, provided we continue to leave the scales available for their use. The department has no legal authority at this time to accept reimbursement, but this would allow the industry to continue use of the scales, and aid in prolonging the life of a highways. The damage by one overload can conceivably cost the state more than an entire scale facility.

Although the primary mission of our size and weight program is to protect the state's roads and bridges, the Commercial Vehicle Enforcement Section is also responsible for enforcing the state's licensing and equipment laws. This includes selling permits for the Department of Licensing and Department of Transportation. Permit sales at the Ridgefield Port-of-Entry total over one million dollars annually. Due to the volume of permit sales, we have instituted a pilot program at the Ridgefield and Spokane Ports to hire temporary clerks to issue permits. This allows more time for Officers to concentrate their efforts on size and weight, safety, and hazardous materials inspections, etc. As a result of this program, they are now spending approximately 75 percent or more of their time on weight enforcement.

The state has also been heavily involved in heavy truck equipment enforcement. In January of 1980 to July of 1981, the state conducted a study of heavy truck equipment defects under a federal grant. Five two-man inspection teams were trained in a special critical item inspection system in which equipment with a high accident potential is given a detailed review. The teams inspected over 18,000 vehicles during the 18 month period. Fifty-nine percent of those inspected were placed out-of-service for hazardous defective equipment. The most prevalent of these violations were improper brake adjustment and defective brake components.

We have continued probable cause and spot check inspections for defective equipment. In 1979, the department requested an administrative law change requiring all vehicles carrying low-level radioactive waste to enter Washington at the Spokane or Plymouth Ports-of-Entry and that they be inspected by the Commercial Vehicle Enforcement personnel. Initially, equipment defects resulted in 65 percent of the trucks being placed out-of-service. Currently, only about six percent are placed out-of-service. Most importantly, Washington has not had a single accident involving a radioactive waste carrier since the program began four years ago.

Another aspect of the inspection program is the accident investigation assistance provided by this Section to line troopers. An Equipment Specialist responds to all accidents involving commercial vehicles to determine if the cause of the accident was due to defective equipment.

In addition, the Commercial Vehicle Enforcement Section is responsible for semiannual inspections of the state's eight thousand school buses.

Scale By-passing:

Officers assigned to portable scales work on an as-traffic-warrants basis. Through the observance of traffic patterns based upon the type of trucking in the area, they basically establish their own schedule to deter as many overweight vehicles as possible. They also work together as teams to saturate by-pass routes as a means of deterrence. A typical example of controlling by-pass routes is in District IV, Spokane. The Port-of-Entry on Interstate 90 operates on a 24-hour basis; but there are other highways in the area that allow truckers to by-pass the Port. These roads are worked extensively by one or more Commercial Vehicle Enforcement Officers with portable scales at varying times, so that no set pattern is established.

Officers also establish rapport with local jurisdictions and businessmen within their geographical areas. These contacts, in turn, provide the Patrol with information concerning trucks running overloads or attempts at circumventing other laws.

Program Improvement Recommendations:

The Washington State Patrol is very interested in the weigh-in-motion concept. The department recognizes its potential as a sorting or screening device for weight enforcement. However,weighing trucks at highway speeds in the lane of traffic is not consistent with our enforcement plan. We need to have trucks enter the scale area to be screened for licensing and equipment violations. We feel that a weigh-in-motion installation on the approach ramp to a scale would eliminate some traffic management problems, provide weight, axle and bridge formula screening, and at the same time route trucks close enough and slow enough to provide visual licensing and equipment checks. The State

Patrol is working with the State Department of Transportation to develop multi-purpose weigh-in-motion installations for sorting and data collection. These joint efforts would reduce the costs and improve programs of both agencies.

At the present time, the State Patrol does not have any weigh-in-motion installations. We are interested in modifying selected existing stations and designing our new port-of-entry near the Canadian border to accommodate weigh-in-motion equipment.

We also feel, that our pilot program to use clerks to sell permits should be continued. This and any other program which enables officers to concentrate on their enforcement duties will improve the effectiveness of our programs.

PENNSYLAVANIA'S PROGRAM AND OPERATION FOR ENFORCING SIZE AND WEIGHT REGULATIONS

MR. J. ROBERT DOUGHTY, CHIEF
DIVISION OF TRAFFIC ENGINEERING AND OPERATIONS
PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
HARRISBURG, PENNSYLVANIA

Pennsylvania's Program and Operation

for

Enforcing Size and Weight Regulations

Denver, Colorado

J. Robert Doughty, Chief
Division of Traffic Engineering & Operations
Pennsylvania Department of Transportation
Harrisburg, Pennsylvania 17120

PENNSYLVANIA'S PROGRAM AND OPERATIONS FOR
ENFORCING SIZE AND WEIGHT REGULATIONS

I. INTRODUCTION

A. 1. Slide 1 shows Pennsylvania as a corridor state between mid-west and the cities of Philadelphia and New York plus the New England States.

2. Major Interstate Routes

East-West - I-90, 80, 76, 70
North-South - I-79, 81, 83, 95

B. 1. Slide 2 shows the areas of the 26 mobile teams

26 Mobile Teams
2 Interstate Mobile Teams
1 Permanent Weigh Station

2. Cooperative Effort with Teams Headquartered at St. Police Barracks

3. a. Mobile Teams = 1 State Trooper and 2 Pa. DOT
b. Mobile I. Team = 2 State Troopers and 4 Pa. DOT
c. Permanent I. Team = 2 State Troopers and 2 Pa. DOT

4. Teams work irregular schedule (7 1/2 hours/day)

5. a. Green Areas are Urban Areas
b. Blue Areas are coal regions

C. Slide 3 shows equipment available:

1. Portable Scales

366	G.E.C.	(385 -19)
140	Haenni	(60 +80)
85	Load-O-Meter	(State Police)
46	Others	(Metrodyne and Load-O-Meter)
637	Units	(283 sets used by our Enforcement Teams) (35 sets used by Districts for Quality Assurance)

2. W.I.M. Portable Scales

3 - P.A.T.
1 - Eldec
4 Units

3. Permanent Scales

   1 W.I.M. Screening
   1 Static Platform - Streeter Amet
   (3 Sections 16 - 10 - 34)

D. Slide 4 shows Specific Limits:

Width	- 8' ; 8'-6" (102") Interstate
Height	- 13'-6"
Length	- Motor Vehicle 40', Combination 60'
Maximum Gross	- 73,280 vehicle; 80,000 Combination
Maximum Axle	- Under 73,280 - 1 of 2 = 18,000
	2 of 2 = 22,400
	Over 73,280 - Federal Bridge Formula
Maximum Wheel	- 800#/inch of Tire width

II. HOW TO IMPROVE PROGRAM?

A. Slide 5

- Semi-permanent weigh sites
- Safety Inspection
- Communications
- Computerization of
  - Team Productivity
  - Magistrates/Courts
  - Location/Truck Volumes
- Legislative Liaison

B. Team Productivity

1. Slide 6 - Monthly Computer Listing
   (Stopped/Weighed/Weight Violations)

2. Slide 7 - Inspected/Violations
   Measured/Violations

3. Slide 8 - Graphic - Weight Violations

4. Slide 9 - Summary of Yearly Values

5. Slide 10- Area Supervisor's Monthly Summary

6. Slide 11- Fiscal Year Graph of Similar Teams - Interstate
   Weighed/Citations

7. Slide 12- Fiscal Year Graph Interstate Inspections

8. Slide 13- Fiscal Year Graph - Portable Scales Only Stopped/Weighed

9. Slide 14- Court Findings

III. IS PROGRAM SUCCESSFUL?

1. Slide 15- Annual Trends - Interstate Permanent Station

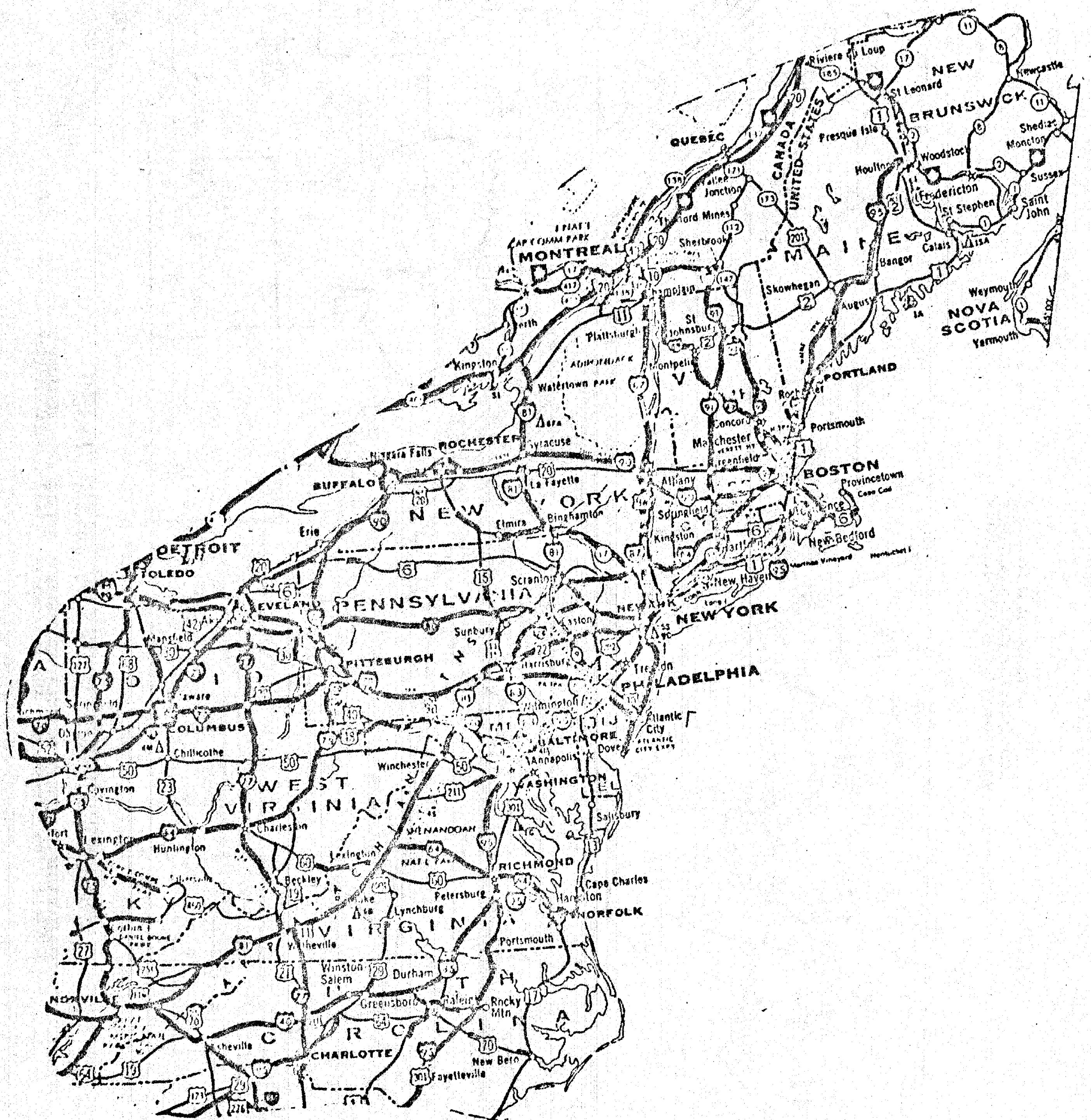
2. Slide 1(- Annual Trends - Interstate Mobile

3. Slide 17- Annual Trends - County Mobile Teams with Portable Scales Only

4. Slide 18- Statistical Evaluation of Program

5. Slide 19- Independent Check

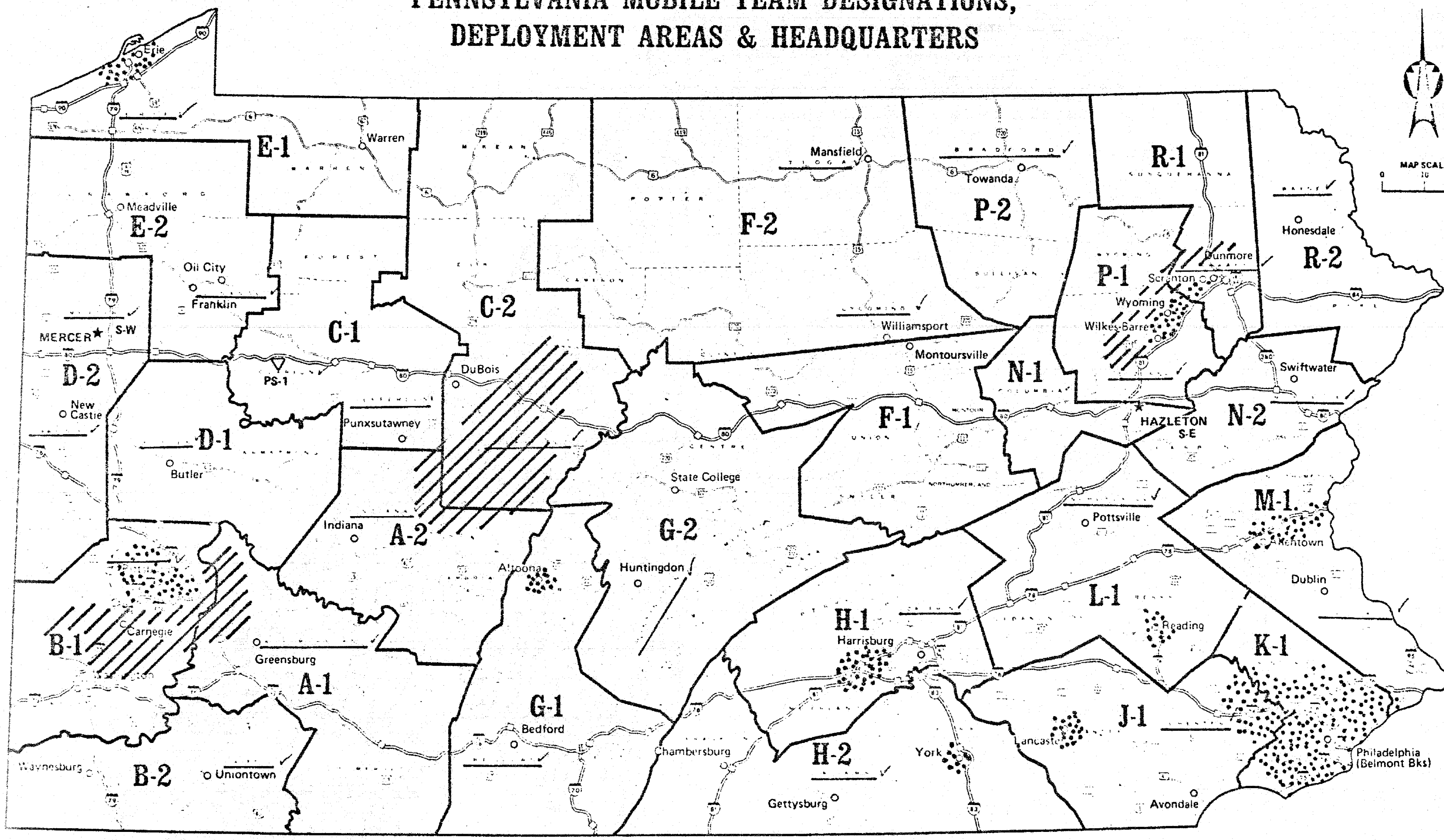
IV. SUMMARY



N.E. United States with Major Corridors

Slide 1

PENNSYLVANIA MOBILE TEAM DESIGNATIONS, DEPLOYMENT AREAS & HEADQUARTERS



10/81

★ HAZLETON—INTERSTATE TEAM "S"—EAST
★ MERCER—INTERSTATE TEAM "S"—WEST
▽ PERMANENT WEIGH STATION

EXHIBIT 1

Prepared By
PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF ADVANCE PLANNING

PENNSYLVANIA'S EQUIPMENT

1. Portable Scales

366 G.E.C.	(385 - 19)
140 Haenni	(60 + 80)
85 Load O Meter	(State Police)
46 Others	(Metrodyne & Load-O-Meter)
637 Units	(283 sets used by our Enforcement Teams)
	(35 Sets used by Districts for Quality Assurance)

2. WIM Portable Scales

3 - P.A.T.
1 - Eldec
4 Units

3. Permanent Scales

1 WIM Screening
1 Static Platform - Streeter Amet
(3 Section 16 - 10 - 34)

Slide 3

Specific Limits:

Width	8' ; 8'-6" (102") Interstate
Height	13' - 6"
Length	Motor Vehicle 40', Comb. 60'

Maximum Gross - 73,280 Vehicle; 80,000 Comb.

Maximum Axle - Under 73,280 - 1 of 2 = 18,000
2 of 2 = 22,400
Over 73,280 - Fed. Br. Form.

Maximum Wheel - 800#/in of Tire Width

Slide 4

HOW TO IMPROVE PROGRAM

- Semi-permanent weigh sites
- Safety Inspection
- Communications
- Computerization of
    - Team Productivity
    - Magistrates/Courts
    - Location/Truck Volumes
- Legislative Liaison

RUN DATE 04/08/83 — BUREAU OF HIGHWAY SERVICE, PENNSYLVANIA DEPARTMENT OF TRANSPORTATION — MARCH 1983

TRUCK WEIGHT ENFORCEMENT ACTIVITIES

	*** PORTABLE ***					*** PLATFORM ***				
TEAM	TRUCKS STOPPED	TRUCKS WEIGHED	TRUCKS CITED	PERCENT IN VIOLATIONS	FACE VALUE OF FINES	TRUCKS STOPPED	TRUCKS WEIGHED	TRUCKS CITED	PERCENT IN VIOLATIONS	FACE VALUE OF FINES
A1	125	38	11	28.9	17,675.00	13	7	2	28.6	300.00
A2	123	29	12	41.4	14,350.00	0	0	0	0.0	0.00
B1	79	29	23	79.3	29,800.00	0	0	0	0.0	0.00
B2	175	41	5	12.2	525.00	73	73	0	0.0	0.00
C1	188	125	47	37.6	8,325.00	0	0	0	0.0	0.00
C2	254	45	24	53.3	4,550.00	0	0	0	0.0	0.00
D1	422	16	8	50.0	2,175.00	2,802	2,483	40	1.6	12,650.00
D2	351	37	7	18.9	5,175.00	2,030	1,959	56	2.9	104,875.00
E1	182	62	36	58.1	15,350.00	0	0	0	0.0	0.00
E2	278	38	24	63.2	9,450.00	0	0	0	0.0	0.00
F1	297	30	19	63.3	15,125.00	0	0	0	0.0	0.00
F2	185	3	1	33.3	300.00	1,517	1,517	18	1.2	5,750.00
SW	5,962	5,546	11	0.2	12,175.00	0	0	0	0.0	0.00
G1	208	12	11	91.7	26,075.00	0	0	0	0.0	0.00
G2	326	17	11	64.7	5,850.00	0	0	0	0.0	0.00
H1	300	44	21	47.7	12,775.00	0	0	0	0.0	0.00
H2	257	11	6	54.5	4,600.00	0	0	0	0.0	0.00
J1	280	100	26	26.0	17,050.00	0	0	0	0.0	0.00
K1	117	60	3	5.0	1,350.00	41	20	2	10.0	150.00
L1	394	47	26	55.3	11,625.00	0	0	0	0.0	0.00
M1	1,102	821	30	3.7	10,350.00	0	0	0	0.0	0.00
N1	339	18	11	61.1	5,550.00	1	1	1	100.0	25.00
N2	481	25	8	32.0	2,000.00	0	0	0	0.0	0.00
P1	302	32	15	46.9	925.00	0	0	0	0.0	0.00
P2	356	50	16	32.0	2,550.00	0	0	0	0.0	0.00
R1	355	40	24	60.0	7,675.00	0	0	0	0.0	0.00
R2	461	12	6	50.0	1,550.00	0	0	0	0.0	0.00
SE	10,606	10,606	21	0.2	15,425.00	0	0	0	0.0	0.00
PS1	0	0	0	0.0	0.00	17,785	17,785	46	0.3	20,200.00
TOTAL	24,505	17,934	463	2.6	260,325.00	24,262	23,845	165	0.7	143,950.00
PORTABLE + PLATFORM										
TOTALS	48,767	41,779	628	1.5	404,275.00					

RUN DATE 04/08/83 BUREAU OF HIGHWAY SERVICE, PENNSYLVANIA DEPARTMENT OF TRANSPORTATION MARCH 1983

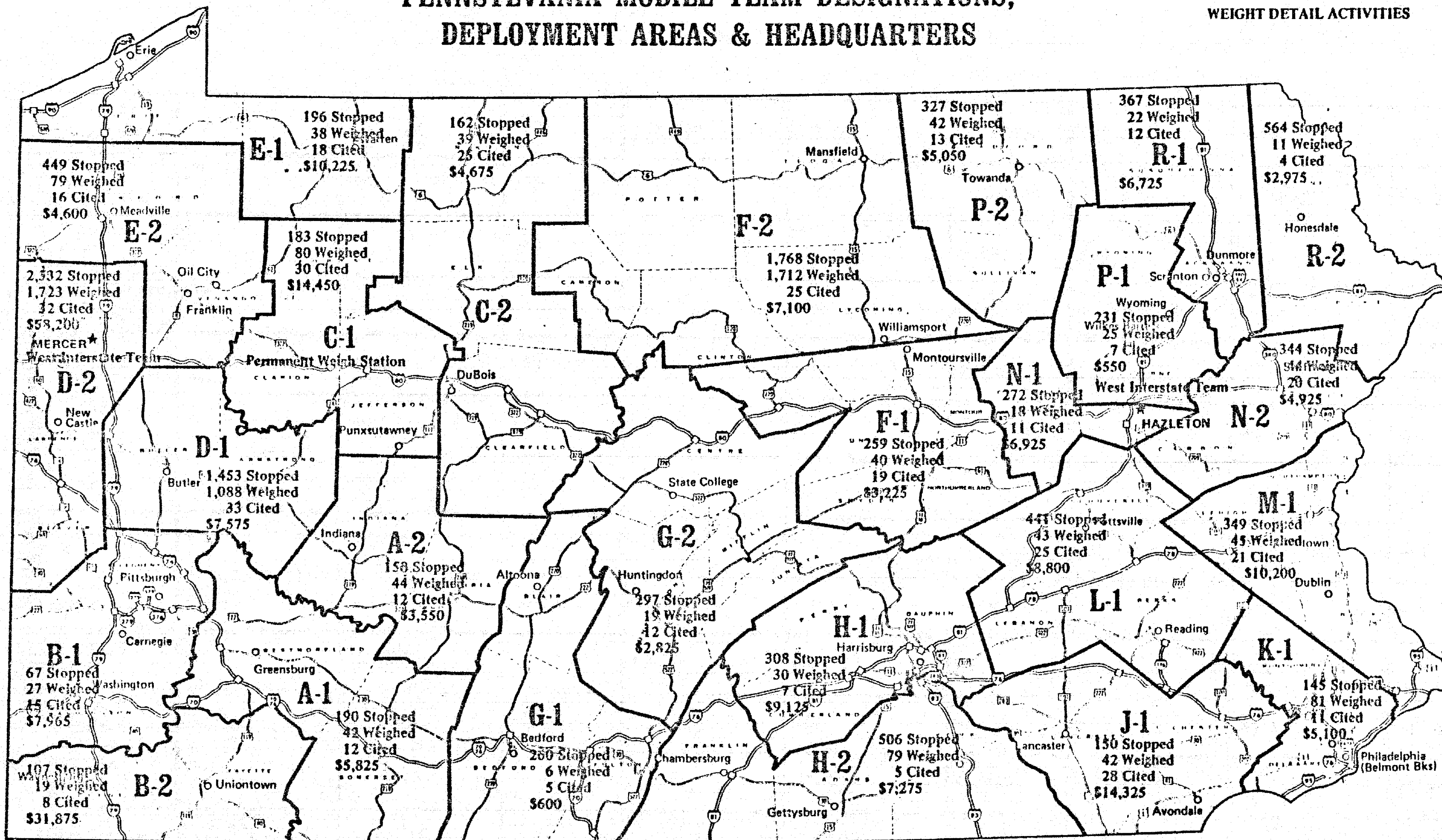
TRUCK INSPECTION AND MEASUREMENT ACTIVITIES

TEAM	TRUCKS INSPECTED	INSPECTION VIOLATIONS	PERCENT IN VIOLATIONS	FACE VALUE OF FINES	TRUCKS MEASURED	MEASUREMENT VIOLATIONS	PERCENT OF VIOLATIONS	FACE VALUE OF FINES
A1	76	10	13.2	450.00	19	8	42.1	500.00
A2	123	24	19.5	1,250.00	5	1	20.0	100.00
B1	76	25	32.9	900.00	6	5	83.3	400.00
B2	139	11	7.9	200.00	1	0	0.0	0.00
C1	18	3	16.7	0.00	5	0	0.0	0.00
C2	11	0	0.0	0.00	25	7	28.0	350.00
D1	305	305	100.0	7,275.00	29	5	17.2	400.00
D2	42	25	59.5	925.00	43	1	2.3	100.00
E1	29	1	3.4	25.00	35	6	17.1	350.00
E2	23	3	13.0	0.00	6	0	0.0	0.00
F1	7	3	42.9	75.00	12	0	0.0	0.00
F2	48	9	18.8	250.00	59	15	25.4	800.00
SW	472	145	30.7	9,550.00	68	1	1.5	100.00
G1	44	16	36.4	800.00	12	4	33.3	0.00
G2	90	27	30.0	175.00	26	6	23.1	300.00
H1	25	20	80.0	25.00	61	0	0.0	0.00
H2	47	11	23.4	0.00	15	0	0.0	0.00
J1	7	3	42.9	150.00	15	5	33.3	400.00
K1	2	2	100.0	50.00	10	0	0.0	0.00
L1	20	13	65.0	0.00	27	0	0.0	0.00
M1	76	10	13.2	250.00	56	4	7.1	100.00
N1	37	6	16.2	75.00	7	1	14.3	50.00
N2	108	71	65.7	1,975.00	54	5	9.3	250.00
P1	76	11	14.5	100.00	25	3	12.0	150.00
P2	22	10	45.5	0.00	23	0	0.0	0.00
R1	88	37	42.0	825.00	122	2	1.6	50.00
R2	160	42	26.3	1,375.00	65	3	4.6	150.00
SE	108	69	63.9	1,700.00	28	5	17.9	250.00
PS1	207	66	31.9	50.00	5,168	51	1.0	2,550.00
TOTAL	2,486	978	39.3	28,450.00	6,027	138	2.3	7,350.00

Slide 7

PENNSYLVANIA MOBILE TEAM DESIGNATIONS, DEPLOYMENT AREAS & HEADQUARTERS

WEIGHT DETAIL ACTIVITIES



East Interstate Team
6,873 Stopped
6,680 Weighed
16 Cited
$9,150

West Interstate Team
7,449 Stopped
6,909 Weighed
8 Cited
$12,750

★ HAZLETON–INTERSTATE TEAM "S"–EAST
★ MERCER–INTERSTATE TEAM "S"–WEST

Permanent Weigh Station (Clarion)
15,830 Stopped
15,830 Weighed
43 Cited
$28,975

TRUCK WEIGHT ACTIVITIES

Month: March, 1983

	PERMANENT STATION (PS-1)			INTERSTATE MOBILE			COUNTY MOBILE TEAMS		
Category	March 1983	March 1982	Difference	March 1983	March 1982	Difference	March 1983	March 1982	Difference
No. Trucks Stopped/WIM	17,785	12,659	+5,126	16,568	9,283	+7,285	14,414	11,722	+2,692
No. Trucks Weighed/Reweighed	5,168	4,345	+823	114	163	-49	36,497	23,240	+13,257
Number of Weight Viol.	46	55	-9	32	41	-9	550	448	+102
Percent of Weight Viol.	0.26%	0.43%	-0.17%	0.19%	0.44%	-0.25%	N.A.	N.A.	N.A.
Face Value of Weight Fines	$20,200	$22,875	-$2,675	$27,600	$23,950	+$3,650	$356,475	$358,450	-$1,975
Number of Trucks Measured	5,168	4,345	+823	96	96	0	763	747	+16
Number of Meas. Viol.	51	10	+41	6	7	-1	81	60	+21
Face Value of Meas. Viol.	$2,550	$500	+$2,050	$350	$350	$0.00	$4,450	$4,500	-$50
Number of Trucks Inspected	207	90	+117	580	163	+417	1,699	1,789	-90
Number of Insp. Viol.	66	23	+43	214	51	+163	698	347	+351
Face Value of Insp. Viol.	$50	$0.00	+$50	$11,250	$760	+$10,490	$17,150	$3,870	+$13,280
Total - Face Value of Viol.	$22,800	$23,375	-$575	$39,200	$25,060	+$14,140	$378,075	$366,820	+$11,255

TEAM C-1
Area Supervisor R.E. Tischler

Month Dec. 1982
Members WEA 2 L. Timmins
WEA 1 W. Minster
Tpr. D. McCleary

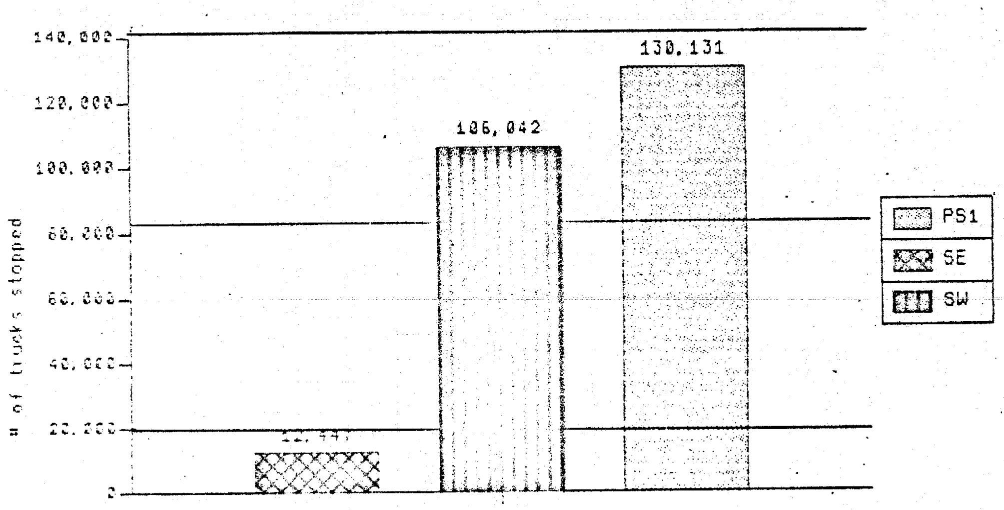
Day	County	Highway Location (US, PA, etc.)	Hours	DOW	S	W/V	M/V	I/V
12-1	Jefferson	PA-36	2P9	4	1			
	Clarion	I-80			8	1/1		
12-2	Jefferson	US-119 (PB) LR33005 PR	8A4	5	22	9/1		
12-3	Jefferson	US-119	6A2	6	2	1/0	1/0	
	Indiana	PA-336			9	5/1	3/1	2/1
12-6	Jefferson	PA-536	1P9	2	1	1/1		
	Clarion	LR 58 I-80			8	3/1	1/0	
12-7	Jefferson	US-119 LR 33088	8A4	3	14	2/2		
12-8	Jefferson	US-322	8A4	1	1	1/1		
12-10	Jefferson	US-119	7A3	6	9	6/4		
	Indiana	Glen Campbell Boro.			2	2/2		
12-13	Clarion	I-80	1P16	2	12			4/6
12-14	Jefferson	PA-36	8A4	3	2		2/0	
12-15	Clarion	I-80	7A3	4	6	3/2		
12-16	Jefferson	PA-36	7A3	5	2			
	Forest	PA-66			1	1/1		
	Clarion	I-80			3	1/1		
12-20	Clarion	PA-68	8A4	2	1	1/1		
12-22	Forest	PA-899 PA-66	7A3	4	4	2/0	1/1	
	Clarion	PA-66			1			
12-23	Jefferson	LR 16004 PA-36	7A3	5	3	3/3		

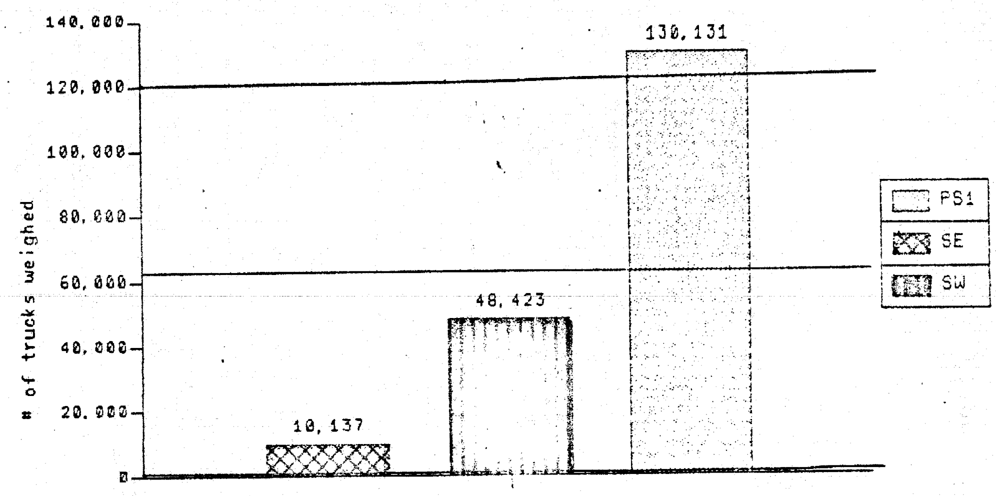
Totals			S	W/V	M/V	I/V
Jefferson Co.	10	(No. of Days)	57	23/12	3/0	
Clarion Co.	7	(No. of Days)	39	9/6	[illegible]/0	4/6
Indiana Co.	2	(No. of Days)	11	7/3	3/1	2/1
Forest Co.	2	(No. of Days)	5	3/1	1/1	
Co.		(No. of Days)				
			112	42/22	8/2	6/1

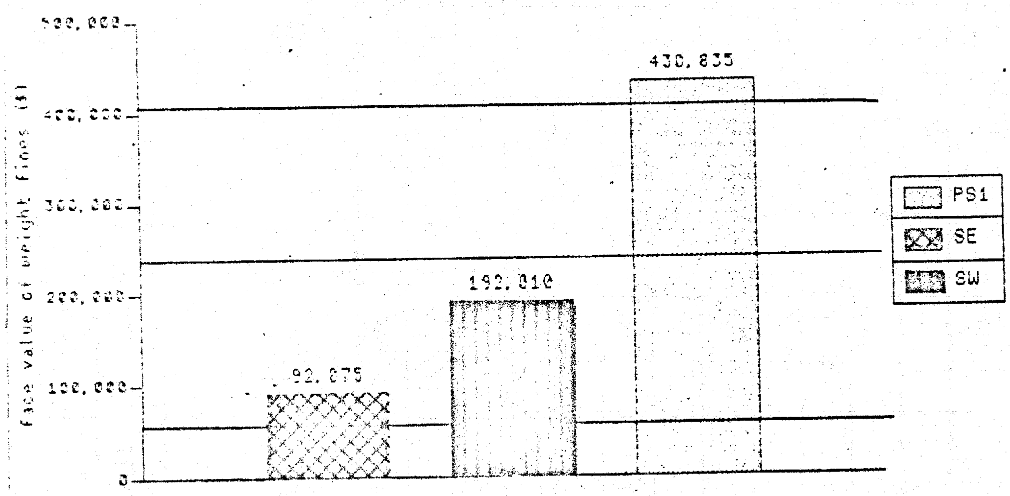
or.: PB = Posted Bridge, PR = Posted Road, W = Location of Weight Citation
M = Location of Measured Citation
I = Location of Inspection Citation

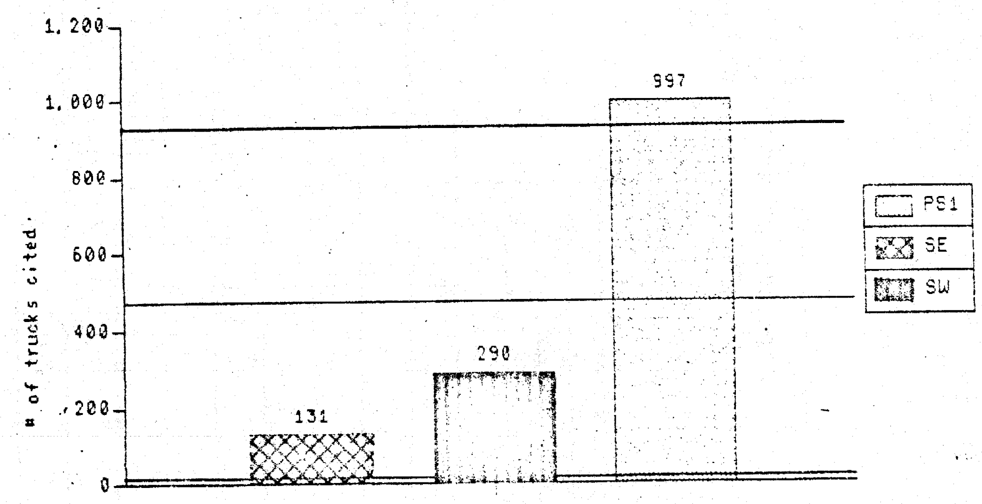
Fiscal Year Comparisons (81-82)

Interstate Teams





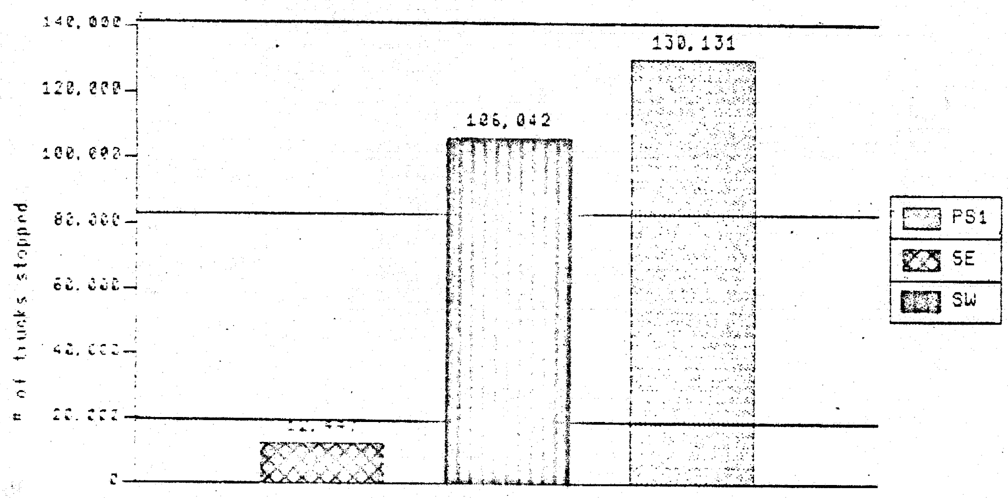


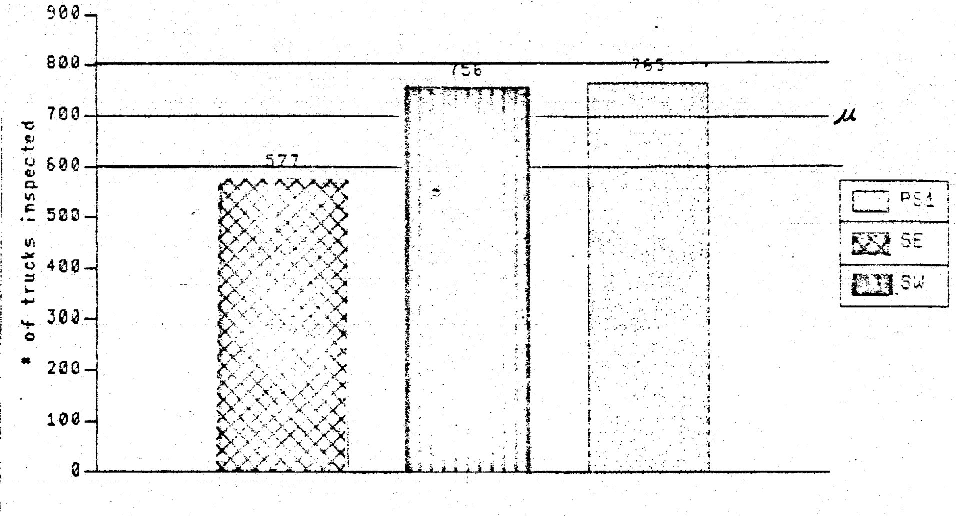


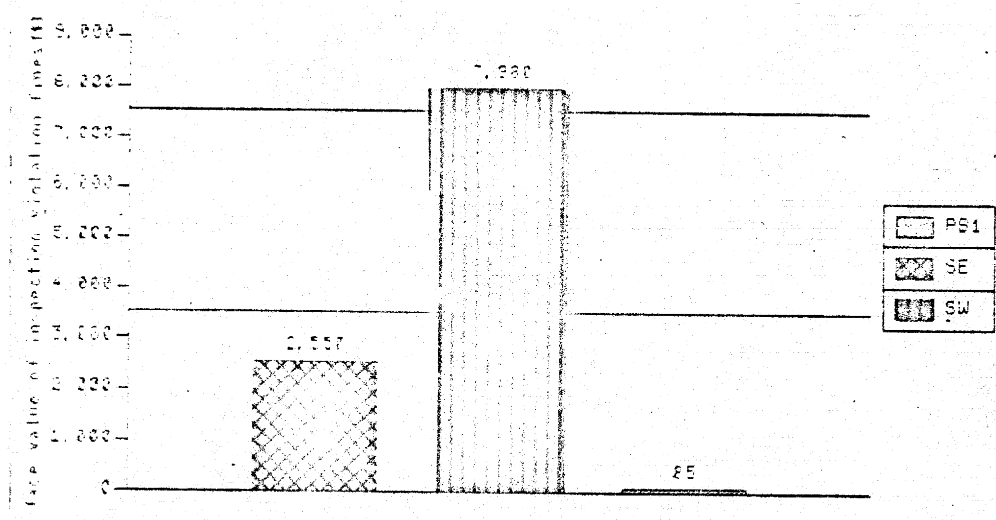
Slide 11

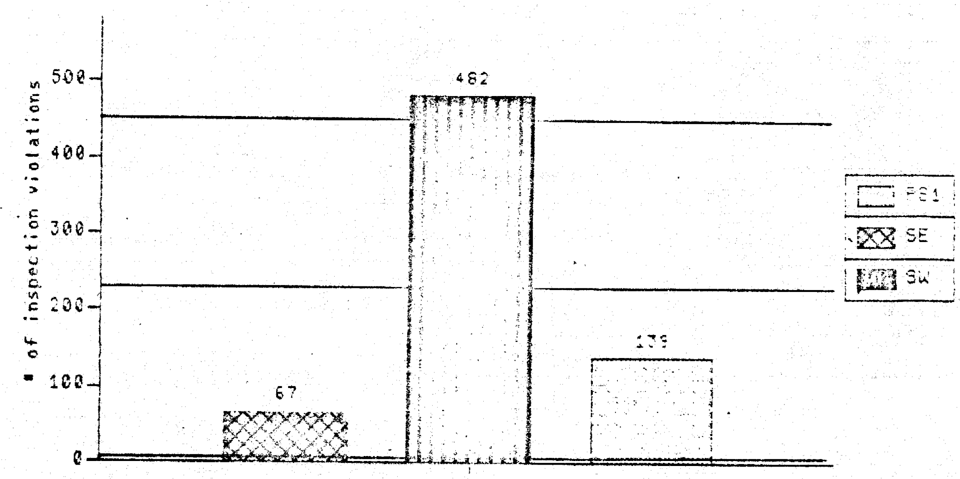
Fiscal Year Comparisons (81-82)

Interstate





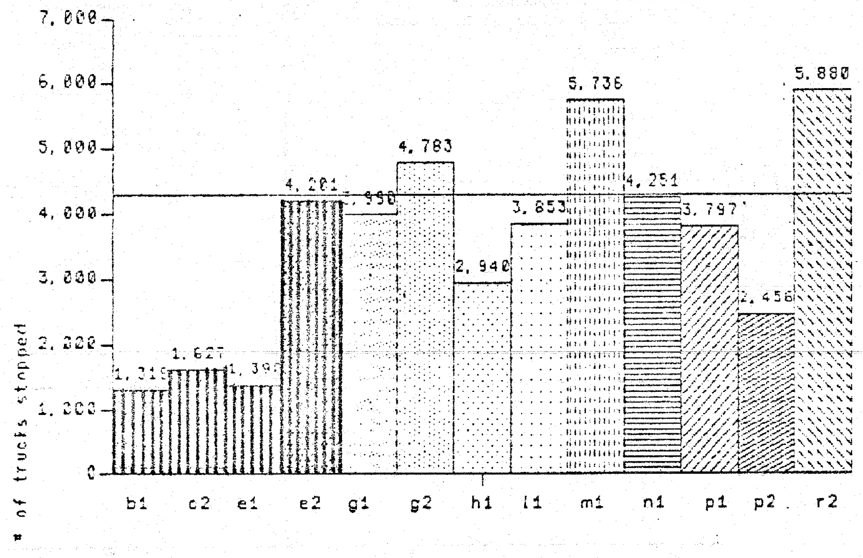


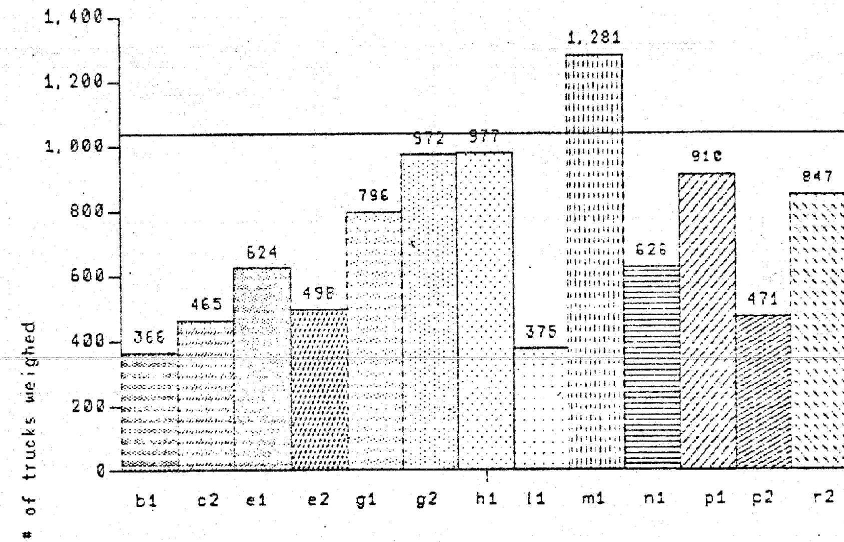


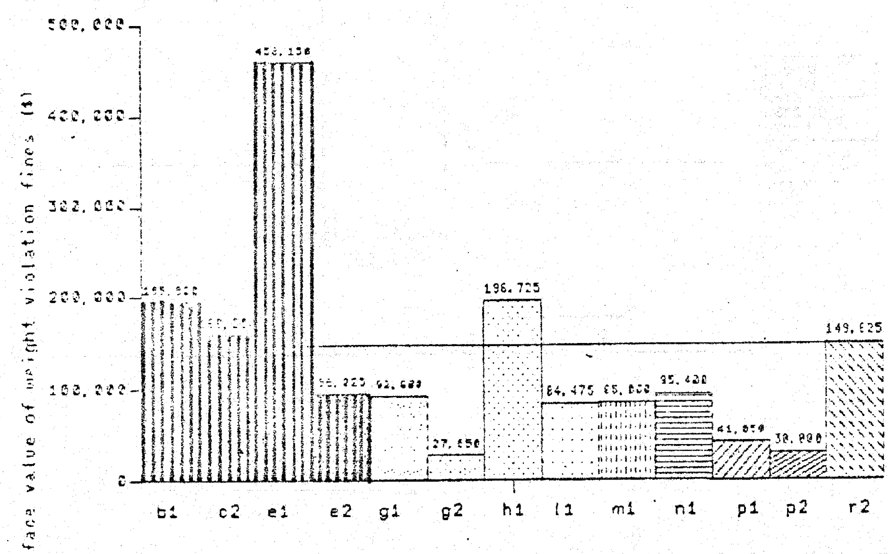
Slide 12

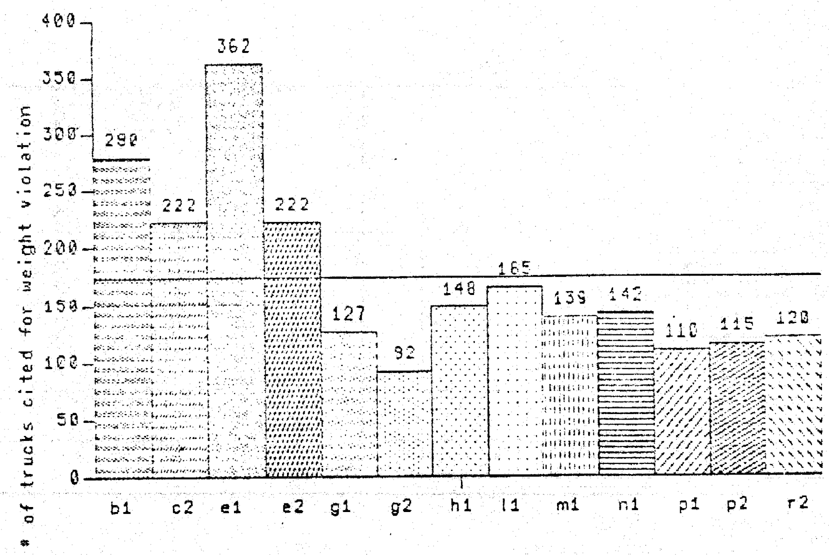
Fiscal Year Comparisons (81-82)

Portable Scales Only





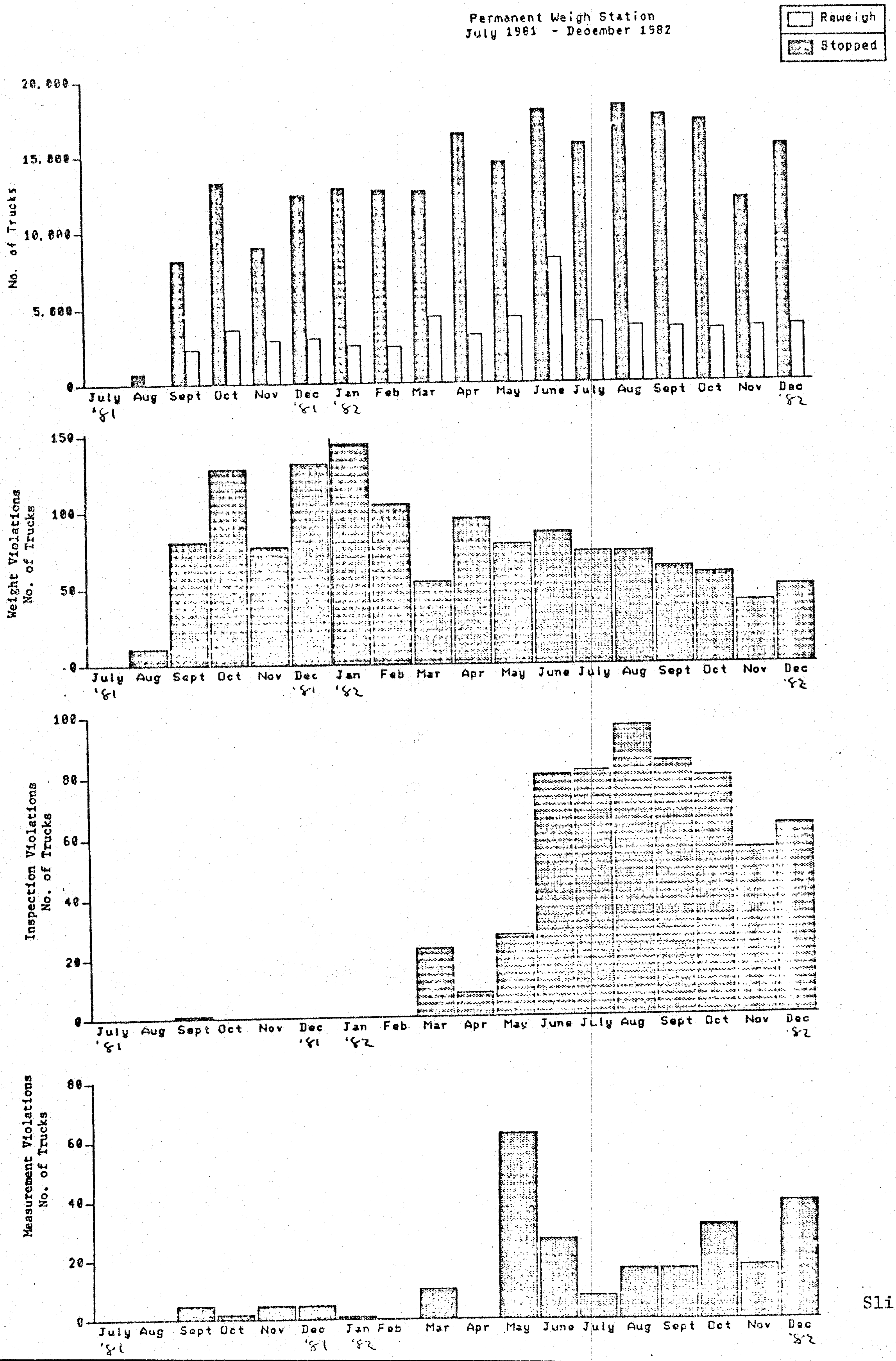




SUMMARY OF GUILTY/NOT GUILTY
FINDINGS BY MAGISTRATE

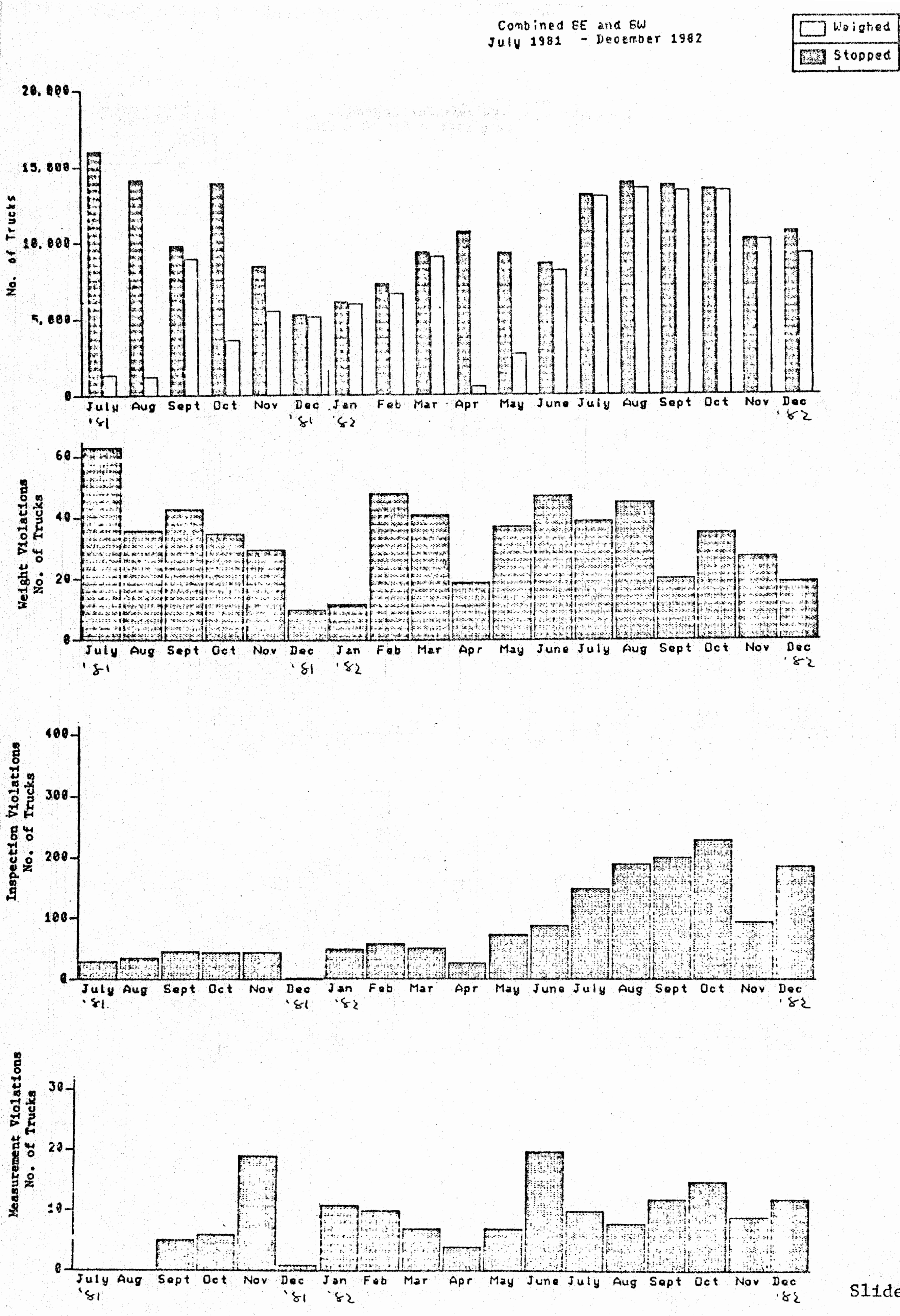
MAGSTR NUMBER	VEH/CD SECTION	GUILTY	NOT GUILTY	TOTAL
11304	4942A	4 80.00%	1 20.00%	5
11304	4943B1	1 100.00%	0 .00%	1
11304		5 83.33%	1 16.66%	6
11305	4941A	2 100.00%	0 .00%	2
11305		2 100.00%	0 .00%	2
11306	4941A	1 100.00%	0 .00%	1
11306	4942A	2 100.00%	0 .00%	2
11306	4943A2	20 95.23%	1 4.76%	21
11306	4943B1	1 100.00%	0 .00%	1
11306		24 96.00%	1 4.00%	25

Totals	1347	260	1607
	84%	16%	

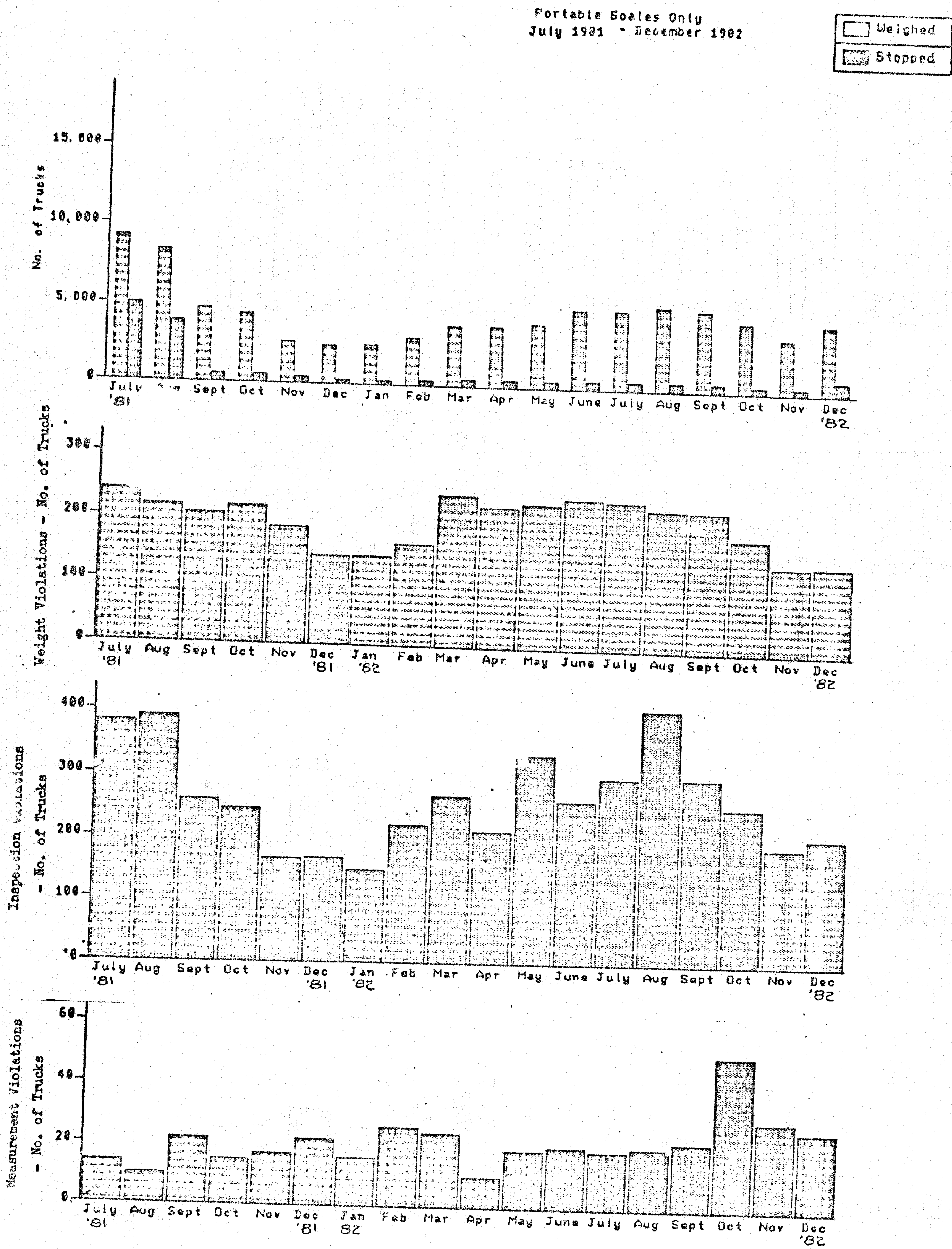


Permanent Weigh Station
July 1981 - December 1982
Reweigh
Stopped
No. of Trucks
20,000
15,000
10,000
5,000
0
July '81
Aug
Sept
Oct
Nov
Dec '81
Jan '82
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec '82
Weight Violations No. of Trucks
150
100
50
0
Inspection Violations No. of Trucks
100
80
60
40
20
0
Measurement Violations No. of Trucks
80
60
40
20
0

Slide 1


Combined SE and SW
July 1981 - December 1982
Weighed
Stopped
No. of Trucks
20,000
15,000
10,000
5,000
0
July '81 Aug Sept Oct Nov Dec '81 Jan '82 Feb Mar Apr May June July Aug Sept Oct Nov Dec '82
Weight Violations
No. of Trucks
60
40
20
0
July '81 Aug Sept Oct Nov Dec '81 Jan '82 Feb Mar Apr May June July Aug Sept Oct Nov Dec '82
Inspection Violations
No. of Trucks
400
300
200
100
0
July '81 Aug Sept Oct Nov Dec '81 Jan '82 Feb Mar Apr May June July Aug Sept Oct Nov Dec '82
Measurement Violations
No. of Trucks
30
20
10
0
July '81 Aug Sept Oct Nov Dec '81 Jan '82 Feb Mar Apr May June July Aug Sept Oct Nov Dec '82

Slide 16


Portable Scales Only
July 1981 - December 1982
Weighed
Stopped
No. of Trucks
15,000
10,000
5,000
0
July '81
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec '82
Weight Violations - No. of Trucks
300
200
100
0
July '81
Aug
Sept
Oct
Nov
Dec '81
Jan '82
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec '82
- No. of Trucks
400
300
200
100
0
July '81
Aug
Sept
Oct
Nov
Dec '81
Jan '82
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec '82
Measurement Violations
- No. of Trucks
60
40
20
0
July '81
Aug
Sept
Oct
Nov
Dec '81
Jan 82
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec '82

Slide 17

Correlation Between Number of Trucks
Weighed and % of Trucks in
Violation July, 81 - Dec., 82

1) All Teams Combined r = -0.85

2) PS-1 r = -0.63

3) SE + SW r = -0.69

4) 26 Mobile Teams r = -0.81

Pennsylvania's Truck Weight Study*
Vehicles Exceeding Weight
Limits

YEAR	VEHICLES WEIGHED (a)	VEHICLES IN VIOLATION	NO. Vehicles Weighed - (% in Violation)
(1) 5 AXLE SEMITRAILER			**COMMODITY (b)**
1982	6,786	449 (7%)	Coal -52 (46%); Petroleum -37 (19%); Farm Products -11 (15%)
1980	3,551	539 (15%)	—
1976	4,149	452 (11%)	—
(2) 4 AXLE SINGLE UNIT (Tri Axle)			**COMMODITY (2)**
1982	179	52 (29%)	Lumber -6 (100%); Coal -15 (83%); Food Products -3 (50%)
1980	151	64 (42%)	—
1976	36	11 (31%)	—
(3) 3 AXLE SINGLE UNIT			
1982	422	52 (12%)	Lumber -3 (43%); Coal 1 (17%); Food Products -5 (14%)
1980	144	31 (22%)	—
1976	240	35 (15%)	—

(a) At 28 locations in 1982, 23 locations in 1976 and 1980

(b) Includes only top 3 commodities percent in violation of all vehicles with indicated commodity; commodity listing available for 1982 only.

*Planning study done every two years for FHWA Report.

UNITED KINGDOM SYSTEM OF TRUCK WEIGHT ENFORCEMENT BY LOW-SPEED IN MOTION WEIGHING

MR. JACK WINDER
DEPARTMENT OF TRANSPORT
LONDON, ENGLAND

UNITED KINGDOM SYSTEM OF TRUCK WEIGHT ENFORCEMENT BY LOW-SPEED IN MOTION WEIGHING

Paper by J Winder, Department of Transport, London

Is truck overloading a serious problem in the UK?

Driving an overloaded truck is a serious offence under United Kingdom law. The truck operator and driver can face fines of up to a maximum of £1,000 (approximately $1,500 (dollars)) for each offence.

The UK Government has made its position towards truck overloading very clear. In a recent Debate in Parliament leading to an increase in UK truck maximum weights from 32.5 tonnes (71,649 US lbs) to 38 tonnes (83,775 US lbs) for 5 axle trucks it was emphasised that roadside enforcement would be increased. More Traffic Examiners would be recruited and development of the national network of inspection sites would be increased.

The decision to increase truck maximum weights in the UK was to allow trucks to carry more payload. Increasing the numbers of axles to 5, and which qualified for certain vehicle tax advantages, would ensure that new and heavier vehicles would be less damaging to roads. The UK Government is therefore committed to stronger enforcement against truck overloading because overloading:

i. increases wear and damage to roads;

ii. is unfair competition, since the truck which complies with UK weight limits carries a smaller payload and the overloaded truck has an unfair commercial advantage - there is some truth in the saying that 'one trucker's overload is another's job'; and

iii. serious overloading can affect a truck's performance on the road and put the safety of other road users at risk.

All UK truck operators are expected to comply with UK weight limits laid down in the Motor Vehicle Construction and Use Regulations 1978 (as amended in 1982). A conviction for overloading before the Courts can result in a heavy fine for the trucker and operator/owner. The operator's 5 year licence to operate can also be put at risk. This is because he would have failed to comply with the undertaking he gave when he applied for a licence in road haulage, that his trucks would not be overloaded.

How does the UK Enforcement system work?

The United Kingdom is divided into 11 geographical Traffic Areas, covering England, Scotland and Wales, for truck licensing and freight and passenger vehicle enforcement purposes. Each Traffic Area has its own Licensing Authority with wide powers to grant licences or take them away for serious offences including overloading. Each Area has its own technical and non-technical staff of the Department of Transport who carry out regular checks on trucks and passenger coaches at the roadside and at depots. Before he can be issued with a licence a truck operator must make an application and show to the Licensing Authority that he is of good character; has adequate finance to operate and maintain the number of trucks he wants licensed safely; he must give undertakings that his truckers will not drive excessive hours - truckers' hours of driving are regulated now by United Kingdom and European Community law - and last but not least, that his trucks will not be overloaded. The depot from which he operates and his truck maintenance facilities will be inspected. Increased concern has been shown in the UK with the effects of heavy trucks on roads, the local environment and in some areas people's homes. This has led to tighter controls due to be introduced shortly on truck operating centres. New Regulations will give people who stand to be affected by noise, fumes and other bad effects of trucks a stronger right to object to licences being granted.

Department of Transport Traffic Examiners (non-technical) provide support for the Licensing Authorities throughout the UK. They and Vehicle Examiners (technical) hold regular programmes of enforcement checks on trucks mostly at special inspection sites. Most sites are being equipped with dynamic axle weighbridges. Examiners work in teams with the traffic Police who have powers to stop vehicles on the highway. Trucks are either brought off the highway under Police escort to the check site or signs are used to warn drivers to be prepared to stop and to direct them in for checking. Most checks are held during the working day, although special checks are often held at night or in the early hours. The aim is to make a comprehensive check on the truck - its weight and mechanical condition - and the drivers' records and other documentation. In the United Kingdom, as elsewhere in the European Community, most drivers are required to use a tachograph which is fitted in the cab and automatically records how long he has been driving. This instrument records distance, time and speed of the truck. The chart used in the tachograph is checked along with the truck's loaded weight and other aspects at an inspection site.

A truck found to be overloaded between 5 - 10% is likely to be placed under immediate prohibition by the Traffic Examiner. Some checks are made at the roadside and lay-bys without axle weighbridges and Examiners have powers to direct trucks suspected of being overloaded to the nearest weighbridge within 5 miles. But if the truck is then found not to be overloaded the law provides for the truck operator to claim costs. The law also provides a defence against prosecution when a trucker can show that he was on his way to the nearest weighbridge when he was stopped at an Enforcement check. Axle overloading is a major problem and trucks found to have overloaded axles, but to be operating within the gross weight limit must have the load adjusted to remove the overloaded axle before being permitted to continue.

UK Axle Weighbridge Sites

The Department of Transport is currently giving priority to developing a national network of check sites with dynamic axle weighbridges. This is part of a 5 year programme at a cost of $1½ million (dollars) per annum. More than 40 dynamic axle weighbridge sites have already been constructed at major ports and strategic sites mostly on major routes. A further 18 are under construction with up to 80 more sites being considered for the future programme.

Checks are also made at all major ports of entry into the United Kingdom and both British and foreign trucks are checked. Because the maximum permitted weight in some European countries is higher than in the UK, for example in Holland and Spain, many trucks reach the United Kingdom overloaded compared with the UK weight limits. Foreign truckers are therefore encouraged to make arrangements to have overloads removed before they leave the port and break UK weight law by travelling on the highway. Enforcement checks are often held just outside ports, and trucks suspected of being overloaded are sent back into the port to be check-weighed and if overloaded, are prohibited there until the excess load has been removed and transferred to another truck.

Equipment is now being connected to the Department of Transport enforcement weighbridge at most ports and at selected inland sites which allows truckers to check their axle and gross weights for themselves at any time of the day and night, free of charge. This equipment connects easily to the Weighwrite dynamic axle weighbridge which is used extensively by the Department. It is simple to use, and UK truckers appear to be making good use of it.

The Department is continuously exploring new methods of enforcement. Some portable weighers have been considered, but none has been found to be sufficiently easy to use and weigh far fewer vehicles than the fixed site using slow speed axle weighing equipment. One advantage of portable weighers is, however, that they can be operated in co-operation with fixed sites, say at locations where trucks are taking alternative routes to avoid roadside checks. Further investigations are to be made into possible use of mobile weighers.

An interesting experiment at one site has combined the use of a high speed weighing pad which gives a signal when crossed by a vehicle travelling at normal speed with an axle weighing more than 10 tonnes. An operator sits by the weighing pad and radios details of the vehicle to the check site some distance ahead. The trucker is told to stop and brought in and check-weighed. At this site an average of more than 40% of vehicles selected for weighing by this method have been found to be overloaded, compared with the national average of approximately 14% of vehicles found to be overloaded at other enforcement sites.

Size of UK Truck Weight Enforcement Effort

In 1982 Examiners checked 198,000 trucks and weighed 55,000, an increase of about 36% on the figure for 1981. There were 6,378 Court prosecutions issued against truck operators and drivers resulting in total fines of $619,197 (dollars) by the Courts. Average fines for overloading offences are expected to rise in the UK following the decision to increase the maximum fine by 150% from April this year. In addition to being fined, truckers and owners of overloaded can put their licences at risk.

Local Authority Consumer Protection Offices and some Police also have powers to weigh trucks. They are encouraged to use the Department of Transport's slow speed weighbridges and many conduct their own checks in co-ordination with the Department.

The UK does not have a system of instant fines for overloading or other offences. Penalties, including fines, are dealt with by the Courts. But in some Traffic Areas drivers of foreign trucks found to be overloaded - mostly from Ireland and Europe - are brought before special courts which sit during the period of the check and impse instant fines. These fines must be paid either by the trucker or his UK agent, and arrangements made to remove excess loads before the truck is allowed to proceed. All prohibited trucks have to be re-weighed before a prohibition can be lifted. Details of serious traffic offences, including overloading, committed by foreign drivers, when in the UK, are reported to the foreign government concerned, who may want to take action.

Why Low-Speed In Motion Weighing is used for UK Enforcement

The low-speed dynamic axle system of weighing offers a number of advantages to the enforcement agencies concerned with overloading. The first prototype equipment, manufactured by Weighwrite Limited of Farnham, England in 1973, was subject to extensive tests by the UK enforcement authorities before the necessary legislation which allows it to be used for enforcement was introduced. There were also detailed consultations with UK transport industry representatives. The advantages which this equipment offers includes the following:

i. Individual axles can be measured more accurately than by any other method. It eliminates errors and unrepeatability caused by the transfer of the load from one axle to another when the vehicle is stopped;

ii. Combinations of vehicles and axles are easily and speedily weighed at a speed of 2.5 miles per hour as the truck passes over the weighbridge. This means trucks can be weighed in less than 30 seconds, and with minimum delay for truckers, particularly those whose trucks are not overloaded and who can then quickly be sent on their way. The Department also uses a few static weighbridges at truck test stations, but these are much slower to use.

iv. Truckers are more likely to be prepared to co-operate at a check site if they can see the weighing operation and truck weight. This is increasing as more weighbridge sites come into operation. Truckers are less likely to seek alternative routes to avoid a check-site.

v. Encouraging drivers to use the equipment to check their weights has helped and is supported by the UK road transport industry and truckers' national associations who are encouraging their members to use the equipment.

vi. Large scale display indicators at the weighbridge site clearly show the individual axle and total gross weights of the trucks passing over the weighbridge. This can be seen by the trucker and Examiners and helps to speed the flow of vehicles through the check-site and to make all concerned aware of the recorded weights.

All this helps to improve the cost-effectiveness of the enforcement site and contributes to greater observance of truck weight laws by truckers and truck operators. This in turn leads to less excessive wear and damage to roads and hopefully, safer road conditions for all UK road users.

TRAFFIC AREA CO-ORDINATION DIVISION (TACD)
Department of Transport, London

July 1983

CONCEPTS, ADVANTAGES, AND APPLICATIONS OF WEIGH IN MOTION SYSTEMS

DR. CLYDE LEE
UNIVERSITY OF TEXAS AT AUSTIN
AUSTIN, TEXAS

NATIONAL WEIGH-IN-MOTION CONFERENCE

Denver, Colorado, July 11-15, 1983

WIM Technology Session, Wednesday, July 13, 1983

CONCEPTS OF WEIGH-IN-MOTION SYSTEMS

by

Clyde E. Lee
Phil M. Ferguson Professor in Civil Engineering
The University of Texas at Austin

In order to understand the complex technical requirements for a highway vehicle in-motion weighing system, it will be instructive to review some basic principles of physics and to define a few terms that are used in engineering mechanics to describe the static and dynamic behavior of objects which exist in the earth's gravitational field.

Weight is the force with which an object is attracted toward the earth by gravitation; it is equal to the product of the mass of the object and the local value of gravitational acceleration. For practical purposes in weighing highway vehicles, gravitational acceleration can be considered constant at 32.2 ft/sec^2 for all locations.

Mass is the measure of the resistance of an object to acceleration, or its inertia. Mass is commonly taken as a measure of the amount of material which makes up an object and causes it to have weight in a gravitational field.

Acceleration is the time rate of change of velocity.

Velocity is the time rate of change of displacement.

Force is that which changes, or tends to change, the state of motion of an object.

Newton's Laws are applicable in defining the state of motion of a highway vehicle at any given instant of time.

1. There is no change in the motion of an object unless an unbalanced force acts upon it.
2. Whenever an unbalanced force acts on an object, it produces an acceleration in the direction of the force; an acceleration that is directly proportional to the force and inversely proportional to the mass of the object.

These concepts can be applied to weighing highway vehicles and interpreted first for the static (no-motion) case and then for the dynamic (in-motion) case. A highway vehicle is made up of several interconnected components, each with its own mass. The connectors, which also have mass, can be viewed as springs, hinges, and motion dampers. A force applied to any component will be transferred to the others through the connectors. (See Fig 1)

STATIC WEIGHING

To weigh a vehicle, a total upward force exactly equal to the downward force of gravity is applied through the motionless (in the vertical direction) tires of the vehicle and measured simultaneously by scales (force transducers) or a balance. This is known as static, single-draft weighing and is the most accurate means of determining gross vehicle weight.

Gross weight can also be determined accurately by successively measuring the downward force on the tires with all the vehicle components motionless and in exactly the same relative position to each other throughout the entire weighing sequence. This condition of juxtaposition can be approximated in practice, but rarely achieved. The center of oscillation of the composite vehicle mass usually changes when the vehicle is moved; therefore, the distribution of the total downward force among the tires changes. Some sacrifice in weighing accuracy can thus be expected if the vehicle is moved between successive tire force measurements as is the case when using axle load or wheel load weighers. This is especially true when the vehicle is moved several times and the weighing surface of the scales is not in the same horizontal plane as the surrounding surfaces supporting the tires which are not being weighed at the time.

A typical spring rate for a rear truck wheel suspension is about 3,500 to 4,000 pounds per inch of displacement and each tire also has a rate of about 4,000 pounds per inch. The front suspension generally has a spring rate of about 500 pounds per inch. Thus, if one wheel of a vehicle is raised or lowered with respect to the others during weighing, the wheel force on the scale, or weigher, will be considerably different than when the wheel is not displaced. Particular attention must be given to this concept when weighing the wheels of tandem or triple axles if reasonable accuracy is to be achieved with wheel load weighers. The same principles also apply to weighing axles and axle groups

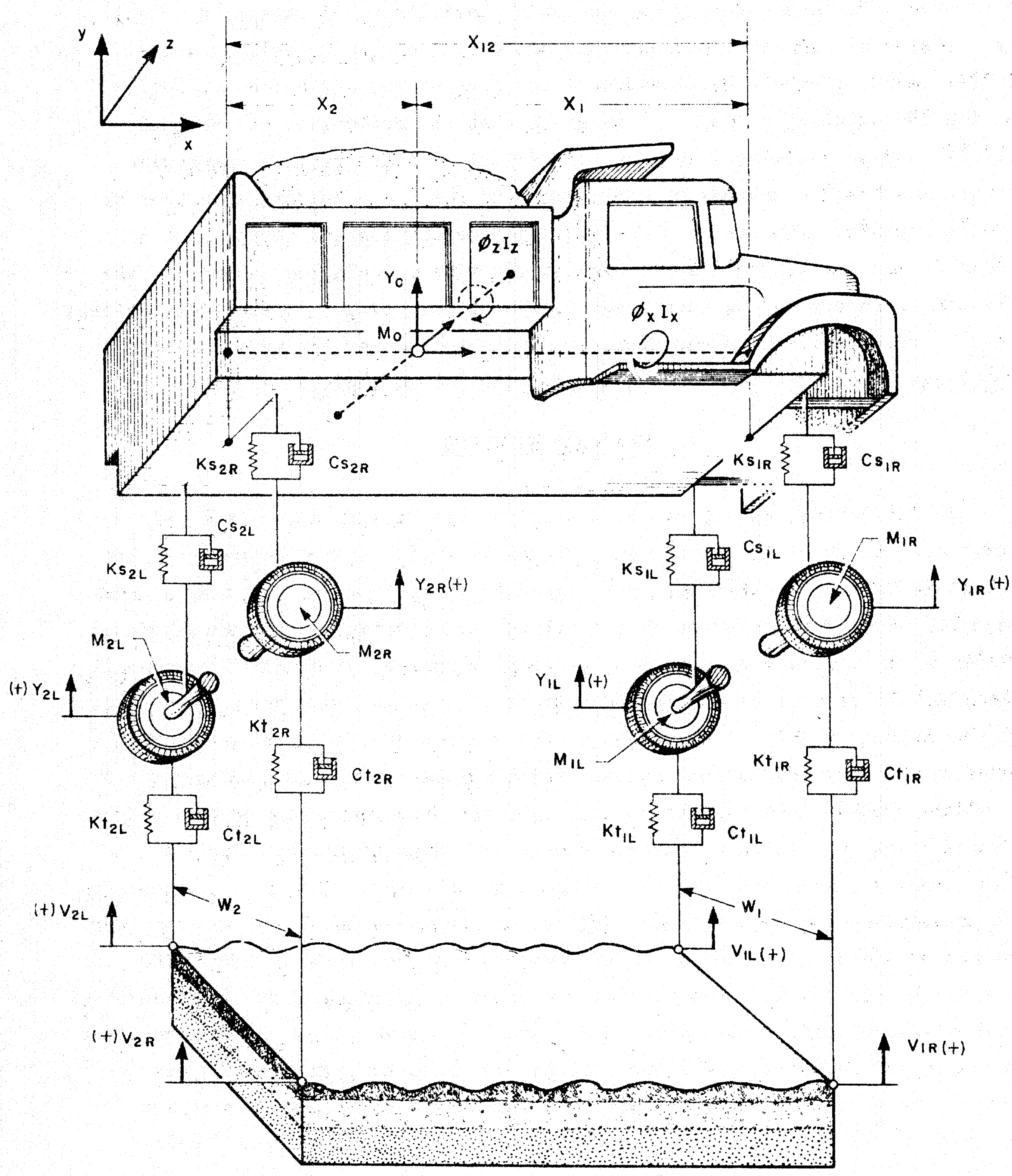

y
z
x
X12
X2
X1
ØzIz
Yc
Mo
ØxIx
Ks2R
Cs2R
Ks1R
Cs1R
Cs2L
Ks2L
Ks1L
Cs1L
M1R
Y2R(+)
Y1R(+)
M2L
M2R
(+) Y2L
Y1L (+)
Kt2R
Ct2R
M1L
Kt1R
Ct1R
Kt2L
Ct2L
Kt1L
Ct1L
(+) V2L
W2
W1
V1L(+)
(+) V2R
V1R(+)

Figure 1

with sets of wheel load weighers or with axle scales. The only way to weigh a highway vehicle accurately by successive positioning of wheels on a scale, or a series of scales, is to maintain all wheels of the vehicle in a horizontal plane (a smooth level surface) and have no redistribution of weight during the weighing process. This means that the deflection of the scale itself must be considered and that the friction in the vehicle suspension, drive, and braking systems must be accounted for. A considerable amount of weight transfer among axles occurs during acceleration and stopping of a vehicle, and the weight distribution at the time of weighing depends on the frictional forces in the suspension system at that time. In practice, efforts must be made to minimize the effects of weight transfer during successive weighings in order to make measurements within acceptable tolerances.

IN-MOTION WEIGHING

By definition, and by common usage, the term weight means that only gravitational force is acting on an object at rest. In-motion weighing of a highway vehicle attempts to approximate the weight of the vehicle, a wheel, an axle, or a group of axles on the vehicle by measuring instantaneously, or during a short period of time, the vertical component of dynamic (continually changing) force that is applied to a smooth, level road surface by the tires of the moving vehicle. The weight of the vehicle does not change when it moves over the road, but the dynamic force applied to the roadway surface by a rolling tire of the vehicle varies from more than double its static weight when it runs up on a bump, thereby exerting a large unbalanced force on the wheel mass, to zero when the tire bounces off the road. Figure 2 illustrates the pattern and magnitude of variability in dynamic wheel force for the left rear wheel (dual tires) of an empty dump truck driven at 30 mph over the relatively smooth road profile shown in the figure. A sheet of 3/8-inch thick plywood was placed on the first pair of the nine wheel force transducers that were arrayed in the road surface as shown in Fig 3 for experimental measurements. Measured wheel forces for three successive runs of the truck are plotted in Fig 2 along with output from a vehicle simulation model called DYMOL. Fig 4 is a similar graph for the loaded vehicle. Several important concepts of dynamic vehicular behavior are illustrated by these figures. First, the pattern of wheel force for a given vehicle traveling over the same

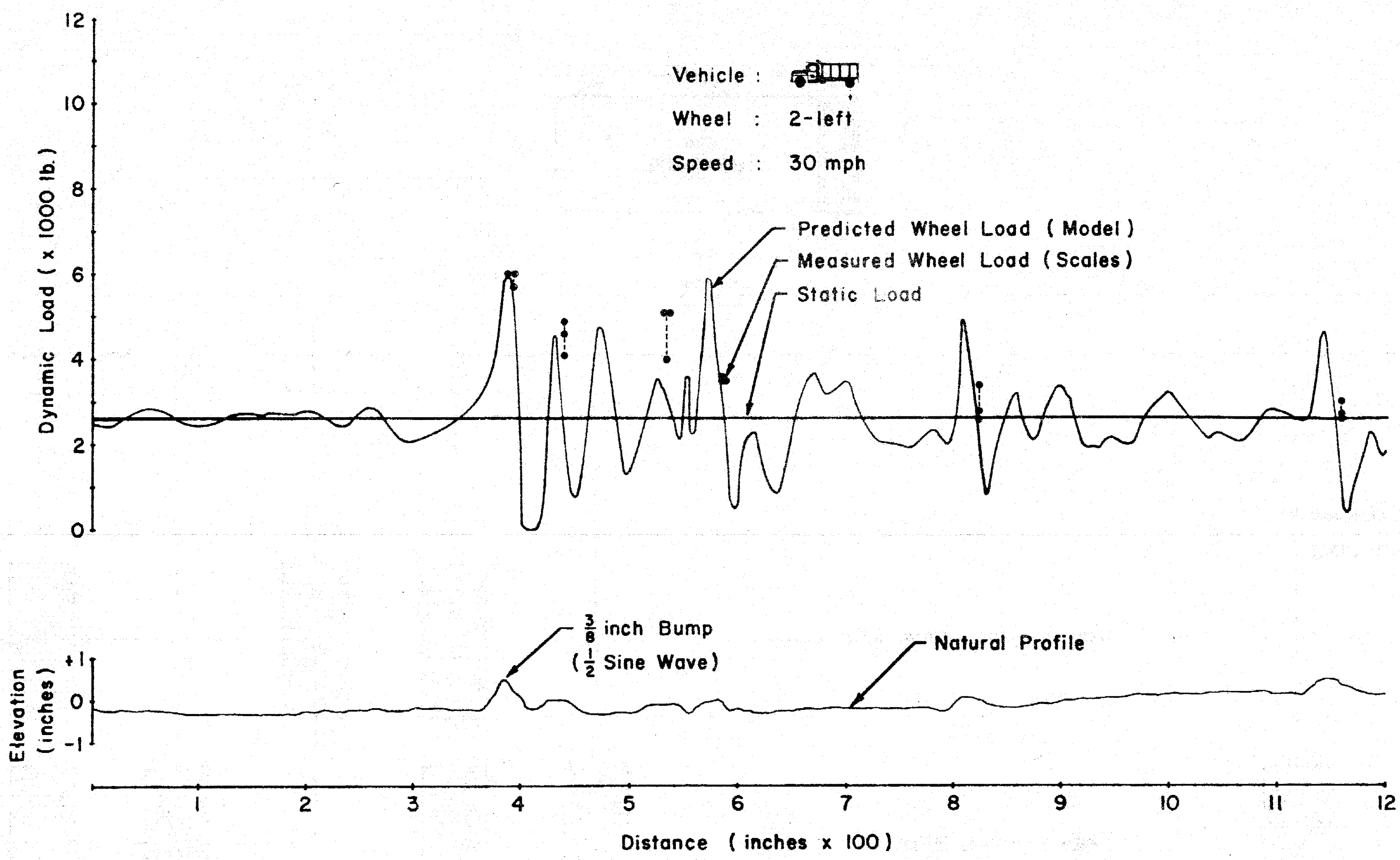

Vehicle :
Wheel : 2-left
Speed : 30 mph
Predicted Wheel Load (Model)
Measured Wheel Load (Scales)
Static Load
Dynamic Load (x 1000 lb.)
12
10
8
6
4
2
0
3/8 inch Bump
(1/2 Sine Wave)
Natural Profile
Elevation (inches)
+1
0
-1
1
2
3
4
5
6
7
8
9
10
11
12
Distance (inches x 100)

Figure 2

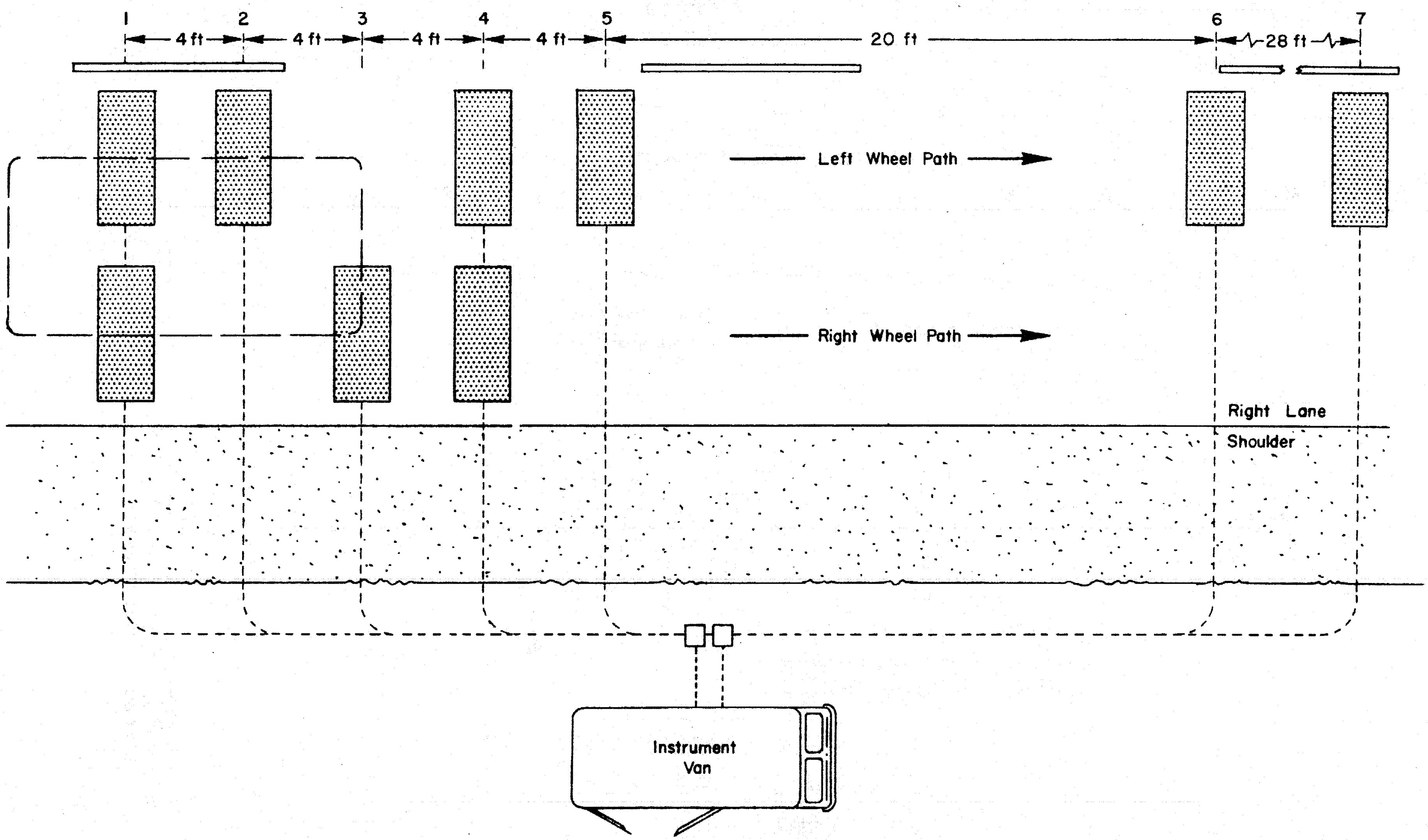

1
2
3
4
5
6
7
4 ft
4 ft
4 ft
4 ft
20 ft
28 ft
Left Wheel Path
Right Wheel Path
Right Lane
Shoulder
Instrument
Van

Figure 3

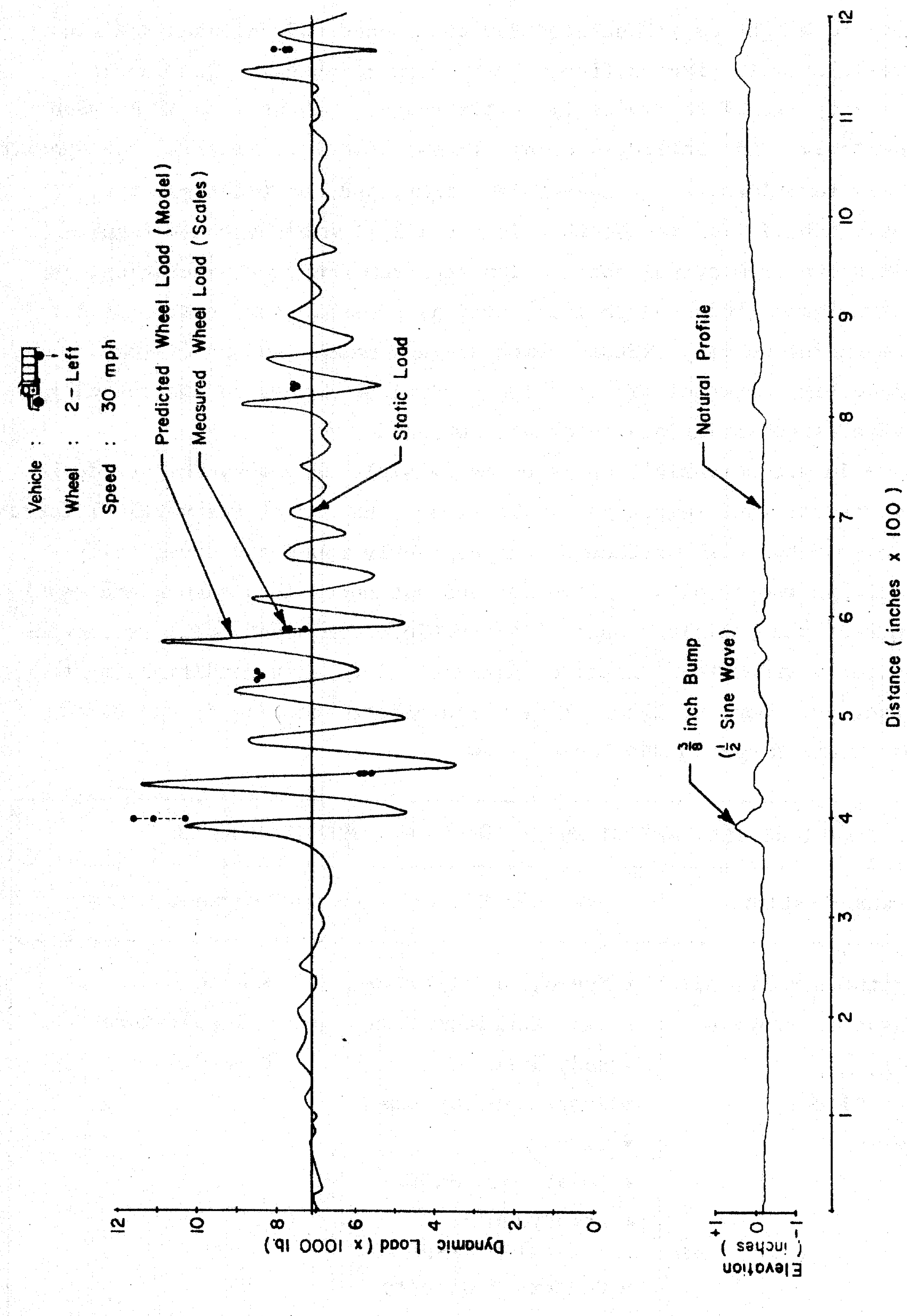

Vehicle :
Wheel : 2 - Left
Speed : 30 mph
Predicted Wheel Load (Model)
Measured Wheel Load (Scales)
Static Load
Dynamic Load (x 1000 lb.)
12
10
8
6
4
2
0
Natural Profile
3/8 inch Bump
(1/2 Sine Wave)
Elevation (inches)
+1
0
-1
1
2
3
4
5
6
7
8
9
10
11
12
Distance (inches x 100)

Figure 4

roadway surface at the same speed is consistent as seen from the small scatter in the experimental measurements. Next, the mass of the vehicle components affects the magnitude and frequency of dynamic wheel forces and their variation from static weight as illustrated for the loaded and unloaded vehicle. Different vehicles will react differently to road roughness. The wheels (unsprung masses) oscillate typically in the range of about 8 to 12 Hz when displaced suddenly, and oscillations damp rather quickly. Finally, the dynamic wheel force is sometimes less than static weight, and sometimes greater. A characteristic behavior of trucks that is not illustrated by these figures, but which is known from actual observation and from computer simulation, is that the sprung mass (body and payload) typically oscillates at about 0.5 to 3 or 4 Hz depending on many factors which include mass. An out-of-round or out-of-balance tire or wheel can also apply vertical forces to the rotating mass and cause large variations in dynamic wheel force.

Accurate in-motion vehicle weighing is possible only when the vertical acceleration of all vehicle components is zero. The sum of the vertical forces exerted on a smooth, level surface by the perfectly round and dynamically balanced, rolling wheels of a vehicle at constant speed in a vacuum are equal to the weight of the vehicle. None of the vehicle components will be accelerating vertically under these ideal conditions. But, such conditions never exist in practice. Some of the factors which affect the tire forces of a moving vehicle are shown in the table below.

FACTORS THAT AFFECT WHEEL LOADS OF A MOVING VEHICLE		
Roadway Factors	Vehicle Factors	Environment Factors
• Longitudinal Profile • Transverse Profile • Grade • Cross Slope • Curvature	• Speed, Acceleration • Axle Configuration • Body Type • Suspension System • Tires • Load, Load Shift • Aerodynamic Characteristics • Center of Gravity	• Wind • Temperature • Ice

No road surface is perfectly smooth and level, no vehicle is perfect, and the existence of the atmosphere cannot be ignored. The nearer actual conditions approach ideal conditions, the better the approximation of vehicle weight that can be made by measuring the vertical forces applied to the roadway surface by the tires of a moving vehicle.

In practice, the adverse effects of the roadway factors can be made quite small by careful site selection and proper installation and maintenance of in-motion weighing equipment. Undesirable environmental effects can be recognized or perhaps avoided by scheduling weighing operations. The vehicle factors, except for possibly speed and acceleration, are largely uncontrollable at a weighing location. Legal and safety regulations restrict the range within which certain other vehicle factors occur, and economic considerations influence the vehicle operating conditions that drivers and owners are willing to tolerate. Perhaps the most significant uncontrolled vehicle factor that affects in-motion weighing is tire condition. Unbalanced or out-of-round tires rotating at high speed can cause large variations in the vertical component of force acting on the wheel mass and can therefore produce vertical acceleration of this mass. Tire inflation pressure also contributes significantly to the dynamic behavior of the tire and wheel mass. Even though the tire-condition variable cannot be controlled in in-motion weighing, observation and experience indicate that the tires on most over-the-road vehicles are maintained in reasonably good condition; therefore, the results of this potentially adverse effect might also fall within tolerable limits for most vehicles and for certain types of in-motion weighing operations. Several years of experience have demonstrated that in-motion weighing is practicable. Properly designed and maintained equipment is a basic requirement. Appropriate use of the equipment and interpretation of the measurements is equally important if satisfactory results are to be achieved with the techniques.

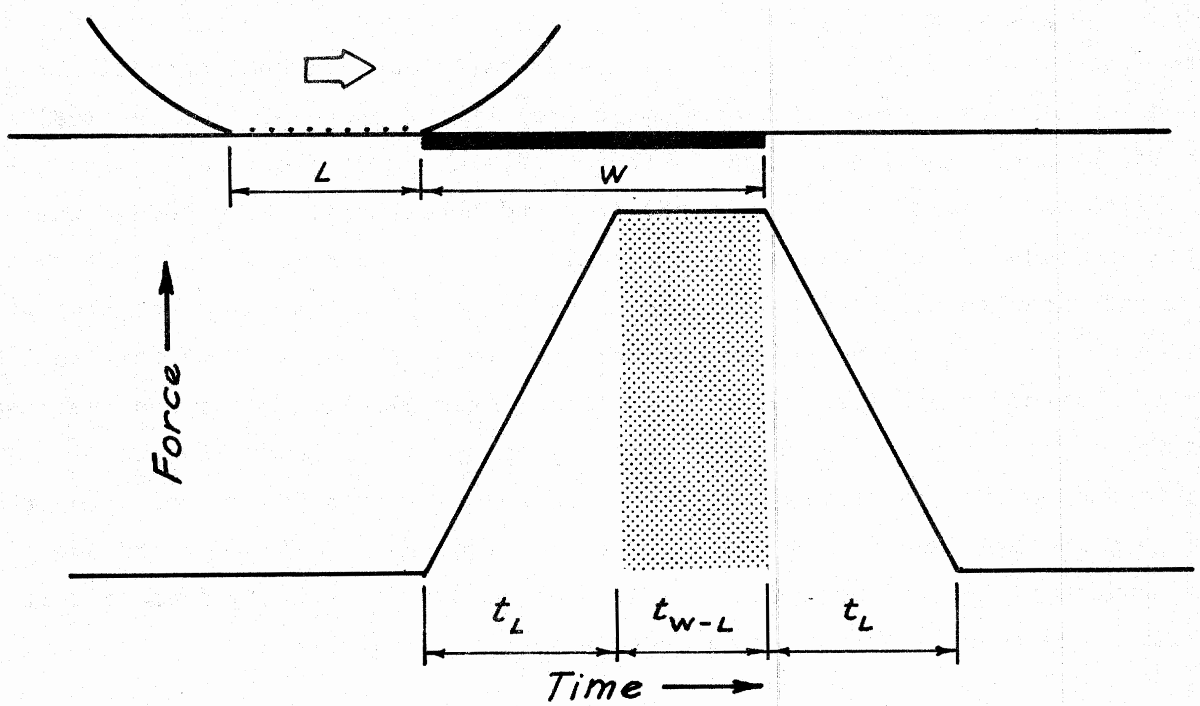
WIM SYSTEMS

A basic in-motion vehicle weighing system consists of one or more wheel force transducers plus the associated signal processing instruments. Supplementary vehicle presence sensors (e.g., inductance loop detectors) or axle passage detectors may also accompany the weighing system to measure speed, axle spacing, overall vehicle length, and lateral placement as the vehicle passes over the system.

Wheel Force Transducer

The key component of any WIM system is the wheel force transducer, which converts the vertical component of force applied to its surface through the tires of a moving vehicle into a proportional signal that can be measured and recorded. In order to measure the total vertical force imposed on the transducer by a selected tire, or by a group of tires, on a vehicle, the full tire contact area/s of interest must be supported completely and simultaneously by the transducer. The transducer must then produce a signal which is exactly proportional to the vertical force applied. This signal must not be affected by (1) tire contact area, stiffness, inflation pressure, nor position on the sensing surface of the transducer, (2) tractive forces, (3) temperature, nor (4) moisture.

An ideal force vs. time signal from a wheel force transducer is shown in the sketch below.



As the tire contact length, L , moves onto the transducer, force increases until the full tire contact area is supported by the transducer. Force does not change (assuming no vertical movement of the vehicle components) during the time t_{W-L} while the tire contact patch continues to be supported only by the transducer. This is the time when wheel force measurements are possible. Typically, t_{W-L} is about 0.006 seconds for a loaded truck traveling at 60 mph over a transducer 1.5 feet long with a tire contact length of 1.0 foot.

The surface of the wheel force transducer must be exactly even with the surface of the level roadway into which it is installed in order not to create an unbalanced force on the wheel/tire mass as the tire passes over the transducer. This unbalanced force will act upward to displace the mass if the transducer stands above the road surface, or it will cause the spring force of the vehicle suspension and the pneumatic tire to act downward on the mass as an unbalanced force if the transducer is below the surface. The inertia of the wheel/tire mass will affect the wheel force and thus the force measurements made by the transducer under either of these conditions. It is not possible to calibrate the signal from the transducer to compensate exactly for differences in elevation of the force-sensing transducer surface with respect to the surrounding road surface as each vehicle will respond differently to the surface irregularity. Such factors as speed, tire stiffness and inflation pressure, and mass of the various unsprung vehicle components are particularly affected, even by small surface irregularities.

Ideally, the transducer should deflect under load the same amount as the road surface. If the transducer is very stiff as compared with the pavement, the net effect upon force measurements will be like that of the wheel running up on a bump. Similarly, if the transducer deflects more than the road surface under load, the wheel will be affected as if it runs into a shallow hole. The transducer should deflect a small amount under load in order to behave like the surrounding road surface.

The mass of the transducer should be small in relation to the dynamic forces that are to be measured. In principle, a force transducer usually measures the displacement in an elastic body that is subjected to an applied force. This displacement is a function of the magnitude and duration of the force as well as the mass of the displaced body. To illustrate, think of your hand as an elastic spring supporting a mass and your nerves as a displacement measuring system. Place your palm upwards on the table and set a 10-pound steel block in your hand. Close your eyes. Have a friend strike the weight a sharp blow with a hammer. Gage and remember your sensation to the force applied by the hammer. Open your eyes and replace the steel block with a penny and close your eyes again. Have your friend strike the penny a similar sharp blow with the hammer. Was the applied force the same? Yes, the applied force was the same, but the displacement in your hand was much more in the second experiment leading you to an erroneous conclusion (if you really let your "friend" hit the penny). The mass of a wheel force transducer must be relatively small if dynamic forces of a few thousand pounds applied for a few milliseconds are to be measured accurately by sensing the displacement of the elastic element of the transducer. The inertia of the transducer mass affects its displacement with respect to time under an applied unbalanced force.

Closely associated with the mass of the transducer is its resonant, or natural, frequency of oscillation. The elastic transducer mass that is displaced downwards by an applied force will rebound when the force is removed and move upwards under the spring force of the elastic body until a restraining force in the opposite direction (gravity) reverses the movement. This pattern of unbalanced forces acting on the transducer mass will cause it to oscillate until some form of damping dissipates the energy stored in the elastic system. The period of oscillation is a function of mass. Generally, the greater the mass, the slower the period of oscillation and the more the energy required for damping.

A wheel force transducer measures the relative displacement of an elastic mass in response to the applied forces. If the transducer mass is being displaced from its reference position by an unbalanced force at the time a wheel force is applied, the net displacement under the wheel will result from the algebraic sum of the unbalanced force associated with the initial displacement plus the unbalanced force from the applied wheel force. If the transducer mass happens to be moving downward due to a previously applied unbalanced force when the tire applies an additional downward force, the mass will move further downward due to the sum of the two unbalanced forces both acting downwards. If, on the other hand, the transducer mass is moving upwards due to a previously applied unbalanced force, the final displacement of the transducer mass with respect to its rest position will result from a force equal to the difference in the upward inertial force and the downward wheel force.

An effective wheel force transducer must be at rest when the wheel force to be measured is applied. A low mass transducer tends to oscillate at high frequency and damp to a rest position relatively quickly; therefore, a low mass, critically damped transducer is generally preferred. Since the time between tandem axles (approximately 4 feet apart) on a vehicle moving at 60 mph is about 4/88 = 0.045 seconds, the transducer should cease oscillation within this short time in order to be ready to measure the wheel forces of such closely spaced axles. To assure that the transducer mass is at rest when an unknown tire force is to be measured, an oscilloscope should be used to examine the signal with respect to time. The force vs. time trace shown in the previous sketch should be closely approximated, particularly in the time just before the tire goes onto the transducer. The transducer should indicate no force except that of gravity when it is not loaded externally.

A wheel force transducer must be designed and constructed with adequate capacity to handle the wheel loads that will occur in practice. Legal axle load limits and possible overloads must be considered. Also, the fact that dynamic wheel force can sometimes be double the static wheel weight should be allowed for. The general relationship between fatigue life of the transducer elements and the expected number of repetitions of various stress levels should also be recognized. Wheel force transducers operate in an extremely hostile environment of impact loading, vibration, climatic extremes, and sometimes intentional abuse. Wear and tear are expected; therefore, good design must be complemented by proper inspection and maintenance if satisfactory service is to be realized from wheel force transducers.

A partial check list of wheel force transducer features is shown in the table below. This might be useful for assessing the adequacy of the transducer design and the potential performance of this important part of a WIM system.

WHEEL FORCE TRANSDUCER FEATURES	
Feature	O.K.
• Insensitive to: Tire contact area (single/dual)	
Tire stiffness	
Tire inflation pressure	
Tire position (edge-to-edge)	
Temperature	
Moisture	
• Installed even with roadway surface	
• Signal directly proportional to applied vertical force	
• Small deflection under load	
• Low mass / High compliance	
• High natural frequency / Critical damping	
• Capacity	
• Durability / Maintainability	

WIM Signal Processing Instruments

Analog signals from the wheel force transducers must be interpreted and recorded by appropriate electronic instruments to yield samples of dynamic wheel forces which serve as estimates of wheel, axle, and vehicle weight. Analog-to-digital conversion of signals is now routine; therefore, most WIM systems are based around digital data processors. The wheel force signal sketched in the previous section is digitized at a typical rate of about 1,000 Hz. The resulting digital array is evaluated rapidly and effectively to isolate the pertinent information and display a measured wheel force in appropriate units. This information is stored for further use in computing estimated axle weights and gross vehicle weights. All data, or only selected items, can be recorded for subsequent recovery and further processing. Proper software must be provided to utilize the hardware capabilities of any WIM system. There are few limitations today on the availability of quality WIM instrumentation systems. Almost any reasonable signal processing specification can be met by qualified and experienced vendors of such services.

ACCURACY OF WIM SYSTEMS

Highway vehicles are normally weighed for one or more of the following purposes: (1) commerce (buying and selling by weight); (2) statistical data (needed for planning, financing, designing, constructing, operating, and maintaining the road system); or (3) enforcement (assuring that design loading is not abused). The need for accurate (correct; without error; deviating only slightly or within acceptable limits from a standard) weighing varies somewhat for each of these purposes because the consequences of using inaccurate weight information involve different degrees of risk to the users. Tolerances, or permitted variations from a correct value, can be set to reflect the relative importance of accuracy in view of both the use of the information and the cost and feasibility of obtaining it. Setting of such tolerances involves the specification of the magnitude of allowable variations as well as the probability that any given measurement will lie within the stated limits. Considerable judgment must be exercised in developing these specifications, and the need for nationwide uniformity must be recognized.

From the previous discussion of in-motion weighing, it should be apparent that the dynamic interaction of an imperfect vehicle with an imperfect road surface in the earth's atmosphere makes highly accurate estimates of vehicle weight impossible by this technique. But the practical question remains, can samples of dynamic wheel force be used to estimate vehicle, axle, and wheel weights within acceptable tolerances for specific purposes? The demonstrated answer to this question is yes. The state-of-the-art in in-motion weighing now permits efficient, safe, economical measurements of vehicle weights and dimensions to be made for statistical data purposes. Properly designed, installed, and maintained WIM equipment is capable of making unbiased measurements of dynamic wheel forces that represent adequately the loading patterns to which our roads and bridges are being subjected. The fact that some of the sampled forces are greater than the true static weight and some areless is important; this is what the road surface actually experiences. As long as our structural design procedures and materials testing procedures are based on static loading, an estimate of the static loading pattern is a useful statistic. When these procedures can utilize a more sophisticated description of dynamic loading, the WIM technique can be adapted for providing such information. For now, however, a WIM system which can measure and record the applied wheel force within about 1 percent tolerance can be installed and used with confidence to collect large samples of data for statistical applications.

Tolerance needed for commercial vehicle weighing applications are long established and well recognized. In-motion weighing at high speeds cannot now satisfy these small tolerances, but this application should not be overlooked in future WIM development.

Enforcement applications of in-motion weighing currently utilize the technique mostly as a screening device to identify suspected weight violators for subsequent checking on static scales certified to the required tolerances. Weight threshold limits on the WIM system can be adjusted to allow for expected differences in dynamic force measurements and static weight and thereby select only those vehicles that are quite likely to be overweight. Some compensation can be made in the WIM system thresholds for site-specific characteristics such as local surface roughness or grade by comparing WIM measurements with actual static weights, but this will not be perfect as each vehicle will behave differently. The overall efficiency of enforcement weighing is considerably enhanced by the WIM technique as static weighing is necessary only for the vehicles which approach or exceed the various legal limits.

It is recognized that axle-by-axle static weighing of a vehicle on an axle-load scale that is certified to small tolerances (e.g., 0.2 percent) does not necessarily yield vehicle or axle weights which all fall within these tolerances. The probability is high that in-motion weighing of successive axles at slow speeds can give very good estimates of such weights; perhaps as good as static axle-by-axle weighing. A series of experiments is now being conducted in Texas by the State Department of Highways and Public Transportation, the Department of Public Safety, and the Center for Transportation Research at The University of Texas at Austin in cooperation with the Federal Highway Administration to obtain a comprehensive data set for comparing the accuracy of WIM at high, intermediate, and slow speeds with that of a static axle-load scale, a semi-portable axle scale, and wheel-load weighers. This experiment should be completed in about a year.

MINNESOTA'S EXPERIENCE WITH THE INTERNATIONAL ROAD DYNAMICS WEIGH-IN-MOTION SYSTEM FROM JUNE 1981 TO JUNE 1983

Minnesota Department of Transportation
Program Management Division

For Presentation at the
National Weigh-in-Motion Conference
in Denver, Colorado - July 11-15, 1983

TABLE OF CONTENTS

I. Introduction

The Minnesota Department of Transportation has long been interested in the concept of weighing vehicles in motion. Systems with this general capability have been developed by a number of different groups over a series of years. Mn/DOT looked at many of these systems but were always concerned whether they could function properly in Minnesota's climatic extremes. Mn/DOT also wanted a system which would operate continuously and automatically. Because of this climatic concern and desire to continuously collect data, Mn/DOT decided to purchase the scales developed by the University of Saskatchewan and marketed by International Road Dynamics (IRD). IRD had scales functioning at a number of locations throughout Canada. This is the first installation of this system in the United States.

Our principal objectives in obtaining this system were as follows:

1) Develop a reliable weight data base which is used as input for designing pavement.

2) Build up a file of a heavy truck trend data, both seasonal and long term, by weight and vehicle type.

3) Relate Minnesota's manually collected weight and vehicle class data to the data recorded by this system.

4) Minimize the manpower required for data collection.

5) Collect data for planning and design purposes.

This system is located in the eastbound lanes of I-494 in the City of Bloomington. I-494 makes up part of the beltline around the Minneapolis - St. Paul Metropolitan Area. I-494 consists of two lanes of traffic in each direction at the site. Only the eastbound lanes have scales which monitor a combination of rural and urban truck traffic. The total 2-way traffic at the site in 1980 was 56,400 in the average day of the year, of which nearly 7%, or 3,800, are trucks.

II. Installation of the System/Cost

The contract for the system was let in November 1980; construction at the site was begun in April 1981.

The roadway is concrete pavement which is nearly 20 years old. It has extensive mid-panel cracking. Ninety feet of this pavement was taken up and replaced in order to: 1) provide a new surface in the vicinity of the scales, and 2) to allow for the installation of expansion joints needed to protect the scales from the lateral movement of the concrete roadway. One lane at a time was shut down during construction.

The hardware installed in each lane consists of frames into which either dummies or scales (one/wheelpath) can be placed. Initially, dummies were placed in the left lane and scales in the right lane. There are also two loop detectors per lane -- one upstream and one downstream from each of the frames. The data processing equipment is housed in a 10' x 10' building which is located at the side of the roadway. The equipment in the building consists of an interface system, a Digital Equipment Corporation (DEC) computer model 1103, and a DEC III printer. The building is climate controlled as the temperature has to be maintained between 50° and 90° F.

The scales in the right lane were installed in mid-June and the system became operational at that time. The surface of the road was planed in mid-July in order to make it as level as possible. The final calibration of the system was made in mid-August.

The installation of the system occurred over a 2 month period from April to June. Actual construction time was approximately 3 days per lane.

In September 1982, we purchased and installed scales in the left lane. It took about 4 hours to remove the dummies and put the scales in their place.

The original contract to install the system was $230,000. This cost was high because the ninety feet of concrete had to be replaced and brick-faced building constructed to conform with local building codes. If installation of the system was done as a part of a contract to rebuild a road, the costs would be less. The scales for the left lane and the interface system cost $35,000.

STATE EXPERIENCES WITH WIM SYSTEMS

IRD SYSTEM

MR. WILLIAM EBERT
MINNESOTA DEPARTMENT OF TRANSPORTATION
ST. PAUL, MINNESOTA

III. Type of Data Collected

The data collected by the system can be stored for a maximum of two weeks. This data is manually retrieved weekly. The data collected by the system is stored in the memory of the computer for one hour. Every hour on the hour, it is transferred to a cassette tape where it remains until we retrieve it weekly.

When visiting the site the purpose is to either 1) pick up the data which the system has collected since last visit, or 2) monitor individual vehicles passing through the system. The following data is collected by the system:

1) Vehicle speed
2) Axle weights
3) Axle spacing
4) Vehicle Classification
5) Vehicle gross weight
6) Vehicle 18-kip ESAL data

All of this data is printed out when viewing individual vehicles. A sample page of this is included on page 15 in the Appendix. During the regular operation of the system, data on the vehicles is sorted into categories for later output in printed tables. The output consists of a series of nine tables which we requested of IRD. A copy of each table is included on pages 17-25 in the Appendix.

IV. Number of Vehicles Weighed

Right Lane
- June 21, 1981 to June 21, 1983
- 11.3 million vehicles through the system (includes cars)
- 9.4 million vehicles weighed (includes cars)
- Approximately 83% properly passed through the system so they could be weighed
- Approximately 820,000 trucks weighed of which 290,000 were 5 axle semis
- Approximately 440,000 ESAL's (flexible)

Left Lane
- September 21, 1982 to June 21, 1983
- 3.3 million vehicles through the system (includes cars)
- 2.6 million vehicles weighed (includes cars)
- Approximately 80% properly passed through the system so they could be weighed
- Approximately 120,000 trucks weighed of which 70,000 were 5 axle semis
- Approximately 80,000 ESAL's (flexible)

V. Accuracy of Data

The WIM system became operational in mid-June 1981. In August the 90' concrete pad which had been replaced was planned. Calibration of the system then took place. Various types of the department's trucks were weighed at a truck station, and then driven repeatedly over the scales. The static and WIM weights were within ± 5% for all trucks except the 3 axle single unit dump truck which was ± 30%. The problem with these axle trucks was that the tandem axles would bounce and set up a pattern as they passed over the regularly spaced joints of the concrete roadway, however, the front axles were stable. The results of the testing was that calibration factors to adjust the weights at various speeds were inserted in the system.

Since visits to the site were weekly to pick up the data, test runs would be made with a car. In June 1982, these test runs showed that the calibration factors in the system were no longer necessary so they were taken out. In the summer of 1982, more testing with trucks was done. The results this time were somewhat different because trucks with different suspension systems were used. The pattern for the 3 axle single unit dump truck was the same as in 1981. The effect of dynamics in combination with varying suspension systems on a concrete roadway became evident to us.

In order to help verify the accuracy of scale weights for the average truck, comparisons were made with data from independent sources. This is mentioned on the following page and is discussed in greater detail in the Appendix. A check of these independent sources verified that the average vehicle weight was correct. However, Mn/DOT still wanted a method to monitor the scales performance on an ongoing basis. Since the weight on the front axle of a 5 axle semi varies little as the gross weight varies, a system was developed to monitor these front axles. This is discussed on page 7. The results of this have verified the validity of the data.

The data on the following page summarize our experience with the accuracy of the weight data. We are satisfied with the scales performance in this area.

Weight

Test Vehicles	Gross Weight	Individual Axles
- Summer 1981		
2 axle 6 tire	± 5%	± 10%
3 axle single unit	± 5	± 10
3 axle single unit dump	± 30	± 30
5 axle semi	± 5	± 10
- Summer 1982		
Automobiles	± 5	± 10
2 axle 6 tire dump	± 10	± 10
3 axle single unit dump	± 30	± 30
6 axle semi	± 15	± 20

Independent Sources

- Distribution of weight on 5 axle semis WIM vs. loadometer - make the same pattern - see page 27 in Appendix

- Loaded 5 axle semi grain trucks WIM vs. weighbills put the averages with ± 5% - see page 28 in the Appendix

- Correlation of front axle weight vs. gross weight for 5 axle semis WIM vs. loadometer for various time periods has correlation from .87 to .95

Monitor front axle weight of all 5 axle semis at WIM

- WIM vs. loadometer shows very close to the front axle weight and standard deviation

The weight of the front axle of a 5 axle semi does not change substantially as the gross weight changes. An analysis of the 2,877 five axle semis weighed in the 1981 loadometer study showed an average weight of 9,341 lbs. with a standard deviation of 1,390 lbs. on the front axle. A modificatin of the WIM program early in 1983 allows us to monitor this information on an ongoing basis. The following shows the data collected to date.

	Right Lane			Left Lane		
Time Period	# of Vehicles	Front Axle Weight	Standard Deviation	# of Vehicles	Front Axle Weight	Standard Deviation
April 4-11	1,275	9,338	1,342	1,857	8,991	1,222
April 11-18	2,388	9,394	1,404	1,328	8,761	1,145
April 18-25	3,014	9,360	1,309	1,935	9,095	1,230
April 25-May 2	1,338	9,378	1,343	2,090	9,007	1,215
May 2-9	1,517	9,442	1,387	2,139	9,104	1,273
May 9-16	3,218	9,486	1,371	2,101	9,027	1,272
May 16-23	3,179	9,499	1,411	2,022	9,118	1,359
May 23-31	3,383	9,463	1,387	2,211	9,042	1,272
May 31-June 6	2,753	9,555	1,370	1,815	9,106	1,258
June 8-14	9,562	9,562	1,387	1,539	9,148	1,349

The weights in the right lane are close to the loadometer average of 9,341 while weights in left lanes are slightly lower. Analysis of this and other related data is being completed to determine if the left lane should be adjusted upward. It may be desirable to monitor these weights by several gross weight ranges. The front axle weights will vary to some degree as the mix of loaded vs. unloaded vehicles changes. One interesting observation is that the standard deviations of the WIM site are the same as that recorded during the loadometer study. Dynamics does not seem to affect the WIM readings on these front axles.

The stability and repeatability of this data instills further confidence in the reliability of the data. This also will serve as an excellent method of continuously monitoring the system.

Vehicle Classification

Vehicle Description	# Observed	% Correctly Classified
2 axle 6 tire	988	90.8%
3 axle single unit	525	99.4
3 axle semi	112	96.4
4 axle semi	157	95.5
5 axle semi	886	99.5
All other Types	131	93.9
Total	2,799	95.8%

Manual observations of vehicles passing over the system were conducted on 5 different days in the fall of 1981. The system determines the classification by first looking at the weight of the front axle. If it is less than 3,200 lbs., the vehicle is considered to be non-heavy commercial, if the vehicle is over 3,200 lbs., it is heavy commercial. The program then looks at the axle configuration to classify it. The 2 axle 6 tire truck was the most difficult to properly classify, yet the classification was nearly 91% correct. Classification of 2 axle, 6 tire vehicles is difficult because there are some relatively light 2 axle 6 tire trucks in addition to some relatively heavy 2 axle 4 tire trucks. The 3,200 lbs. axle break seems to be best for our classification purposes.

The system does an excellent job of classifying all other vehicle types. The 5 axle semi was properly classified 99.5% of the time. All trucks except the 2 axle 6 tire were correctly classified 98.6% of the time.

Axle Spacing*

	1976 Plymouth 3-2-82	2 axle 6 tire 8-5-82	Spacing between tandem axles of 5 axle semis on 10-11-82			
			Right Lane		Left Lane	
			1st Tandem	2nd Tandem	1st Tandem	2nd Tandem
# of runs or vehicles	28	30	79	79	75	75
Static measurement	117	162	--	--	--	--
WIM measurement	116.1	161.5	51.5	49.1	52.6	50.2
Standard deviation	.57	.78	1.30	1.00	1.31	1.12
Minimum value	115	160	49	47	50	48
Maximum value	117	163	56	53	56	56

* in inches

Speed

The following speed data was recorded for selected se
on 8-6-82.

Subject Vehicle	WIM*	Radar
1	56 MPH	56-57 MPH
2	56	57
3	58	59
4	49	53
5	60	62
6	48	49
7	52	53
8	54	54
9	51	53
10	62	64
12	56	57
13	49	49-50
14	54	54
Average	54.2 MPH	55.4 MPH

* The speeds are calculated by rounding as in the following example. A speed between 56.0 and 56.9 is rounded to 56.

VI. System Performance/Reliability

Right Lane - June 21, 1981 to June 21, 1983
- 17,520 possible hours of operation
  - 44 hours of system failure for unknown reason (2 separate times)
  - 266 hours of system failure for bad off scale detector
- 310 hours total of system failure, or 1.8% of the time
- 225 other hours when data not collected due to power failure, testing, etc; 1.3% of the time
- Properly operating for 96.9% of the time

Left Lane - September 21, 1982 to June 21, 1983
- 6,552 possible hours of operation
  - 44 hours of system failure for unknown reason (same as right lane)
- 44 hours total of system failure, or 0.7% of the time
- 87 other hours when data not collected due to power failure, etc; 1.3% of the time
- Properly operating for 98.0% of the time

See comments on page 29 in the Appendix.

Record of Maintenance/Adjustments
- scales - one offscale detector needs replacing, scales okay
- electronics - no replacement of parts needed
  - 95 hours of maintenance/training/testing cost $1,300 for 2 years
- computer -no replacement or parts needed
- printer - replaced encoder motor
  - cost $1,600/year for maintenance contract for printer and computer
- frequency of calibration - inserted factors in August 1981 and removed them in June 1982. No other adjustments needed.

VII. Applications

As data has been collected, the following uses of the data has become evident:

1) ESAL's by day to determine when it is the best time to weigh trucks
2) ESAL's by day to determine how to adjust short term weight data
3) vehicle classification counts by hour to determine when it is the best time of the day to count
4) vehicle classification counts by hour to determine how to adjust short term counts
5) use vehicle classification and ESAL factors in forecasts for pavement design
6) long term trends to aid in forecasting
7) evaluate the effect of dynamic loadings on pavement
8) influence policy decisions on truck weight regulation

VIII. Impact on Previous Program & The Future of WIM

Up to this time, WIM has not replaced our manual data collection, however, WIM is feasible to use as an alternate to manual weighing. Generally Mn/DOT felt that two types of WIM systems are needed; one system should be permanent and would operate continuously, the other system should be highly mobile in order to move frequently to collect data at numerous locations. The long term data collected at a few continuously operating stations is needed to adjust the short term data collected at numerous sites. It is the same concept as using Automatic Traffic Recorder data to adjust 48 hour machine counts for total traffic volume. Page 30 in the Appendix indicates what degree of variation in flexible ESAL loading existed during our first year of operation of the system. The factors represent the amount of deviation between each individual weekday and the average day of the year. An adjustment has to be made for the daily, weekly, monthly and seasonal variations when data is collected for short periods of time.

From Mn/DOT's perspective, the IRD system will be used to collect data at permanent locations. A Mn/DOT study recommended installing the system at four additional sites on the state trunk highway system. At this time, it is impossible to definitely determine how many sites are needed. It is not known to what degree the data trends will repeat from one site to another. Mn/DOT is planning on installing one additional site this fall on TH 2 near Bemidji. This will be used to monitor the movement of grain to the ports at Duluth/Superior as well as the local movement of forest products. Scales will be installed to monitor both directions. The other 3 sites are yet to be determined.

This study also recommended acquiring a mobile system. The specific system has not yet been determined. Reliability and durability are important considerations for the Department. By 1985, Mn/DOT would like to be able to replace the current manual loadometer program with WIM.

A study is currently underway to address the telemetering of our I-494 and Bemidji IRD sites, to survey other WIM systems including portable equipment, and to develp a plan of sites and WIM equipment that will supplement or replace our loadometer operations.

APPENDIX

IX. Appendix

```
Weight: 2182 lbs.
Axle Spacing(in) Weight(lbs)
  1        94          918
  2     -----         1264

Tue Jun 21 11:09 Lane 1
Type: 1     18-K ESAL Rigid:0.000    Flexible:0.000
Speed: 51 mi/hr.
Weight: 2514 lbs.
Axle Spacing(in) Weight(lbs)
  1        93         1220
  2     -----         1294

Tue Jun 21 11:09 Lane 2
Type: 1     18-K ESAL Rigid:0.000    Flexible:0.000
Speed: 60 mi/hr.
Weight: 3402 lbs.
Axle Spacing(in) Weight(lbs)
  1       119         1926
  2     -----         1476

Tue Jun 21 11:09 Lane 1
Type: 1     18-K ESAL Rigid:0.000    Flexible:0.000
Speed: 50 mi/hr.
Weight: 2757 lbs.
Axle Spacing(in) Weight(lbs)
  1        92         1688
  2     -----         1069

Tue Jun 21 11:10 Lane 1  Hit offscale detector.
Speed: 52 mi/hr.

Tue Jun 21 11:10 Lane 2
Type: 1     18-K ESAL Rigid:0.000    Flexible:0.000
Speed: 58 mi/hr.
Weight: 4382 lbs.
Axle Spacing(in) Weight(lbs)
  1       134         2237
  2     -----         2145

Tue Jun 21 11:10 Lane 2
Type: 1     18-K ESAL Rigid:0.000    Flexible:0.000
Speed: 57 mi/hr.
Weight: 2182 lbs.
Axle Spacing(in) Weight(lbs)
  1       106         1691
  2     -----          491

Tue Jun 21 11:10 Lane 1
Type: 8     18-K ESAL Rigid:0.131    Flexible:0.109
Speed: 56 mi/hr.
Weight: 34640 lbs.
Axle Spacing(in) Weight(lbs)
  1       135         9620
  2        51         6309
  3       327         6423
  4        49         5616
  5     -----         6672

Tue Jun 21 11:10 Lane 2  Hit offscale detector.
Speed: 62 mi/hr.

Tue Jun 21 11:10 Lane 2
Type: 1     18-K ESAL Rigid:0.000    Flexible:0.000
Speed: 62 mi/hr.
```

Number of Vehicles and 18-K ESAL by Day of Week (Lane 1)

Minnesota Test System
From: Monday May 23 00:00 To: Monday May 30 00:00

Type	Monday #	Monday Rigid	Monday Flex	Tuesday #	Tuesday Rigid	Tuesday Flex	Wednesday #	Wednesday Rigid	Wednesday Flex	Thursday #	Thursday Rigid	Thursday Flex	Friday #	Friday Rigid	Friday Flex	Saturday #	Saturday Rigid	Saturday Flex	Sunday #	Sunday Rigid	Sunday Flex	Total #	Average Rigid	Average Flex
1	13589	0.00	0.00	13821	0.00	0.00	14254	0.00	0.00	13992	0.00	0.00	13977	0.00	0.00	10424	0.00	0.00	9643	0.00	0.00	89700	0.00	0.00
2	195	0.00	0.00	157	0.00	0.00	208	0.00	0.00	218	0.00	0.00	246	0.00	0.00	276	0.00	0.00	304	0.00	0.00	1604	0.00	0.00
3	741	0.15	0.15	709	0.16	0.16	796	0.13	0.13	816	0.11	0.11	799	0.13	0.13	284	0.05	0.05	209	0.04	0.04	4354	0.12	0.12
4	182	1.46	1.00	231	1.05	0.72	244	0.69	0.50	224	0.79	0.58	154	0.70	0.52	41	1.00	0.80	13	0.85	0.71	1089	0.93	0.66
5	12	1.03	1.22	5	2.25	3.34	6	0.68	0.75	9	1.62	2.37	7	0.79	0.95	0	0.00	0.00	0	0.00	0.00	39	1.22	1.64
6	83	0.19	0.20	86	0.17	0.18	86	0.25	0.25	75	0.16	0.17	82	0.20	0.21	37	0.03	0.03	37	0.01	0.01	486	0.17	0.17
7	117	0.33	0.29	110	0.50	0.44	115	0.35	0.32	123	0.41	0.36	94	0.34	0.30	24	0.24	0.18	11	0.13	0.10	594	0.38	0.33
8	592	1.85	1.10	576	2.06	1.22	577	1.95	1.15	637	2.08	1.23	557	1.93	1.14	107	1.46	0.87	50	2.00	1.19	3096	1.96	1.16
9	12	2.84	2.35	10	1.85	1.51	11	2.85	2.29	9	3.83	3.06	12	1.43	1.15	3	4.77	3.93	1	5.26	4.36	58	2.67	2.17
10	26	0.97	0.66	41	0.39	0.29	49	1.03	0.68	47	0.81	0.57	41	0.65	0.46	2	0.91	0.82	0	0.00	0.00	206	0.77	0.53
11	0	0.00	0.00	1	3.04	6.38	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	3.04	6.38
12	0	0.00	0.00	2	3.74	3.43	2	0.18	0.19	3	0.11	0.11	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	7	1.17	1.08
13	10	2.45	1.73	12	1.59	1.10	10	0.25	0.18	11	0.12	0.08	10	0.32	0.26	5	0.06	0.06	3	0.02	0.03	61	0.83	0.60

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total
Total Trucks Weighed	1775	1783	1896	1954	1756	503	324	9991
Total Vehicles Weighed	15559	15761	16358	16164	15979	11203	10271	101295
Total 18-K ESAL	1621.83	1685.38	1544.56	1743.85	1383.04	234.96	125.99	8339.62
	1070.87	1113.26	1012.73	1136.94	901.71	160.27	82.65	5478.44
Total not weighed	2303	2326	2114	2308	1913	1409	1157	13530

175

Number of Vehicles and 18-K ESAL by Day of Week (Lane 2)

Minnesota Test System
From: Monday May 23 00:00 To: Monday May 30 00:00

	Monday			Tuesday			Wednesday			Thursday			Friday			Saturday			Sunday			Total	Average	
Type	#	Rigid	Flex	#	Rigid	Flex	#	Rigid	Flex	#	Rigid	Flex	#	Rigid	Flex	#	Rigid	Flex	#	Rigid	Flex	#	Rigid	Flex
1	11927	0.00	0.00	11941	0.00	0.00	12715	0.00	0.00	12957	0.00	0.00	12516	0.00	0.00	6118	0.00	0.00	5358	0.00	0.00	73532	0.00	0.00
2	150	0.00	0.00	151	0.00	0.00	131	0.00	0.00	179	0.00	0.00	178	0.00	0.00	114	0.00	0.00	107	0.00	0.00	1010	0.00	0.00
3	173	0.33	0.32	165	0.34	0.33	178	0.27	0.27	191	0.35	0.34	171	0.20	0.20	37	0.11	0.11	20	0.02	0.02	935	0.29	0.28
4	70	1.00	0.74	129	0.94	0.71	96	0.42	0.34	88	0.69	0.51	58	0.74	0.54	12	0.28	0.21	5	0.21	0.15	458	0.74	0.56
5	2	0.98	1.50	3	0.84	1.11	3	0.81	0.94	4	1.46	1.58	2	0.51	0.88	1	0.42	0.43	1	0.52	0.54	16	0.92	1.14
6	20	0.29	0.29	14	0.12	0.13	12	0.36	0.37	19	0.23	0.24	19	0.18	0.19	2	0.20	0.21	1	0.04	0.04	87	0.23	0.24
7	36	0.25	0.23	51	0.26	0.25	41	0.27	0.24	35	0.27	0.24	43	0.27	0.24	6	0.17	0.17	2	0.09	0.06	214	0.26	0.24
8	406	1.65	0.98	369	1.29	0.77	409	1.69	1.00	370	1.66	0.98	378	1.37	0.82	56	1.29	0.77	28	1.83	1.08	2016	1.54	0.91
9	11	1.95	1.55	10	1.46	1.12	8	0.61	0.45	6	0.80	0.59	11	0.45	0.35	3	1.73	1.38	1	0.05	0.05	50	1.12	0.87
10	21	0.83	0.63	34	0.30	0.25	38	0.51	0.44	24	0.52	0.39	24	0.33	0.28	2	0.23	0.19	0	0.00	0.00	143	0.48	0.38
11	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.81	1.29	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.81	1.29
12	1	0.06	0.07	2	1.39	1.37	1	5.47	5.30	0	0.00	0.00	2	0.13	0.14	0	0.00	0.00	0	0.00	0.00	6	1.43	1.40
13	6	1.31	0.83	5	0.77	0.50	5	0.83	0.52	6	0.66	0.51	6	0.91	0.61	2	0.98	0.83	0	0.00	0.00	30	0.91	0.62

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total
Total Trucks Weighed	746	782	791	744	714	121	58	3956
Total Vehicles Weighed	12923	12874	13637	13880	13408	6353	5523	78498
Total 18-K ESAL (Rigid)	860.17	704.13	832.18	783.76	631.03	89.06	53.41	3953.75
Total 18-K ESAL (Flex)	556.81	472.68	534.65	510.13	404.14	57.72	32.19	2568.33
Total not weighed	3086	3457	3439	3115	3491	1400	1320	19308

Weight Distribution and Average 18-K ESAL by Vehicle Type

Minnesota Test System
From: Monday May 23 10:34 To: Tuesday May 31 12:56

Weight Range	2 axle (3) #	Rigid	Flex	3 axle (4) #	Rigid	Flex	4 axle (5) #	Rigid	Flex	3 axle semi (6) #	Rigid	Flex	4 axle semi (7) #	Rigid	Flex	5 axle semi (8-11) #	Rigid	Flex	5 axle twin (12) #	Rigid	Flex	Other (13) #	Rigid	Flex
< 4	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
4-6	697	0.00	0.00	0	0.00	0.00	0	0.00	0.00	4	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
6-8	1431	0.00	0.00	1	0.01	0.01	0	0.00	0.00	54	0.00	0.00	3	0.00	0.00	0	0.00	0.00	0	0.00	0.00	2	0.00	0.00
8-10	741	0.01	0.01	3	0.01	0.00	0	0.00	0.00	96	0.00	0.00	26	0.00	0.00	0	0.00	0.00	0	0.00	0.00	4	0.00	0.00
10-12	676	0.02	0.02	22	0.02	0.02	0	0.00	0.00	72	0.01	0.01	43	0.00	0.00	2	0.00	0.00	0	0.00	0.00	6	0.01	0.00
12-14	513	0.04	0.04	51	0.03	0.03	0	0.00	0.00	68	0.02	0.03	54	0.01	0.01	2	0.01	0.01	0	0.00	0.00	9	0.02	0.02
14-16	460	0.07	0.07	90	0.05	0.05	0	0.00	0.00	33	0.04	0.04	36	0.02	0.02	7	0.02	0.02	0	0.00	0.00	13	0.03	0.03
16-18	306	0.12	0.13	117	0.06	0.06	0	0.00	0.00	35	0.05	0.05	50	0.03	0.03	26	0.03	0.03	0	0.00	0.00	4	0.06	0.07
18-20	278	0.22	0.23	150	0.07	0.07	0	0.00	0.00	32	0.08	0.08	51	0.05	0.05	102	0.03	0.03	0	0.00	0.00	6	0.08	0.08
20-24	337	0.45	0.46	273	0.11	0.10	2	0.11	0.12	109	0.11	0.12	121	0.08	0.08	536	0.04	0.04	1	0.06	0.06	7	0.11	0.12
24-28	216	1.04	1.03	207	0.20	0.16	2	0.19	0.20	87	0.20	0.21	126	0.13	0.13	453	0.07	0.06	2	0.10	0.10	7	0.09	0.08
28-32	93	2.08	1.98	156	0.36	0.27	3	0.24	0.25	53	0.38	0.39	107	0.20	0.19	637	0.09	0.08	2	0.17	0.18	4	0.10	0.06
32-36	28	3.43	3.16	119	0.76	0.60	2	0.37	0.38	21	0.78	0.80	86	0.40	0.39	663	0.14	0.10	3	0.13	0.13	2	0.15	0.09
36-40	4	4.83	4.36	95	1.29	0.99	0	0.00	0.00	12	1.02	1.05	57	0.54	0.51	366	0.20	0.15	1	0.16	0.17	1	0.49	0.36
40-44	1	11.41	9.74	104	1.98	1.53	2	0.18	0.20	3	2.91	2.73	39	0.90	0.83	228	0.32	0.22	0	0.00	0.00	7	0.36	0.33
44-48	0	0.00	0.00	78	2.33	1.71	1	0.30	0.33	3	2.50	2.44	22	1.11	0.97	184	0.45	0.29	0	0.00	0.00	4	0.38	0.32
48-52	0	0.00	0.00	60	2.86	2.07	4	0.65	0.72	0	0.00	0.00	18	1.78	1.54	143	0.65	0.41	1	2.68	2.63	2	0.65	0.47
52-56	0	0.00	0.00	50	3.63	2.52	10	0.80	0.91	0	0.00	0.00	14	1.98	1.59	153	0.87	0.54	0	0.00	0.00	2	0.41	0.35
56-60	0	0.00	0.00	18	5.17	3.39	6	1.02	1.19	0	0.00	0.00	8	2.75	2.30	149	1.20	0.74	1	0.45	0.38	0	0.00	0.00
60-64	0	0.00	0.00	13	6.78	4.20	6	1.23	1.65	0	0.00	0.00	4	3.84	3.05	164	1.55	0.94	0	0.00	0.00	4	0.77	0.63
64-68	0	0.00	0.00	7	8.60	5.15	8	1.53	1.98	0	0.00	0.00	3	4.32	3.15	210	1.92	1.16	0	0.00	0.00	5	1.77	1.28
68-72	0	0.00	0.00	1	10.51	6.22	4	2.20	2.98	0	0.00	0.00	0	0.00	0.00	228	2.48	1.49	0	0.00	0.00	0	0.00	0.00
72-76	0	0.00	0.00	0	0.00	0.00	2	2.54	3.31	0	0.00	0.00	0	0.00	0.00	342	3.21	1.92	0	0.00	0.00	1	2.98	1.74
76-80	0	0.00	0.00	0	0.00	0.00	1	2.33	4.35	0	0.00	0.00	0	0.00	0.00	450	3.93	2.33	1	7.04	6.47	1	3.36	2.00
80-84	0	0.00	0.00	0	0.00	0.00	3	2.90	4.79	0	0.00	0.00	0	0.00	0.00	374	4.80	2.83	0	0.00	0.00	3	2.05	1.37
84-88	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	322	5.98	3.52	1	5.47	5.30	1	6.05	5.22
88-92	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	168	7.26	4.28	0	0.00	0.00	0	0.00	0.00
92-96	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	50	8.39	4.93	0	0.00	0.00	0	0.00	0.00
96-100	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	11	9.10	5.30	0	0.00	0.00	1	8.69	4.96
100-104	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	2	11.21	6.40	0	0.00	0.00	0	0.00	0.00
104-108	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	11.93	6.93	0	0.00	0.00	1	1.83	3.67
108+up	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	2	2.57	5.33	0	0.00	0.00	2	7.39	4.37
Total Average 18-K ESAL	5781	0.15	0.15	1615	0.84	0.61	56	1.14	1.52	682	0.15	0.16	868	0.33	0.30	5975	1.75	1.05	13	1.29	1.23	99	0.66	0.49
Average Weight	11871			29006			56002			18056			26739			50869			42219			33968		

Car and Single Unit Truck volumes by Hour and Day of Week

Minnesota Test System
From: Monday May 23 00:00 To: Monday May 30 00:00

Class A: Light Vehicles and Light Vehicles with Trailers (Types 1, 2)
Class B: Single Unit Trucks (Types 3, 4, 5)

	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday		Total			
Time	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	%	B	%
0-1	140	4	170	7	207	9	209	6	237	5	368	9	278	4	1609	1.0	44	0.6
1-2	56	1	89	1	82	2	80	4	105	2	219	2	250	4	881	0.5	16	0.2
2-3	27	2	69	0	55	1	58	6	63	5	110	2	123	3	505	0.3	19	0.3
3-4	33	3	36	5	31	5	37	1	41	5	67	6	54	3	299	0.2	28	0.4
4-5	72	17	65	10	69	8	82	8	96	12	62	2	34	3	480	0.3	60	0.9
5-6	344	21	305	22	314	27	298	31	287	16	136	5	67	5	1751	1.1	127	1.8
6-7	1651	56	1385	37	1505	54	1412	38	1260	49	307	12	155	4	7675	4.6	250	3.6
7-8	2780	65	2417	78	2651	71	2660	67	2288	74	499	17	209	5	13504	8.1	377	5.5
8-9	2045	110	2089	106	2064	120	1952	107	1698	114	655	33	327	5	10830	6.5	595	8.6
9-10	1342	106	1343	116	1379	109	1347	127	1371	98	918	35	511	9	8211	5.0	600	8.7
10-11	1140	107	1221	107	1198	116	1261	100	1401	121	1184	29	767	13	8172	4.9	593	8.6
11-12	1339	100	1347	98	1489	112	1450	102	1599	108	1228	25	873	17	9345	5.6	562	8.2
12-13	1332	76	1295	119	1338	95	1415	91	1633	99	1376	28	1196	17	9585	5.8	525	7.6
13-14	1341	84	1314	99	1347	115	1415	139	1447	103	1250	28	1214	18	9328	5.6	586	8.5
14-15	1362	102	1348	104	1447	116	1509	109	1644	97	1195	29	1183	23	9688	5.8	580	8.4
15-16	1837	81	1868	105	1895	83	1979	122	2099	90	1128	27	1103	28	11909	7.2	536	7.8
16-17	2318	73	2441	89	2518	91	2502	85	2355	60	1039	21	1169	16	14342	8.6	435	6.3
17-18	2148	60	2216	59	2304	83	2281	72	1949	44	927	11	1140	11	12965	7.8	340	4.9
18-19	1260	33	1444	35	1650	41	1482	37	1423	31	945	16	1010	14	9214	5.6	207	3.0
19-20	928	25	1084	16	1237	23	1180	27	1205	19	866	9	927	14	7427	4.5	133	1.9
20-21	732	29	803	12	817	14	914	20	888	13	742	9	893	11	5789	3.5	108	1.6
21-22	759	9	756	8	765	17	833	20	717	11	641	7	855	18	5325	3.2	90	1.3
22-23	562	9	545	4	551	4	607	9	608	8	552	6	617	2	4062	2.4	42	0.6
23-24	294	7	400	5	395	7	383	4	503	7	518	7	457	1	2950	1.8	38	0.6
Total	25861	1180	26070	1242	27308	1323	27346	1332	26917	1191	16932	375	15412	248	165846	100.0	6891	100.0
Subtotals																		
6-20	22843	1078	22812	1168	24022	1229	23845	1223	23372	1107	13517	320	11784	194	142195	85.7	6319	91.7
9-16	11758	766	11825	854	12157	866	12328	897	12892	830	8934	234	7174	130	77068	46.5	4577	66.4

5 Axle Semi's and Other Truck Volumes by Hour and Day of Week

Minnesota Test System
From: Monday May 23 00:00 To: Monday May 30 00:00

Class A:5 Axle Semi's, 5 Axle Truck Trailers, 5 and 6 Axle Twin Trailers (Types 8, 9, 12)
Class B: Other Trucks (Types 6, 7, 10, 11, 13)

Time	Monday A	Monday B	Tuesday A	Tuesday B	Wednesday A	Wednesday B	Thursday A	Thursday B	Friday A	Friday B	Saturday A	Saturday B	Sunday A	Sunday B	Total A	Total %	Total B	Total %
0-1	26	3	25	1	29	2	32	2	25	0	6	1	1	1	144	2.8	10	0.5
1-2	16	1	20	0	14	1	19	2	17	1	6	0	1	0	93	1.8	5	0.3
2-3	14	0	14	1	8	1	17	0	21	0	7	0	3	1	84	1.6	3	0.2
3-4	17	1	12	1	12	3	17	2	12	1	4	3	2	0	76	1.5	11	0.6
4-5	20	3	24	3	17	1	30	4	28	1	5	1	2	0	126	2.4	13	0.7
5-6	46	5	26	2	26	4	42	2	45	5	7	3	1	0	193	3.7	21	1.2
6-7	44	9	38	13	35	10	44	13	44	10	12	2	0	0	217	4.1	57	3.1
7-8	29	14	24	14	30	22	42	24	41	13	8	6	1	0	175	3.3	93	5.1
8-9	76	29	59	28	60	17	60	30	52	24	13	7	1	0	321	6.1	135	7.4
9-10	65	26	65	26	77	29	73	26	75	28	12	4	6	1	373	7.1	140	7.7
10-11	78	22	72	34	82	38	75	20	82	27	9	4	3	1	401	7.7	146	8.0
11-12	66	20	76	33	93	29	79	23	96	33	10	11	3	3	423	8.1	152	8.3
12-13	65	25	65	31	75	29	64	29	78	26	11	6	4	5	362	6.9	151	8.3
13-14	72	22	70	21	64	32	53	23	70	21	10	6	7	7	346	6.6	132	7.2
14-15	55	22	67	26	69	27	65	24	61	29	5	2	4	6	326	6.2	136	7.5
15-16	65	36	69	33	56	31	54	35	39	34	6	2	5	2	294	5.6	173	9.5
16-17	42	39	49	36	44	24	45	25	49	27	9	3	5	9	243	4.6	163	8.9
17-18	40	16	42	22	48	29	36	29	31	10	7	3	3	3	207	4.0	112	6.1
18-19	38	5	27	11	35	8	42	10	19	7	4	5	5	2	170	3.2	48	2.6
19-20	35	5	29	8	34	8	36	10	20	12	6	5	7	4	167	3.2	52	2.9
20-21	32	5	24	6	26	3	30	1	17	3	4	3	4	3	137	2.6	24	1.3
21-22	23	5	19	3	23	6	27	3	21	3	1	1	7	4	121	2.3	25	1.4
22-23	34	5	33	1	24	0	21	3	9	4	5	1	2	2	128	2.4	16	0.9
23-24	24	1	20	0	27	2	22	1	8	0	2	1	3	0	106	2.0	5	0.3
Total	1022	319	969	354	1008	356	1025	341	960	319	169	80	80	54	5233	100.0	1823	100.0
Subtotals																		
6-20	770	290	752	336	802	333	768	321	757	301	122	66	54	43	4025	76.9	1690	92.7
8-16	542	202	543	232	576	232	523	210	553	222	76	42	33	25	2846	54.4	1165	63.9

Numbers of Truck Axles by Weight

Minnesota Test System
From: Monday May 23 10:34 To: Tuesday May 31 12:56

Lane:1 3381 5-axle semi's (8,9). Front axles:9463 (1387)
Lane:2 2210 5-axle semi's (8,9). Front axles:9042 (1272)

Front Axles Weight	#	Single Axles Weight	#	Tandem Axles Weight	#	Tridem Axles Weight	#
< 4	3439	< 4	2740	< 8	2098	< 8	46
4-5	965	4-5	779	8-10	1392	8-10	78
5-6	862	5-6	663	10-12	1209	10-12	68
6-7	1109	6-7	707	12-14	1163	12-14	36
7-8	1656	7-8	692	14-16	967	14-16	17
8-9	2311	8-9	600	16-18	653	16-18	21
9-10	2065	9-10	429	18-20	470	18-20	17
10-11	1351	10-11	325	20-22	428	20-22	7
11-12	600	11-12	278	22-24	391	22-24	5
12-13	234	12-13	281	24-26	423	24-26	3
13-14	114	13-14	216	26-28	436	26-28	7
14-15	84	14-15	171	28-30	568	28-30	10
15-16	60	15-16	142	30-32	739	30-32	5
16-17	55	16-17	108	32-34	783	32-34	14
17-18	44	17-18	102	34-36	701	34-36	10
18-19	30	18-19	73	36-38	590	36-38	15
19-20	19	19-20	66	38-40	429	38-40	17
20-21	15	20-21	60	40-42	264	40-42	17
21-22	7	21-22	47	42-44	132	42-44	16
22-23	9	22-23	41	44-46	62	44-46	18
23-24	12	23-24	17	46-48	21	46-48	11
24+up	48	24+up	25	48-50	12	48-50	6
				50+up	7	50-52	4
						52-54	5
						54-56	2
						56-58	0
						58-60	3
						60-62	1
						62-64	4
						64-66	0
						66-68	0
						68-70	0
						70-72	0
						72-74	0
						74+up	0
Total	15089		8562		13938		463
Average Weight	7439		7187		19944		22073

Vehicles with Highest Flexible 18-K ESAL

Minnesota Test System
From: Monday May 23 10:34 To: Tuesday May 31 12:56

#	Type	Day	Time	Axle (or Axle Group) Weights 1st	2nd	3rd	4th	5th	6th	Axle Configuration	Vehicle Weight	18-K ESAL Rigid	18-K ESAL Flexible
1	3	Thu May 26	17:23	7543	32767					11	40310	11.406	9.742
2	9	Thu May 26	03:49	7908	43658	21201	22237			1211	95004	9.582	7.113
3	8	Thu May 26	06:52	14711	44426	45367				122	104504	11.927	6.926
4	8	Thu May 26	00:01	10513	44523	46219				122	101255	12.105	6.864
5	8	Thu May 26	12:29	9821	53192	27723				122	90736	12.112	6.677
6	13	Tue May 24	05:21	15393	52480	36648	10512			1231	115033	11.412	6.673
7	9	Fri May 27	06:12	7032	38015	22863	22133			1211	90043	8.074	6.483
8	9	Sat May 28	11:38	11190	36892	22311	22844			1211	93237	7.920	6.475
9	12	Tue May 24	10:21	10246	19980	26777	8712	12867		11111	78582	7.036	6.470
10	11	Tue May 24	14:31	13679	63030	58560				133	135269	3.041	6.381
11	8	Fri May 27	19:28	9783	35542	50321				122	95646	11.348	6.364
12	9	Wed May 25	10:47	12396	30019	23876	22765			1211	89056	7.227	6.334
13	4	Mon May 23	12:53	17814	51086					12	68900	10.511	6.225
14	8	Wed May 25	04:39	13556	37386	48217				122	99159	10.691	6.154
15	8	Sun May 29	20:37	9510	47273	40266				122	97049	10.849	6.143
16	8	Tue May 31	08:07	12650	41365	45898				122	99913	10.655	6.128
17	8	Wed May 25	13:47	10840	51260	29253				122	91353	10.820	6.049
18	9	Thu May 26	00:44	9517	39043	21315	21852			1211	91727	7.658	6.025
19	8	Wed May 25	19:39	9006	35281	49309				122	93596	10.566	5.939
20	10	Wed May 25	05:27	11646	51607	38932				123	102185	10.313	5.931
21	9	Tue May 31	05:47	8205	39654	20776	21806			1211	90441	7.615	5.911
22	8	Fri May 27	10:53	10338	47885	37100				122	95323	10.198	5.783
23	8	Wed May 25	10:09	9337	49056	34307				122	92700	10.171	5.725
24	8	Tue May 24	07:21	10534	43688	42695				122	96917	9.985	5.705
25	9	Thu May 26	08:24	10351	36057	22494	21057			1211	89959	6.966	5.705
26	8	Thu May 26	15:56	13515	40365	44855				122	98735	9.804	5.695
27	3	Tue May 24	09:07	5952	28399					11	34351	6.458	5.691
28	8	Tue May 24	23:55	10246	42352	43895				122	96493	9.923	5.665
29	8	Tue May 24	17:03	9023	49945	31011				122	89979	10.092	5.650
30	9	Tue May 24	02:30	10512	35403	21574	22091			1211	89580	6.823	5.637
31	4	Mon May 23	12:28	28274	15749					12	44023	6.414	5.632
32	8	Fri May 27	16:13	10099	42982	42936				122	96017	9.754	5.570
33	3	Mon May 30	20:32	8708	28169					11	36877	6.290	5.560
34	4	Sat May 28	07:18	28220	11203					12	39423	6.308	5.559
35	8	Wed May 25	12:25	10809	48950	32664				122	92423	9.796	5.541
36	4	Tue May 24	12:43	15529	50160					12	65689	9.420	5.469
37	8	Thu May 26	11:20	10669	41995	43374				122	96038	9.550	5.468
38	9	Tue May 31	00:17	9622	32786	21741	22296			1211	86445	6.350	5.401
39	8	Tue May 24	15:24	11198	49695	28180				122	89073	9.572	5.399
40	4	Mon May 30	00:27	27901	15550					12	43451	6.085	5.360

Traffic Volumes by Speed Range

Minnesota Test System
From: Monday May 23 00:00 To: Monday May 30 00:00

Speed Range	Monday cars	Monday trks	Tuesday cars	Tuesday trks	Wednesday cars	Wednesday trks	Thursday cars	Thursday trks	Friday cars	Friday trks	Average Weekday cars	Average Weekday trks	Saturday cars	Saturday trks	Sunday cars	Sunday trks	Average Day of Week cars	Average Day of Week trks	%	cum %
00-30	7	0	8	0	2	1	9	0	4	0	6	0	6	0	4	0	5	0	0.0	0.0
31-40	14	3	65	7	21	6	9	2	86	11	39	5	1	2	5	2	28	4	0.1	0.2
41-45	67	13	252	42	78	26	83	17	351	72	166	34	72	6	98	7	143	26	0.7	0.8
46-50	734	174	1349	206	945	177	930	201	1902	304	1172	212	830	49	793	44	1069	165	4.8	5.6
51-55	5989	774	6268	729	6364	836	6286	878	7537	855	6488	814	4233	216	4047	126	5817	630	25.1	30.7
56	2065	227	2057	234	2161	225	2177	243	2126	185	2117	222	1460	50	1378	38	1917	171	8.1	38.9
57	2234	202	2119	214	2172	246	2381	243	2319	167	2245	214	1538	50	1350	42	2016	166	8.5	47.4
58	1945	150	1938	177	2108	192	2022	175	2073	153	2017	169	1317	43	1199	19	1800	129	7.5	54.9
59	1729	137	1729	160	1890	150	1921	159	1796	128	1813	146	1114	36	1017	22	1599	113	6.7	61.5
60	2345	203	2294	193	2505	184	2628	190	2349	147	2424	183	1446	41	1303	21	2124	139	8.8	70.4
61-65	7169	528	6636	535	7551	554	7499	515	5567	409	6884	508	3959	117	3448	55	5975	387	24.8	95.1
66-70	1424	109	1221	66	1376	88	1288	73	738	39	1209	75	836	13	673	5	1079	56	4.4	99.5
71-99	139	1	134	2	135	2	113	2	69	0	118	1	120	1	97	1	115	1	0.5	100.0
Total	25861	2521	26070	2565	27308	2687	27346	2698	26917	2470	26700	2588	16932	624	15412	382	23692	1992		
Average Speed	58.5		57.9		58.4		58.4		57.0		58.0		57.9		57.7		58.0			
		57.2		56.8		56.9		56.8		55.5		56.6		56.5		55.7		56.6		
	58.4		57.8		58.3		58.2		56.8		57.9		57.9		57.7		57.9			

Average Weight Distribution by Axle Configuration

Minnesota Test System
From: Monday May 23 10:34 To: Tuesday May 31 12:56

Axle Configuration	Weight Range	# of Groups	Average Weights 1st	Average Weights 2nd	Average Weights 3rd	Average Weights 4th	Smallest Variation 1st	Smallest Variation 2nd	Smallest Variation 3rd	Smallest Variation 4th	Largest Variation 1st	Largest Variation 2nd	Largest Variation 3rd	Largest Variation 4th
Tandem	<34000	11733	8012	8521			2684	2685			23183	2491		
											19206	2499		
											21851	5165		
											19634	3298		
											20688	4400		
Tandem	>34000	2218	18519	19449			20217	20211			13504	28746		
											26189	11907		
											14827	28902		
											12848	26853		
											26883	13076		
Tridem	<43000	386	4788	6315	6811		9890	9767	9844		7187	21466	14030	
											7778	19435	10182	
											20340	16758	1964	
											5486	19986	16245	
											5685	18778	14092	
Tridem	>43000	63	14547	18437	15997		15803	15879	16039		1305	15502	27239	
											7673	23054	16219	
											8662	27378	26990	
											28388	23916	10349	
											4349	17724	21599	
Quadrem	<51000	15	6282	4255	6449	5178	3413	3743	3143	3630	13072	3449	13979	13711
											13869	8188	14591	10512
											6933	3032	7794	2095
											7980	3856	8140	4880
											10816	6836	10748	7619
Quadrem	>51000	0	0	0	0	0	0	0	0	0	0	0	0	0
											0	0	0	0
											0	0	0	0
											0	0	0	0
											0	0	0	0

Vehicle Classification Categories

Type	Axle Configuration	Description
1		Cars and Pickups (under 3200 front axle)
2		Cars and Pickups with Trailers
3	o o	2 Axle 6 Tire
4	o oo	3 Axle Single Unit
5	o ooo	4 Axle Single Unit
6	o o o	3 Axle Semi (or 3 axle Trk Trlr)
7	o o oo	4 Axle Semi (or 4 axle Trk Trlr)
7	o oo o	4 Axle Semi
8	o oo oo	5 Axle Semi (or 5 axle Trk Trlr)
9	o oo o o	5 Axle Semi
10	o oo ooo	6 Axle Semi (or 6 axle Trk Trlr)
10	o ooo oo	6 Axle Semi
11	o ooo ooo	7 Axle Semi
10	o o ooo	5 Axle Trk Trlr
10	o ooo o o	6 Axle Trk Trlr
12	o o o o o	5 Axle Twin Trlr
12	o oo o o o	6 Axle Twin Trlr
13		other

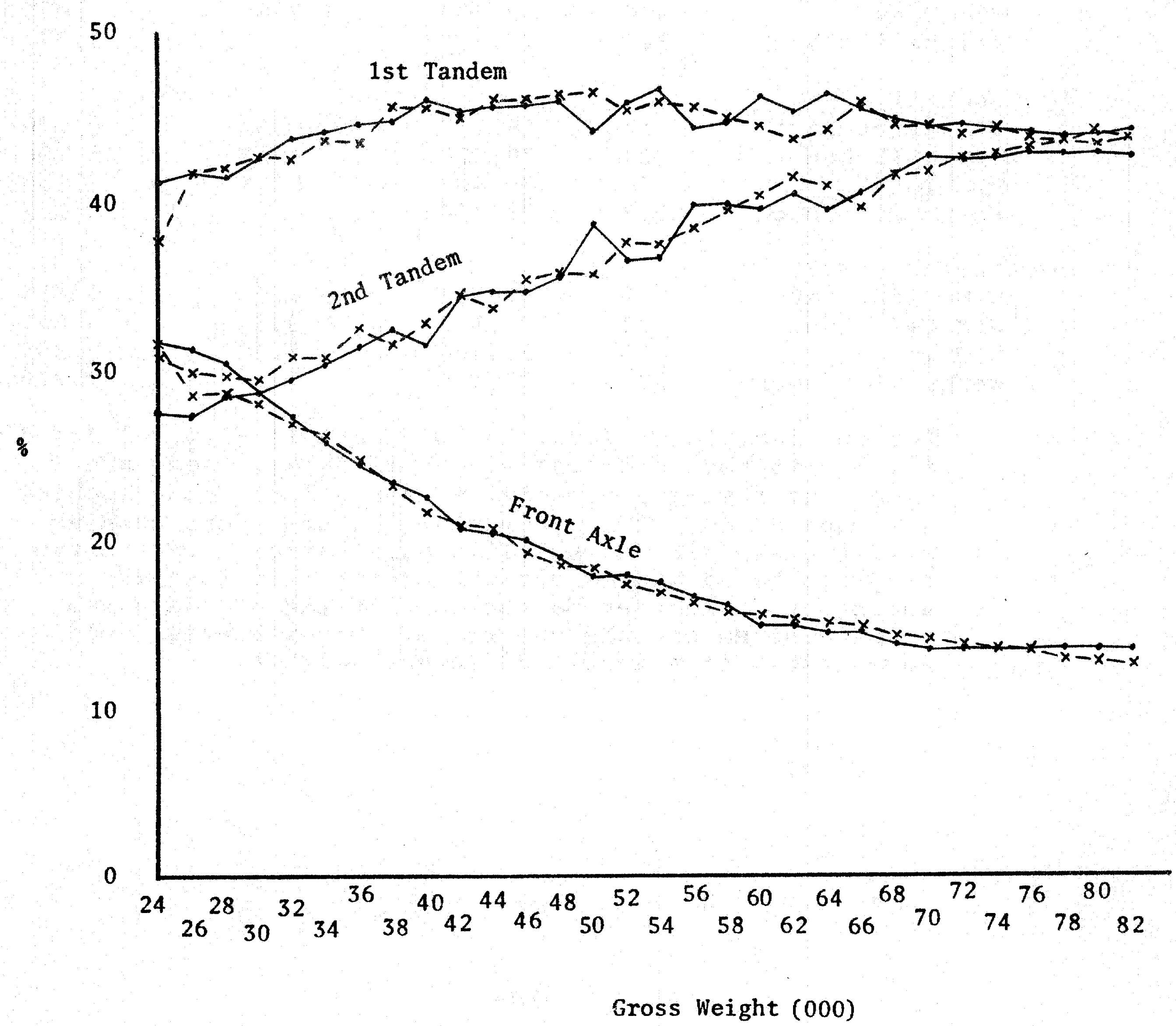
Distribution of Weight

on 5-Axle Semis

Legend

•—•—• Statewide Loadometer 1981

×–×–× WIM July 6-14, 1982



Loaded Grain Trucks

The WIM scales weigh loaded grain trucks coming to the river ports at Minneapolis/St. Paul. A visual identification of grain trucks was made at the WIM site for 3 days in September and October 1982. These WIM weights were compared to the weights recorded on weighbills from logical destination elevators for the same 3 days. A summary of this data follows:

	# of Trucks	Average Weight	% Deviation WIM / Weighbill	Standard Deviation
September 30, 1982				
WIM Right Lane	66	80,011	+ 3.1%	7,723
WIM Left Lane	40	79,290	+ 2.2%	5,980
WIM Total	106	79,739	+ 2.8%	7,095
Weighbill Check	344	77,572		2,977
October 11, 1982				
WIM Right Lane	17	78,239	+ 0.6%	7,140
WIM Left Lane	24	76,920	- 1.1%	5,806
WIM Total	41	77,467	- 0.4%	6,359
Weighbill Check	148	77,744		2,657
October 25, 1982				
WIM Right Lane	27	82,561	+ 6.6%	9,814
WIM Left Lane	23	80,170	+ 3.5%	6,661
WIM Total	50	81,461	+ 5.2%	8,364
Weighbill Check	235	77,429		2,739

For the individual days, the WIM data is +2.8, -0.4 and +5.2% different from the weighbill data. These are excellent results, especially when all of the variables are considered. The particular mix of trucks passing over the WIM site on specific days varies with the type of grain being hauled and the elevator it is being shipped to. Another factor is that the WIM data has been gathered on only one route. Other routes could have trucks of slightly different weights.

System Performance/Reliability

The percent of down time of the system is directly related to two factors. They are 1) the frequency of checks on the system, and 2) the priority it has with maintenance personnel when there is a problem. Personnel checked the system once a week while retrieving data for the past two years. Consequently, if a problem developed in the interim, they were not identified until the next check. Using the system, the problem could have been present for up to one week before detection. The low frequency of monitoring the system automatically lengthens the possible down time.

Mn/DOT does not have a high maintenance priority on the system. The maintenance personnel have to maintain the radios for the State Highway Patrol as well as other high priority communications equipment. Maintenance is scheduled when time permits.

The duration of these failures would be reduced if the frequency of checking were more frequent and maintenance were assigned a higher priority. The use of telemetry will improve system performance monitoring. Operation of the system is at the 97% to 98% range despite these problems.

Inclement weather does not affect the operation of the scales. The following listing shows what the scales have been subjected to in this area.

November 23, 1981	Freezing rain - scales okay
January 10, 1982	-25° F - scales okay
January 16, 1982	-26° F - power out for 4 hours, scales okay
January 20, 1982	17" of snow - scales okay
January 22-23, 1982	19" of snow - scales okay
December 28, 1982	16" of snow - right lane vehicles off wheelpath left lane okay
April 14, 1983	13" of snow - scales okay

Factors representing the amount of deviation between the actual ESAL's for each weekday and the ESAL's in the average day of the year.

Week Beginning		Mon.	Tues.	Wed.	Thur.	Fri.	Average of Mon-Fri
Jun	22, 1981	1.50	1.42	1.58	1.47	1.21	1.44
	29	1.61	1.86	1.34	.91	.31	1.21
Jul	6	1.24	1.28	1.64	1.95	2.06	1.63
	13	1.71	1.47	1.28	1.77	1.77	1.60
	20	2.34	1.61	1.73	2.02	1.44	1.83
	27	1.54	1.58	1.98	1.55	1.55	1.64
Aug	3	1.53	1.90	1.48	1.57	1.40	1.57
	10	1.94	1.79	1.60	1.51	1.19	1.61
	17	2.11	1.77	1.55	1.67	1.28	1.68
	24	1.63	1.40	1.48	1.09	1.33	1.39
	31	2.23	1.77	1.81	1.65	1.51	1.79
Sept	7	.54	2.12	1.95	1.49	1.59	1.54
	14	2.34	2.03	1.90	2.07	1.61	1.99
	21	1.40	1.86	1.76	1.91	1.21	1.63
	28	2.39	1.74	1.66	1.73	1.40	1.78
Oct	5	1.62	1.49	1.76	1.58	1.46	1.58
	12	1.34	1.62	1.32	1.48	1.20	1.39
	19	1.67	1.46	1.41	1.39	1.23	1.43
	26	1.58	1.67	1.85	1.68	1.52	1.66
Nov	2	2.28	1.87	1.87	1.91	1.72	1.93
	9	1.85	1.26	1.39	1.41	1.53	1.49
	16	1.61	1.39	1.40	.86	1.02	1.26
	23	.89	.99	.91	.19	.48	.69
	30	1.12	.64	1.13	.96	.89	.95
Dec	7	1.18	.95	.88	.73	.73	.90
	14	.86	.67	.88	.83	.66	.78
	21	.96	1.20	.71	.35	.08	.66
	28	1.05	.78	.69	.33	.07	.58
Jan	4, 1982	1.12	.91	.67	.82	.72	.85
	11	.64	1.23	.99	1.56	.72	1.03
	18	1.26	1.05	.48	.71	.28	.76
	25	.66	.98	1.00	.64	.70	.79
Feb	1	.85	.85	.91	1.43	1.14	1.03
	8	.95	1.12	1.83	1.27	1.03	1.24
	15	1.23	1.49	1.20	1.26	.98	1.23
	22	1.24	1.17	.86	.94	.70	.98
Mar	1	1.04	.83	.88	.90	.72	.87
	8	.72	.84	1.03	.98	.90	.89
	15	1.01	.84	.89	.96	.68	.88
	22	1.15	.95	1.04	.91	.69	.95
	29	1.08	1.03	.83	1.03	.86	.96
Apr	5	1.09	1.27	1.31	.86	.54	1.01
	12	1.35	1.20	1.27	1.23	.89	1.19
	19	1.33	1.25	1.31	1.19	.77	1.17
	26	1.24	1.34	1.31	1.47	1.10	1.29
May	3	1.54	1.35	1.27	1.48	1.17	1.36
	10	1.57	1.37	1.27	1.33	.98	1.30
	17	1.40	1.61	1.38	1.51	.98	1.38
	24	1.74	1.53	1.51	1.38	1.03	1.44
	31	.44	1.69	1.58	1.48	1.14	1.26
Jun	7	.97	1.33	1.22	1.15	.90	1.11
	14	1.55	1.57	1.53	1.69	1.11	1.49

Findings

- 2 axle 6 tire + 3 axle single unit trucks have trends that repeat by season for both numbers + ESAL factors
- 5 axle semis have trends that repeat by season for numbers but the ESAL factors do not repeat
- The automobile trend is more stable and predictable than trucks
- The lane distribution has 70% of the trucks and ESAL loadings in the right lane
- The speed in the right lane averages 55 MPH while in the left lane it is 60 MPH
- Automobiles average 1 MPH faster than trucks
- 2 axle 6 tire trucks have higher ESAL factors in the winter then in the summer
- ESAL factors for 5 axle semis are fairly stable for average days from Monday through Saturday and then rise sharply on Sunday.
- 2 axle 6 tire trucks make up 40% of the number of trucks and 10% of the ESAL loadings
- 5 axle semis make up 35% of the number of trucks and 65% of the ESAL loadings
- The percentage of numbers of trucks and their ESAL's is highest in the summer and fall and lowest in the winter
- The right lane has approximately 7% trucks in the winter and 9-10% in the summer
- For the year, the right lane has about 10-11% trucks for Monday through Thursday and then it drops to about 4% on Saturday and Sunday.
- A time plot series shows cars and pickups increasing at a steady rate, while numbers of trucks and their ESAL's are more erratic

STATE EXPERIENCES WITH WIM SYSTEMS

PAT SYSTEM

MR. JOHN HAMRICK
IDAHO DEPARTMENT OF TRANSPORTATION
BOISE, IDAHO

IDAHO TRANSPORTATION DEPARTMENT

PAT RESEARCH PROJECT 95

The concept of weighing trucks at highway speed is extremely attractive for purposes of statistical data gathering and as a means of screening for weight limit enforcement.

Of the equipment now in use for weighing trucks in motion, the German PAT system is unique in that the weighing elements, or weighplates, are quite thin and are mounted in very compact and shallow support frames. Installation is relatively simple, requiring only a shallow recess to be cut into the pavement surface, followed by careful anchoring of the support frames. Then the weighplates are installed and the associated electronic data gathering equipment is connected.

PROJECT HISTORY

As a result of interest within Idaho Transportation Department in the weigh-in-motion concept, and in the particular features of the PAT equipment, acquisition of one PAT system was begun in 1978. In the fall of 1979, four weighplates and associated traffic detector loops were installed in the right-hand lane of I-84 eastbound near the permanent weigh station at Bliss, Idaho, at a cost of $12,000 for the equipment. The market price was $65,000, but interest by the supplier in the research potential resulted in the reduced cost. Installation including labor, materials, electrical and equipment cost was $9,900.

Appendix A includes a site layout diagram, photographs of the installation procedure and a list of the installation costs. Initially, the company furnished only a rudimentary data acquisition system to permit functional checking of the weighplates. This was done in the fall of 1979, but no serious calibration nor data gathering could begin before installation of the complete electronic system.

The data system ordered from PAT was specified to include visual CRT display, paper printout and data recording on magnetic tape cartridges. Among the data items to be furnished were axle weights, axle spacings, bumper to bumper distance, gross vehicle weight and speed. As part of the package, a program was requested which would automatically classify trucks according to the number and grouping of axles, conforming to the classification contained in the Idaho weight limit law.

Delivery of the electronic equipment was quite slow. When this project began, PAT had no service organization in the United States and only a single sales representative in this country. Shipping and customs, the language barrier, unfamiliarity with U.S. electronic and data processing standards and the specialized Idaho programming requirements, all contributed to the delays. A final factor which might have been partly responsible for early delays was that, during 1979, PAT was negotiating for a merger with the much larger Siemens-Allis, Inc. The merger took place during the first half of 1980 and it was hoped the association with the worldwide Siemans-Allis, Inc. organization would ease some of the problems mentioned above.

In May of 1980 a PAT technical representative checked the output pulses from the weighplates in preparation for delivery and installation of the remaining equipment. One of the four plates was found to be giving a weak and erratic signal, so a replacement was ordered. During July and August the replacement weighplate and the remaining data acquisition components were installed. Problems with the field computer program and some of the computer circuit boards delayed initial calibration.

By the spring of 1981, initial calibration runs had been made. In April, two of the weighpad frames had to be removed and rebedded in the roadway. A thin layer of quick-setting concrete patching mix had been used originally as a bedding compound for these two frames, but this material broke-up under traffic and weather action causing the frames to loosen. This emphasizes the desirability of accurately cutting the pavement recess to insure that the frame bears directly against the pavement, with only a very thin layer of mastic between the two. After reinstallation, one of the weighplates was found to be giving erratic readings. It was replaced in May.

During the remainder of 1981, data was collected intermittently. Further minor but disabling electronic problems occurred. The CRT display unit had to be replaced, then the operator's keyboard had to be sent to the manufacturer for repair. Also, the Columbia data tape recorder was sent in for repair.

Late in the year, the electronic equipment was installed in an air-conditioned motor home type van. This allows the automatic data acquisition features of the fixed installation to be used in conjunction with the portable PAT weighplates used by ITD for loadmeter-type studies at various locations throughout the State.

By February 1982, most of the initial problems appeared to have been overcome. Enough experience and confidence had been gained to begin data collection on a routine basis.

FIELD CALIBRATION

A three-axle truck of about 30,000 pounds gross weight was used. Multiple runs were made at speeds of 20, 40 and 60 mph and weighplate calibration potentiometers were adjusted to minimize the average differences between PAT gross weights and known static gross weights.

Periodic calibration checks have been carried out, roughly on a quarterly basis, using only the three-axle truck (five runs at each speed). In some cases no system adjustments have been indicated by calibration checks and in others, minor potentiometer adjustments have been required. Multiple check runs are made if potentiometer settings are changed. Appendix B contains results of some calibration checks.

DATA COLLECTION AND DATA ENTRY

Each month, the field crew spends three eight-hour shifts at the weigh-in-motion site, rotated to cover an entire 24-hour period. As vehicles in the normal traffic stream pass over the weighplates, the identities of trucks selected essentially at random are radioed ahead to the Bliss weigh station. These trucks are weighed on the static scales for comparison with PAT dynamic weights. The selection procedure isn't completely random in that trucks which can not be properly identified at the Bliss weigh station are omitted. Also when trucks are backed up waiting to be weighed on the static scale, causing confusion in truck identities, the weigh station is cleared, following which, the first truck that can be properly identified are selected for weighing.

Trucks are excluded also for the following reasons:

1. Obvious speed change by braking or acceleration.
2. Truck are observed to miss one or more weigh pads.
3. Steering axles are on either the left or right one-third of the weigh plates, which cause the trailing axles to miss the weigh plates.
4. Tailgaters, which cause faulty axle classification.

The PAT system has a number of automatic self-checking features which are helpful during data collection and analysis. First, the two pairs of weighplates actually provide two separate weighings of each axle. Large differences between the two weight measurements indicate possible equipment problems and the operator is alerted by an error message. Similarly, comparisons between left and right side indicated weights are made and error messages are generated if the differences exceed certain limits. These features serve as quality control checks and also help in locating the sources of problems which occur from time to time.

The interface program to enable automated reading of field data tapes into headquarters computer storage has not been completed. Therefore, data has, so far, been entered manually through a data terminal. The separate files for PAT and weigh station data are merged by using the proprietary SAS computer package of data manipulation programs.

As part of this data preparation phase, the individual axle weights of tandem pairs, measured by the PAT system are combined to give an overall weight for each tandem pair. This is necessary for valid comparison with weigh station data since both axles of each tandem set are weighed together as a unit at the weigh station.

At this time, the first six months of the twelve-month study have been completed. Faulty communication and equipment contributed to generally unsatisfactory results relating to individual axles. Protracted discussions, and exhaustive equipment analyses and repair during March 1983 appear to offer hope for significant improvement for the remaining six months effort.

All weighplates were replaced along with the analog board, and a detector was installed to isolate vehicles which fail to cross the weighplates properly.

Additionally, equipment problems seem to be solved in relation to automation of computer storage of field data.

Prior to these improvements there appeared to be no alternative to completing the research project on the basis of six months unsatisfactory results. Expectations now are that the concluding six months will provide the equivalent of a successful "after" study.

Exhibit "B" shows two sets of data which suggest equipment, maintenance and communication difficulties have been improved.

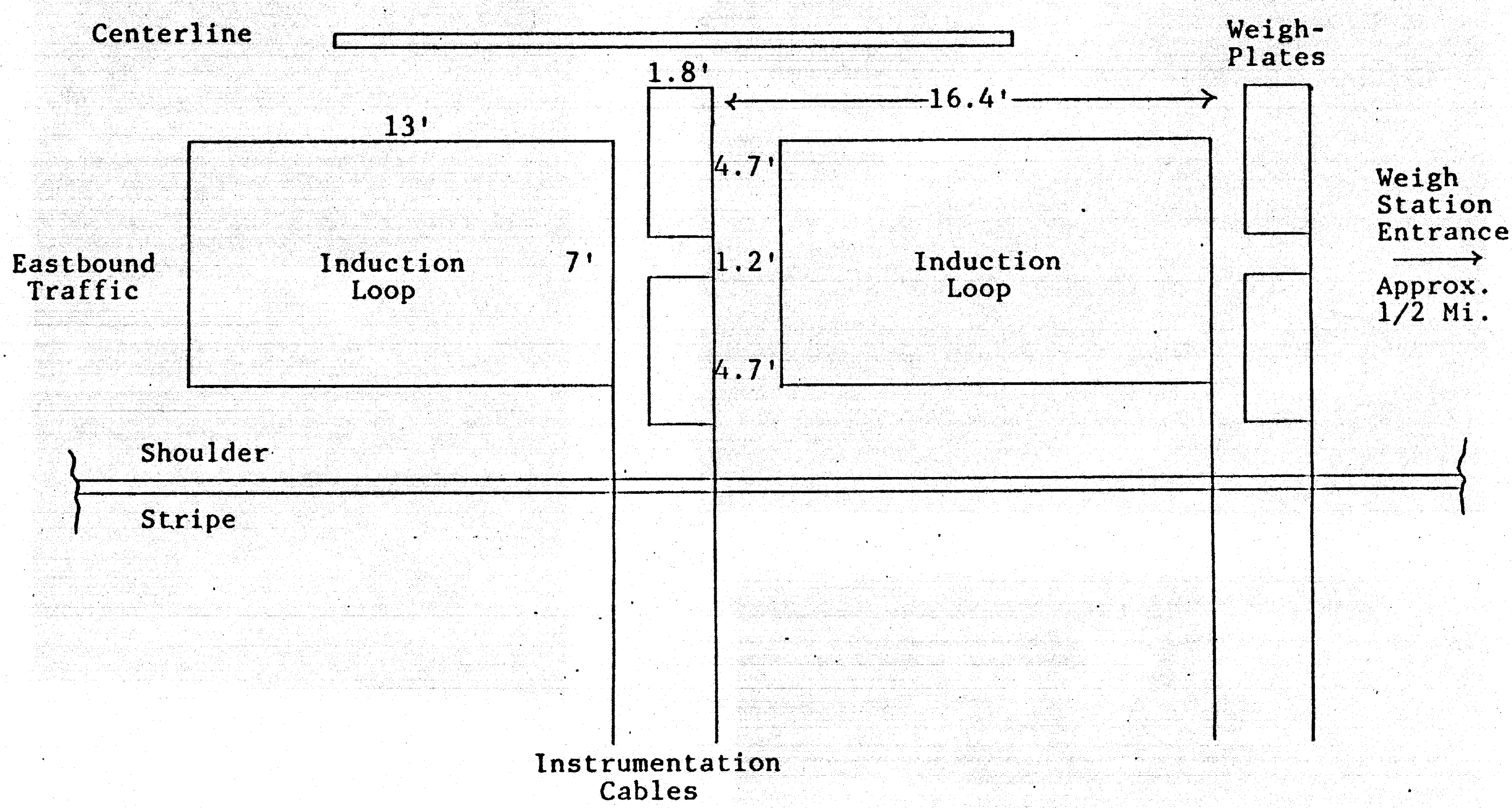
For the period February through July 1982, 804 gross weights (66% of the total) recorded by WIM scales were within ± 5% of the gross weights produced by static platform scales. Following replacement of WIM weigh pads which had been in service since August 1979, 136 gross weights were recorded on April 27-28, 1983 (75% of the total) which were within ± 5%.

Similar improved results were achieved for the weight difference ranges ± 10% and greater while no change occurred in the range of ± 5% to ± 10%. Gross weights in 1982 in 5% to 10% range totaled 219 for 18% of the total. The April 1983 gross weights for this same range totaled 33 for 18% of the total also. Gross weights in 1983 in the range difference greater than 10% totaled 195 for 16% of the total. April 1983 gross weights for differences greater than 10% totaled 13 for 7%.

Idaho is presently using the PAT portable WIM system for collection of truck weight data to satisfy the annual truck weight study and for the Long Term Pavement Management systems. We are able to operate more safely with half of the manpower. Truckers are more responsive and we will reduce coding and data entry efforts better than 50%.

Depending on effective communication, responsive maintenance and supply, Idaho will be looking at WIM systems to collect data for planning and design purposes as well as screening devices at ports-of-entry.

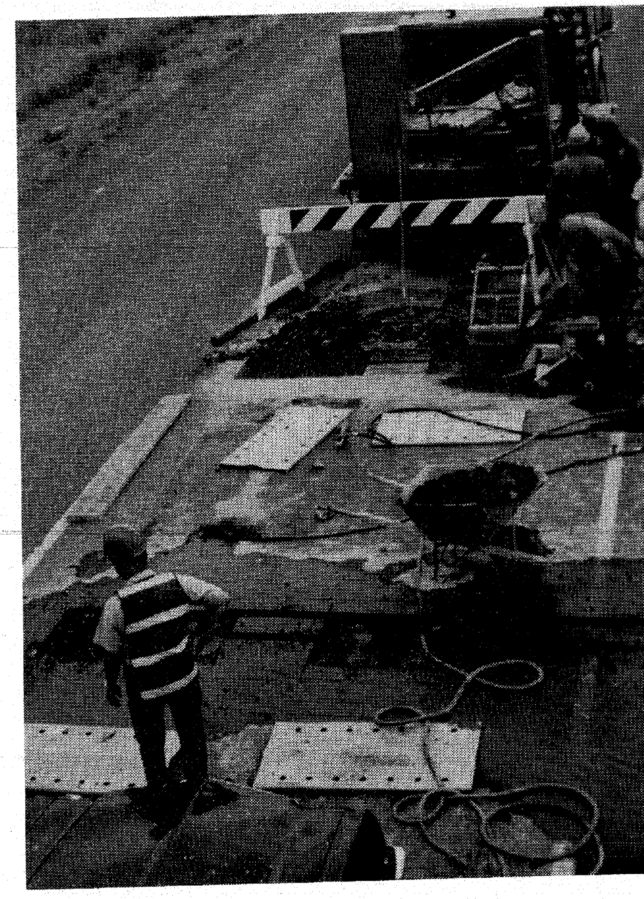
APPENDIX A



PAT WEIGHPLATES AND INDUCTION LOOPS

I84 NEAR BLISS WEIGH STATION

1



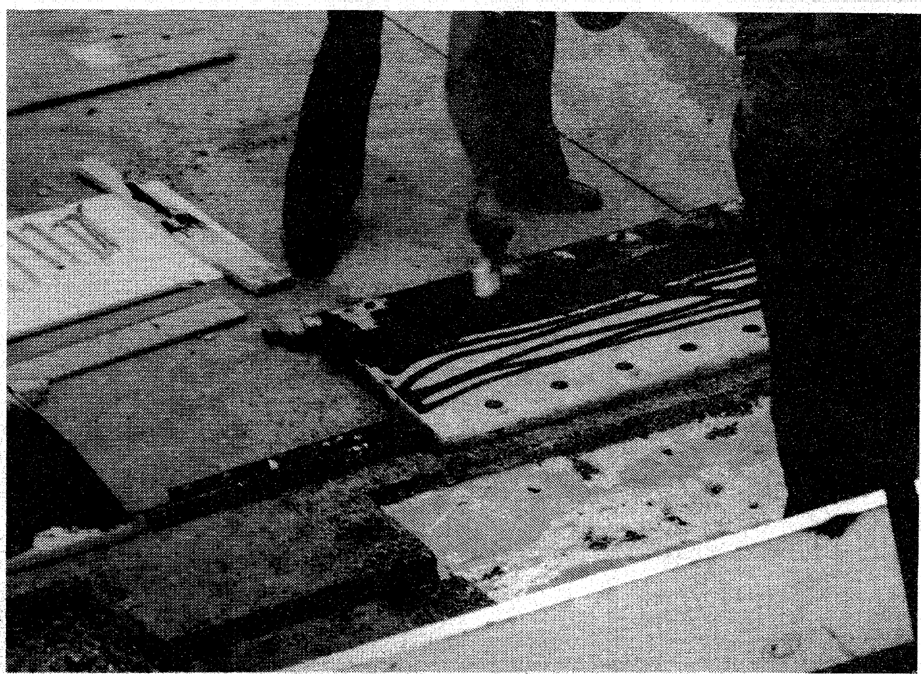
2

3

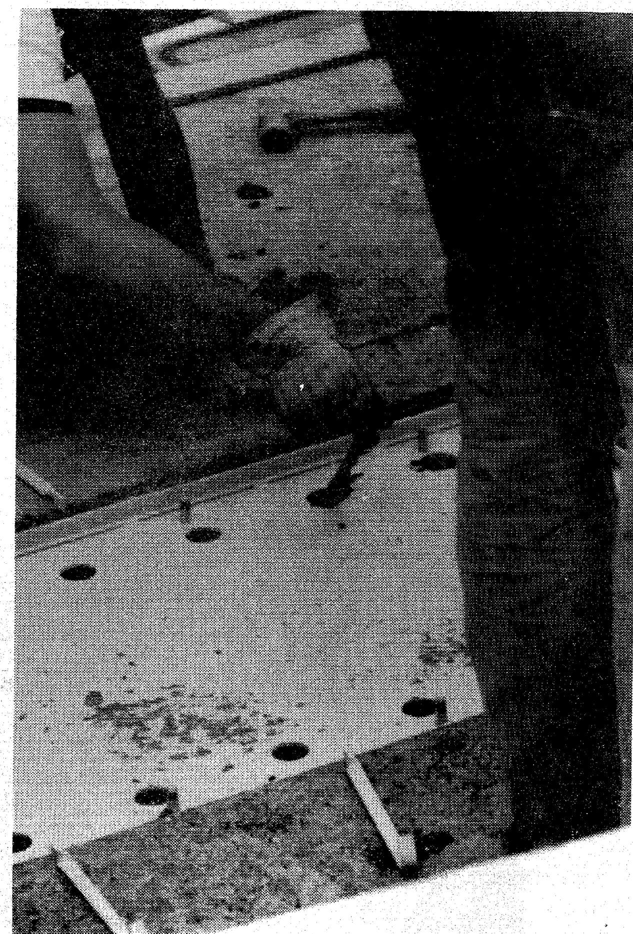
1. Cutting recess for weighplate mounting frame.

2. Finished pavement cuts.

3. Mounting frames (Inverted) with anchor straps.



4



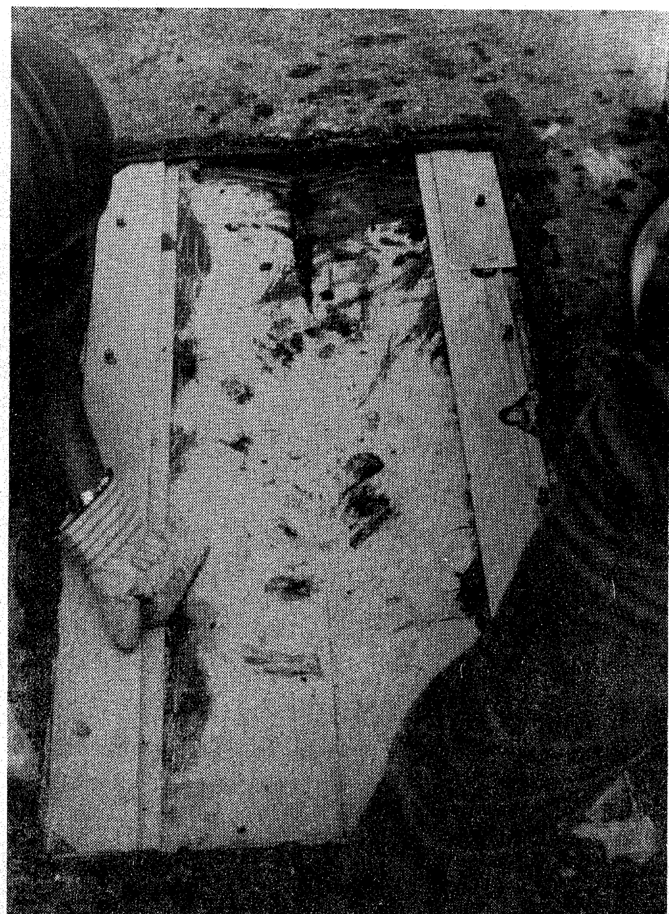
5

6

4. Coating bottom of mounting frame with mastic.

5. Inserting anchor straps into drilled hole filled with mastic.

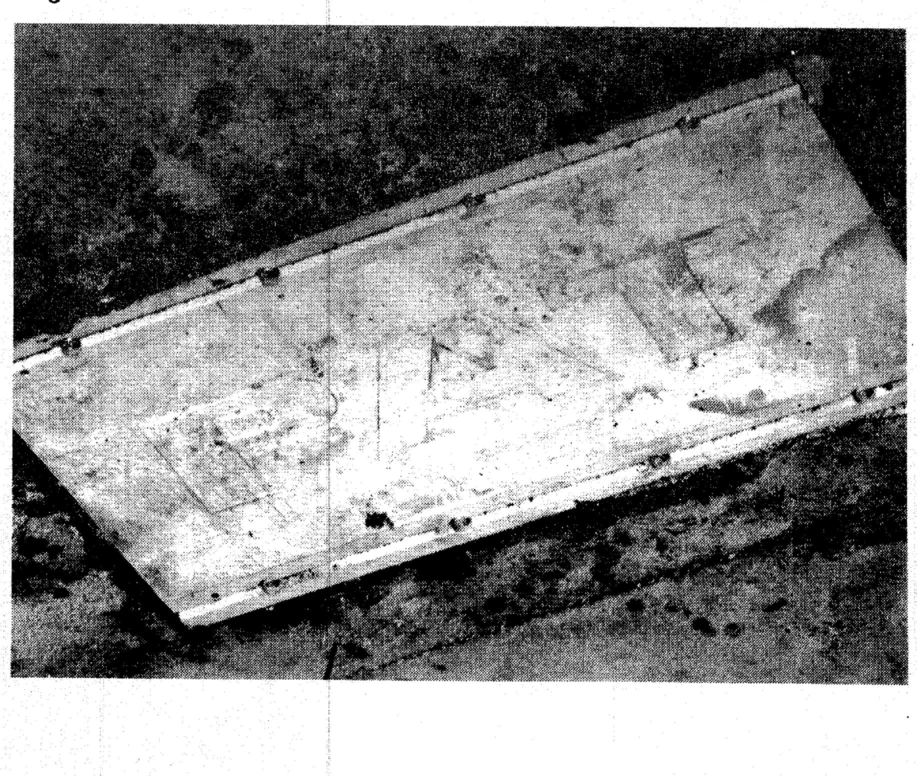
6. Mounting frame installed.



7

9

8

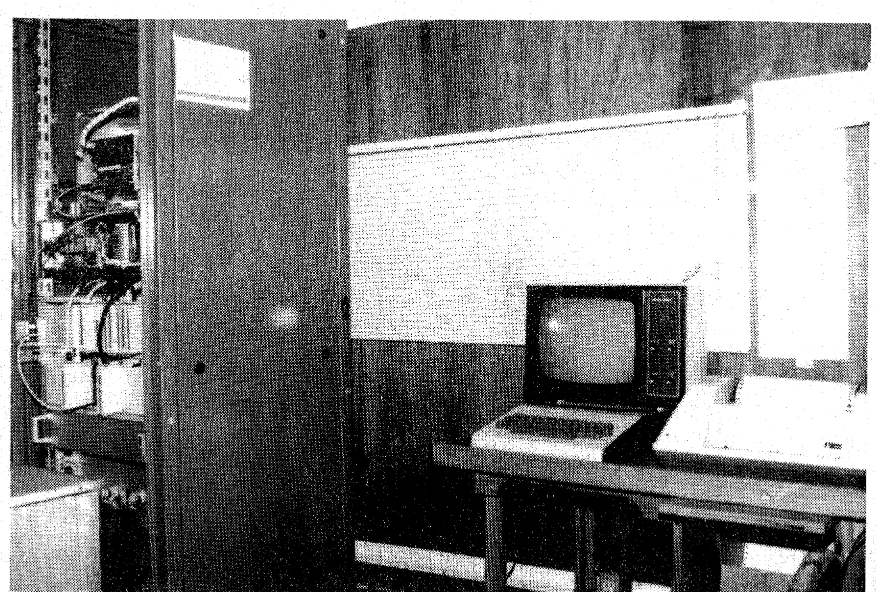


'. Installing weigh-plate support shims.

8. Weighplate installation completed.

). Three axle calibration truck traveling across weighplates.

Computer



Printer

10

Operator's
Keyboard and
CRT Display

10. Interior of Instrumentation Van

IDAHO TRANSPORTATION DEPARTMENT

PAT RESEARCH PROJECT 95

PAT WIM EQUIPMENT AND INSTALLATION COST

PAT WIM Equipment		$12,000
Labor	$6,300	
Travel & Subsistance	1,500	
Materials	600	
Equipment Ditchwitch, Air Compressor, Tar Pot, chippers, Tampers, and Concrete Saw	700	
Electrical Installation Cost	800	9,900
Total Installation & PAT Equipment		$21,900

Total cost of PAT Research Project 95 through September 30, 1982, for data collection and Analysis is $82,000.

EXHIBIT "B"

IDAHO TRANSPORTATION DEPARTMENT

PAT RESEARCH PROJECT 95

Difference between Static Weights and PAT Weights

February through July 1982 Data

xle .ng.	Total Obser.	Percent Diff.	+5% Diff Per. Tot	+ 10% Diff Per. Tot.	>- 10% Diff Percent Tot	>+ 10% Diff Percent Tot.
\	1217	-4.7	54	80	18	2
3	133	-3.6	48	75	20	5
:	94	-6.4	40	63	33	4
)	144	-4.7	44	67	24	9
:	136	-7.0	35	63	33	4
'	66	-5.5	39	64	32	4
;	49	-4.7	24	45	39	16
l	6	-4.2	--	50	33	17
ndem						
:	1083	-3.8	58	81	15	3
)&DE*	1033	-4.1	53	76	18	6
'	4	-4.5	50	75	25	-
oss ight	1218	-4.3	66	84	15	1

April 1983

After New Weigh Pads and Analog Board were Installed

le ng.	Total Obser.	Percent Diff.	+5% Diff Per. Tot	+ 10% Diff Per. Tot.	>- 10% Diff Percent Tot	>+ 10% Diff Percent Tot.
	182	-5.6	47	82	18	--
	24	-0.2	79	92	4	4
	29	2.0	55	93	--	7
	27	1.2	59	81	7	11
	18	2.0	78	94	--	5
	6	-2.0	67	83	--	16
	6	-3.0	33	100	--	--
ndem						
	157	-0.5	69	90	6	3
&DE*	147	-2.5	65	83	14	3
	4	3.3	100	--	--	--
	2	-23.0	--	--	50	50
oss ight	182	-2.2	75	93	7	--

Combined as an expedient

STATE EXPERIENCES WITH WIM SYSTEMS

RADIAN SYSTEM

MR. DONALD PRAY
NEVADA DEPARTMENT OFTRANSPORTATION
CARSON CITY, NEVADA

NATIONAL WEIGH-IN-MOTION CONFERENCE

DENVER, COLORADO
JULY 1983

TOPIC: STATE EXPERIENCES WITH WIM SYSTEMS

SPEAKER: DON PRAY, NEVADA DEPARTMENT OF TRANSPORTATION

THEME: NEVADA'S EXPERIENCE WITH THE RADIAN SYSTEM

NEVADA DEPARTMENT OF TRANSPORTATION ACQUIRED A WIM-ID SYSTEM FROM RADIAN CORPORATION IN 1978, AND THE TOTAL COSTS FROM ALL SOURCES WAS ABOUT $90,000. THIS PRICE INCLUDED A 22 FOOT MOTORHOME, MODIFIED TO OUR SPECIFICATIONS, ALL WIM RELATED EQUIPMENT, AND EIGHTEEN SEMIPORTABLE SITE INSTALLATIONS. ALSO PROVIDED BY RADIAN WAS NECESSARY SOFTWARE, AND TRAINING TO NDOT PERSONNEL ON SITE INSTALLATION AND SYSTEM OPERATION.

NEVADA'S SYSTEM IS SEMIPORTABLE IN OPERATION IN THAT SAMPLE DATA IS ROUTINELY COLLECTED IN EIGHT HOUR SHIFTS AT ALL LOCATIONS EACH YEAR. SHIFTS ARE SCHEDULED TO PROVIDE A SAMPLING OF ALL HOURS, DAYS, WEEKS AND MONTHS OF A YEAR. TWO DIRECTIONAL INSTALLATIONS PLACED IN 1978 HAVE SINCE BEEN REDUCED TO A SINGLE INSTALLATION IN THE HEAVIEST WEIGHTED DIRECTION OF TRAVEL; AND WEIGHTS ARE COLLECTED ONLY ON THE INSIDE LANE OF FOUR LANE ROADS. CURRENTLY, WE HAVE WIM SITES INSTALLED AT FOUR INTERSTATE RURAL LOCATIONS, ONE INTERSTATE URBAN LOCATION, AND SIX RURAL PRIMARY LOCATIONS. WE ALSO PLAN TO CUT IN A SITE ON A FEDERAL-AID-URBAN SYSTEM ROAD SOMETIME THIS SUMMER.

OUR WIM SYSTEM WAS PURCHASED FOR USE AS A SCREENING DEVICE IN NEVADA'S WEIGHT ENFORCEMENT PROGRAM, AND THIS IS STILL THE TOP PRIORITY. I'VE BROUGHT SOME PAMPHLETS THAT DESCRIBE OUR PROGRAM WITH ADDENDUMS THAT SUMMARIZE ANNUAL OPERATIONS. THEREFORE, I WON'T GO INTO DETAILS; HOWEVER, SOME ASPECTS OF OUR OPERATIONS NEED TO BE EMPHASIZED.

TOTAL NDOT WEIGHING PERSONNEL FOR STATIC AND WIM PROGRAMS CONSISTS OF TWO FIELD TECHNICIANS, ONE FIELD SUPERVISOR, AND AN OFFICE ANALYST. WE USE ELDEC PORTABLE PLATFORM SCALES FOR STATIC OPERATIONS, AND BY LAW AN ENFORCEMENT OFFICER MUST BE ON THE SITE.

WITH THE WIM, AN OPERATOR IS ALWAYS ATTENDING THE SYSTEM, AND CONDUCTING A CLASSIFICATION COUNT OF ALL LANES OF TRAVEL. IN AN ENFORCEMENT MODE, STATIC WEIGHTS ARE RADIOED BACK TO THE WIM VAN, AND CALIBRATION ADJUSTMENTS ARE MADE AS NECESSARY. IN ADDITION, A DUPLICATE STATIC WEIGHT SLIP IS MADE WITH THE CORRESPONDING WIM SERIAL NUMBER, AND THIS DATA IS THEN COLLECTED BY NDOT.

IN A PLANNING MODE, A MAINTENANCE VEHICLE WILL MAKE FIVE OR MORE PASSES BY THE WIM SETUP, AND CALIBRATION ADJUSTMENTS WILL BE MADE AS NECESSARY. STATIC WEIGHTS OF THE MAINTENANCE TRUCK ARE OBTAINED USING PORTABLE SCALES CARRIED AS PART OF OUR WIM SYSTEM.

IN THE OFFICE, CLASSIFICATION COUNTS ARE INTEGRATED INTO OUR TRAFFIC COUNTING DATA FILES. WIM DATA IS EDITED, AND UNACCEPTABLE TRUCK WEIGHTS ARE DELETED. STATIC AND WIM DATA ARE THEN ENTERED INTO COMPUTER FILES FOR USE IN DESIGN DESIGNATIONS, PAVEMENT MANAGEMENT AND HIGHWAY COST ALLOCATION ANALYSES, AND OTHER PLANNING AND RESEARCH FUNCTIONS.

THE BOTTOM LINE THAT I'VE BEEN LEADING UP TO IS THAT WE HAVE INCLUDED A CONTINUING AND PERMANENT QUALITY CONTROL MAINTENANCE EFFORT AS AN INTEGRAL PART OF OUR WIM PROGRAM. I PULLED ONE HUNDRED WIM TRUCK WEIGHTS AT RANDOM FROM UNEDITED DATA COLLECTED AT THREE STATIONS OVER THE LAST FOUR MONTHS. WEATHER CONDITIONS RANGED FROM HOT TO COLD, AND WET TO DRY; SPEEDS RANGED FROM 23 TO 66 MPH; AND INDIVIDUAL AXLE VARIATIONS FROM THE CORRESPONDING STATIC WEIGHTS WERE AS HIGH AS THIRTY PERCENT. IT APPEARS ABOUT TEN OF THESE ONE HUNDRED TRUCKS WILL EVENTUALLY BE EDITED OUT OF THE FILES AS BEING UNACCEPTABLE.

FOR ALL VEHICLES THE WIM AXLE WEIGHTS COMPARED TO STATIC WEIGHTS RANGED FROM -5.5% TO +7.2%, AND THE TOTAL OF ALL GROSS WEIGHTS SHOWED A DIFFERENCE OF -0.7%. OF THIS SAMPLE, ONE-THIRD OF THE TRUCKS WERE 3S2 EIGHTEEN WHEELERS. FOR THIS TYPE, THE WIM WEIGHTS SHOWED -4.1% FOR THE FRONT AXLE, -2.1% AND -2.3% FOR THE TANDEMS, AND -2.5% DIFFERENCE FOR THE GROSS. THIS LEVEL OF ACCURACY IS DEFINITELY ACCEPTABLE FOR OUR PLANNING AND RESEARCH NEEDS.

WITH OUR WIM WE HAVE INCREASED WEIGHINGS FIVE-FOLD, AND WE'RE GETTING A MORE ACCURATE REPRESENTATION OF THE WEIGHTS PRODUCED BY ANNUAL TRUCK VEHICLE MILES OF TRAVEL. OUR WIM PROGRAM ACCOUNTS FOR ONE-THIRD OF THE WEIGHTS TURNED IN FOR CERTIFICATION, AND IT ALSO SATISFIES REQUIREMENTS FOR THE FHWA BIENNIAL TRUCK WEIGHT STUDY.

WHERE DO WE GO FROM HERE? WE ARE UNDER FUNDING RESTRAINTS; HOWEVER, WE ARE COMMITTED TO CONSTRUCT SIX WEIGH INSPECTION STATIONS ON OUR INTERSTATE SYSTEM BY 1986, AND EACH WILL HAVE A WIM SITE INSTALLED. WE CANNOT PROVIDE COVERAGE OF THESE NEW INSTALLATIONS WITH EXISTING PERSONNEL AND EQUIPMENT, SO AN ADDITIONAL WIM UNIT IS EXPECTED TO BE IMPLEMENTED BY 1985.

IN CLOSING I'LL EMPHASIZE THAT A WIM PROGRAM WILL NEVER BE A MEANS TO ALL ENDS; THERE ARE MANY THORNS AMONGST THE ROSES; AND YOU ALWAYS NEED TO HAVE "PLAN B" IN RESERVE. I CAN POSITIVELY STATE THAT WE ARE SATISFIED WITH THE HIGHWAY SPEED WEIGHINGS AND SEMIPORTABLE MODE OF OPERATIONS; THAT THE RADIAN SYSTEM IS SERVING OUR NEEDS; AND THAT WITH OUR LIMITED STAFF, WE SIMPLY COULD NOT MAINTAIN AN ADEQUATE WEIGHING PROGRAM IF WE DID NOT USE WIM.

NEVADA

DEPARTMENT OF TRANSPORTATION

INTRODUCTION TO NEVADA'S WEIGH-IN-MOTION PROGRAM

NEVADA
DEPARTMENT OF TRANSPORTATION

PREPARED BY
SPECIAL STUDIES/SAFETY SECTION
PLANNING DIVISION
NEVADA DEPARTMENT OF TRANSPORTATION
IN COOPERATION WITH
DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The Nevada Department of Transportation (DOT) has implemented the Weigh-In-Motion (WIM) system for weighing of trucks while they travel upon our highways. The system is being used to gather data for planning and research and as a screening device for truck weight enforcement. Nevada DOT wishes to express its thanks to A. W. "Tony" Gonzales, Planning Director, J. M. "Mac" Moore (retired), Joe Wood and the entire planning staff of the New Mexico State Highway Department for their time and expertise in introducing their WIM system to us.

No acknowledgement for Weigh-In-Motion can be complete without acknowledging the father of the present method of Weigh-In-Motion, Dr. Clyde Lee of the University of Texas and his research and development conducted in cooperation with the Texas Highway Department.

In keeping with the spirit of cooperations in helping overcome operational problems, Nevada heartily thanks the States of California, Florida, Oklahoma and Texas, and the cooperation extended by the Federal Highway Administration.

Without private industry providing the equipment needed for Weigh-In-Motion this program would not have been possible. The Radian Corporation and Rainhart Corporation in Austin, Texas are the manufactures of the WIM system. A special thanks goes to Mr. Fred Stockbauer, of the Radian Corporation, for providing the unique service of meeting the needs of Nevada rather than providing a product private industry thought we needed. This unique service is immeasurable.

SUMMARY

Nevada's Weigh-In-Motion (WIM) system resulted from a need to reduce the increasing costs associated with the Annual Truck Weight Study and at the same time eliminate the safety hazard posed to both the motoring public and the truck weight crews. Subsequent to the purchase of the WIM System and with the revision of Title 23 U.S.C. requiring annual truck weight and size certification, the increased emphasis on enforcement again created a need to reassess the truck weight program.

The role of Nevada's WIM system has thus become two fold; first, as a research and planning tool, and second, as an enforcement and truck weight monitoring tool.

INTRODUCTION

At the highway speed of the vehicle being sampled, the WIM system will gather and display on the computer console the vehicle wheel and axle weight, gross weight, axle spacing, wheelbase and overall length, speed, vehicle classification and body style. The vehicle classification and body style are operator entered with the appropriate six digit FHWA truck code and editing accomplished through inhouse programming. Sample costs are approximately $2.60 for each truck weighed by WIM versus $17.40 per sample via static weight based on 1974 costs. Nevada's WIM System eliminated the need to construct three new static weight sites with a construction and right-of-way cost estimated at $270,000. Total WIM cost was $86,765 which included $58,515 for computer hardware and motorhome plus $28,250 to replace the ten original static weight sites for a statewide system. The Annual Truck Weight Study utilizing the WIM System can be accomplished by two employees at a cost of $5,000 versus $35,000 and eight employees for the static weight program. Additionally, 100% of all trucks are weighed opposed to approximately 30% for the static method. Total gross weight obtained off the WIM system are within ±1% of static gross weight with individual axle weights varying ±5%. Axle variations are due to dynamic movement at the moment of being weighed and are considered "true action weight" upon the pavement versus "standing" static weights.

The truck weight enforcement program is being conducted in cooperation with the Motor Carrier Division of the Department of Motor Vehicles. The WIM System is used as a screening device which eliminates the need to stop and statically weigh each vehicle. Nevada truck weight limits for single and tandem axle plus gross weight are pre-programmed in the computer. These weights are checked together with each individual axle group weight by applying the "bridge formula"* $W = 500 [(LN/N-1) + 12 N + 36]$. If any weight category exceeds the state limit the printer is activated and a hard copy of the vehicle's weight data is printed. The printed copy displays all weight data, state weight limits that were exceeded, and legal allowable weights for each violation. All truck data collected is recorded on flexible disk in IBM-compatible format providing inter-changeability in having data diskettes processed at any IBM 3741 compatible data processing center. When the WIM unit is being used for enforcement, all truck data is stored and becomes usable data for research and planning.

* W = Maximum Load in Pounds carried on any Group of Two or More Consecutive Axles
L = Distance in Feet Between the Extremes of any Group pf Two or More Consecutive Axles
N = Number of Axles in Group under Consideration

OPERATIONAL FEATURES

The statewide semi-permanent WIM sites are activated by installing the Rainhart Corporation portable scale into frames which have been installed into the roadway surface (Picture No. 1). The scales are connected to the mobile van, containing the Radian Corporation computer hardware, through a junction box located near the travelway. To install or remove the scales requires closing the travel lane and takes approximately 30 minutes with a minimum of two people. A semi-permanent site capability is also possible with the scales remaining installed indefinitely at a single location.

WIM site installation of scale frames, junction box and inductive loops requires approximately two days and four employees. Scales are installed in the right travel lane with speed detection loops installed in all travel lanes (Picture No. 2). All vehicle speeds are recorded by lane of travel with speeds recorded in five MPH increments.

The WIM System is powered from a 10 KW portable power unit mounted upon a trailer. The trailer also carries an extra power unit, regulatory signing, portable weight scales, extra WIM scales, traffic cones and accessory equipment. The Weigh-In-Motion system is completely self-contained (Pictures No. 3 and 4).

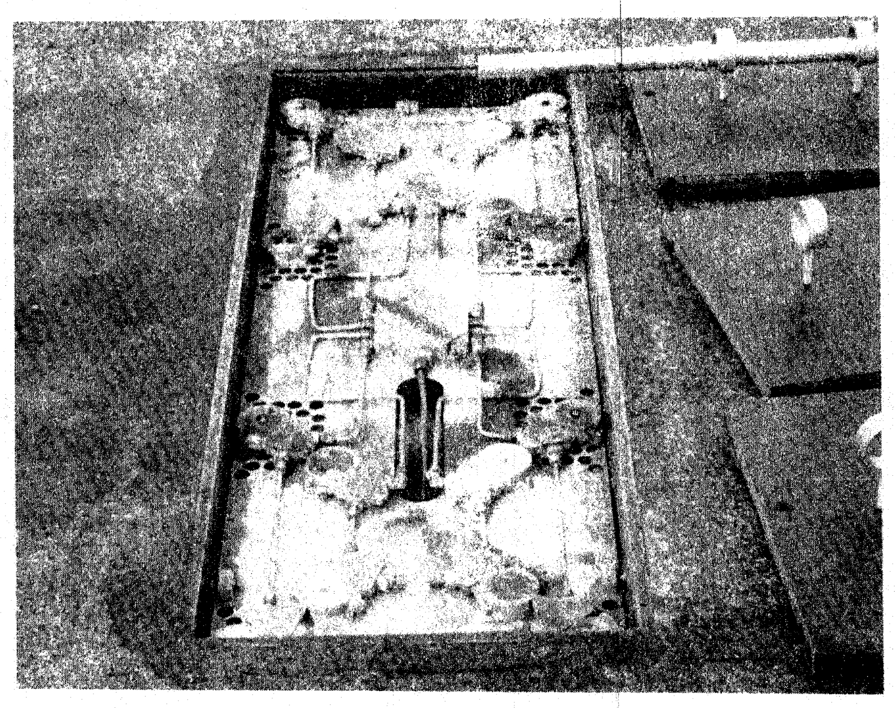
The weighing operation (Picture No. 5) can be accomplished by a single employee during any time period and weather condition. All weight data from each vehicle/truck passing over the scales are displayed on the operator console Cathode-Ray Tube (CRT) screen. This gives the operator the opportunity to accept the data gathered or reject the data if he feels it was not proper.

The computer is programmed to display the system monitoring parameters to ensure proper balance and gain of the equipment. This allows the operator to recognize a potential imbalance of the system and adjust prior to a vehicle being weighed. (Picture No. 6)

The high speed printer provides a hard copy of the truck weight data and speed data that is collected. The printer can be placed on line for every sample taken, or upon demand only, or is programmed to provide a printout of overweight vehicles. (Picture No. 7)

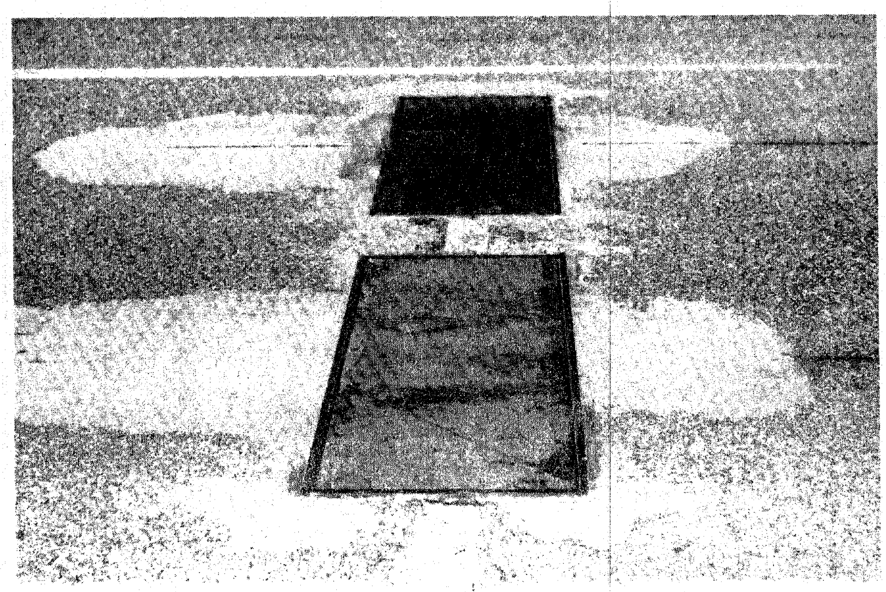
ENFORCEMENT SCREENING OPERATION

The WIM System is used as a screening device in detecting potential overweight vehicles. Advance regulator traffic signs advises the truck driver, in trucker terms, "Weight Watcher Ahead", "Hang the Right Lane," "Hold'er Steady," and "Thanks" upon approaching and leaving the WIM station. Thus, weight data can be obtained on every truck traveling at highway speeds. Any truck that, for whatever reason, does not register correctly on the computer or fails to move into the right travel weighing lane is subject to being stopped downstream from the WIM scales by the Motor Carrier Division of the Nevada Department of Motor Vehicles, responsible for enforcing the Nevada vehicle weight laws. Radio communication between the WIM van and the enforcement agency is used to identify the suspect vehicle (Picture No. 8). The suspect vehicle is pulled off the travelway and statically weighted. (Pictures No. 9 and 10). All citations for overweight violators are issued from weights obtained from certified static portable or permanent scales. Citations are not issued from the weight data gathered from the Weigh-In-Motion scales.



PICTURE NO. 1

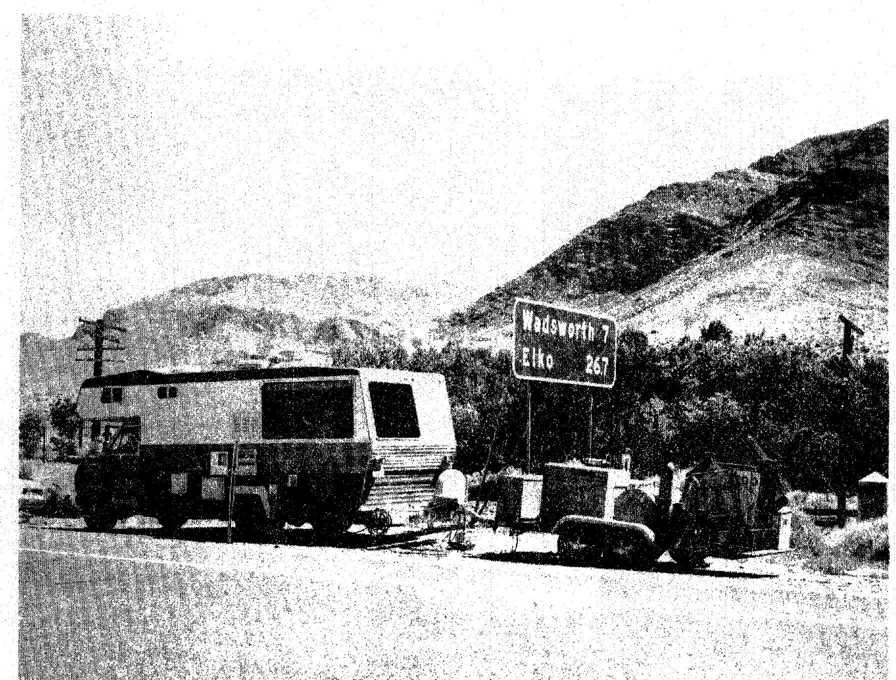
WIM SCALE PIT, TRANSDUCER SCALE AND LOAD PLATES.



PICTURE NO. 2

SCALE PITS WITH LOAD PLATES IN EACH WHEEL PATH.
NEVADA,AT PRESENT, USES RIGHT TRAVEL LANE ONLY.

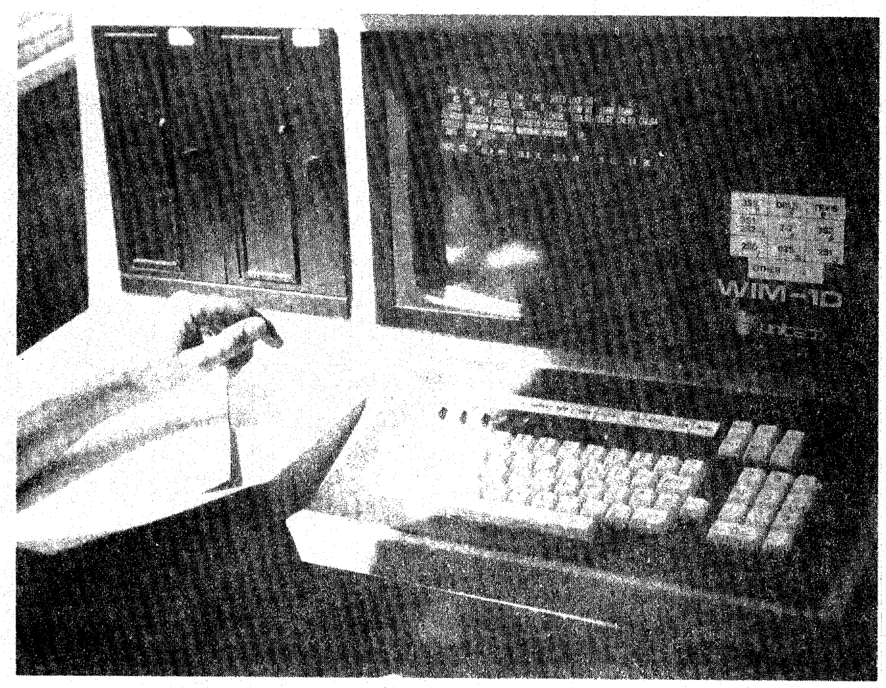
PICTURE NO. 3
WIM MOTOR VAN, WITH ACCESSORY TRAILER
CONNECTED TO ROADSIDE JUNCTION BOX.



PICTURE NO. 4
WIM MOTOR HOME PARKED ALONG ROADWAY AT SCREENING
WEIGHT SITE ON I – 80 EAST OF RENO, NEVADA

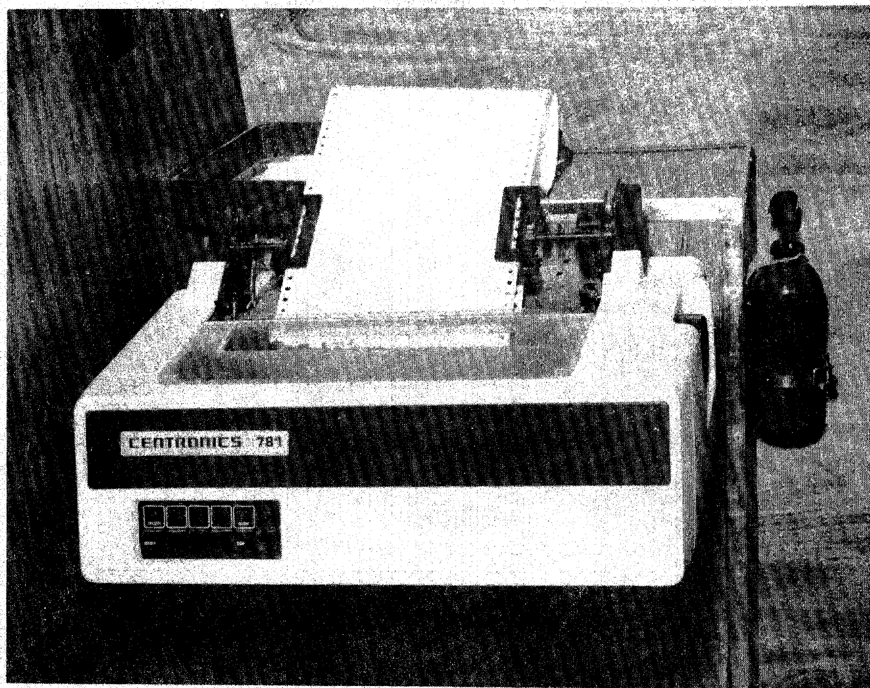
PICTURE NO. 5

WEIGHT OPERATOR AT WIM CONSOLE WITH FULL VIEW OF ROADWAY AND APPROACHING TRUCK TRAFFIC.



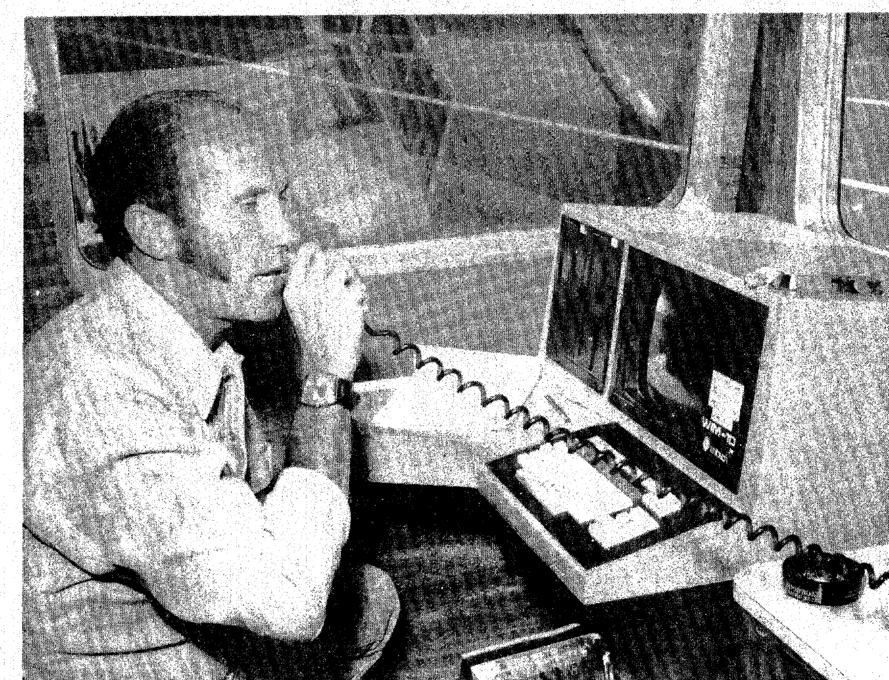
PICTURE NO. 6

WIM CRT DATA VIEW SCREEN DISPLAYING SYSTEM MONITORING PARAMETERS AND VEHICLE WEIGHT DATA



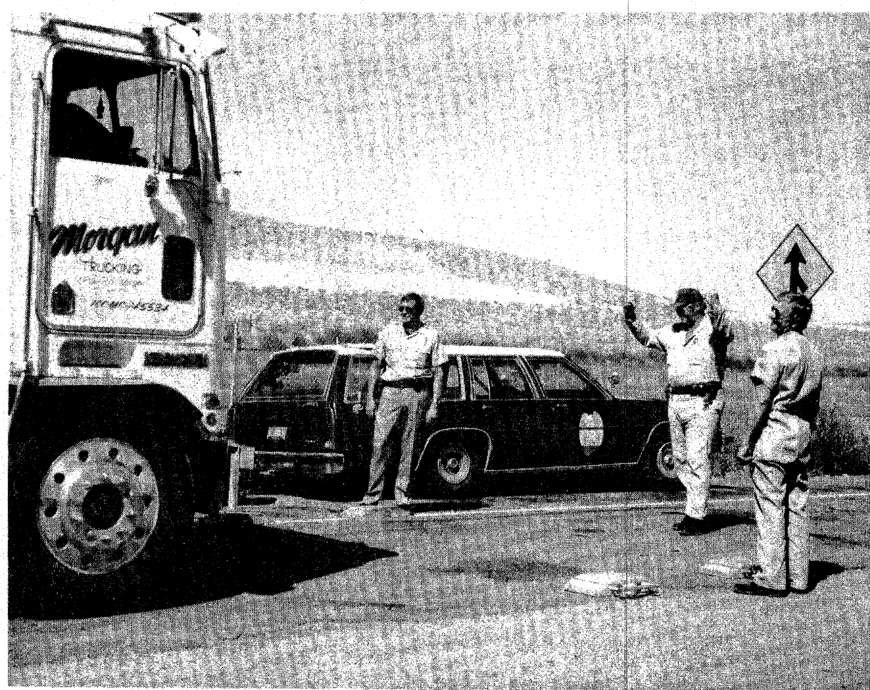
PICTURE NO. 7

HIGH SPEED PRINTER PROVIDING A HARD COPY OF SPEED AND WEIGHT DATA UPON DEMAND BY OPERATOR.



PICTURE NO. 8

ALL TRUCK TRAFFIC WEIGHTS ARE SCREENED BY THE WIM VAN. RADIO COMMUNICATION IS USED BETWEEN VAN AND ENFORCEMENT TO IDENTIFY SUSPECT VEHICLE



PICTURE NO. 9

STATIC WEIGHT OF SUSPECT VEHICLE IS ACCOMPLISHED DOWNSTREAM FROM WIM VAN BY THE MOTOR CARRIER DIVISION, NEVADA DEPARTMENT OF MOTOR VEHICLES.

PICTURE NO. 10

PORTABLE SCALES ARE USED TO FACILITATE THE PORTABILITY OF THE COMPLETE WEIGHT ENFORCEMNT PROGRAM. CITATIONS FOR OVERWEIGHTS ARE ISSUED FROM DATA GATHERED FROM STATIC SCALES ONLY.

COST EFFECTIVENESS OF WEIGH-IN MOTION OPERATIONS

In 1981 NDOT participated in a year long Truck Weight Case Study under contract with FHWA. The objective was to gather a sample of weights for all truck types, and on all functional classifications of roads. Realizing that the emphasis was to collect quality data rather than large volumes of truck weights, the following is a summary of information.

Data Collection	Total	Static	WIM
Trucks Weighed	17087	8292	8795
Field Shifts	168	108	60
Shift Hours	1272	792	480
Personnel Hours	7553	5873	1680
Personnel cCosts	86706	65193	21513
Vehicle & Equip. Costs	32723	24357	8366
Data Reporting			
Personnel Hours	2616	2224	392
Personnel Costs	32218	27385	4833
Program Administration			
Personnel Hours	2420	1900	520
Personnel Costs	30000	23400	6600
Total			
Personnel Hours	12589	9997	2592
Total Costs	181647	140335	41312
Weighed Per Shift Hour	13.4	10.5	18.3
Cost Per Truck Weighed	10.63	16.92	4.70

COST EFFECTIVENESS OF WEIGH-IN MOTION OPERATIONS

In 1981 NDOT participated in a year long Truck Weight Case Study under contract with FHWA. The objective was to gather a sample of weights for all truck types, and on all functional classifications of roads. Realizing that the emphasis was to collect quality data rather than large volumes of truck weights, the following is a summary of information.

Data Collection	Total	Static	WIM
Trucks Weighed	17087	8292	8795
Field Shifts	168	108	60
Shift Hours	1272	792	480
Personnel Hours	7553	5873	1680
Personnel cCosts	86706	65193	21513
Vehicle & Equip. Costs	32723	24357	8366
Data Reporting			
Personnel Hours	2616	2224	392
Personnel Costs	32218	27385	4833
Program Administration			
Personnel Hours	2420	1900	520
Personnel Costs	30000	23400	6600
Total			
Personnel Hours	12589	9997	2592
Total Costs	181647	140335	41312
Weighed Per Shift Hour	13.4	10.5	18.3
Cost Per Truck Weighed	10.63	16.92	4.70

NEVADA DEPARTMENT OF TRANSPORTATION

WEIGH-IN-MOTION (WIM) SYSTEM

OPERATIONS SUMMARY, JANUARY 1978 - MAY 1981

The following is a summary of notes kept by NDOT technicians involved with Nevada's Weigh-In-Motion System. It is not a technical report that goes into details or presents an argument for or against any particular weighing system; and is only an informal presentation of NDOT experiences that could be of interest to other personnel involved with dynamic weighing.

Nevada's WIM system was implemented in 1978; however, it was not relied upon for extended use where accuracy was a critical factor until late 1980. Prior to that time the WIM was used for enforcement screening whereby suspect overweight trucks were also being weighed on certified portable scales, and for comparative weighings to establish quality control of the WIM data where portable scale crews were weighing and measuring the same trucks.

Since August 1980 the WIM has been used to collect data for the bi-annual truck weight study required by the Federal Highway Administration, to collect planning data as part of a year long national case study that NDOT has contracted, and as a screening device in an accelerated program of weight enforcement. Under heavy duty use, and in all types of weather conditions, the WIM has collected reliable data with only minor problems that were quickly resolved.

During the trial period of 1978 through mid-1980 NDOT learned that operators of the WIM must have at least a basic knowledge of electronics in order to understand the system and perform emergency repairs in the field. The alternative is to have a technician from the company that manufactured the system fly in and resolve the problem which will be expensive, and the use of the WIM may be lost for considerable periods of time. By the same token, the WIM system is complex, and it is equally important to recognize when an outside technician is necessary to correct a problem. Radian, the manufacturer of the NDOT WIM equipment, has been very cooperative in designing a system, immediately transmitting parts for testing and replacement, and sending a technician on short notice on two occasions when a problem could not be resolved.

Likewise, at least one person must be familiar with all steps from the initial collection of data in the field, through the software programs that format the collection and conversion of data to useable form, and the uses of the data for planning, pavment design and enforcement purposes.

Currently there are thirteen installations in the outside travel lanes of major highways at strategic locations statewide, and all WIM data is collected at normal highway speeds. Alternatives were considered of installing plates in all lanes and in both directions; however, based upon costs it was decided data collected in the heaviest weighted direction for only one lane would suffice. Additional installations are planned for urban locations, and in conjunction with six motor carrier inspection stations programmed for construction on the interstate system by 1985.

The WIM system at any given installation is in operation for periods of a few hours up to twenty four hours, and has never been operated continuously for over forty eight hours. Since August 1980 the WIM system has completed an equivalent of 65 eight hour shifts, and with additional time screening for enforcement, has logged over 1,000 hours of duty. There was one problem with a module board in the computer console that required five consecutive shifts to be rescheduled.

Once weighing is completed at a given site, the transducers (weigh scales) are removed and "dummy" scales are placed under the plates that remain in the roadway. Originally it was planned that the transducers would remain in the roadway; however after the first winter it was discovered that water was getting into the pits and rust was forming on the scales.

Major problems have not been encountered with site installations, and NDOT personnel are learning 'tricks of the trade' that make for a better operation. For example, presence loop detector wires were breaking where they pass under the scale frames - plastic tubing now houses all wires including those from the scale pit to the junction box where the manufacturer recommended copper tubing be used. A recent check indicates the plastic tubing may be contracting such that water is getting to the wires; and copper tubing may be necessary, despite the cost. MC (porous) asphalt instead of the recommended epoxy is used to fill the loop saw cuts to allow replacement of broken wires, and to facilitate a power trace when necessary.

Two installations had to be removed. At one site the water table would rise such that the pit was filled with water, and the scale frame was sinking into the pavement. The second site had been in place since early 1978, and was also plagued with drainage problems. This installation was planned for removal; however, before being removed one of the "dummy" scales broke, and the plates came onto the roadway when a truck passed over. Fortunately there was only minor damage to the truck. Seven million car axle repetitions and five million truck axle repetitions are estimated to have passed over the plates. Whether the breakage occurred as a result of the pounding effect of the wheel repetitions, or as a result of slack that may have developed between a plate and it's resting point on the "dummy" scale, cannot be stated.

Dirt and sludge collecting in scale pits during periods of non-use is a problem. To facilitate drainage away from the pit, the trough from the pit to the junction box is now cut deeper such that the opening where the wiring lays also serves as a drain. The blower action of a shop vacuum cleaner serves well to clean a pit prior to operation, and NDOT is establishing a program of preventive maintenance whereby all sites will be regularly checked by properly trained personnel.

The NDOT WIM system is portable in that all equipment necessary to operate a site is carried by a motor home and smaller trailer. This includes five transducers (two are needed for a site), traffic control signs, portable scales for calibration, and two generators for power. Commercial power from a pole was tried at the first installation; however, electrical noise was effecting weights. External signals transmited by radio, television and overhead power lines will also effect readings, and grounding of equipment and the motor home is necessary. Power from the generators will also become "dirty", and current outputs are regularly checked and generators kept in the best operating condition. Radian sells an in-line filter that will stabilize the power going into the computer; however, this was not included on NDOT's system.

A single generator initially provided power for the WIM, and the air conditioner and lights inside the motor home. Again, there was a conflict in the electrical supply, and a second generator was installed such that one unit provides power only for the WIM system. The trailer with the generators is also disconnected from the motor home while weighing due to vibration.

Large temperature variations, such as Nevada experiences between day and night at any time of year, can effect the calibration of the system. This requires the attention of an experienced operator to maintain calibration. Operations in the southern part of Nevada required that a second heavy duty air conditioning unit be installed in the motor home where the computer console is housed.

Hardware problems have related to modules for the computer console, and the transducers. Radian officials have readily worked with NDOT personnel over the phone to trace a problem, and immediately shipped modules for trial and error checking. NDOT personnel are not formally trained in eleectronics, and Radian technicians are able to patiently explain procedures in a layman's terms such that a problem can usually be resolved. As previously indicated, a Radian technician came on very short notice on two occasions when a solution could not be reached, and the system was back in operation on the same day the technician arrived.

Occasionally a transducer will not stay calibrated. If water has gotten into a load cell, the unit can sometimes be dried out in an oven located in the NDOT Testing Lab and the problem is solved. If this does not resolve the problem, or if a load cell is damaged, the item is shipped to Radian and a correctly functioning transducer is usually back within two weeks. Load cell damage may be the result of wheels pounding on the surface plate that sets on the load cell, and NDOT has recommended to Radian that the plates be manufactured to specifically fit the frame in which they are installed. The plates are now made to fit together as a set; however, they are not made to fit a particular frame, and adjustable bolts are used to obtain the best fit. It should be noted that NDOT transducers were manufactured by Rainhart, and Radian has assumed this operation to assure better quality control for their system as a total unit.

Software problems have primarily been from communications, e.g., NDOT being able to identify needs, and Radian being able to understand and program for these needs. At this point, NDOT is very satisfied with their software package. Outputs are with FHWA codes for vehicle type and body type, the "bridge formula" is internally programmed to activate the printer and display at least one violation of each weight type (gross, axle and/or group), and all data will be correct if the calibration is maintained. A very important alteration by Radian allows the balance mode to display during weighing operations which lets the operator verify and, if necessary, recalibrate just prior to a truck being weighed. One minor problem resulted when a module was changed in the computer console wiithout a corresponding program change.

Data collected in the motor home is stored on flexible diskettes in IBM compatible format, and read and transferred to magnetic tape at a central computer facility. NDOT has had problems transferring data which is primarily due to loss of quality control at the computer facility. In cases where the facility claims the diskette will not run, the total data is ran on the printer in the motor home, then manually entered into the computer via Phase Four Terminals located in the office. NDOT is investigating other alternatives including telephone transfer or acquiring their own reader.

With the software provided by Radian, NDOT programmers have been able to format data to meet FHWA and departmental needs. Until recently all edit checks had to be performed in the motor home and changes made to the diskette prior to transferring to magnetic tape. Now NDOT programmers have provided changes that allow any changes to be accomplished through Phase Four Terminals. Likewise NDOT is able to run FHWA W-Tables and process 18 Kip evaluations for project design.

Obviously, NDOT believes the WIM system is an asset to operations as long as the user is prepared to work within the capabilities of the system, and is willing to work with the system.

OPERATIONS SUMARY (CONTINUATION), JUNE 1981 - MAY 1982

Since May 1981 the system has completed 50 field shifts (300 WIM hours) for enforcement screening and the FHWA Annual Truck Weight Study. Beginning in January 1982 enforcement screening operations were increased such that approximately 20 field shift days (150 WIM hours) are being logged each quarter, and the WIM van is on the road 50 percent of the time.

Four problem areas indicated in the previous "Operations Summary" have become more apparent during the last year:

1. Some roadway sites are deteriorating

   Roadway installations have now been in place 3-4 years. Of the original 18 installations, 11 remain. 2 installations were removed for convenience; however, in the other 5 sites removed, the frames were either sinking into the pavement, or the pavement surrounding the frames had deteriorated.

   Solutions being considered are (1) pouring a concrete subbase under the frames, and (2) additional preventive maintenance surrounding the installations, such as spot overlays.

2. Frame and covering plate problems

In three of the installations the "dummy" scales that are placed in the frames under the covering plates have broken. Part of the problem may be related to the sinking frames that allows a greater pounding effect however, experience is indicating the metal content and weld joints of the "dummy" scales do not hold up under continued stress.

We currently are developing experimental prototype "dummy" scales that will have this problem solved by the end of this year.

3. Transducer (load Cell) malfunctions

Each transducer (weigh scale) has eight outside load cells that are individually sealed and factory calibrated to perform as an integrated unit. In the past, when a malfunction occurred, the entire transducer was sent to Radian Corporation in Texas for repair. Shipping costs have made this practice prohibitive, and our technicians are now "cannibalizing" one of the transducers to keep the remaining four units operational. Maintaining correct recalibration records for each load cell as it related to the total integrated transducer unit is the critical concern in this process.

4. <u>Data conversion from diskette to magnetic tape</u>

NDOT originally had direct access to a diskette reader when plans were formulated to purchase a WIM system in 1977. Subsequently, computer services for basically all State agencies were absorbed into a central Data Processing center, and likewise, direct access to the diskette reader was lost. We have had continuing problems maintaining quality control of data in the transferral process, and have recently been informed by CDP that the service will be discontinued.

NDOT is in the process of analyzing all alternatives for access of field collected data, and it now appears we will be arranging for telephone modems to allow direct transfer of data from diskettes to magnetic tapes at CDP.

NDOT relies upon WIM to conduct the FHWA biennial truck weight study, and as a screening device for enforcement of State weight laws. Data collected is also used for roadway design criteria and must be within an acceptable tolerance level.

Although we do have problems with our WIM operations, we too often neglect to point out the positive side. As previously pointed out, we are able to solve problems as they are occurring and maintain weighing operations. By comparison, problems with the WIM are no more so than we experienced with portable scale operations, only of a different nature (portable scale operations involved increased personnel, lights and standards plus cords to cover the entire site, scales, signing and traffic control, and vehicles to transport the personnel and equipment).

With the WIM we are annually running 100 shifts and approximately 1000 hours of operations (including calibration time), and we could not accomplish this workload with portable scales and available manpower. Six planned additional sites in conjunction with motor carrier inspection stations are currently inactive due to project fund cutbacks; however, two sites are still planned for urban locations in 1982.

OPERATIONS SUMMARY (CONTINUATION), JUNE 1982 - MAY 1983

NDOT has now had an operational WIM system for five years. Although the system and the various components necessary for operation are too complex to be called a routine operation; the program is collecting most of our planning data, annd it's an integral part of the Nevada weight enforcement and Federal certification process.

In a given year 15,000 weights are collected using WIM, and half are reported for certification. WIM weighings could be increased by concentrating more on the Interstate System; however, the overall quality of the program would be diminished as less time would be spent weighing on other road systems. In addition, the Motor Carrier Division has been assigned new duties related to wrecker and taxi inspections, and hazardous material inspections; and Agents have less time to devote to the weighing program. Total static and WIM weights reported for certification are about 35-40,000 trucks. Basically all components of the Radian WIM system originally purchased are still in operation, and increasing maintenance costs are not out of line.

For example, the motor home has over 60,000 miles while pulling a trailer that carries two generators, gas tanks, signs and portable scales. NDOT Equipment Division has indicated the trailer weight is pulling the motor home body away from the frame, and recommends that a separate pickup be used to pull the trailer. The two-axle trailer also had one wheel totally break off during a recent field trip.

Concerning the actual WIM system, NDOT has been trying to upgrade components. We have developed and are using an improved substitute transducer, or "dummy scale" that rests under the roadway plates when weighing is not in effect; however, there is still the problem of deteriorating pavements at some sites. In particular we have had site problems where the location is in an remote area experiencing low traffic and truck volumes, and the site is not used for weighing on a regular basis. Now that we have replaced our portable "jump" scales with more efficient portable platform scales, we are considering using WIM only where there are larger numbers of trucks (500 in one direction), or where total traffic volumes pose a safety hazard to static operations.

Most recently we have placed an order with Radian for sealed transducer units. These are an improved scale; however, NDOT will probably not be able to work on these units if a malfunction occurs the way we do with the older Rainhart scales.

In the system maintenance process, our printer had to be repaired. There are no local electronics services available, so the unit had to be shipped to California. This type of malfunction is obviously a bothersome inconvenience, and combined with the vehicle problems, the WIM system was inoperable for over a month of time.

The most serious and continuing problem is in the area of data processing, and it's an area over which planning personnel responsible for the WIM program have no control. As indicated in a previous summary, diskette reader services offered by Nevada Central Data Processing have been discontinued. We have tried to establish a direct transfer from the WIM motor home computer to the State's main-frame computer via telephone modem; however, CDP maintains there is too much interference on the telephone lines. Now we are trying to establish a transfer from the motor home onto a Four-Phase System which can then be directly input into the main computer. This procedure will hopefully be established by August, and at present Radian is processing our diskettes.

STATE EXPERIENCES WITH WIM SYSTEMS

STREETER AMET SYSTEM

MR. KENNETH COPELAND, CHIEF
OFFICE OF PERMITS AND ENFORCEMENT
BEORGIA DEPARTMENT OF TRANSPORTATION
ATLANTA, GEORGIA

STATE'S EXPERIENCES WITH WEIGH-IN-MOTION SYSTEM (STREETER AMET)

By:

M. Ken Copeland, Chief, Office of Permits & Enforcement

Georgia Department of Transportation

Presented At:

National Weigh-In-Motion Conference, Denver, Colorado

July, 1983

IT WAS THE DESIRE OF THE GEORGIA D.O.T. TO HAVE FULLY OPERATIVE SYSTEMS WHICH WOULD ACCURATELY AND AUTOMATICALLY, PRE-SELECT VEHICLES WHILE IN MOTION FOR ENFORCEMENT WEIGHING AND AUTOMATICALLY DIRECT THE SELECTED VEHICLES TO THE ENFORCEMENT SCALES.

GEORGIA DID INSTALL HER FIRST TWO SYSTEMS AND BEGAN OPERATING IN MAY 1978 WHICH WAS THE FIRST W.I.M. SYSTEM USED IN ENFORCEMENT IN THE U.S. WE HAVE SINCE OUR FIRST INSTALLATION, PUT INTO OPERATION AN ADDITIONAL NINE MORE FOR A TOTAL OF 11 AND TWO MORE WHICH WILL BE OPERATIONAL IN SEPTEMBER. IT IS OUR GOAL TO HAVE A TOTAL OF 18 IN OPERATION WITHIN THE NEXT TWO YEARS. ALL OF OUR W.I.M. SYSTEMS ARE LOCATED IN OUR PERMANENT STATIONS ON THE INTERSTATE SYSTEM.

IN 1980 WE INSTALLED FOUR W.I.M. SCALES MANUFACTURED BY STREETER AMET, TWO SYSTEMS IN EXTREME SOUTH GEORGIA AND TWO IN NORTH GEORGIA. SINCE THAT DATE, WE HAVE INSTALLED ONE MORE SYSTEM BY STREETER AMET. THE LATEST STREETER AMET W.I.M. SCALES HAS BEEN INSTALLED IN CARROLL COUNTY WHICH IS APPROXIMATELY FIVE MILES FROM THE ALABAMA LINE ON I-20. THIS STATION HAS BEEN IN OPERATION ABOUT ONE MONTH.

WE DID HAVE A FEW PROBLEMS WITH THE W.I.M. SYSTEMS IN GEORGIA. THEY WERE OUR DESIGN PROBLEMS, NOT OF THE MANUFACTURE OF THE W.I.M. SYSTEM. OUR STATIONS WERE SO DESIGNED THAT WE USED ASPHALT OFF-RAMPS IN WHICH OUR W.I.M. SYSTEM WAS INSTALLED. BY USING THIS DESIGN THERE WAS ONLY A SHORT PERIOD OF TIME BEFORE RUTTING BECAME VERY NOTICEABLE AND MUCH DECREASE IN THE ACCURACY OF OUR W.I.M. SYSTEM. TRUCKS ARE ROUTED ACROSS THE W.I.M. SCALES SUCH THAT THERE IS LITTLE LATERAL DISTRIBUTION OF WHEEL PATHS. THIS WAS CONSISTANTLY

RESULTING IN RUTTING OF THE ASPHALT PAVING AND HAVING HARMFUL EFFECTS ON THE SCALES' STRUCTURE AND PERFORMANCE.

WHERE STOPPING AND STARTING OF TRUCKS TAKE PLACE WITHIN THE STATIONS, RUTTING AND CORRUGATION OF THE ASPHALT PAVING RESULTS. BETWEEN THE W.I.M. SCALES AND THE STATIC SCALES, THIS CONDITION WAS VERY NOTICEABLE.

LEAKAGE OF FUEL AND OIL FURTHER AGGRAVATED THE PROBLEM BY SOFTENING THE PAVEMENT, AS DID THE HIGH SURFACE TEMPERATURE OF THE ASPHALT PAVING DURING THE SUMMER MONTHS.

A RIGID PAVEMENT STRUCTURE APPROXIMATELY 600 FEET PRIOR TO AND A MINIMUM OF 50 FEET PAST THE W.I.M. SCALE IS DESIRED TO ALLOW TIME FOR VERTICAL OSCILLATIONS TO DAMPEN IN THE VEHICLES TRAVELING AT SPEEDS TO 50 M.P.H., THUS CAUSING GREATER ACCURACY OF THE W.I.M. WE HAVE, AT THE PRESENT TIME, REPLACE ALL ASPHALT RAMPS WITH CONCRETE AND ARE NOW EXPERIENCING EXCELLENT WEIGHTS FROM THE SYSTEM. I WOULD DISCOURAGE THE USE OF ASPHALT PAVING IN THE W.I.M. SCALES.

OTHER PROBLEMS OCCURRING HAVE BEEN GENERATED BY LIGHTNING. THIS PROBLEM HAS OCCURRED AT NEARLY ALL STATIONS AT ONE TIME OR ANOTHER REGARDLESS OF MAKE OF EQUIPMENT.

THE W.I.M. SCALES AT THE NEW CARROLL COUNTY LOCATION IS USED, AS OUR OTHER INSTALLATION, AS A SORTING DEVICE. IN ADDITION TO SORTING AS TO SPEED, GROSS WEIGHT, AXLE WEIGHT, AND TANDEM WEIGHTS, EACH VEHICLE HAVING A GROSS WEIGHT OF 65,000 POUNDS OR MORE IS CHECKED FOR COMPLIANCE WITH THE BRIDGE FORMULA.

THE GROSS WEIGHT OF EACH VEHICLE IS ACCURATELY ESTABLISHED TO WITHIN (+=5%) OF THE ACTUAL VEHICLE GROSS WEIGHT AND WITHIN A (90%) CONFIDENCE LEVEL. THE AXLE WEIGHT OF EACH VEHICLE IS ACCURATELY ESTABLISHED TO WITHIN (+-10%) OF THE ACTUAL VEHICLE AXLE WEIGHT AND IS WITHIN A (75%) CONFIDENCE LEVEL. THESE ACCURACIES ARE ATTAINED AS A VARIETY OF MULTIPLE AXLE TRUCKS PASS OVER THE SCALES AT SPEEDS FROM 10 MILES PER HOUR UP TO 55 MPH.

AT SLOWER SPEEDS, OUR ACCURACY IS MUCH BETTER, GIVING US HOPE THAT ONE DAY W.I.M. SCALES MAY BE USED FOR WRITING OVERWEIGHT CASES. FOR EXAMPLE, AT SPEEDS BELOW 10 MILES PER HOUR, THE TRUCKS' GROSS WEIGHT IS WITHIN (+-2%) OF ACTUAL GROSS WEIGHT AND WITHIN A (95%) CONFIDENCE LEVEL AND AXLE WEIGHT WITHIN (+-5%) WITHIN A (75%) CONFIDENCE LEVEL. THE ACTUAL VEHICLE WEIGHT IS THAT WEIGHT ESTABLISHED BY OUR STATIC SCALES USED FOR ENFORCEMENT.

THE ACCURACY ESTABLISHING THE DISTANCE IN FEET BETWEEN THE EXTREMES OF ANY GROUP OF TWO OR MORE CONSECUTIVE AXLES OF VEHICLES HAVING A GROSS WEIGHT OF 65,000 POUNDS IS WITHIN (5%) OF THE DISTANCE MEASURED BY OUR ENFORCEMENT OFFICERS USING STANDARD MEASURING EQUIPMENT AND TECHNIQUES FOR (90%) OF VEHICLES CHECKED FOR COMPLIANCE WITH THE BRIDGE FORMULA.

IF ANY OF THE OPERATOR ENTERED CRITERIA IS EXCEEDED BY THE TRUCK, THEN THE EQUIPMENT WILL AUTOMATICALLY ACTIVATE A TRAFFIC CONTROL SYSTEM AND DIRECT THE DRIVER TO THE ENFORCMEENT STATIC SCALES FOR A MORE PRECISE WEIGHING FOR A POTENTIAL VIOLATOR.

OUR SIGNALIZATION CONTROL IS REFLECTOR LAMPS USING INTERRATIONAL TRAFFIC ENGINEERING COLORS IN RED FOR THE "X" AND GREEN FOR THE ARROW, AND ARE CLEARLY VISABLE AT 1/4 MILE AT ALL TIMES UNDER NORMAL ATMOSPHERIC CONDITIONS AND ARE USED TO PROVIDE OVERHEAD LANE CONTROL FOR THE W.I.M. EQUIPMENT AND TO REGULATE AND SORT TRUCKS ON THE EXIT RAMP.

THERE IS A LOOP DETECTOR IN THE BY-PASS LANE WHICH DETECTS A VEHICLE THAT HAS BEEN DIRECTED BY THE AUTOMATIC SORTING SYSTEM TO PROCEED TO THE STATIC AXLE SCALES BUT INCORRECTLY PROCEEDED TO THE BY-PASS LANE. THE LOOP DETECT ACTIVATES A BUZZER AT THE OPERATOR'S CONSOLE TO ALERT THE OPERATOR.

THERE IS A HIGH INTENSITY LIGHT ON THE BACK OF EACH OVERHEAD SIGNAL WHICH IS ILLUMINATED WHEN THE GREEN ARROW IS ILLUMINATED. TWO SMALL PIN LIGHTS AT THE W.I.M. CONSOLE ALSO INDICATE THE VEHICLE HAS BEEN DIRECTED TO THE STATIC SCALE OR THE BY-PASS LANE. THERE IS A MANUAL SWITCH IN THE OPERATION OFFICE TO OVERRIDE THE AUTOMATIC MODE OF OVERHEAD SIGNS.

THE INSTRUMENTATION PRE-SELECTS VEHICLES WHERE SUCCESSIVE VEHICLES ARE ONE SECOND APART, FROM TAIL TO HEAD OR GREATER.

THE W.I.M. SYSTEM WILL PERFORM ALL THE FUNCTIONS JUST MENTIONED AS A VARIETY OF VEHICLES PASS OVER THE W.I.M. SCALES AT THE MAXIMUM RATE OF 12 PER MINUTE.

THE IMPACT OF THE W.I.M. SYSTEM TO OUR ENFORCEMENT PROGRAM HAS BEEN GREAT. ARE NOW ALLOWED TO WEIGH 100% OF THE TRUCK TRAFFIC WHICH PASS THROUGH OUR STATIONS. LAST YEAR WE WEIGHED IN EXCESS OF FOUR MILLION VEHICLES

OUR SIGNALIZATION CONTROL IS REFLECTOR LAMPS USING INTERRATIONAL TRAFFIC ENGINEERING COLORS IN RED FOR THE "X" AND GREEN FOR THE ARROW, AND ARE CLEARLY VISABLE AT 1/4 MILE AT ALL TIMES UNDER NORMAL ATMOSPHERIC CONDITIONS AND ARE USED TO PROVIDE OVERHEAD LANE CONTROL FOR THE W.I.M. EQUIPMENT AND TO REGULATE AND SORT TRUCKS ON THE EXIT RAMP.

THERE IS A LOOP DETECTOR IN THE BY-PASS LANE WHICH DETECTS A VEHICLE THAT HAS BEEN DIRECTED BY THE AUTOMATIC SORTING SYSTEM TO PROCEED TO THE STATIC AXLE SCALES BUT INCORRECTLY PROCEEDED TO THE BY-PASS LANE. THE LOOP DETECT ACTIVATES A BUZZER AT THE OPERATOR'S CONSOLE TO ALERT THE OPERATOR.

THERE IS A HIGH INTENSITY LIGHT ON THE BACK OF EACH OVERHEAD SIGNAL WHICH IS ILLUMINATED WHEN THE GREEN ARROW IS ILLUMINATED. TWO SMALL PIN LIGHTS AT THE W.I.M. CONSOLE ALSO INDICATE THE VEHICLE HAS BEEN DIRECTED TO THE STATIC SCALE OR THE BY-PASS LANE. THERE IS A MANUAL SWITCH IN THE OPERATION OFFICE TO OVERRIDE THE AUTOMATIC MODE OF OVERHEAD SIGNS.

THE INSTRUMENTATION PRE-SELECTS VEHICLES WHERE SUCCESSIVE VEHICLES ARE ONE SECOND APART, FROM TAIL TO HEAD OR GREATER.

THE W.I.M. SYSTEM WILL PERFORM ALL THE FUNCTIONS JUST MENTIONED AS A VARIETY OF VEHICLES PASS OVER THE W.I.M. SCALES AT THE MAXIMUM RATE OF 12 PER MINUTE.

THE IMPACT OF THE W.I.M. SYSTEM TO OUR ENFORCEMENT PROGRAM HAS BEEN GREAT. ARE NOW ALLOWED TO WEIGH 100% OF THE TRUCK TRAFFIC WHICH PASS THROUGH OUR STATIONS. LAST YEAR WE WEIGHED IN EXCESS OF FOUR MILLION VEHICLES

THIS SYSTEM. AS WE ADD MORE W.I.M. SCALES TO OUR PROGRAM, THIS NUMBER
LL SUBSTANTIALLY INCREASE.

MUST BE OBVIOUS, THE W.I.M. SYSTEM IS VALUED HIGHLY IN GEORGIA D.O.T.
ARE PLANNING NOW TO USE W.I.M. SCALES IN SPECIAL AREAS ON OUR STATE
STEM ROADS WHERE PROBLEM AREAS ARE NOTED.

IN GEORGIA ARE WEIGH-IN-MOTION MINDED FOLKS. THANK YOU.

STATE EXPERIENCES WITH WIM SYSTEMS

BRIDGE WIM SYSTEM

MR. ANTHONY MANCH
OHIO DEPARTMENT OF TRANSPORTATION
COLUMBUS, OHIO

ODOT's EXPERIENCE USING A
BRIDGE WEIGH-IN-MOTION SYSTEM

I. Introduction - I am priviledged to have the opportunity to speak to you today about the Ohio Department of Transportation's (ODOT) experience using a bridge Weigh-In-Motion (W-I-M) system.

A. Listening to our experience should give you food for thought if you are considering incorporating a bridge W-I-M system as a part of your overall truck weighing program.

B. My remarks will have to be prefaced by saying that we now have a third generation system. There have been some changes that we have not yet incorporated.

1. We believe that the system has been proven, however, it is still primarily used as a research tool.

2. We have no experience using the system to develop bridge loading data.

C. The presentation is organized into three parts:

1. A very brief description of how the system works.

2. A description of some of our experiences using the system over the past three years.

3. A brief discussion of our ongoing contract with Case Western Reserve University and cover some future developments.

II. Background and Development

A. Concept was developed under the auspices of the Federal Highway Administration.

1. Measure girder stress histories due to heavy truck traffic

2. Research found that the weights of trucks could be determined.

3. ODOT executed a research contract with Case Western Reserve University in Cleveland, Ohio to build a bridge W-I-M system in 1978.

B. The bridge W-I-M system utilizes existing bridges to serve as equivalent static scales to obtain truck gross and axle weights, dimensions and speed.

1. Slides showing the system features

a.	Schematic layout of Field Instrumentation	#1
b.	Slide of Strain Gauge	#2
c.	Installation of gauge on bridge	#3
d.	Installation of gauge on bridge	#4
e.	Signals are sent to the van	#5

f. Inside the van #6

g. Need a calibration vehicle #7

2. We use the system in either of two modes of operation

   a. Data acquisition only

      1. Data is taken back to the office for reduction

   b. Data reduction in the field

      1. Used primarily for enforcement screening

III. ODOT's Experience Using the Bridge W-I-M System

A. Case Western Reserve University delivered to ODOT a bridge Weigh-In-Motion system in 1979. We have used the system for:

1. Planning purposes

   a. Before/during/after studies in conjunction with the standard loadometer operations
   b. Ohio's Highway Cost Allocation Study
   c. Developing 18-kip equivalents for pavement and overlay design
   d. Pavement management activities by special request

2. Enforcement Purposes

   a. Identified locations, time of day, and day of week for potential violators
   b. Monitored potential bypass routes that could be used by trucks to avoid permanent scales
   c. In conjunction with the State Highway Patrol as a screening tool to identify potential violators.

3. We have monitored ten sites recently:

a)	1 site for system verification	Rural I
b)	2 enforcement sites	Urban & Rural I
c)	1 site to weigh coal trucks	Rural I
d)	1 Urban Principal Arterial	Urban P.A.
e)	1 site to monitor a truck bypass route of a permanent scale	Rural P.A.
f)	4 sites for FHWA Case Study Seasonal Data	4 Functional Classes

B. How accurate is the bridge W-I-M system?

1. Very confident that the system can accurately weigh gross vehicle weights (GVW) within $\pm$ 10%.

   a. One-on-one verification study with a permanent scale

      1. Calibrated a bridge using a single unit truck weighing 26,500 pounds
      2. Identified trucks that we weighed for the scale master to weigh at a downstream location.
      3. A one-on-one comparison of the gross vehicle weights showed under $\pm$ 10% difference.

b. A single calibration factor is accurate for all weight ranges.

2. The accuracy for individual axle weights (tandem axles if in the 4 foot range) is more variable.

   a. Still investigating this aspect but it seems that the axle weight accuracy is dependent on individual site.

C. Assets of the bridge W-I-M system:

1. Tremendous flexibility and mobility
2. Cost of the system is about $80,000 minus a vehicle
3. Crew size is two

   a. Set-up time for that crew is 2 hours maximum
   b. Set-up time to reestablish a site is 30 minutes

4. Can weigh a large number of trucks per hour at highway speeds
5. Minimize detection by trucks which leads to unbiased data
6. System is reliable - very little maintenance of major system components
7. Easy to weigh at night using an automatic system initiator
8. Theoretically, once a bridge has been calibrated, the need for a calibration truck is eliminated.

   a) A caution here: Suggest that a schedule be established to verify the reliability of the calibration factor dependent on program goals. (e.g., once a year).

D. Liabilities of the bridge W-I-M system

1. We have found that some bridges are better than others:

   a. Up to a maximum of 40 degree skew. (Skew - the angle that the bridge is built in relation to the roadway). The smaller the skew the more reliable the results.

   b. Smooth approach slab. Next time that you drive home from work, try to count the number of bridges that have smooth approaches.

   c. Steel or prestressed concrete girder bridges are the only types we have monitored.

2. Our present system monitors only one lane

   a. During our enforcement activities, we had to put out dummy tapeswitches.

   b. In a 3-lane section, 50% of the trucks may be in the center lane. (It takes special effort to monitor center lane.)

3. We believe that, the tapeswitches are the weakest link in the system.

a. May need traffic control to put them on the roadway. For safety purposes need to follow the "Ohio Safety Manual of Uniform Traffic Control Devices"

b. Replacement of a tapeswitch on a high volume roadway is difficult.

c. During wet weather conditions, the placement of tape-switches is cumbersome.

4. Special set of problems in urban areas

   a. High traffic volumes
   b. Multi-lane facilities
   c. Numerous bridges with skews.
   d. Ramps
   e. Generally takes longer to collect data.

E. Maintenance Aspects of the system

1. No failures in major system components
2. We have unintentionally abused the system
   a. Collected data for entire year with no climate control in our first vehicle
   b. Removed the computer many times with no adverse affects.
3. Be prepared for routine minor wiring repairs at the site.
   a. Hopefully eliminate this problem by rewiring all the minor connections this summer.
4. May need to schedule downtime for maintenance on the truck and/or generator frequently, depending on the number of hours worked.

F. Data Management can be broken down into two categories:

1. Monitoring the quality of data in the field

   a. During data acquisition the strain signals can be monitored on an oscilloscope. These are predictable patterns.

   b. Can run a simple program to evaluate the strain values "felt" by each beam. This is normally done initially after set-up.

   c. Necessary to keep a daily log of set-up, locations, beams monitored, etc.

2. Data Reduction at Central Office

   a. Analyzed on-board because the Digital MINC-11 computer has a great deal of versatility.

   b. Data output can be taylored to suit your needs (e.g. loadometer format)

   c. We remove the computer from van, reduce data

      1) Plug into "black box" data conversion system
      2) Put data on 9-track tape for analysis on our IBM 4341 computer at Central Office

3) Hard copy of data, to punch cards as a back-up.

G. There has been no formal impacts on previous programs.

1. We would like to use the system to obtain the truck weight portion of our loadometer study.

   a. Basically on hold until we receive further guidance from FHWA on revision to Truck Weight Study.

2. Routinely give the State Highway Patrol data on overweight vehicles for their use.

IV. Ongoing Contracts and Future Improvements

A. Just completed a contract, "Insturmentation for Weighing Trucks-In-Motion for Highway Bridge Loads"

1. Extreme load occurrences such as trucks moving side-by-side or closely followed were monitored. Attempted to monitor a worse case situation.

2. The data obtained are useful for evaluating bridge loads and performance.

3. Field results are applicable to prediction of fatigue life, maximum bridge loads, and accurate evaluation of rated capacity.

4. Our system may be modified later this summer.

B. A third study with Case Western is underway, "A Comprehensive Study of Bridge Loads and Reliability" to be completed January, 1985.

1. Aim of the study is a rational coordination and assessment of bridge loading data in a reliability-based framework.

2. Calibrated bridge load model

3. Results will be tested and utilized to aid decision making for design loads, legal load limits, permit evaluation, rating and posting for bridges.

C. Future Improvements

1. Less expensive microprocessors substituted for routine data collection
2. Battery operated equipment and simplified electronics
3. Telemetry system to transmit data
4. Incorporate video-tape system for visual examination of over-weight vehicles
5. Vehicle classification on a sample basis
6. Replacement of tapeswitches with infra-red lights

V. Summary

A. In conclusion, I hope ODOT's experiences using the bridge W-I-M system will help you gain some insights to its capabilities and limitations. Thank you.

References:

Weighing Trucks- In-Motion Using Instrumented Highway Bridges dated December, 1981, by Dr. Fred Moses and Michel Ghosn

Instrumentation for Weighing Trucks-In-Motion for Highway Bridge Loads dated March, 1983 by Dr. Fred Moses and Michel Ghosn

Professor Fred Moses
Department of Civil Engineering
Case Institute of Technology
Case Western Reserve University
Cleveland, Ohio 44106
Tel: 216-368-2950

For cost details on Ohio's Bridge Weigh-In-Motion system, contact:

Mr. Richard Snyder
Bridge Weigh-In-Motion Systems Inc.
4423 Emery Industrial Parkway
Warrensville Heights, Ohio 44128
Tele: 216-831-6131

STATE EXPERIENCES WITH WIM SYSTEMS

BRIDGE WIM SYSTEM

MR. JOHN WYMAN
MATERIALS AND RESEARCH DIVISION
MAINE DEPARTMENT OF TRANSPORTATION
BANGOR, MAINE

WEIGH IN MOTION INSTRUMENTATION

OF A BRIDGE

A paper prepared for presentation
at the National Weigh In Motion
Conference at Denver, Colorado
July 11-15, 1983

Prepared and Presented By:
John H. Wyman
Materials & Research Division
Maine Department of Transportation
Bangor, Maine
June 1983

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES
Cont'd.

ABSTRACT

This paper presents the results of an experimental strain gauge instrumentation of a simple single span bridge in Skowhegan, Maine, and tests conducted to calibrate the bridge as a vehicle scale.

Sample data obtained are presented and future plans for automatic data recording are outlined. A brief review of the system costs are provided.

INTRODUCTION

The realization of the need for faster and less expensive means of collecting vehicle weights has resulted in this conference.

Most of the states have experienced increased truck loading and the resulting increase in deterioration of much of the recently constructed interstate system and other highways. Maine has a special problem in that the chief loads contributing to vehicle overweight is that of forest products. The wood and paper industry is a major one in the state.

Since about 1976 to 1978 the paper companies have been forced to give up using the rivers to move their pulp wood and go to highway vehicles for transport. This has resulted in a great increase in truck weight, in some cases double the previous average, and thus illegal overloading of vehicles, and attendant increase in rate of pavement damage.

Loadometer data obtained in the mid-seventies has been insufficient and misleading. The need to stop the vehicles and use of portable scales make data collection expensive, slow and less accurate than is needed. The use of C-B radio by the truckers has tended to compromise the validity of the data obtained. Since 1978 no valid loadometer data has been obtained because of this factor.

The Materials and Research Division of the Maine Department of Transportation has been cognizant of the need for accurate data and since the early 1970's has conducted several studies concerned with load versus pavement damage. The Research Department realized that in order to obtain valid data a technique would be required to weigh the vehicles in motion and also not be obvious to truckers.

Several studies have been undertaken by others; Gobel 1974, Daniels 1977, Moses 1979, in obtaining the weight of vehicles in motion by instrumenting single span bridges. Much of this work has been sponsored by the FHWA. In 1981, Maine Materials and Research Division decided to undertake a study of instrumenting a simple single span bridge with strain gauges to test whether such a system might supply vehicle weight data rapidly and at a low cost. At that time other types of W.I.M. equipment were very expensive and had never been successfully operated at normal roadway speeds and in the severe winter environment existing in Maine and other northern states.

METHODOLOGY

Theory of strain gauge application to beam type scales indicates that if all stressed members are equipped with strain gauges and the electrical outputs summed then the total strain output will bear a direct linear relationship to the total stress. A search for a suitable bridge on which to test if this theory applied to more complex structures, was undertaken.

As was mentioned, forest products are a major cargo in our state, and transportation of this cargo by truck, either as tree lengths or as cut logs for pulp or lumber generates the major overloads.

In searching for an acceptable bridge to instrument for an experimental test site the criteria were that it be on a route heavily travelled by forest product trucks and be a simple single span bridge.

Several routes intersect in the Skowhegan area and vehiches carrying forest products for several paper mills must cross the river at Skowhegan. All traffic must cross one bridge. This bridge, the Margaret Chase Smith Bridge over the north channel of the Kennebec is a new simple span bridge 125 feet long and 58 feet wide and constructed with nine I beams. It has an 8 inch Portland Cement Concrete deck. This bridge appeared ideal as it was longer than any truck, new and well maintained and provided suitable stiffness.

Figure 1 shows the major construction of details of the bridge. The I beams are connected with suitable diaphragms for transverse distribution of loads.

Since there was some question as to whether the bridge might be so stiff as not to provide output from strain gauges it was decided to instrument one I beam and conduct tests on this before spending the money to instrument all I beams.

The Hitec Corp., Westford, Massachusetts agreed to equip one I beam and conduct output tests. They instrumented one I beam, #4, at the center of the bridge and took sufficient data to indicate that output levels were high enough to warrant completion of the planned instrumentation. The decision was then made to have Hitec complete the instrumentation of the eight girders which was completed shortly.

Strain gauge instrumentation consisted of HBW2-35-125-6-10HP single weldable gauges. After welding to the steel beam each gauge was properly covered with a waterproofing compound.

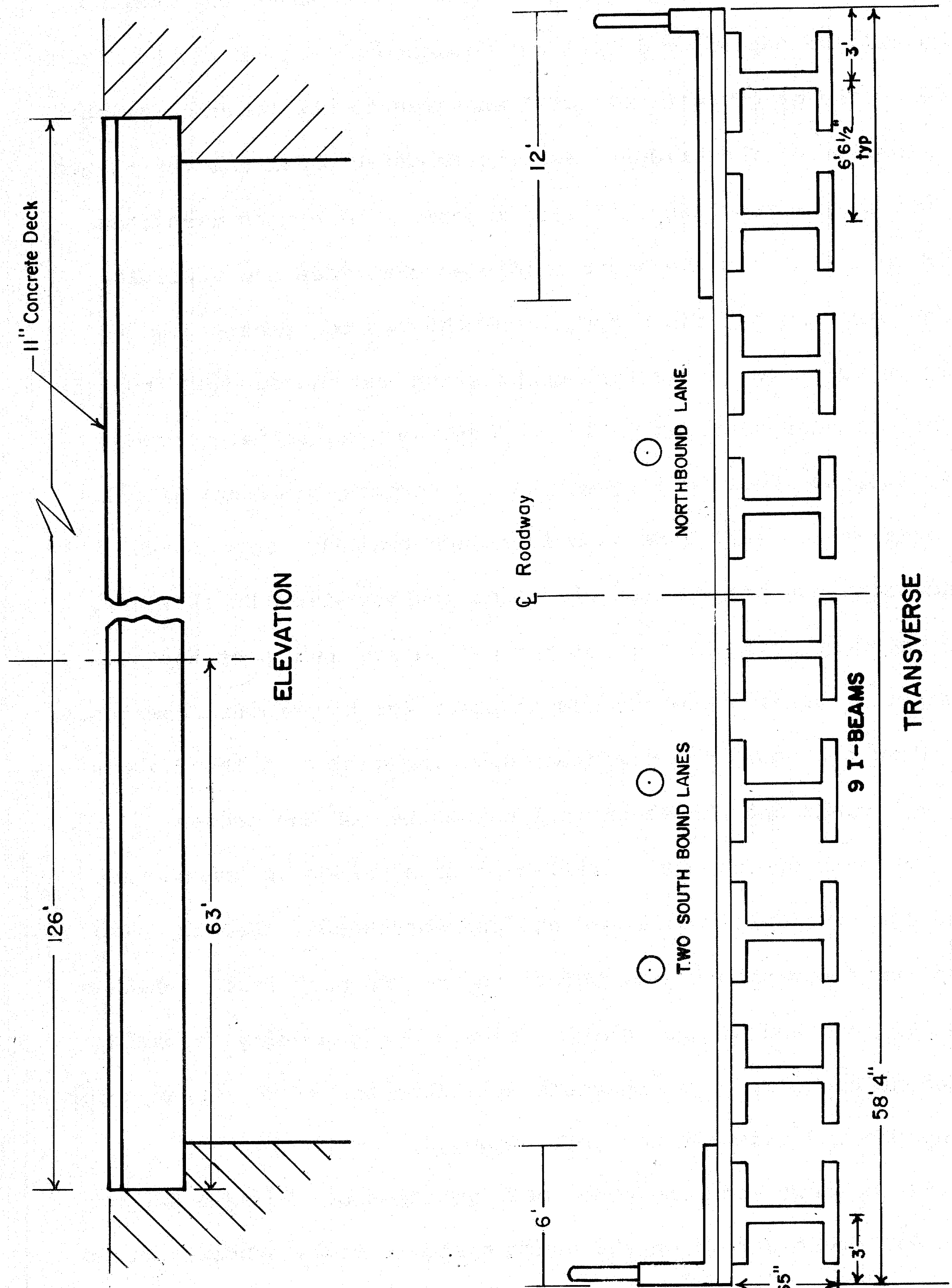


Figure 1 North Channel-Kennebec River Bridge

Each I beam of the eight (the ninth was omitted for reasons which will be explained later) was equipped with four of the single gauges. The gauges were placed transverse to the traffic flow at the midpoint of the bridge. Two were mounted on the bottom flange and two on the top flange of each I beam. The gauges were then wired in a four arm Whetstone bridge so that when the vehicular bridge was stressed the outputs from the two top flange gauges would be negative, indicating compression and the outputs from the two bottom flange gauges would be positive, indicating tension. Thus, stresses would all result in a resistive unbalance of all the arms of the strain gauge bridge such that the changes would be additive and the maximum electrical output would be obtained. Also the fact that all arms of the bridge are gauges of the same material provides automatic compensation for temperature changes.

Figure 2 shows the positioning of the gauges on the flanges of the I beams and the electrical connection of the gauges.

The bulk of the heavy traffic on this bridge is southbound. There are two lanes southbound and one northbound. Because of a sharp curve southbound just before the bridge most large vehicles straddle both southbound lanes. Because our temporary recording equipment had only eight channels available the ninth I beam under the northbound sidewalk was left ungauged.

Since short and long wheel base vehicles of the same weight cause different strain on the gauge system a co-ax sensor, set up to detect and record axle counts, was installed on the transverse center line of the bridge directly over the gauges and covering

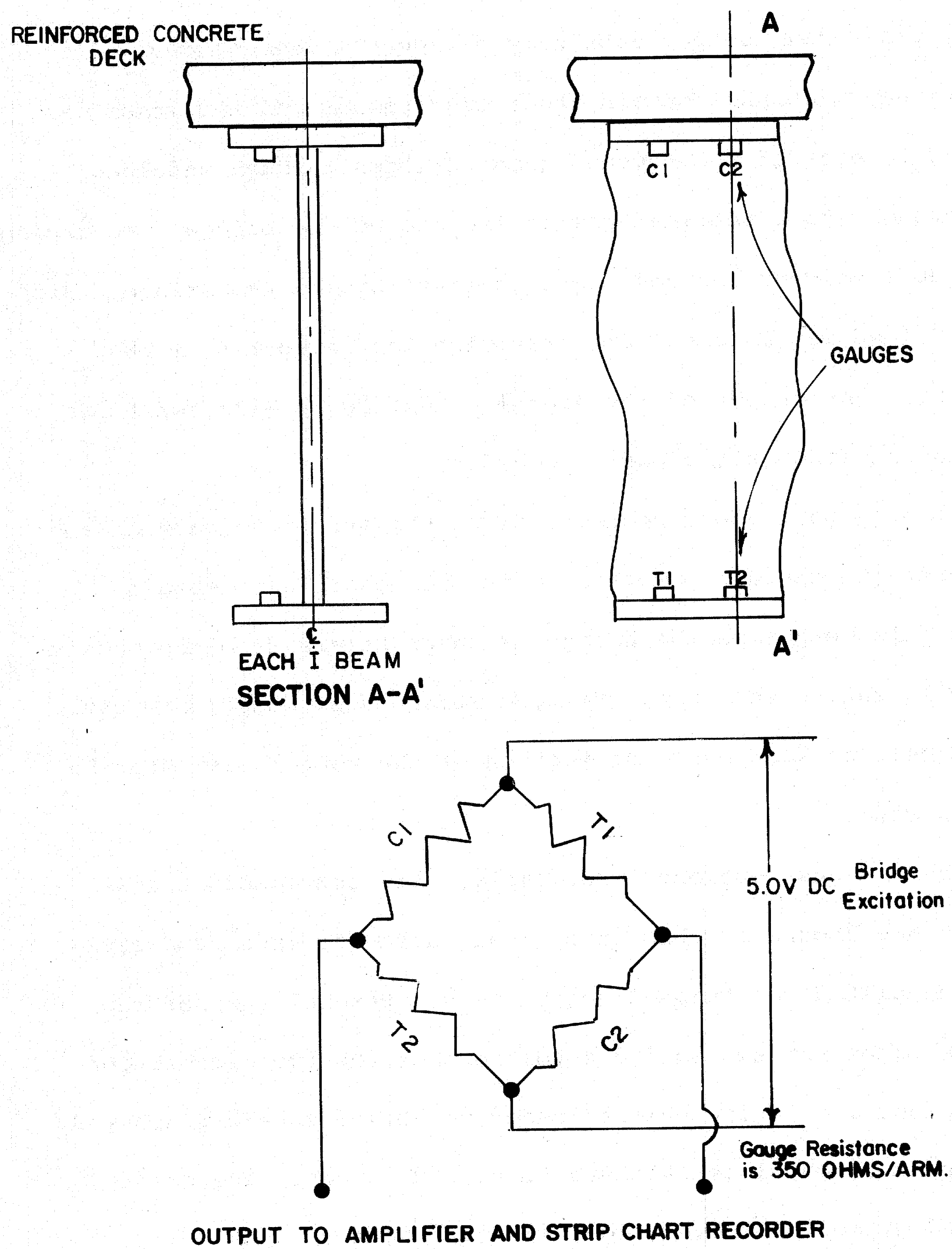


Figure 2 Strain Gauge Details

the two southbound lanes. The output of this sensor was recorded on the last or eighth channel of the recorder. Thus, the preliminary tests have output data only on seven I beam gauges.

A Vishay 8 channel strain gauge conditioner and amplifier was connected to each of the seven 4 gauge bridges through shielded cables brought to a terminal box at the end of the bridge. Balancing of the gauge bridges was done with no live load on the bridge, thus the dead load was balanced out providing zero output from the amplifiers. The output of the signal conditioners were fed to an eight channel Gould strip chart recorder.

Strain gauge readout occurs showing the strain as each axle passes over the gauges. Hoever, it is not possible to obtain separate axle weight as the bridge is under stress from the moment the vehicle enters the span. Maximum strain does occur, however, when the heavier load carrying section of the vehicle is spanning the gauge line.

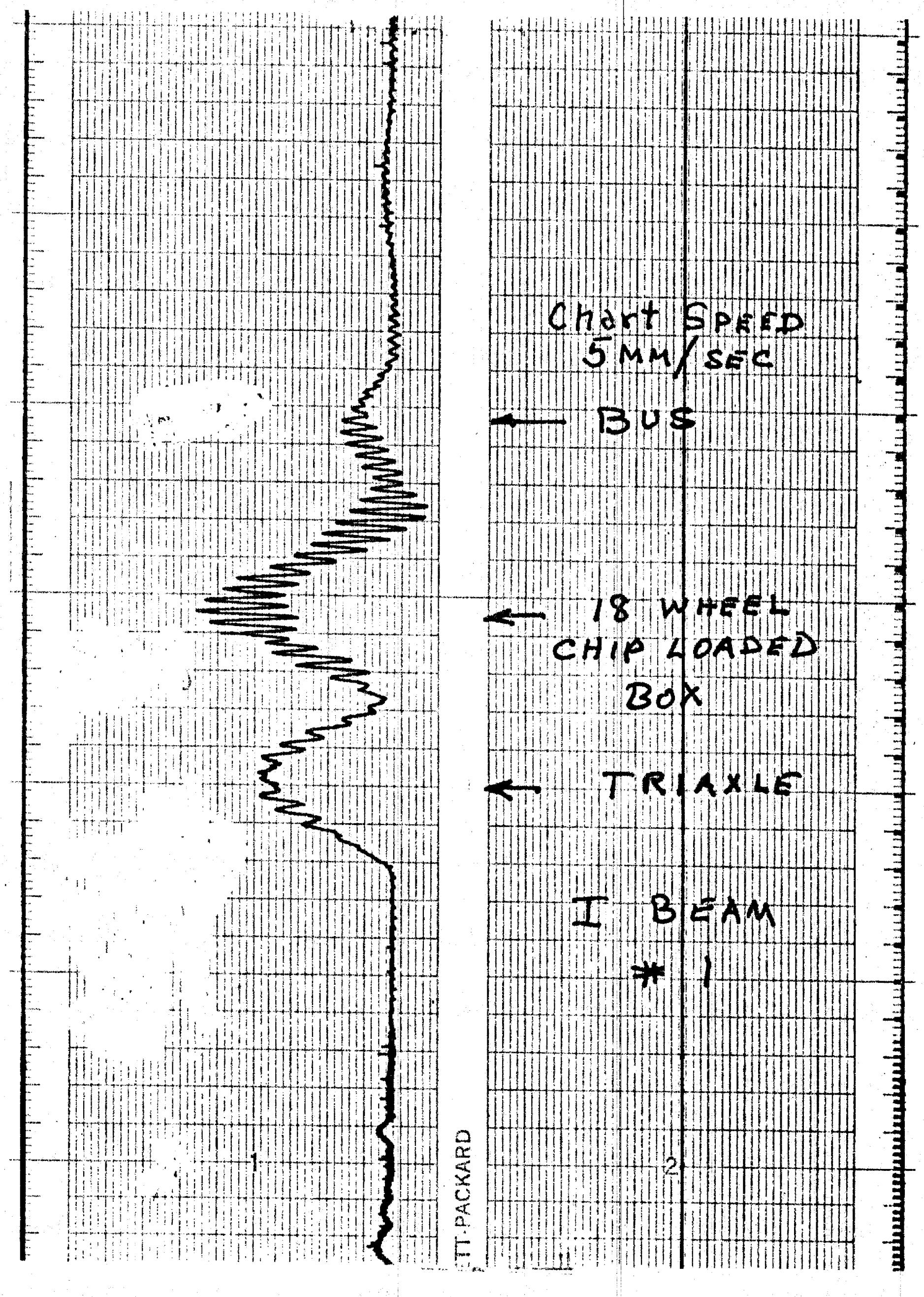
Since, as was mentioned previously, heaviest loaded truck travel is southbound on this bridge, all data was taken and calibration completed for this direction only. Several runs of raw data were taken for two loaded conditions of the two calibration vehicles, one a triaxle vehicle loaded to 70,400 pounds gross and the other an 18 wheel semi-loaded to 80,100 pounds. One point , for a road grader of known weight is also shown.

Several days data were taken on representative types of truck traffic moving southbound. Summaries of the readout data on representative types of vehicles is included. Since the raw data on chart paper are difficult to reproduce for report purposes, including it all has not been attempted. However, a representative readout of 3 vehicles is reproduced on Figure 3 to help in understanding the form in which the data were recorded and also to provide a look at the dynamic portions of the strain signal. This will be discussed later.

Figure 4 gives the strain gauge output for each of the calibration vehicles studied, by channel. Values are in divisions of deflection proportional to strain for each channel of the strip chart recorder.

Figure 5 shows a plot of the calibration runs for 4 vehicle types. As was expected the different vehicle axle spacings stress the bridge differently so that calibrations must be done for each type of vehicle. This chart represents the data from the rough first trial to prove feasibility.

Another observation of interest can be seen on Figure 3, which shows the dynamic effect on the bridge. The output for the 18 wheel chip truck shows a 3 Hertz, approximately sinusoidal variation in the strain with an amplitude indicating a dynamic stressing of the girders and bridge deck equivalent to about 20-30,000 pounds, assuming the vehicle weighed 80,000 pounds plus which in all probability it did. (Based on raw data calibration



Strain Gauge Outputs
Typical Outputs - Gauge #1
Weight Unknown

Figure 3

Veh. #	Weight	I Beam or Channel Number							Total	Average
		1	2	3	4	5	6	7		
				Tractor Trailer (5 Axle)						
5	80,100	60	30	40	45	35	30	25	265	38
7	80,100	93	55	52	38	30	18	15	301	43
9	80,100	52	28	38	44	42	30	28	262	37
										39
				Triaxle (2 Axles down)						
4	70,400	90	60	65	50	30	20	5	320	46
6	70,400	40	42	52	70	60	40	40	344	49
										47.5
				Triaxle (3 Axles down)						
10	70,400	70	48	56	85	70	60	56	445	63
				Road Grader						
21	27,500	30	20	28	26	18	12	10	144	21

FIGURE 4 Calibration Runs

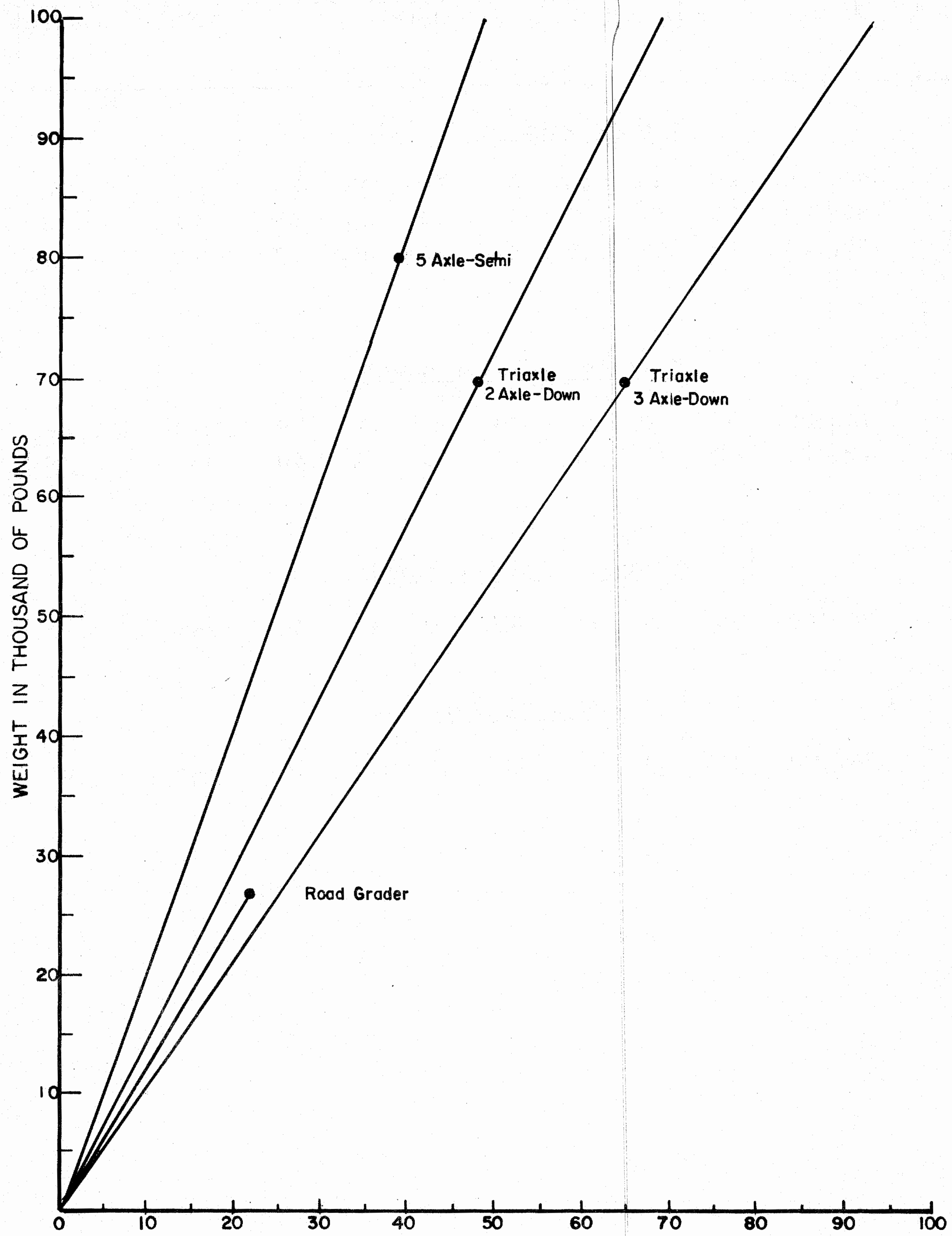


Figure 5 AVERAGE OUTPUT IN MMS. CALIBRATION RUNS – FIRST ROUGH CALIBRATION

for this type of truck) A rough calculation of the resonant frequency of the bridge indicates that it is of the order of several hertz so that any truck with a poorly balanced suspension is going to excite the bridge in this range. Any misalignment of the roadway at the bridge boundary which permits a drop or bounce of the vehicle will also excite such a resonance. In addition to the observation of the dynamic variations another unusual feature was noticed. For most all heavy vehicles the strain recorded decreased in the girders as the distance from the truck increased, which was to be expected. However, the strain increased markedly again in the last girder, i.e., #1, which at first appeared unlikely. Discussion with several bridge designers and engineers indicated that this phenomenon is not unknown and has been documented by several other investigators. The cause is complex and probably the result of several interactions. (See Research Project HPR-175-332 David G. Bowers, Conn. D.O.T. R & D Section).

Prior to taking the next step towards a more accurate calibration and automation of data recording, a study of the way the strain is distributed across the bridge to other lanes was undertaken. It was obvious that loads in the northbound lane would reflect strains to southbound lanes, a potential source of error. Also lane 1 data was not representative. Detailed studies showed that for automobiles northbound, reflected strain would be well within the error of the system when dealing with vehicles of the order of

80,000 to 120,000 pounds. Also eliminating the gauge outputs under the northbound lane would further decrease opposing traffic error.

Since the preliminary studies indicated that an acceptable system was possible, a ten channel electronic summing amplifier was purchased which could accept outputs from any of the gauge outputs, 1 thru 10, it desired to sum. The output of the summed channels would be displayed on a 2 channel Hewlett Packard chart recorder. The second channel displayed the axle count. A block diagram of the summer is shown on Figure 6. Each gauge can be balanced and output gain adjusted to provide a satisfactory drive for the HP chart recorder.

One problem occurred. It was observed that a different output was produced depending on where in the two southbound lanes the vehicle travelled. A small error will be experienced because of this but tests indicated that the error was smallest when outputs from beams 2, 3, 4, 5, 6, were summed. This was the technique used for the final calibration and truck weight recording.

Calibration was accomplished using a 5-axle semi-trailer loaded to 82,700 lbs., a tri-axle vehicle (3 rear and one steering axle) loaded to 70,000 lbs. with 3 rear axles down, and a tandem rear axle vehicle loaded to 58,340 lbs. and also at 41,500 lbs.

As mentioned previously vehicle identification is accomplished using a co-ax cable across the two southbound lanes at the center of the bridge coincident with the strain gauges line. This co-ax and

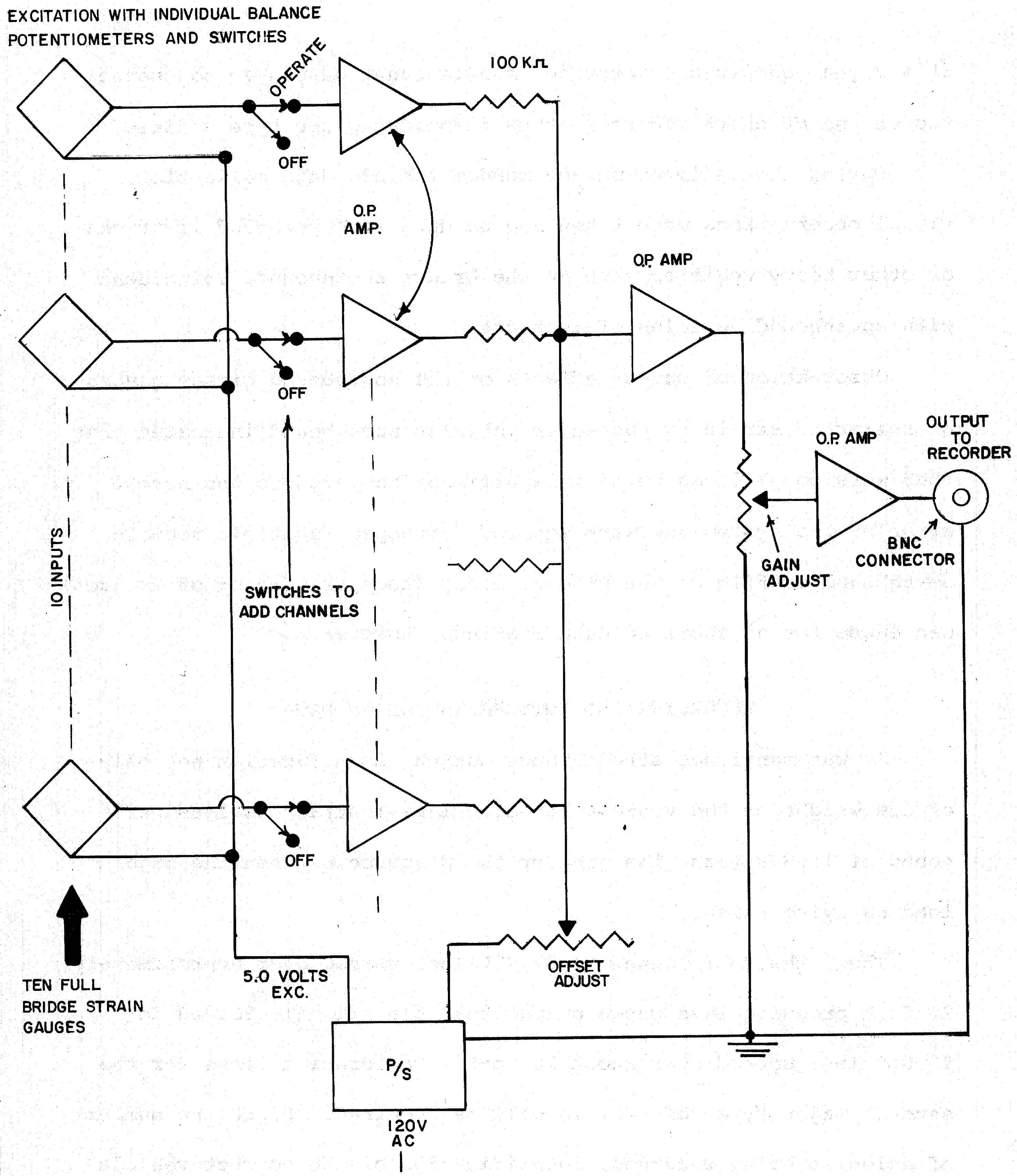


FIGURE 6 BLOCK DIAGRAM OF SUMMING AMPLIFIER

it's signal conditioner provide an axle count displayed on channel two of the HP chart recorder, thus identifying the type vehicle.

During the calibration and random vehicle data collection, visual observations were taken and no data were recorded if trucks or other heavy vehicles were on the bridge northbound, coincident with southbound vehicles of interest.

Observation of output effects on the southbound girder gauges of reflected strain by passenger vehicles northbound indicated that they were so small as to be insignificant compared to the normal error of the system and were ignored. Stopped, multiple vehicle, northbound traffic on the bridge, i.e., (noon traffic or other jams) was cause for an abort of data readings, however.

RECORDING AND INTERPRETATION OF DATA

As was mentioned strain gauge output is a function not only of the weight of the vehicle but also I beam strain is less per pound of load stress, the greater the distance between the major load carrying axles.

Thus, the semi, loaded to 82,700 lbs. spread over approximately 25 feet produced less gauge output than the tri-axle loaded to 70,060 lbs. spread over about 16 feet. Calibration lines for the several major types of vehicle will be required. Since the number of axles is being recorded, identification of the correct vehicle calibration line to use is easy.

In automatic computerized recording of data axle count will flag the computer logic to choose from memory the proper linear calibration formula to use. Axle spacing will also be measured.

Figure 7, shows the calibration lines for a 5 axle semi, Figure 8 for a triaxle and 9 for a tandem.

Raw data was taken with a two channel HP paper chart recorder. The right channel recorded the output from the summing amplifier showing the output from channels 2, 3, 4, 5, 6 added, while axle counts appeared in the left channel. Speed of the chart was 5 mm/second. Reference to some sample chart data, Figure 10 thru 14, will show that for practically all vehicles the output showed an oscillatory output superimposed on the gauge output as the vehicle crossed the bridge.

On the calibration runs, a reading was also taken for each set with the vehicle stopped at the center over the gauge centerline. This reading is less in all cases than the peak of the dynamic output with the vehicle moving.

In order to compensate for this variation, the tops of the dynamic output curves were rounded off to average the three oscillatory peaks for each vehicle output. The figure so obtained compares favorably with the output with the calibration vehicle stationary. This averaging will be done automatically when computerized recording of the data is implemented.

Figure 15, shows axle spacing and length for the three calibration vehicles. Because of the nature of the roadway as it approaches the bridge, a sharp curve immediately following an inter-

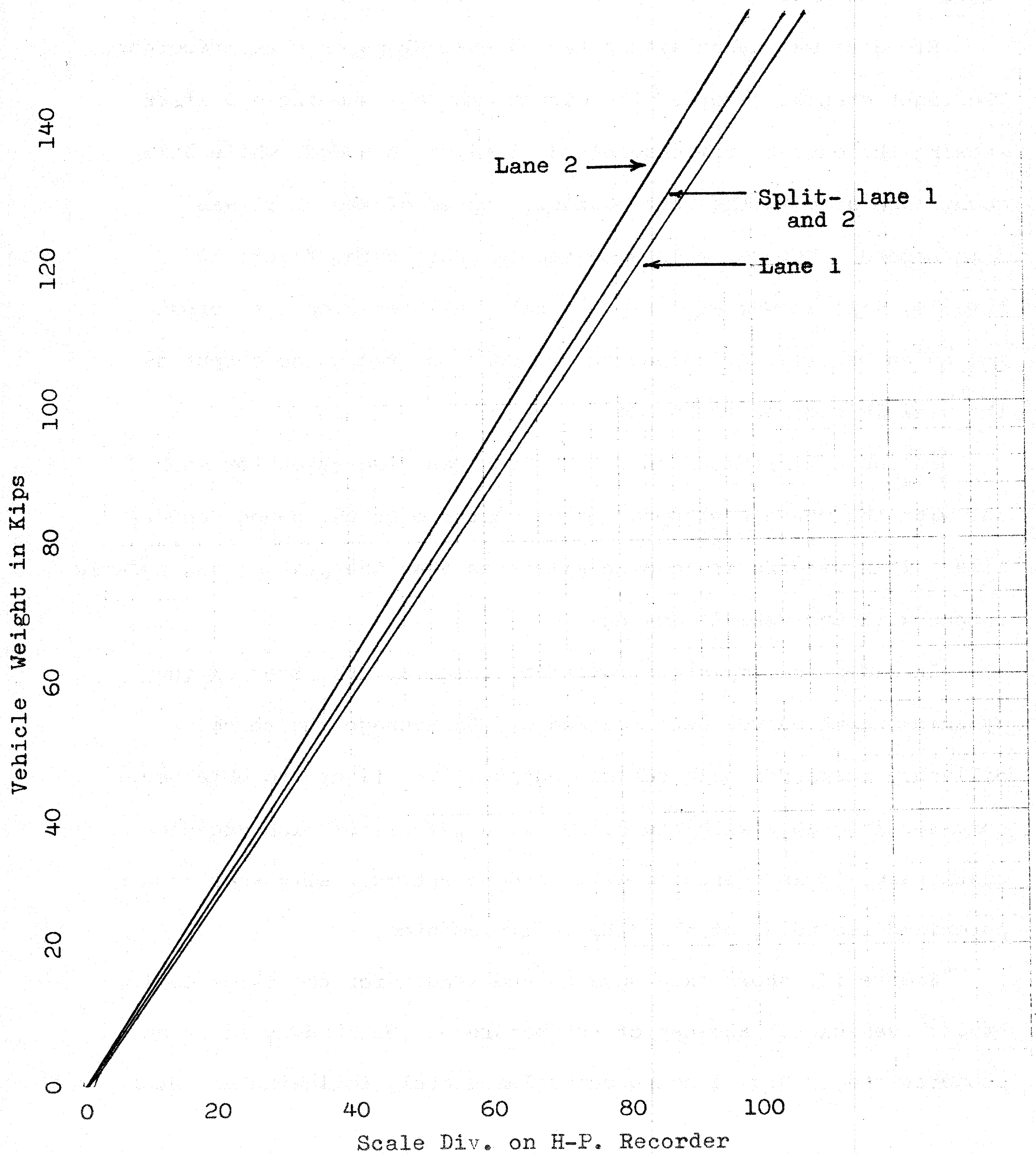


Figure 7 ---- Calibration of 5 Axle Semi. 84,300 lbs.Gross

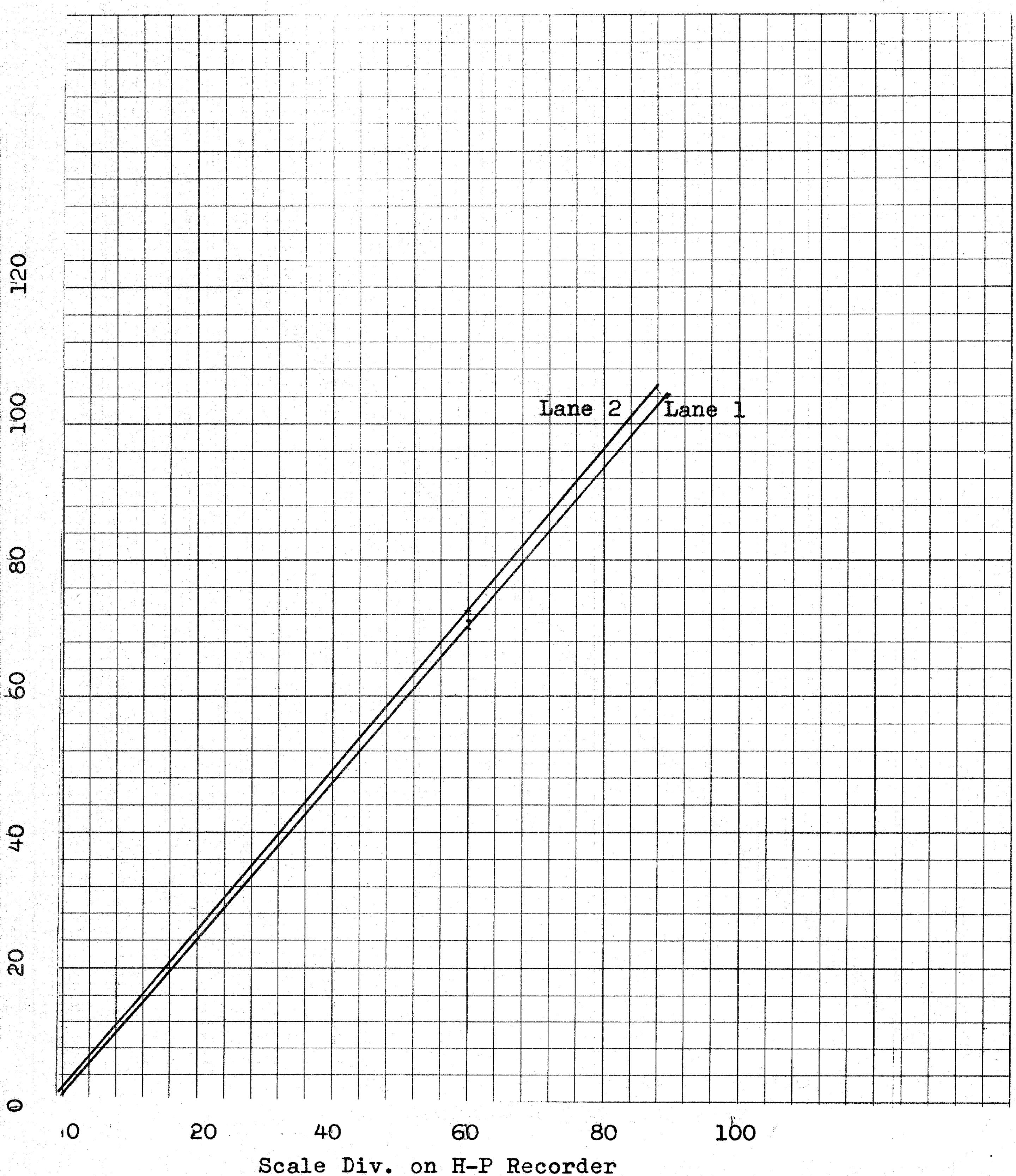


Figure 8 ----- Calibration of Triaxle Vehicle 67,000 lbs.Gross

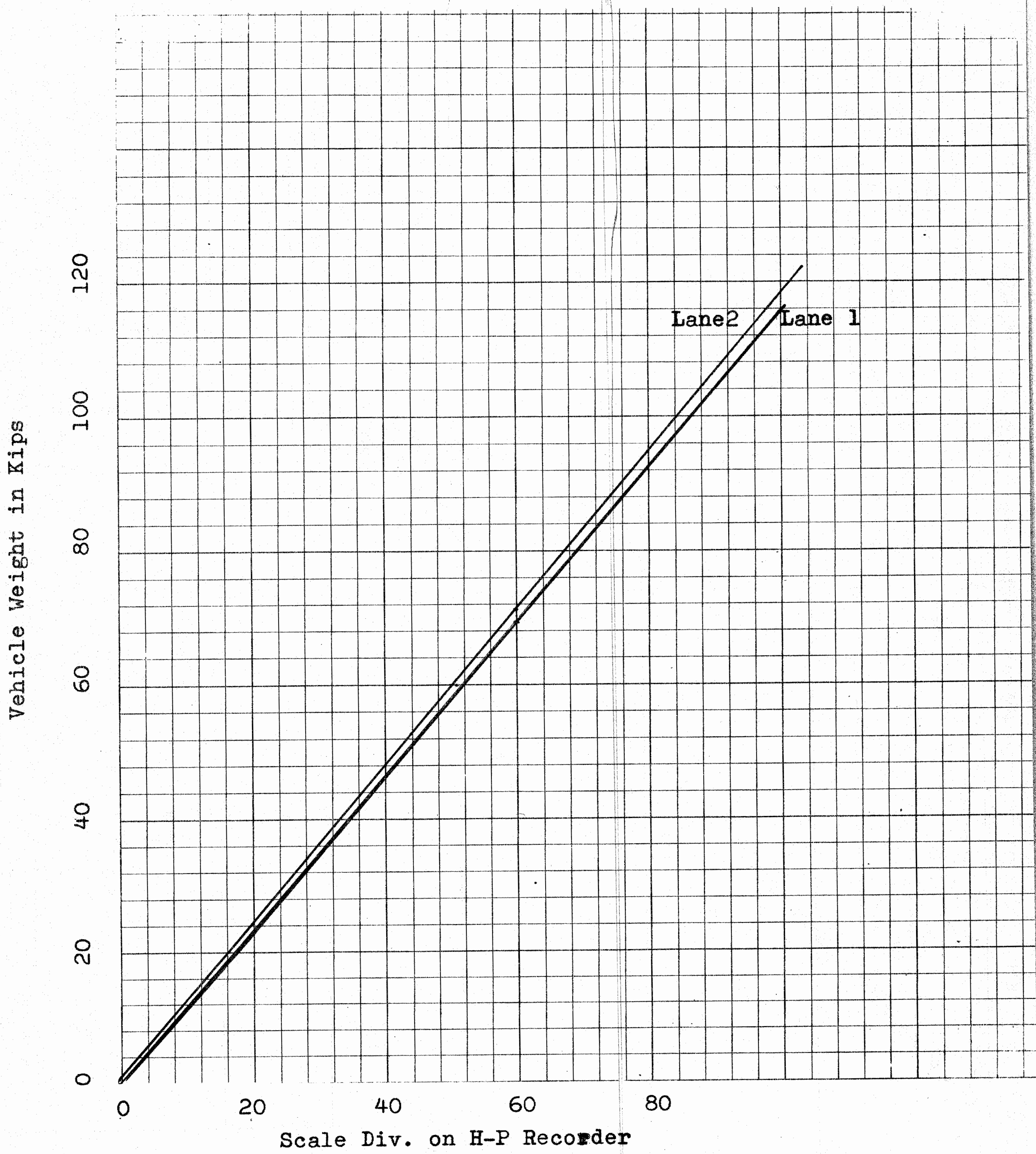


Figure 9 ------ Calibration of Tandem Vehicle 48,800 lbs. gross

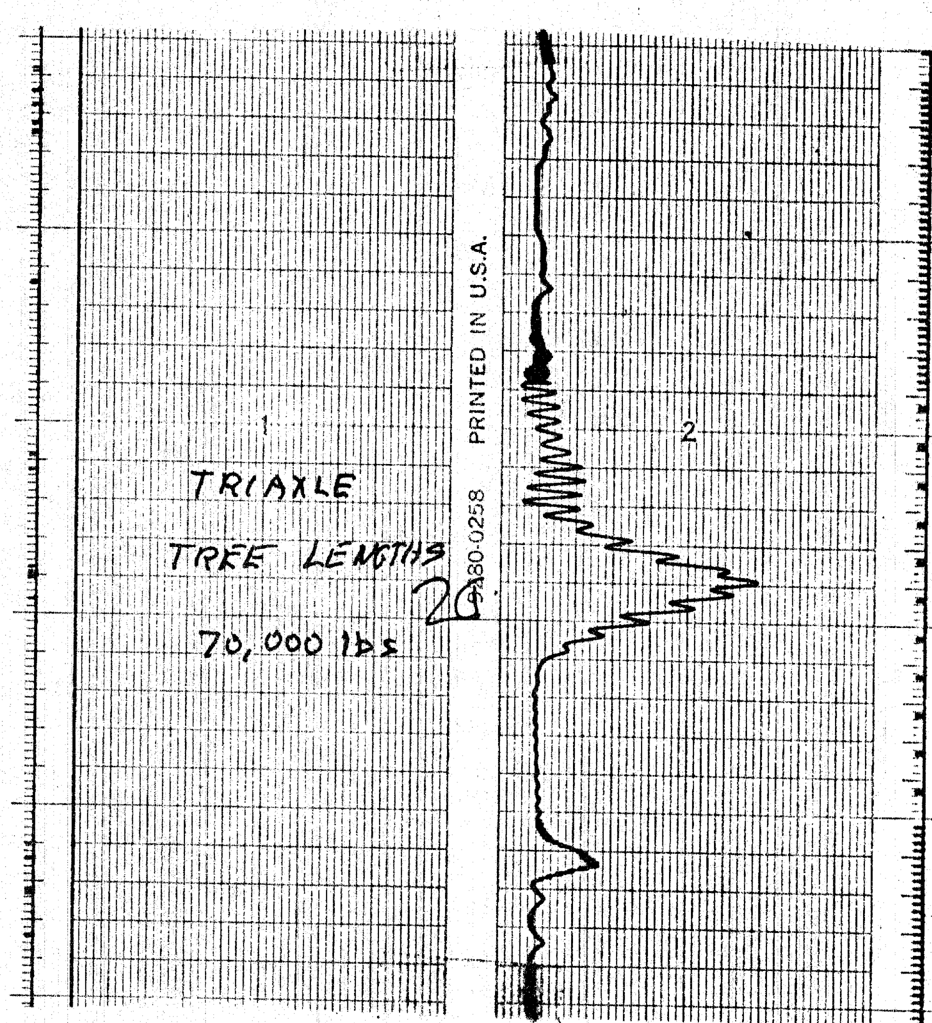


FIG. 10 H-P Readout for Random Vehicles

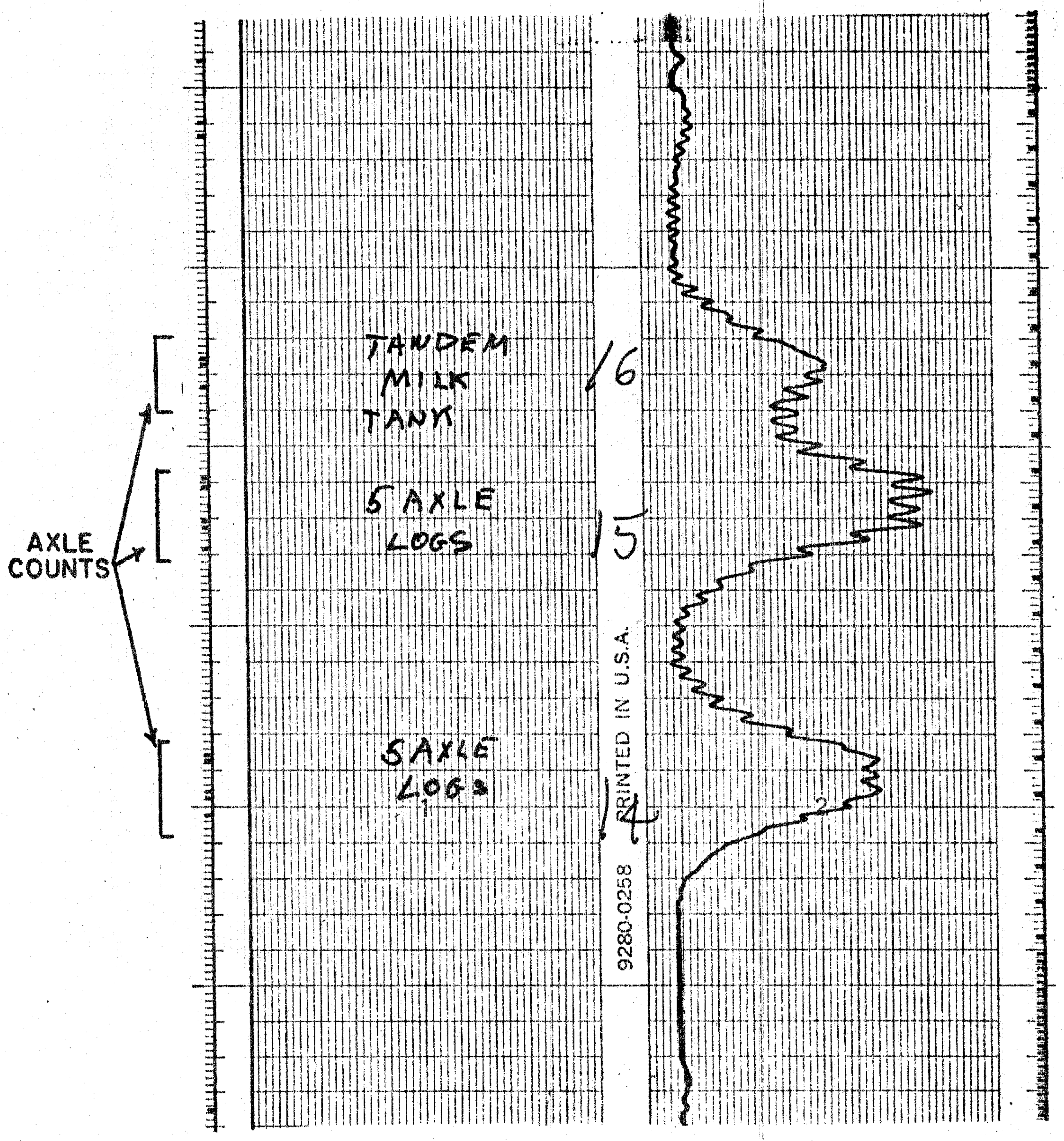


FIG. 11 H-P Readout for Random Vehicles

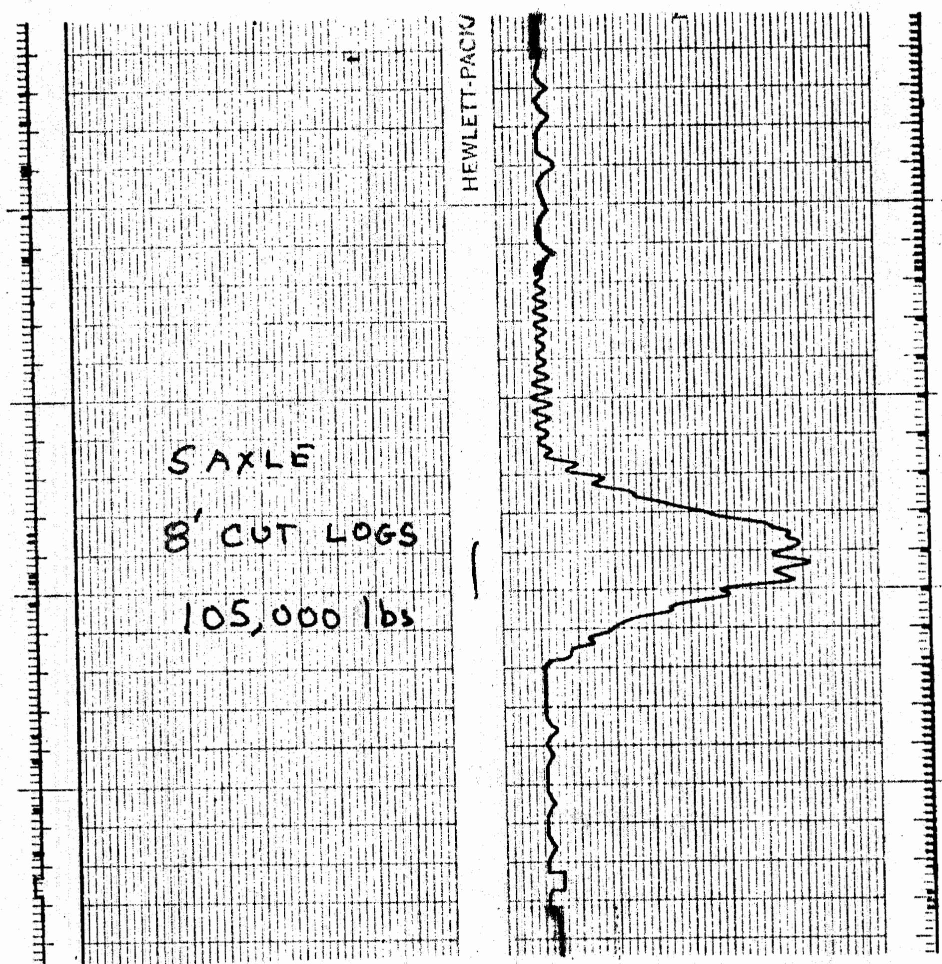


FIG. 12. H-P Readout for Random Vehicles

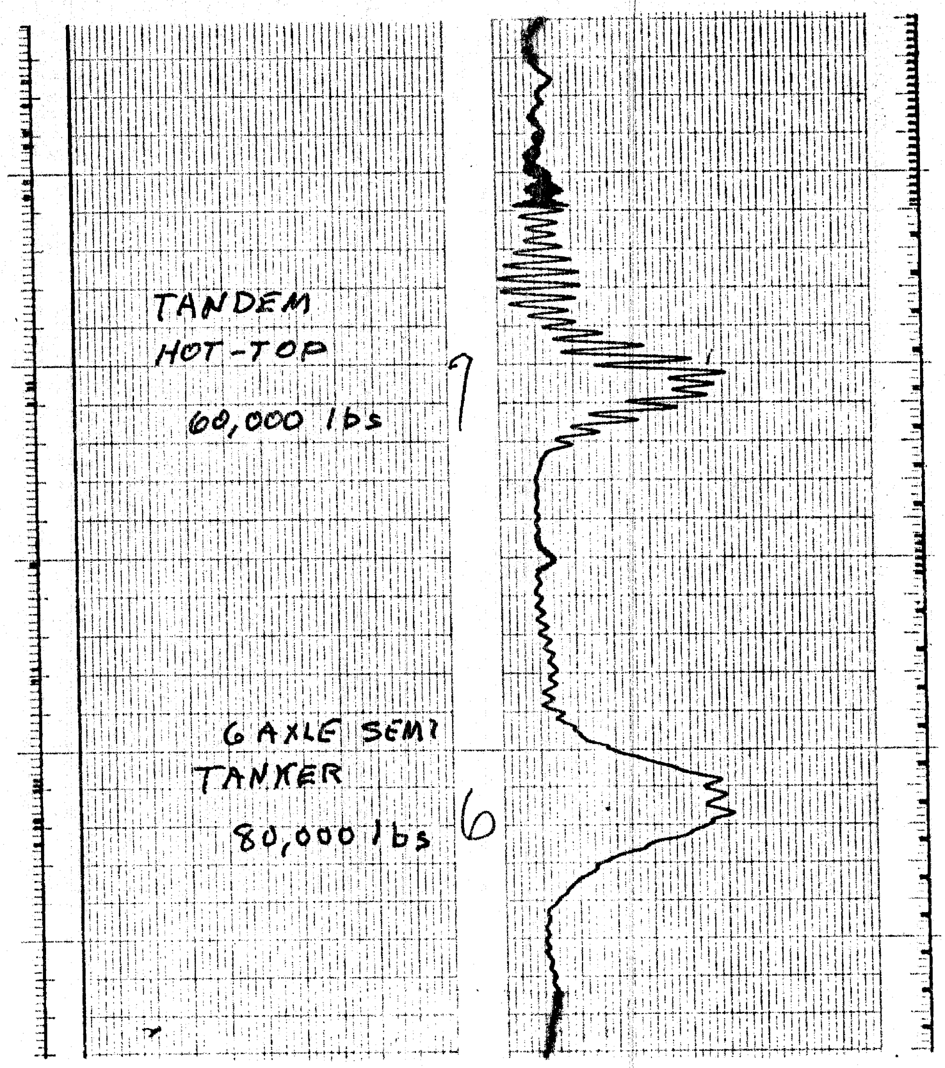


FIG. 13 H-P Readout for Random Vehicles

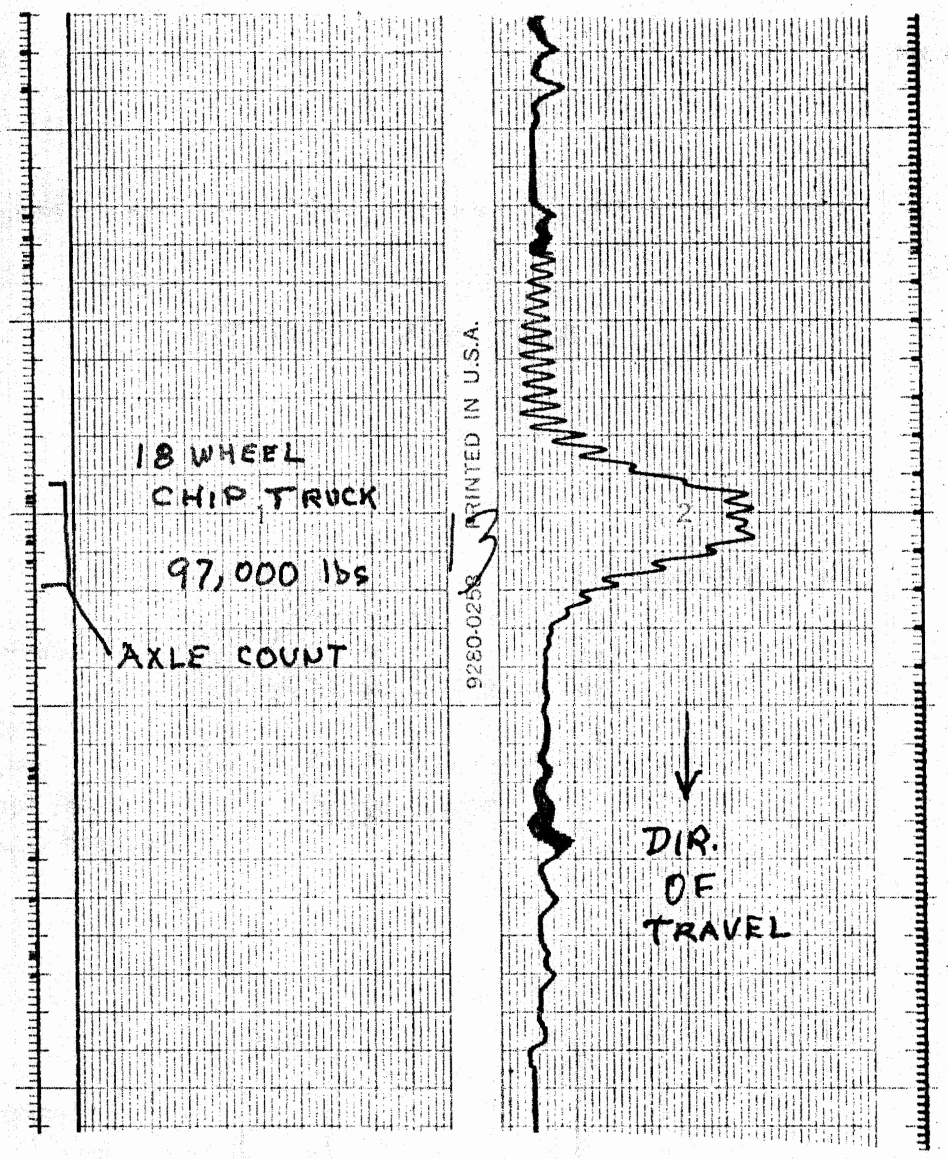


FIG. 14 H-P Readout for Random Vehicles

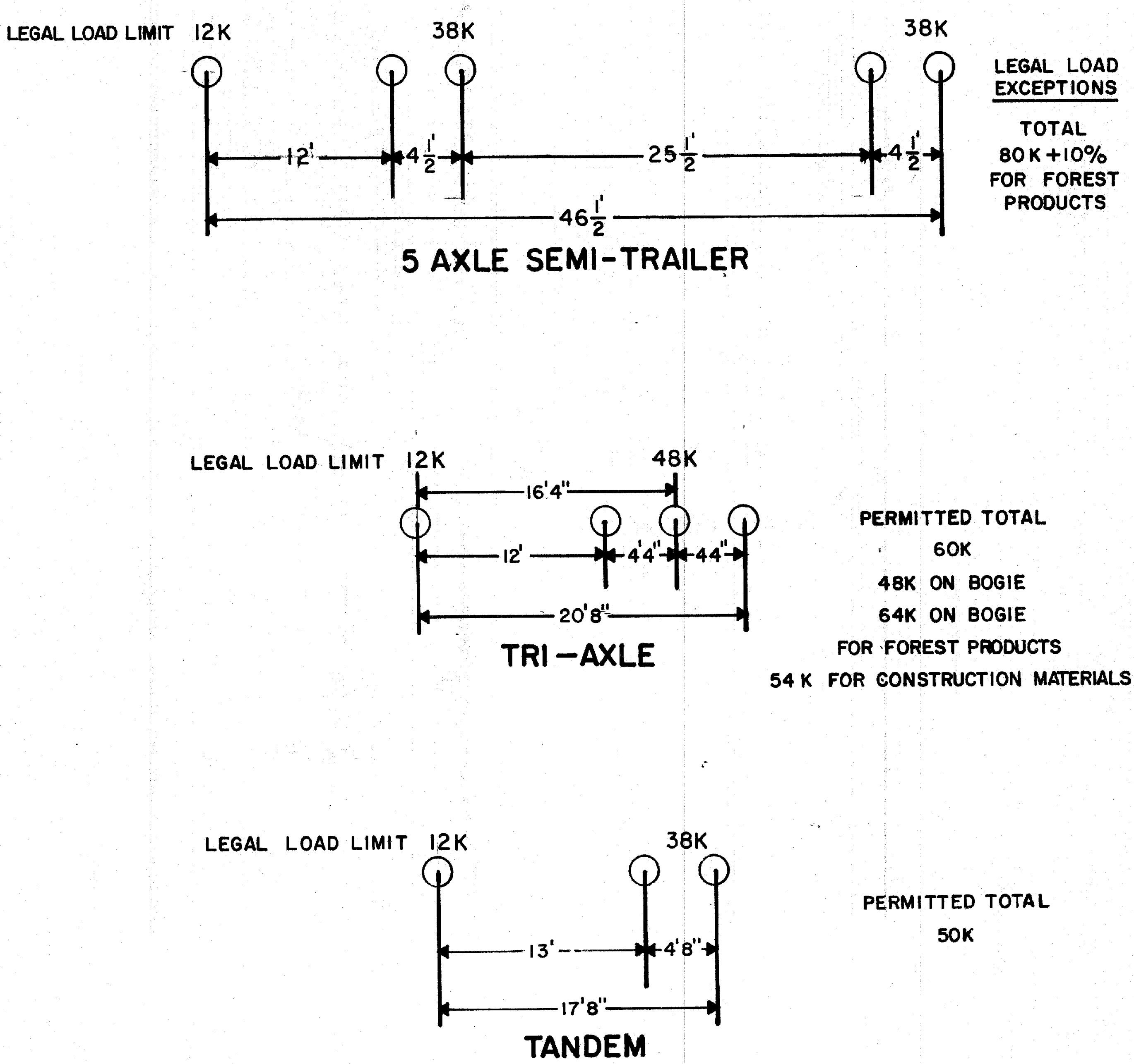


FIGURE 15 Axle Spacing of Calibration Vehicles

section in downtown Skowhegan, the speed of all heavy vehicles is within the range of 20-25 mph, reducing somewhat any additional errors that might be introduced by higher dynamic oscillations.

RANDOM VEHICLE WEIGHT DATA

During the month of November of 1982, data was taken on 7 randomly chosen days for approximately 4 hours each day. A total of 623 vehicles other than automobiles were observed and weight data taken. Figure 16 is a bar chart showing the number of vehicles in incremental categories of 10,000 pounds. All trucks under 20,000, mostly pickups, were lumped together. Truck traffic over this bridge averages about 25 per hour during daylight hours.

Figures 17, 18, 19, 20, 21, 22 and 23 show weight distribution for several representative vehicles and load types.

COMMENTS ON OVERLOADS

Although the products carried by the vehicles, shown on Charts 17 thru 23, are probably not representative of other states, the overloads probably are representative and these charts have been included because of potential interest.

It can be seen from these charts that between 30-60 percent of vehicles loaded with forest products are over the legal maximum weight.

Refering back to Figure 3, a vehicle with typical heavy oscillations is shown. It is obvious that the peak to peak value of some

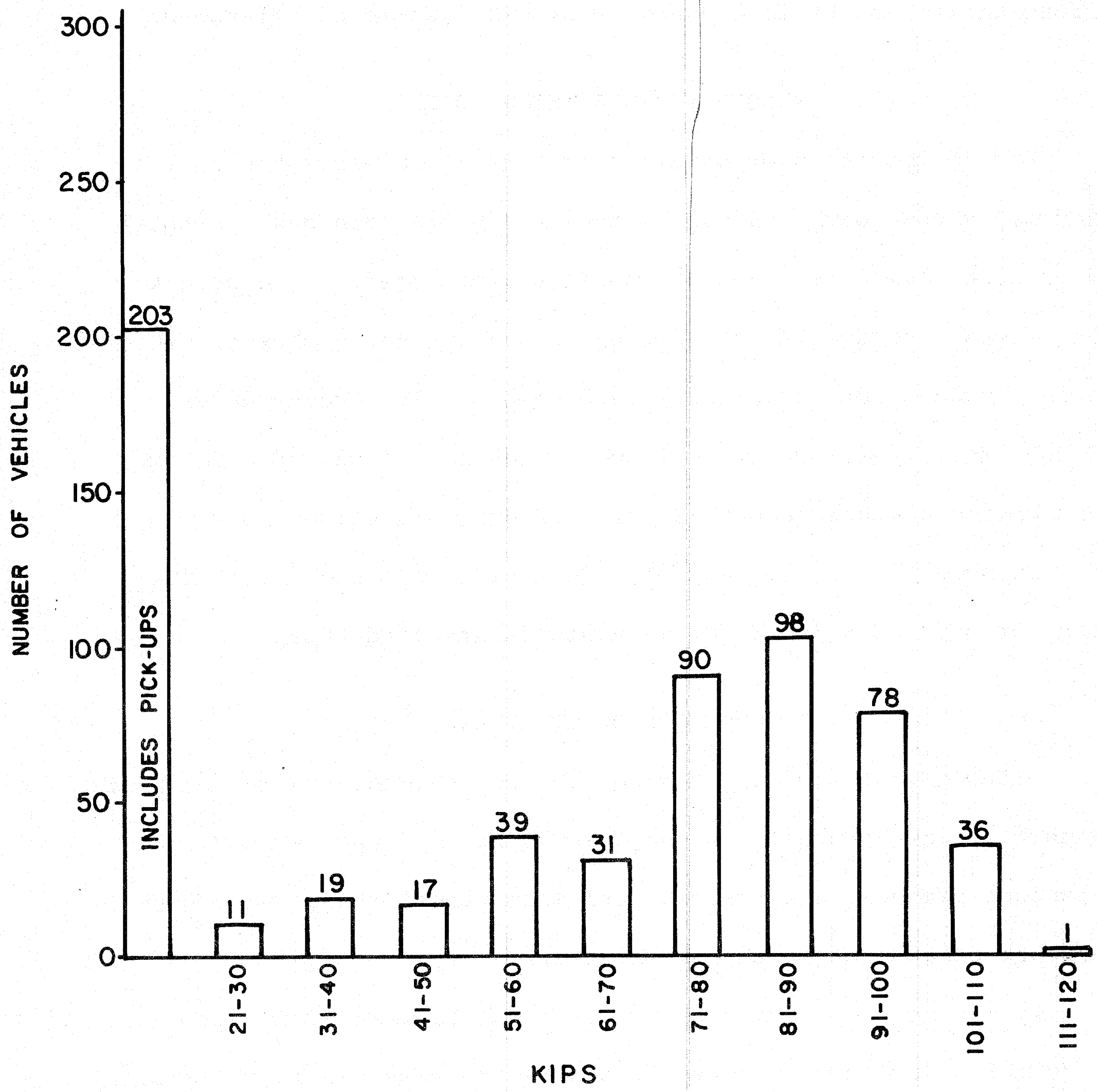


FIG. 16 DISTRIBUTION OF TRUCK TRAFFIC WEIGHT (4± HRS./DAY, 7 DAYS AT RANDO
NOVEMBER, 1982

RANDOM TRUCK TRAFFIC BY TYPE AND LOAD

83,000 Lbs.	94,000 Lbs.
80,000	91,500
80,000	80,000
77,000	79,000
77,000	91,000
96,000	84,000
71,000	80,500
83,000	91,000
83,000	90,500
68,000	79,000
71,000	94,000
85,000	70,000
85,000	74,000
74,000	74,000
70,000	83,000
62,000	77,000
80,000	74,000
58,000	105,000
64,000	77,000
86,000	84,000
86,000	79,000
68,000	74,000
	77,000
	84,000

Mean ($\bar{X}$)	*76,681 Lbs.*
Standard Deviation ($S\bar{x}$)	*9,122*
Number of Vehicles	*22*
Range	*58,000-96,000*
% over Legal Limit	*4.5*

Mean ($\bar{X}$)	*82,700 Lbs.*
Standard Deviation ($S\bar{x}$)	*8,253*
Number of Vehicles	*24*
Range	*70,000-105,000*
% over Legal Limit	*29.29*

FIG. 17 Large 5 Axle Semi-Trailer with Tree Length Logs

RANDOM TRUCK TRAFFIC BY TYPE AND LOAD

8'	120,000 Lbs
8'	108,000
8'	103,000
4'	86,000
8'	105,000
4'	89,000
8'	103,000
4'	104,000
4'	91,000

Mean ($\bar{X}$)	*101,000*
Standard Deviation ($S\bar{x}$)	*10,066*
Number of Vehicles	*9*
Range	*86,000–120,000*
% over Legal Limit	*88.8*

FIG. 18 5 Axle Semi-Trailer with 8' or 4' Length Logs

RANDOM TRUCK TRAFFIC BY TYPE AND LOAD

Gravel	73,000 Lbs.
Log	67,000
Dump	59,000
Hot Top	36,000
Hot Top	60,000
Gravel	67,000
Logs	62,000
Logs	47,500
Gravel	69,000
Logs	65,000
Gravel	73,000

Mean ($\bar{X}$)	*61,600*
Standard Deviation ($S\bar{x}$)	*10,700*
Number of Vehicles	*11*
Range	*36,000 - 73,000*
% over Legal Limit	*81.0*

FIG. 19 Tandem Axle with Various Loads

RANDOM TRUCK TRAFFIC BY TYPE AND LOAD

94,000
76,000
79,000
83,000
91,500
94,000
91,500
72,000
70,000
56,000
84,000
70,000
80,000
66,000
66,000
82,000
82,000
66,000
63,000
66,000
84,000

Mean (X)	*76,950*
Standard Deviation ($S\bar{X}$)	*10,800*
Number of Vehicles	*21*
Range	*56,000-94,000*
% over Legal Limit	*57.0*

FIG. 20 **Tri-Axle with Tree Length Log**

RANDOM TRUCK TRAFFIC BY TYPE AND LOAD

	100,000 Lbs.
	74,000
	77,000
	74,000
	97,000
	73,500
	67,000
	105,000
	70,000
	81,000
	82,500
Mean ($\bar{X}$)	*81,818*
Standard Deviation ($S\bar{x}$)	*12,364*
Number of Vehicles	*11*
Range	*70,000–105,000*
% over Legal Limit	*27.3*

FIG. 21 5 Axle Semi-Trailer Box with Wood Chips

RANDOM TRUCK TRAFFIC BY TYPE AND LOAD

88,000 Lbs.
73,000
83,000
98,000
98,000
80,000
75,500
83,000
72,000
94,500
98,000
101,000
70,000
73,500
80,000

Mean ($\bar{X}$)	*84,500*
Standard Deviation ($S\bar{x}$)	*10,600*
Number of Vehicles	*15*
Range	*72,000-101,000*
% over Legal Limit	*33.3*

FIG. 22 Medium 5 Axle Semi-Trailer Tree Length Logs

RANDOM TRUCK TRAFFIC BY TYPE AND LOAD

Propane	80,000 Lbs.
Tank	88,000
Tank	80,000
Tank	88,000
Box	44,000
Empty Flat Bed	32,000
Flat Bed-Steel	42,000
Flat Bed-Wood	62,000
Tank	82,000
Box	44,000
Box	64,000
Box	26,000
Box	64,000

Mean ($\bar{X}$)	*61,200*
Standard Deviation ($S\bar{X}$)	*20,836*
Range	*26,000-88,000*
Number of Vehicles	*13*
% over Legal Limit	*23.0*

FIG. 23 5 Axle Semi-Trailer with Misc. Loads

WEIGHTS DERIVED FROM SUMMED AMPLIFIED OUTPUT AND CALIBRATION LINES

DATE	TYPE	LOAD	NUMBER VEHICLES	MEAN ($\bar{X}$)	STANDARD DEVIATION *($S\bar{x}$)	RANGE MIN — MAX	**% OVER LEGAL LIMIT
5-27-82	5 AXLE SEMI-TRAILER	TREE LENGTHS	22	76,700	9,100	58K — 96K	4.5%
6-3-82	5 AXLE SEMI-TRAILER	TREE LENGTHS	24	82,700	8,200	70K — 105K	29.2%
5-28-6-3	5 AXLE SEMI-TRAILER	BOX-CHIPS	11	81,800	12,300	70K — 105K	27.3%
5-27-6-3	5 AXLE SEMI-TRAILER	TREE LENGTHS	15	84,500	10,600	72K — 101K	33.3%
5-27-6-3	5 AXLE SEMI-TRAILER	8' OR 4' CUT LENGTHS	9	101,200	10,000	86K — 120K	88.8%
6-3-82	5 AXLE SEMI-TRAILER	MISC LOADS	13	61,200	20,836	26K — 88K	23.0%
5-28-6-3	4 AXLE TRI-AXLE	TREE LENGTHS	21	76,900	10,800	56K — 94K	57.0%
5-28-6-3	TANDEM	VARIOUS LOGS, GRAVEL, HOT TOP	11	61,600	10,700	36K — 73K	81.0%

* Standard Deviation is not used as a measure of accuracy in this case, but to show the general range of values to supplement the max. & min. figures.

** Legal weight figured to include over weigh allowance for special products

FIG. 24 Summary of Weights of Various Ramdom Loaded Trucks of these oscillations represents the strain induced by a stress of the order of 25,000 to 30,000 lbs. Repeated 3 times per second this represents a fatigue loading of the bridge hundreds of times more severe than the usual passenger sedan.

A study of a variety of vehicles and loads, indicate a large variation in the degree of excitation of bridge oscillation. In all probability off center or unbalanced drive wheels or bogies with defective suspensions are the cause. With this in mind it is obvious that a great deal of road pavement damage starts with this type of off center pounding and when ruts or holes of as little as an inch or two have developed the dynamic loads can easily equal double or more than the static weight of the vehicle. Thus the extent of the cracks and ruts increase exponentially and rapid failure follows.

Although previously undermanned the Maine State Police Vehicle weight enforcement group has recently been reinforced with increased staff from the P.U.C. Copies of the data collected on the vehicles traversing the Skowhegan bridge have been made available to them.

AUTOMATIC DATA RECORDING

At this time preparations are underway to program an Apple II computer with a Cyborg (Isaac) interface to automatically record southbound vehicle data on the bridge. The Isaac provides strain gauge signal conditioning and conversion of the analog output to digital data which along with other needed data, will be multiplexed into the system and recorded on a floppy disc. It is planned to dump the data via a modem, each day, to a main frame computer for final calculation and recording on 9 track tape. Ultimately data will be printed out to provide planners and designers the information.

Vehicle speed will be obtained by using two inductive loops ten feet apart just ahead of the bridge.

The co-ax axle counter will provide the axle count and thus vehicle identification.

A co-ax in the northbound lane will provide a signal to void any data if a coincident northbound truck is present. Thus, data will be recorded southbound as follows: vehicle count, time of arrival to one millisecond, headway, vehicle type, speed, axle spacing and summed strain gauge output which will be converted to weight by the host computer.

This system is not intended to be a legal enforcement weighing system, but one of reasonable accuracy to provide general vehicle weights for road and bridge design data.

The probable accuracy is nevertheless of interest.

Several portions of the system have separate errors which can be estimated, and are shown below.

Gauge Calibration	± 2%
Summer Amplifier Drift	± 2%
Coincident Northbound Light Vehicles	± 2%
Total Possible Error	± 6%

Since the errors can be + or - at random the probability of all being of the same polarity simultaneously is small. So the estimate used of ± 5% or a total of 10% max. error is reasonable. For this kind of system recording vehicle weight and type, for design data collection ± 5% is very acceptable.

GENERAL COMMENTS ON SYSTEM

The strain gauges and installation cost approximately $12,000. The computer and installation will cost about $15,000. Engineering costs are not included. The computer can be moved to other bridges. Other bridges can either have permanently welded gauges or clamp on types can be installed.

Maine is undertaking the installation of several sites which will use the I.R.D. W.I.M. system. One site will be near the Skowhegan bridge W.I.M. system discussed here. Cross checks of vehicle weights can then be made.

Even though this bridge system does not give axle weights it represents the least expensive vehicle W.I.M. system for general vehicle classification and weights available. As we are using the system, data are being accumulated by the Research Division for planning and design purposes as well as providing a means of measuring the effectiveness of the State's overweight enforcement program.

DESIGN AND OPERATION OF WEIGH-IN-MOTION SITES FOR ENFORCEMENT WEIGHING

MR. E. E. RUGENSTEIN
HIGHWAY ENGINEER
OFFICE OF TRAFFIC OPERATIONS
FHWA
WASHINGTON, D.C.

DESIGN AND OPERATION OF WEIGH-IN-MOTION SITES FOR ENFORCEMENT WEIGHING

PRESENTED BY

E. E. Rugenstein
Highway Engineer
Office of Traffic Operations
Federal Highway Administration

at the National Weigh-in-Motion Conference

Denver, Colorado
July 11-15, 1983

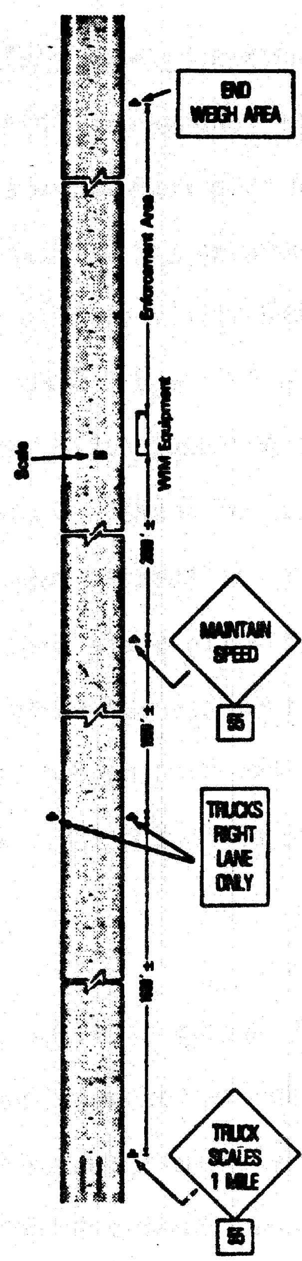
DESIGN AND OPERATION OF WEIGH-IN-MOTION SITES FOR ENFORCEMENT WEIGHING

Use of WIM equipment for vehicle weight enforcement requires that traffic control features be considered during the initial stages of a project to ensure efficiency and encourage operational safety. This report provides typical traffic control applications for the three basic categories of WIM: High Speed WIM (prevailing highway speeds); moderate speed WIM (located on a ramp); and Low Speed Wim (selected roadside areas). The information presented is a result of on-site reviews of WIM operations, experience gained from States that utilize WIM equipment for weight enforcement and reflects existing practice as well as recommended refinements.

High Speed WIM

For WIM at prevailing highway speeds, the scales may be located in the right lane or in multiple lanes with transducers and loops connected to a curbside junction box. The operator's console and other necessary equipment is located in a van, motor home, trailer, or other vehicle and positioned adjacent to the curb-side junction box but parked far enough from the edge of the travel lane to provide a clear roadside.

Right Lane Only Scale (Figure 1)--Weighing trucks at high speeds should be done on rural highways with ADT's below 10,000 vehicles per day. Thus, problems associated with lane changes and enforcement actions as a result of the WIM operation can be minimized.



Notes:

1. Enforcement area usually 2-3 miles in length. Desirable to have turnout, rest area or other location at downstream end of enforcement area so truck suspected of being overweight can be pulled over for enforcement weighing.

FIGURE 1

TYPICAL TRAFFIC CONTROL APPLICATION HIGH SPEED WIM OPERATION

Since lane assignment is necessary when scales are located in one lane, an advance warning sign is recommended to alert drivers to the type of activity ahead followed by a regulatory sign directing all trucks into the right lane. Another warning sign informing all drivers to maintain their speed supplemented with a 55-mile per hour advisory speed plate should minimize reductions in speed. Since the WIM equipment is used only at locations where preconstructed frames and junction boxes have been installed, installation of permanent posts and signs (with provisions for covering, folding, or turning away from traffic) will expedite set-up time. If portable signs are used, set-up time will be reduced if proper sign locations are marked on the pavement. It should be emphasized that any signs used during the WIM operation must be removed, covered, or turned away from traffic when the WIM operation is terminated.

Enforcement activities are usually conducted 2 to 3 miles downstream of the weighing operation to enable enforcement personnel to receive the radio message and safely direct the potentially overweight vehicle to a suitable roadside area for enforcement weighing. Rest areas, turnouts, or areas constructed specifically for enforcement actions and/or safety inspections are more suitable than shoulder areas or one of the through lanes.

Potential problems associated with a right lane only high speed WIM operation include:

- Weaving that takes place after encountering the "Trucks Right Lane Only" sign
- Drivers who deliberately avoid or incorrectly traverse the scale
- Drivers who slow or stop on the scale
- Problems associated with directing potentially overweight vehicles out of the traffic stream for enforcement weighing.

Multiple Lane Scales -- The use of WIM scales in all through lanes is advantageous because: (1) little or no advance signing is required, (2) it allows drivers to stay in their lanes, and (3) provides for the weighing of more trucks and results in fewer erroneous weighings due to drivers incorrectly traversing the scales. It does, however, increase the cost of the operation and complicates the sorting of potentially overweight vehicles out of the traffic stream because trucks can use all through lanes and volumes are usually higher.

Under these circumstances, the need for off-the-road enforcement areas is even more critical. It may also be necessary to increase the distance from the WIM operation to the enforcement area to permit a safer sorting operation of potentially overweight vehicles.

Moderate Speed WIM

Figure-2 shows a typical traffic control plan for a permanent weigh station that has been redesigned to provide for a moderate speed WIM operation. Conventional scale operation control devices such as advance guide signs and gore signing is assumed to remain in place. General design values for the ramp will vary depending on the geometrics of each particular weigh station. Following are some of the design considerations necessary for the installation of WIM scales at permanent weigh stations:

1. Ramp grades should be such that drivers traverse the WIM scale on relatively flat grades and have a clear view of traffic control devices beyond the scale and roadway geometrics in the vicinity of the scale house.
2. It is suggested that a design speed of about 30 miles per hour be used to weigh trucks in motion on ramps and to determine the location of lane designation signals.
3. The length of a ramp leading to a permanent weigh station is one of the critical elements necessary for adapting an existing site to a WIM operation. The deceleration lane and ramp should be of sufficient length to permit adequate time to communicate with drivers and to provide sufficient deceleration distance to avoid backup on the main line. The distance from the gore of the exit ramp to the WIM equipment located in the ramp should be adequate for vehicles to decelerate to 30 miles per hour

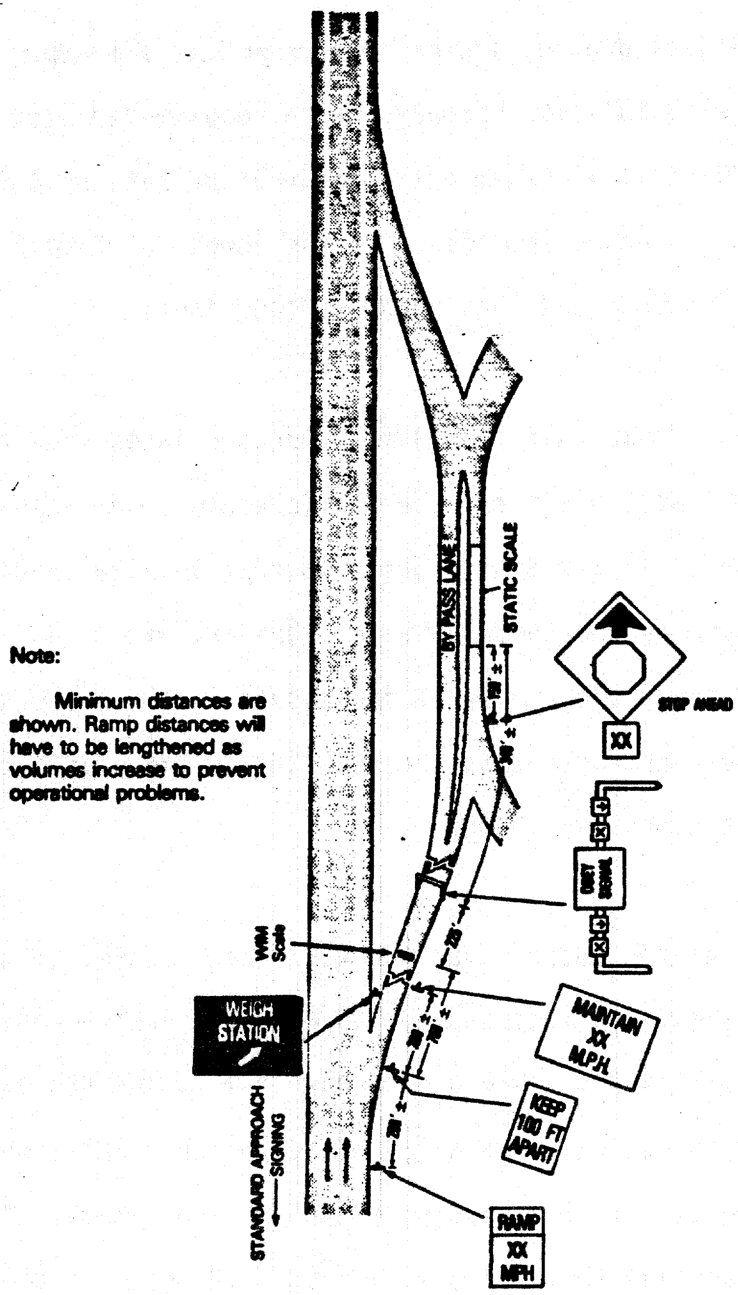


FIGURE 2

TYPICAL TRAFFIC CONTROL APPLICATION MODERATE SPEED WIM OPERATION

with minimal braking and/or to accommodate a minimum of five trucks with 100-foot headways. The recommended distance of about 700 feet is based on a deceleration rate of 4 feet per second-per second (660 feet) or the length of five trucks (300 feet) plus four 100-foot headways (400 feet).

4. It is desirable that the pavement be two lanes wide between the WIM installation and the static scale. One lane is used as a bypass of the static scale so that legally loaded vehicles can return to the through lanes. Drivers with legal loads should have a clear view of the bypass lane. The other lane accommodates trucks that are directed to the static scales for enforcement weighing.

5. Once a vehicle passes over the WIM scale located in the ramp, lane assignments must be made to either direct a vehicle to bypass the static scales or direct them to the scales for weighing. Assuming a design speed of 30 miles per hour and a perception reaction time of 3.5 seconds after the rear wheels of a 60-foot truck and trailer pass over the WIM scale, a minimum distance of 225 feet is recommended from the WIM scale to the lane designation signals. A 225-foot distance minimizes the possibility that a second truck will enter the area beyond the WIM scale before the first truck passes under the lane designation signal (assuming the 100-foot headways are maintained).

The limited experience to date suggests that drivers react better to the signal if it is presented to each driver from a "no signal" display to a positive indication, even though the signal controller holds the first signal display until the first truck passes.

It is preferable that lane assignments be made by lane-use control signals located approximately over the center of the lanes to be controlled. These lane use control indications should not be less than 15 feet nor more than 19 feet above the pavement grade.

6. The distance from the lane-use control signals to the static weigh station should be adequate for a truck passing under the signal to comfortably decelerate from the assumed speed of 30 miles per hour to a stop condition before going across the scale. Using a deceleration rate of 3 to 6 feet per second requires a minimum distance of 160 feet--with a more desirable distance being about 350 feet.

Two States that use WIM utilize a second set of lane use control signals immediately beyond the scale house, which is common practice at many conventional weigh stations. These signals can benefit a WIM operation by:

a. Reinforcing the first lane-use control signal for legal vehicles, indicating that it is permissible to return to the freeway in the bypass lane.

b. Stopping, through manual actuation, potentially overweight trucks that are using the bypass lane. Stopped trucks can be directed to return to the scale by using the turn around.

7. At permanent weigh stations that have incorporated moderate speed WIM equipment, traffic control must guide the drivers confidently through the station at appropriate speeds with safe headways. A sign opposite the exit gore and 700 feet in advance of the WIM scale, directs the drivers to keep 100 feet apart. About 200 feet closer to the WIM scale a sign advises the driver to maintain the speed that is appropriate for that particular WIM installation. Approximately 50 feet from the WIM scale, pavement edgelines should begin to taper inward to the edge of the scales to help center the truck laterally in the lane as it passes over the WIM scale.

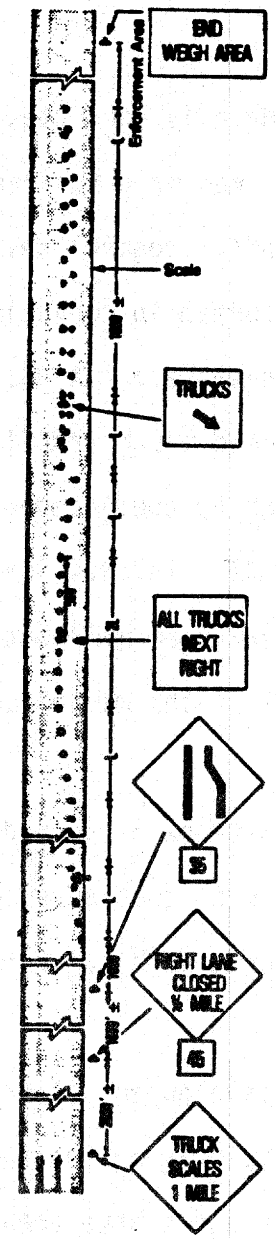
Low Speed WIM

Low speed WIM operations are generally conducted utilizing equipment that is brought to a site in either a van or a trailer that contains all WIM equipment and appropriate traffic control devices. Ideally, the weighing operation should be performed in convenient turnouts or other off-the-road areas. If these sites are not available, a shoulder area sufficient to accommodate low speed truck traffic can be used. It is suggested that shoulder weighing be conducted only on rural sections of highway with volumes below 7,000 ADT. In addition, shoulder weighing operations should be treated as a short-term maintenance zone and signed and marked in accordance with Part VI of the Manual on Uniform Traffic Control Devices (MUTCD).

One of the fundamental considerations of shoulder weighing operations is the selection of sites with good advance sight distance. While flat grades are suitable, long sag vertical curves are even more desirable.

The selection of sites and the development of traffic control plans for individual sites should be done jointly by traffic engineering and enforcement personnel. Once suitable sites have been located, premarking the pavement for signing and other devices can reduce set up time and ensure consistency of application.

Figures 3 and 4 illustrate two typical applications for a weighing operation on the right shoulder of an Interstate highway.



• Channeling Devices
⇐ Arrow Pannel (Optional)

Notes:

1. Taper Formula:
   $L = S \times W$ for speeds of 45 or more.
   $L = \frac{WS^2}{60}$ for speeds 40 or less.

   Where:
   L = Minimum Length of Taper.
   S = Posted Speed Limit.
   W = Width of Offset.

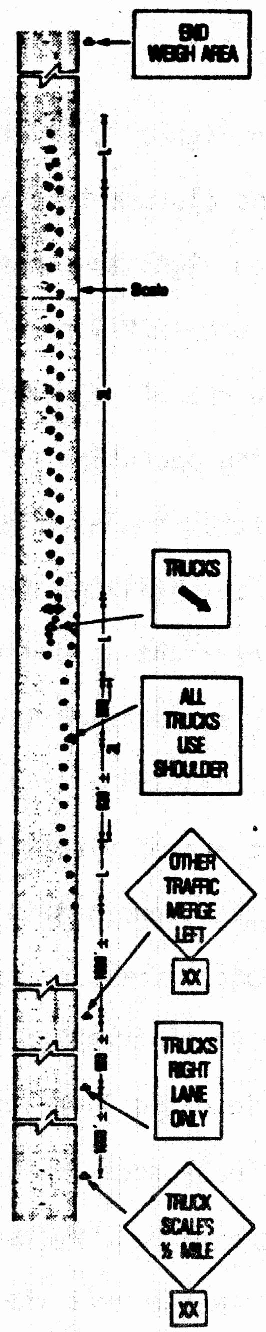
2. The maximum spacing between channelizing devices in a taper should be approximately equal in feet to the speed limit.

3. Flashing warning lights and/or flags may be used to call attention to the warning signs.

4. Enforcement area usually 2 to 3 miles in length. Desirable to have turnout, rest area or other location at the downstream end of enforcement area so trucks suspected of being overweight can be pulled over for enforcement weighing.

FIGURE 3

TYPICAL TRAFFIC CONTROL APPLICATION
LOW SPEED WIM OPERATION
ALTERNATIVE "A"



• Channelizing devices
◆◆ Arrow Panel (Optional)

Notes:

1. Taper Formula:
   $L = S \times W$ for speeds of 45 or more.
   $L = \frac{WS^2}{60}$ for speeds 40 or less.

   Where:
   L = Minimum Length of Taper.
   S = Posted Speed Limit.
   W = Width of Offset.

2. The maximum spacing between channelizing devices in a taper should be approximately equal in feet to the speed limit.

3. Flashing warning lights and/or flags may be used to call attention to the warning signs.

4. Enforcement area usually 2 to 3 miles in length. Desirable to have turnout, rest area or other location at the downstream end of enforcement area so trucks suspected of being overweight can be pulled over for enforcement weighing.

FIGURE 4

TYPICAL TRAFFIC CONTROL APPLICATION
LOW SPEED WIM OPERATION
ALTERNATIVE "B"

In the typical application in Figure 3, which is being used by at least one State, a standard lane closure treatment with appropriate advance warning and speed reduction signs and channelizing devices, is used to merge all traffic into the left lane. Once in the left lane, trucks are instructed, through the use of regulatory signs, to exit onto the shoulder where the weighing operation is conducted on either portable WIM scales or portable static scales. The exit path across the right lane is delineated with channelizing devices and from this point past the portable scales, the right lane remains closed.

A potential problem with this application involves the screening of trucks from the traffic stream, resulting in the slowing of all traffic at the truck exit area. Also, because of visibility problems, some automobiles will inadvertently follow trucks into the weigh area.

Figure 4 presents another typical traffic control application for weighing trucks on the shoulder. In contrast to the previous application where all traffic is channelized into one lane before trucks are sorted, this alternative requires trucks to be sorted while maintaining two lanes of traffic. Regulatory signs direct trucks to the right lane while other traffic is directed to merge left where it can bypass the weighing operation with only a minimal reduction in speed. The sorted trucks in the right lane are channelized to the right shoulder for weighing.

In conclusion WIM can:

1. Monitor the weight of all trucks on high volume routes.

2. Void-user costs associated with stopping legally weighed trucks.

3. Increase enforcement effort with the same or less personnel commitments.

RTAP DEMONSTRATION PROGRAM

MR. OTTO WEHRING
TEXAS STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTAION
AUSTIN, TEXAS

RTAP - Demonstration of Coordinated Weight Monitoring and Enforcement Program Using WIM Equipment in Texas

Otto Wehring
Texas State Department of Highways
and Public Transportation

History of WIM System Development in Texas

Texas State Department of Highways and Public Transportation (SDHPT) has been involved in the development of the weigh-in-motion (WIM) concept since 1963 through research and practical applications. The development of our system has been in cooperation with The University of Texas at Austin's Center for Transportation Research (CTR) and the Federal Highway Administration (FHWA). The basic goal has been to find an effective, efficient and safe means of obtaining representative statistical truck weight data. Data that will provide the basis for geometric and structural design of highway pavements and bridges. The data are also invaluable in the planning, operation, maintenance and budgetary processes for the entire highway system.

The RTAP project is viewed as an excellent opportunity to extend the WIM concept into an improved operational truck weighing program in Texas and to provide baseline evaluation information in the national interest. This project allows application and evaluation of state-of-the-art equipment in an operational environment.

State Agency Organization and Responsibilities

The SDHPT and Department of Public Safety (DPS) are organized as separate agencies of the State. The SDHPT has the responsibility for planning, construction, maintenance and operation of the highway system. The DPS has the responsibility of law enforcement and other activity concerning the safety of the motorist using the highway system. The DPS, as the chief law enforcement agency, also has other customary responsible duties in the protection of our citizens.

A very important function of DPS is the size and weight enforcement. An extensive and continuing program is conducted to deter oversize or overweight vehicles from using Texas highways. Vigorous enforcement enhances safety and protects the tremendous investment in the highway system. All weight enforcement presently is based on legally recognized static weights obtained with permanent, semi-portable or portable scales. Considerable resources are needed to cover approximately 3000 miles of interstate highways and 70,000 miles of the various other types of highways in our system.

Size and Weight Enforcement Operation

The DPS License and Weight Service utilizes 196 commissioned officers to operate 8 permanent scales, 15 semi-portable (trailer transported) scales, and over 700 portable wheel-load weighers (4 per car) in weight enforcement activities over the State. Six additional semi-portable (trailer transported) units will be placed into operation after September 1, 1983.

Texas does not use the port of entry truck weight system but relies upon the patroling method of stopping a truck any time it is suspected of being in violation. This procedure does not preclude the operation of road blocks for an indefinite period to detect violaters. A total of 675,356 trucks were stopped in 1982, of which approximately one-third were weighed. Some trucks had oversize and overload permits and others had a weight receipt issued for the particular load by a legal public weigher. A number of those stopped were obviously not in any weight violation and, consequently, were not weighed. The officer must determine whether his weighing operation would produce substantial evidence to issue a citation.

In the 1982 calendar year, citations were issued for the following violations:

Over 20,000 lb. axle load	882
Over 34,000 lb. tandem axle load	12,782
Over gross weight	19,483
Over Size	11,358
Over weight by bridge formula	14,546
Miscellaneous weight violations	53
Total citations issued	59,104

The DPS is interested in any practical means of improving the effectiveness of size and weight enforcement. The WIM demonstration project will allow current weight enforcement procedures to be appraised and provides an opportunity for evaluating new techniques and technology which may be adopted into practice when proven adequate.

Equipment Selected for the Demonstration

The WIM demonstration will be a cooperative effort of the FHWA, SDHPT, DPS AND CTR, UT at Austin. The demonstration will be a coordinated program using the in-pavement WIM equipment manufactured by Radian Corporation. Data will be collected for statistical purposes for use in highway design and as a tool in the size and weight enforcement program.

Demonstration Objectives

The demonstration project will be directed at accomplishing the following objectives:

1. Obtain improved truck weight and classification data samples at a designated SDHPT weigh site(s) that have been operated in previous years. This will include weighing in two-directions and in multiple lanes.

2. Contract with Radian Corporation for expanding current SDHPT WIM system to handle in-pavement weighing in four lanes simultaneously.

3. Install WIM transducers (1) in the through-traffic lanes, (2) on the exit ramp, and (3) near the static axle-load scale at a selected permanent weigh station for direct comparison of WIM vs. static weighing accuracy at a full range of speeds including low-speed weigh-in-motion (LSWIM). (i.e. less than about 10 mph)

4. Define the range of accuracy within which present portable and semi-portable static truck weighing equipment performs in typical usage and document the time requirements for static weighing and dimensioning that are needed to apply the "bridge formula" for enforcement.

5. Define the attainable accuracy of low-speed weigh-in-motion (LSWIM) and evaluate the feasibility of "bridge formula" application with this technique. Productivity rates will also be defined.

6. Collect sufficient data to determine whether LSWIM weighing can be utilized for legal evidence of weight law violation.

7. Demonstrate the feasibility of using high-speed weigh-in-motion (HSWIM) techniques for simultaneously collecting statistical data and sorting suspected overweight vehicles from the traffic stream for legally-acceptable weighing.

8. Study the effects of weigh station operations on "by-passing" or "waiting-it-out" truck traffic and evaluate practical means of solving these problems.

9. Evaluate the practicability of combining enforcement and statistical data collection weighing operations using WIM equipment in Texas.

<u>Project Activities</u>

The project will be conducted in three phases. As the project progresses, there will be an overlap of phases.

Phase I Work Plan and Equipment Procurement

Organizing available resources, providing personnel and appropriate training and procurement of new equipment are initial functions for this project. We are currently in this phase of the project. A coordinated effort by all participants will be provided throughout the project and is particularily essential in this phase. An interagency agreement has been executed between SDHPT and CTR to provide resources for project management, experimental design, statistical sampling, data analysis and presentation of results. Inventory of available resources, determining equipment needs and acquisitions are currently in various stages. Work plans and tentative schedules of activity are in the early stages.

The SDHPT presently owns a Radian WIM-1E system with data telemetering capabilities. This system can handle two lanes of in-pavement weighing simultaneously and records data on flexible disks. The current truck weighing program consists of data collection in the outside lane only in one direction at six locations. Each location is operated twice annually during daylight hours for approximately three consecutive days on a rotational basis. Approximately 500 to 1000 trucks are weighed during the three day session at each station. Numbers are variable in proportion to ADT at the WIM site.

For the demonstration and the future, it was determined that the existing WIM system be modified to have the capability of collecting data in four lanes simultaneously. A contract is being made with Radian Corporation to furnish the necessary system improvements. Equipment procurement should be completed within the first nine months of the project which is about January, 1984.

Phase II Data Collection

Data will be collected for an approximate one year period relative to the statistical data sampling, enforcement and coordinated weighing objectives of the project.

Statistical Data Sampling

To evaluate the adequacy of our current truck weight data sampling procedure, a series of data samples will be taken at one or more of the weighing sites. Multiple lane weighing in both directions of travel simultaneously for seven consecutive days, 24 hours per day, at least three times in the year will be scheduled. Analysis of these data will aid in the appropriate scheduling of future operations and possibly indicate the need for site relocation.

The existing six SDHPT WIM stations are all located on rural, principal arterial interstate and rural, principal arterial other highways. It is desirable to identify other appropriate weigh site locations for other functional highways.

Data Relative Enforcement Operation

In the enforcement operations, Texas laws state that a vehicle, axle or axle group may exceed the maximum allowed weight by 5 percent before unloading is required. Permanent scales and semi-portable scales are certified at 1 percent tolerances and the portable wheel-load weighers carry 3 percent maintenance tolerances when tested under a known applied static load. Even though it is recognized by experienced users of these devices that load transfer occurs as a vehicle maneuvers over the scales, little quantitative data are available to indicate the magnitude of error which might be involved in wheel and axle weighing procedures. One objective of this project is to obtain such data. Some observations indicate that inaccuracy up to 20 percent or more can occur in using scales certified to 1 percent or better tolerances.

Under this project, the permanent DPS vehicle inspection station on IH 10 approximately 5 miles East of Seguin which is equipped with the permanent axle-load scale, has been selected as a WIM demonstration site. DPS will participate with its portable and semi-portable scales in this study to determine accuracy of their equipment in routine operations. Trucks from the normal traffic stream will be systematically weighed by the various portable DPS scales and the permanent Eldec scale (Model Series 31, Electronic Scale) which is periodically certified.

These same trucks will be weighed with (1) High Speed WIM on the main traffic lanes in advance of the station, (2) WIM at intermediate speed in the vicinity of the exit ramp and (3) Low Speed WIM (LSWIM) near the permanent scales. Comparative statistics will be developed for the weight data obtained by the various weighing techniques. The time required for processing each truck via LSWIM and static weighing will be noted. An adequate sample of LSWIM weights will be obtained to determine the feasibility of utilizing these weights in lieu of static weight for legal evidence of weight violations.

It is anticipated that sufficient data for the above stated purposes can be collected in less than 10 days of operation at this site. Additional time for demonstrating the sorting and statistical data collection feature of WIM will be available.

In order to study the effect of weigh station operations on truck traffic which divert to alternate routes (by-pass) or park their vehicle during weighing operations to avoid being weighed, DPS will devise a traffic monitoring scheme which could possibly include helicopter surveillance of adjacent roads and trucks stops. Automatic classification counts of several days duration to obtain quantitative data are also planned.

Dual Purpose Operation

The permanent WIM station in our current routine operation located on IH10, West of Seguin which is approximately 40 miles East of San Antonio, has tentatively been selected to be instrumented for 100 percent truck sampling operation. The station will be operated in a sorter mode to demonstrate the feasibility of utilizing this technique for enforcement as well as statistical data collection if the existing station geometrics can be adapted to safe operations.

Phase III Data Analysis and Evaluation

Analysis of data will begin immediately upon collection and continue into the evaluation phase of the project. A final report will be prepared within six months after data collection is completed to document the experiences of using WIM techniques for data collection and for enforcement.

Project Cost

The total project costs will be shared by five participants: FHWA, SDHPT, DPS, CTR and Radian. Each will contribute in various ways to the coordinated effort. FHWA funds will support the procurement of equipment from Radian and technical services from CTR for project management, data analysis, and presentation of results. SDHPT will provide the equipment and the personnel needed to install and operate the WIM system in support of the project. They will retain the equipment upon project completion. DPS will allocate equipment and personnel as needed to obtain data required for accomplishing the stated objectives. CTR will make available its personnel and facilities as needed to attain the study goals, and Radian Corporation will furnish the supplemental resources needed to expand the existing WIM System.

Cost of project is estimated to be $342,300.00. Funding sources are:

RTAP WIM project Funds	$135,000.
HPR Fund (Planning and Research Funds - our operational budget)	101,000.
SDHPT Fund (our operational budget)	20,300.
DPS (personnel and operational cost)	17,000.
Radian Corporation (contribution of engineering and development cost of equipment for the Project)	60,000.
UT-CTR (contribution of technical services, project management, data analysis and report preparation)	9,000.
Total of Funding Source	$342,300.

Most of the data which will be collected under the project will serve both normal operational requirements and demonstration project needs.

Project Summation

The DPS is interested in developing techniques which will give data to enhance their programs for planning their enforcement operations. Future WIM technology will continue and an investigation of application to the enforcement operation appears logical. The coordination of size and weight enforcement and truck weight studies will explore the usefulness of new technology. Technology advancement of WIM when eventually proven acceptable for legal evidence, would improve the effectiveness of the enforcement program.

The opportunity of our two independent agencies working together is a unique occurrence. It will give us on-the-job experience to actually explore operational problems, determine how severe data is biased when enforcement officers are present and a cost analysis of our combined operations.

Any techniques developed in this project and continued as a coordinated team or operating independently would certainly improve the program efficiency and consequently help our budgets.

RTAP DEMONSTRATION PROGRAM

MR. WILLIAM GARDNER
WISCONSIN DEPARTMENT OF TRANSPORTATION
DIVISION OF PLANNING AND BUDGET
MADISON, WISCONSIN

WISCONSIN DEMONSTRATION OF COORDINATED WEIGHT MONITORING AND ENFORCEMENT USING WEIGH-IN-MOTION (WIM) EQUIPMENT

William D. Gardner
Wisconsin Department of Transportation
Division of Planning and Budget

For Presentation at the
National Weigh-In-Motion Conference
Denver, Colorado

July, 1983

WISCONSIN DEMONSTRATION OF COORDINATED WEIGHT MONITORING AND ENFORCEMENT USING WEIGH-IN-MOTION (WIM) EQUIPMENT

Introduction

The Wisconsin Department of Transportation (WISDOT) is participating in FHWA's Rural Technical Assistance Program demonstration of WIM technology. WISDOT's Division of Planning and Budget will direct the project. The Division of State Patrol, responsible for state motor carrier enforcement, will play a major role. The demonstration project will allow WISDOT to test the operational performance of a WIM system, to establish a comprehensive and representative base of truck weight data, to test new approaches to motor carrier enforcement, and to promote coordination between the various weighing programs.

Project Description

WISDOT's objectives in conducting the project can be summarized as follows:

1. Acquire, install, and operate a bridge WIM system.
2. Use WIM to implement a new Truck Weight Study that is cost-effective and statistically reliable.
3. Use WIM to develop special data for the planning and evaluation of the Motor Carrier Enforcement Program.
4. Use WIM to test new enforcement techniques and to promote coordination between weighing programs.
5. Assess the operational performance of WIM as compared to previous methods of weighing vehicles.

The project will consist of three major activities. The first activity will be to conduct a newly created Truck Weight Study (TWS). A recently completed WISDOT research project[1] recommends major changes in the program including the use of weigh-in-motion for data collection. The bridge WIM, in particular, is needed to expand geographic, functional road type, seasonal, and temporal coverage of survey operations. This type of program is essential for developing useful data for application in motor carrier enforcement, pavement design and pavement management, and highway cost allocation studies.

The second major activity consists of evaluating the operational performance of the bridge WIM. Special tests and analyses will be conducted to determine the accuracy of data outputs and equipment performance under various conditions. The costs of operation will be examined. WIM data will be compared to that obtained through other methods of weighing vehicles. The ease of operation, portability, and reliability of the equipment will be addressed. The WIM will also be tested as an enforcement screening device. All of these evaluation efforts will help determine the limits and utility of the bridge WIM system.

The third major activity area involves more closely coordinating the Truck Weight Study and the Motor Carrier Enforcement (MCE) Program through several phases of work. In the first phase, weight data generated by the TWS and other available data will be used by MCE to establish a long-range (4-5 year) highway preservation/motor carrier enforcement plan. The

---

[1] Wisconsin Truck Weight Study - Final Report, Wisconsin Department of Transportation, July, 1982.

WIM data will serve to define the extent of overloads on a statewide basis and evaluate the impact of enforcement activity. Impact can be defined as illegal 18-kip equivalent single axle loads (ESAL's) that are prevented or not prevented through enforcement. The results of this planning process can be integrated into the annual size and weight enforcement plan submitted to FHWA.

The second phase of this coordination activity will consist of short-range selective enforcement planning. Because of the present lack of timely and adequate truck traffic data, scheduling and placement of MCE personnel is currently done instinctively on the basis of perceived or anticipated patterns of overweight trucks. As part of this project the bridge WIM will be used to collect comprehensive truck weight data at a number of sites within a special target area. These sites will be located on both major trucking corridors and on suspected bypass routes. The resulting data will be compared to that collected during the TWS as a possible supplement to the TWS data base. The greatest potential for this data would be for the planning of MCE activity. In this phase, the bridge WIM would determine the actual patterns of overweight trucks. An enforcement plan will be created to guide the targeting of enforcement by day of week, time of day, by location, and by scale type. Nearly 800 person-hours will be dedicated to this total planning phase.

The final phase of the coordination activity will be a pilot test of selective enforcement operations. Actual operations will be carried out on the basis of the enforcement plan. Several different enforcement strategies will be tested as appropriate including operating static scales for long periods of time and maximizing the use of wing patrols. As this enforcement activity occurs in the target area, the bridge WIM will be used simultaneously to monitor truck traffic. The bridge WIM will be able to document bypassing of static scales and detect changes in truck weight patterns resulting from enforcement activity. Over 5,000 person-hours of direct enforcement activity will be dedicated to this phase of the project.

In support of its overall commitment to this demonstration project, WISDOT plans to reconstruct its Rusk Static scale on Interstate 94 west of Eau Claire. Subject to state and federal authorization, a single new permanent pavement scale will be installed that will be capable of weighing vehicles either staticly or in-motion at low speeds. This new concept in weighing will function as a screening device for the regular enforcement program (vehicles weighed in-motion that are suspected of being overweight will be returned to the same scale for certified static weighing). Assuming this scale will be constructed prior to the close of the demonstration project, WISDOT will compare the accuracy and capabilities of the bridge WIM to those of this new retrofitted WIM/static scale. Creative enforcement strategies using a combination of this equipment can be devised and tested.

Project Tasks

WISDOT received delivery of a bridge WIM in May, 1983, and has recently completed training of field personnel. Starting in late July, 1983, the bridge WIM will be operated at nine Truck Weight Study stations distributed across rural interstate and rural state trunk-principal arterial highways.

These 9 stations represent part of 21 total stations (including 7 functional road classes) necessary for developing a comprehensive truck weight data base through the Truck Weight Study. (The other 12 TWS stations will be surveyed in the year following the demonstration project.) The 9 stations were assigned to counties using a random numbers technique; specific sites were selected using both operational and survey criteria. All 9 stations will be surveyed for approximately one week each during the summer/fall months. Two of the 9 stations will be surveyed at night, on weekends, and during other seasons to reveal possible variations in truck weights.

It is expected that the bridge WIM will be used at 8-10 sites in a target area for the selective enforcement planning to determine overweight truck patterns. Selective enforcement operations (using portable and static scales for enforcement and the bridge WIM to monitor the results of the enforcement activity) will then be carried out in the target area.

All field work will be completed between July, 1983, and September, 1984. The bridge WIM will be operated at an estimated 20 to 30 total sites during the course of this project. The sites will be located across the state and cover several road types. Large amounts of truck weight data will be collected while the equipment is being used for various purposes. The equipment will be used during all seasons and thoroughly tested as described below.

Evaluation of the WIM System

A. Capabilities of the System

A series of special tests and studies will assess the capabilities of the bridge WIM system and compare it to previous methods of weighing. These efforts will include the following:

(1) Classification. The WIM system's ability to correctly classify vehicles at various ranges of traffic speed will be tested by an observer. Ability to distinguish between cars and trucks and classification into the correct axle configuration category will be tested. Performance can be measured by the percent of vehicles correctly classified.

(2) Accuracy. The WIM system's ability to accurately record gross weight, single and tandem axle weights, and axle spacings will be tested in several ways. One test will involve crossing one or more test trucks of known weight and dimension across the WIM scale. Performance can be measured by calculating a standard deviation and coefficient of variation around known values. In order to test the WIM system with a range of vehicle types, the system will be set-up upstream of a static scale. Truck traffic will be monitored by both scales. Performance of the WIM scale can be measured by conducting an analysis of the variance in the data between the two scale types.

(3) Violations. The WIM system will be used to check for weight violations. WISDOT has worked with the vendor to program Wisconsin's weight laws, including the bridge formula, into the system software. Because certain weight laws vary by commodity type, the use of a keypad to identify the commodity type and signal the computer to match the estimated weights against the correct set of weight laws will be tested.

(4) High Speed and (5) High Volume. The bridge WIM will be operated primarily on major thoroughfares with large volumes of vehicles. Many of these routes carry high speed traffic. The ability of the WIM to collect data from high speed vehicles and in high volume traffic will be evaluated. Performance can be measured by calculating the number of trucks accurately weighed compared to the number of vehicles (trucks and other) crossing the bridge. (Note: WISDOT plans to operate the WIM system in two lanes under most circumstances.)

B. Accuracy vs. Speed

The accuracy of the WIM system at various vehicle speeds will be tested by running one or more test vehicles of known weight across the scale at different speeds. Performance will be measured through the variance in weights at different speeds. Accuracy of the WIM's speed measurements can be checked with a radar gun.

C. Ease of Operation

WISDOT plans to operate the bridge WIM with two technicians. The feasibility of operating the system with one technician by installing a camera system to take the place of a manual observer on the roadway will be examined.

D. Portability

WISDOT has installed the bridge WIM in a van which can be driven from site to site on any road type. Portability will be assessed by describing the tasks and time required for proper set-up of the system. Records will be kept on set-up time, calibration time, and tear-down time.

E. Telemetry

WISDOT will examine the feasibility of telemetric data transmission by working with the vendor to assist in the testing of any system prototypes they produce. WISDOT is currently completing the installation of telemetry at 72 automated traffic recorder sites. The desirability and feasibility of connecting WIM system into such sites will be explored.

F. Cost-Effectiveness

WISDOT will document all initial equipment purchase, maintenance, and operational costs of the WIM system. Indicators such as cost per hour of operation and cost per vehicle weighed will be developed.

G. WIM vs. Non-WIM

WISDOT will examine how the bridge WIM compares to current methods of weighing with respect to the data produced. Total number of trucks weighed per site and the number of trucks weighed per hour will indicate the quantity of data. Quality of data will be determined through the performance evaluation tests, an analysis of the scope of data collected (seasonal, geographic coverage, etc.), and documentation on the problem of scale bypassing and possible biasing of the data with WIM versus non-WIM systems.

H. Coordination - TWS and Weight Enforcement

The ease or difficulty in coordinating vehicle weighing programs will be assessed. The extent to which TWS data assists enforcement activity will be evaluated. The possibility of using data collected from enforcement activity in the TWS data base will be assessed. Conflicts or benefits in sharing equipment and manpower will also be described.

I. Additional: WIM for Enforcement Screening

The capability of WIM as an overweight screening device will be tested at several sites. Truck traffic will be screened for suspected overweights which will then be directed to certified scales for weighing. Effectiveness of the operations, scale bypassing, and safety will be evaluated.

Final Report

A final report documenting the above activities will be written within six months of project completion. Data collected with the WIM will be presented where appropriate. WISDOT will identify advantages and disadvantages of using WIM, suggest where improvements should be made and desirable future research, and identify those applications of the bridge WIM that were tested which appear to be most promising.

Conclusions

The application of weigh-in-motion technology to motor carrier enforcement and to truck weight studies is expected to reap numerous benefits. For enforcement, WIM can function as an effective screening device to improve productivity while minimizing the disruption to truck traffic. Equally important, WIM can help create more effective enforcement by documenting the scope and location of overweight truck traffic. A better understanding of the truck weight problem, including the relationship between levels of enforcement and pavement conditions, can generate greater support for enforcement programs.

The bridge WIM will provide immediate benefits to the Truck Weight Study including expanded road coverage, reduced costs per sample, and minimization of trucker avoidance of the scales. As a bonus, valuable strain data will be collected for possible use in bridge rating and evaluation. Coordination of these programs can be achieved by sharing information and equipment. Better coordination will help direct both programs towards the common goal of highway preservation.

FUTURE ADVANCES IN WIM TECHNOLOGY

DR. ARTHUR BERGAN
ASSISTANT DEAN
COLLEGE OF ENGINEERING
UNIVERSITY OF SASKATCHEWAN
SASKATOON, SASKATCHEWAN

FUTURE ADVANCES IN WIM TECHNOLOGY

A. T. Bergan
Assistant Dean
College of Engineering
University of Saskatchewan
Saskatoon, Saskatchewan
S7N OWO

This is the closing session of the 1983 National Workshop on Weigh-In-Motion, (WIM), Technology. The workshop was successfully organized by the Federal Highway Administration, (FHWA), and was hosted by the Colorado Department of Transport. The contribution of both these agencies is greatly acknowledged. It is also recognized that the United Kingdom experience with WIM technology has broadened the scope of the conference. Canadian delegates would like to thank the FHWA for the opportunity have been offered to participate in the conference.

The highlights of the conference will be reviewed and the future developments and the applications of WIM technology will be put into perspective. The conference was an excellent opportunity to observe the operation and discuss with the users of the various types of WIM equipment. During the last ten years, a number of different types of WIM systems have been developed. The rapid development of WIM systems should mainly be attributed to the improved electronics available. Regardless of manufacturer type, WIM systems can be classified with respect to vehicle speed. Slow speed systems record at vehicle speeds of 2 mph or less. Medium speed systems record at vehicle speeds of 10 to 40 mph. High speed systems record at usual highway operational speeds. In terms of portability, the demonstrated WIM equipment can be classified as portable, semiportable and permanent.

The potential areas of application of WIM equipment are different for the various scale types. Slow speed systems are widely used elsewhere, (e.g., England) for enforcement of load limit regulations. Slow speed scales can be used to replace or complement static mechanical scales for load enforcement in the United States. Medium speed systems are mainly used for sorting, that is automated selection of heavy vehicles to be accurately weighed by a static or slow speed scale. High speed systems are used for continuous recording of traffic and axle load data at normal highway speeds. Such information is essential in pavement management, planning, budgeting and traffic engineering. A major step in choosing the appropriate type of WIM equipment is to carefully identify the user's needs and the level of accuracy desired in a specific application. The popularity of WIM systems is increasing rapidly with highway agencies across North America. WIM systems have been reported operating in various states, (e.g., Minnesota) on a continuous basis. WIM technology has improved rapidly the past 5 years. Further improvements should be expected in the near future mainly in the areas of data recording and data processing. Automated recording and data transmission by telemetry to main frame computers will eliminate labor needs in data collection and processing.

Load values recorded by WIM scales are, in general, different than the static values. There are various factors affecting dynamic load readings such as pavement roughness, vehicle speed, vehicle dynamics and the type of the scale used. Dr. Lee in his presentation did an excellent job putting all these factors into perspective. The various types of WIM equipment would be expected to provide different degrees of accuracy. High speed scales should provide accurate gross weight data for a large population of vehicles of various classifications. In continuous load data recording, there is little interest in the accuracy of load readings of individual truck axles. Instead, the average and the standard deviations of the gross weight of a given vehicle class should be representative of the values obtained by static scales. Tolerance limits should be established for the differences between static and dynamic load data. Medium speed scales should be accurate in determining the weight of individual vehicle axles. Appropriate tolerance limits in weight determination should be established for sorting overloaded truck axles. Low speed scales should be more accurate in determining the weight of individual axles and the gross weight of vehicles. Narrower tolerance limits would provide the accuracy required for load enforcement purposes.

One of the most important factors in adopting WIM technology is the development of uniform calibration procedures for the various types of scale systems. The type of scale and the accuracy desired in an application should determine the appropriate calibration procedure. Slow speed scales should provide readings within ±0.2% of the static weight of individual axles and the gross static weight of a vehicle. A slow rollover test of a standardized vehicle can be used for calibration. Medium speed scales should provide readings within ±5% of the static weight of individual axles. To eliminate the dynamic suspension effects caused by pavement roughness, a large number of vehicles should be used for calibration. A method involving 50 5-axle semi-trailer trucks is proposed for calibrating medium speed WIM systems. The system should be calibrated by minimizing the total difference between static and dynamic gross vehicle weight for the 50 trucks tested. The proposed method is illustrated in the following table.

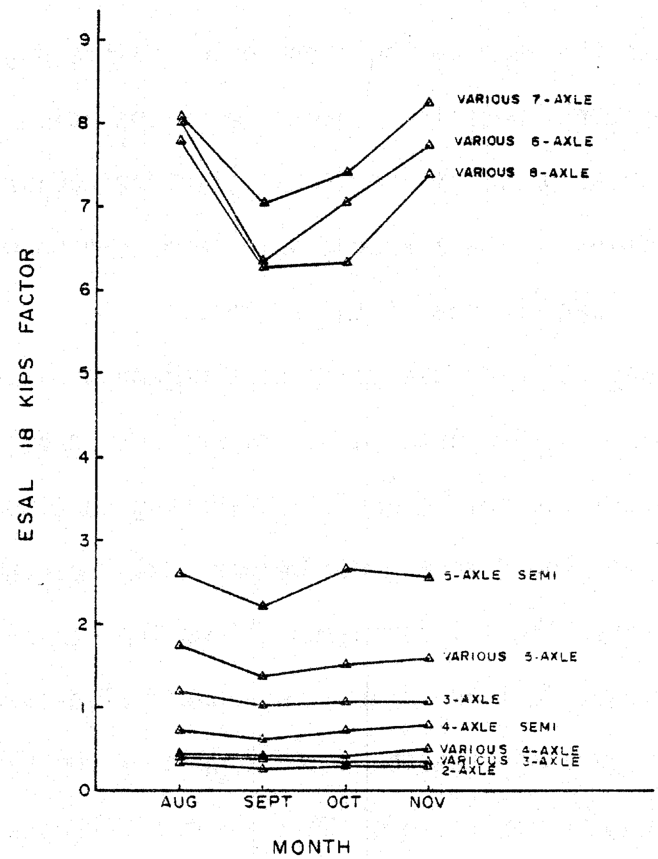
CALIBRATION TABLE FOR MEDIUM SPEED WIM SYSTEMS

		STATIC WEIGHT (lb)		DYNAMIC WEIGHT (lb)		% DIFFERENCE	
TRUCK #	AXLE #	AXLE	GROSS	AXLE	GROSS	AXLE	GROSS
	1	9,200		9,500		+ 3.26	
	2	15,600		14,900		- 4.49	
1	3	12,370	57,070	13,100	56,700	+ 5.90	- 0.65
	4	10,100		9,200		- 8.91	
	5	9,800		10,000		+ 2.04	
	.						
	.						
	.						
	.						
	.						
	.						
	.						
	.						
	1	11,300		13,000		+ 6.19	
	2	16,800		15,900		- 5.36	
50	3	14,750	63,350	15,200	65,200	+ 3.05	+ 2.92
	4	11,300		12,100		+ 7.08	
	5	9,200		10,000		+ 8.70	

TOTAL % DIFFERENCE IN GROSS WEIGHT
FOR ALL 50 TRUCKS SHOULD BE 0.0%

The standard deviation of the test differences between static and dynamic loads of individual axles provides a measure of the accuracy of the system. High speed WIM systems should be calibrated using a larger population of vehicles. The calibration method proposed for high speed scales can be based on the known mean and standard deviation values for the front axle of 5-axle semi-trailer trucks. In most states, the load on the front axle of 5-axle trucks is 9,300 lb. with a standard deviation of 1,300 lb. These values are fairly constant for both loaded and empty trucks since the load from the cargo rarely contributes to the load on the front axle. Since high speed WIM systems are used for continuous load recording, front axle loads from a population of 10,000 trucks would not be unrealistic for calibrating the scale. The standard deviation of the measured axle loads can be used for long-term monitoring of the performance of the system.

Most North American highway agencies use pavement management systems based on axle load information. In the past, such data was not readily available. WIM technology offers the only means of collecting continuous axle load data. A typical WIM system detects axle weight, axle spacing, vehicle speed and time of the day. This information allows the classification of vehicles into categories. Most agencies have adopted classification systems based on the axle configuration and the total length of the vehicles. WIM data can be used to observe the variation of Equivalent Axle Loads (EAL), factors in time for various vehicle classifications. An example of such a relationship is illustrated on the following page. It can be seen that the average EAL factor of a well defined truck class is fairly constant in time. Representative average EAL factors throughout a state or province can be used in conjunction with simple count and classification data to predict total pavement damage in the whole highway network. Progressing to more advanced WIM systems, it would be necessary to integrate automatic traffic recorder information, classifier systems, portable WIM systems and permanent WIM systems into one complete data collection package. The available information should be brought together into a large data bank within a main frame computer. Software should be developed to analyze the data and make it readily available to decision-makers.



VARIATION OF EAL FACTORS IN TIME FOR VARIOUS TRUCK CLASSES

Continuous traffic and loading data throughout a highway network can be projected into the future to predict rehabilitation planning needs. Furthermore, the level of service provided by the various links in the network can be monitored. The changes in the level of service would provide a measure of the congestion level at different links in the highway network. Statistical analysis of continuous load data allows the determination of the pavement damage component caused by overloaded trucks. Such a study would assist the identification of the truck class that causes excessive pavement damage.

WIM technology is a powerful tool in pavement research. Many projects are currently underway, employing various types of WIM systems. Experiments are conducted to determine the relative pavement damage caused by different truck suspension types. WIM scales are used to determine the effect of pavement roughness and vehicle speed to pavement damage. WIM technology allows in-situ measurements of the load carrying characteristics of multiple axle systems such as tandems and triaxles. Such studies would allow the determination of axle and suspension systems minimizing pavement damage.

One of the areas of application of medium speed WIM systems is their use as "sorters" on main highway lanes. Mr. Phang of the Ministry of Transportation and Communications of Ontario presented a new system being installed in Ontario this year. This sorter system incorporates traffic management of the overloaded vehicle traffic through the weigh scale site. This would be the first high volume (i.e., 600-800 trucks/h) system in operation in North America. The installation, when completed this fall, will be the first step in developing a system integrating traffic management and a sorter system. The next generation of sorter systems should incorporate WIM systems in the main traffic lanes. Such a system should provide a means of communicating with the drivers of overloaded trucks. The communication system should be able to direct the truck off the highway to a static scale site without causing safety hazards to the travelling public. A system of TV cameras, possibly capable of reading licence plate numbers, could be used for enforcement.

Attention is recently given to a weight-distance taxation system for heavy trucks. The assigned tax should be a function of weight and miles travelled through a jurisdiction. A system of transponders would identify each truck and its weight will be recorded by a WIM system as it enters and exits the jurisdiction. Such a taxation system would directly reflect the actual pavement damage caused by the given truck. To materialize such a system, the transponders technology should be coordinated with WIM technology to evolve a workable system. This system would revolutionize the method of taxation of the trucking industry.

The conference offered an insight to the state-of-the-art of WIM technology. Various WIM equipment was demonstrated and the various applications were described and discussed. The development of WIM technology is expected to be rapid in the future having a significant impact in many areas of highway management. Attention should be given in developing universal standards for WIM technology. Calibration procedures should be established to ensure the user of obtaining reliable data at all times. Appropriate factors must be established to objectively describe the pavement smoothness requirements in the immediate vicinity of the scale site. It is important to widely communicate with other users of WIM systems. The information from the demonstration projects in progress should be reported in another meeting in the year to come. Since most projects will not probably be completed by next summer, another meeting should be scheduled in a year from now. This meeting should discuss and select calibration procedures for various types of WIM equipment. Calibration systems should be developed for low speed, medium speed and high speed equipment. The adoption of a standardized system by all participants in the demonstration project will assure a fair and reasonable comparison between all systems.

SUMMARY OF WORKSHOP A

RECOMMENDATION FOR IMPORVING THE FHWA TRUCK WEIGHT STUDY

Summary Note on Workshop A

Patrick R. Cain

Recommendations For Improving The FHWA Truck Weight Study

We had around fifty persons attend Workshop A. Most of the attendants were involved with the survey side or both survey and enforcement.

Workshop A had papers presented from Iowa, Alaska, and Arkansas describing their state's truck weighing and enumerating recommendations for improving the FHWA Truck Weight Study.

I will attempt to summarize some of the main recommendations. However, let me preface my comments by the disclaimer that these recommendations do not necessarily reflect consensus of opinion.

One of the clearest revealments of the Workshop was the diversity in need and uses various states make of truck weight data.

This diversity quickly surfaced through the slides and statements made by Ms. Karen Morehouse describing Alaska's vantage point.

Alaska is much more concerned with whether equipment can function at 50 below zero than it is with truckers taking alternate routes to avoid an open scalehouse.

Most of the concerns aired during the workshop were discussed in presentations earlier in the week or were brought up as questions directed to the speaker.

Since the three states papers will be included in the conference proceeding I will just cite some of the recommendations made:

Recommendations made by Iowa:

- Include weekends in the weighing program to reflect identified daily variations in average weight.
- Seasonal classification counts can reduce the need for seasonal weighing.
- Hours of weighing should be reduced through statistical sampling techniques.
- High volume urban and rural highways and low volume secondary road sites should be included in the program. WIM equipment might allow this.
- Safety to both motorists and surveyors must be considered as it relates to collecting data.

- The weight program should be scheduled to identify impact of truck weight and size law changes.

- Additional data critical to monitoring truck activity such as length and width, special permits, etc. should be collected.

- The FHWA should take a leading role in the truck weight program by providing technical and financial support to states for evaluating and installing state-of-the-art equipment. This should lessen duplication of effort among states. This conference and the WIM demonstration program are a good start.

Recommendations made by Alaska:

- W-2 Tables are not very useful.

- Accept data that can be gathered through WIM as sufficient for the Truck Weight Study.

- Good sample data and consistency of data gathering is important.

- Flexibility in FHWA requirements is needed to allow experiments in data collection procedures and equipment.

- The Truck Weight Study should be linked to Highway Performance Monitoring sample sections so that data files can be meshed.

- Simplicity of reporting is important.

Recommendations made by Arkansas:

- FHWA guidelines have been acceptable.

- States should be encouraged to share weight data. (e.g. borderline stations).

- Should develop national screenline to get better feel for cross-country travel.

- Financial aid should be available for construction weighing turnouts.

- Include WIM to get seasonal variations and access to urban areas.

- Need less conspicuous ways of gathering data.

Recommendations made by other Workshop attendants:

- Jerry Legg - West Virginia; Reduce the number of items required for reporting.

- George Novinski - Wisconsin; Collect gross weight, axle weight, and axle spacing for four years -- on the fifth year do a thorough vehicle classification.

- Larry Brown - Michigan; Need quicker results from key sites to know what is happening.

- Bob Hayden - Colorado; Need to exclude weighing pickups or at least not consider them with single unit trucks.

Many of the recommended changes center around incorporating weigh-in-motion equipment into their operations. The FHWA Truck Weight Program needs to accommodate this change. WIM as a tool for data collection is close at hand.

Concerns for trimming costs and the need for inconspicuous data collection have generated a strong interest in making a transition to weigh-in-motion wherever possible. This was evident by the number of participants at our Workshop.

There is, however, a lot of work that needs to be done with WIM equipment. The demonstration programs are ideal for shaking out some of these bugs.

The truck weight program must be designed around information the states need too. In light of the diversity of needs and programs, I feel FHWA is doing a pretty good job in tayloring the program to these needs.

Many of the recommendations that were made are being addressed currently by the FHWA. An example is the request for states to comment on vehicle classifications used.

RECOMMENDATIONS FOR IMPROVING THE FHWA TRUCK WEIGHT STUDY

MR. PATRICK R. CAIN
IOWA DEPARTMENT OF TRANSPORTATION
AMES, IOWA

Recommendations For Improving The FHWA Truck Weight Study

Presented By
Patrick R. Cain
Iowa Department of Transportation

Truck weight surveys have been conducted in Iowa since 1939 and have been a part of Iowa's Highway Planning and Research Program since 1956.

Truck weight surveys were conducted annually until 1976 when it was changed to a biennial program with weighing and classification conducted on odd numbered years and classification counts only on even numbered years.

Currently truck survey data is collected at 19 locations. Both portable and permanent scales are used for gathering truck weight data.

System coverage is as follows:

Highway System	Scales		
	Permanent	Portable	Total
Interstate (Rural)	7	-	7
Primary (Rural)	2	4	6
Primary (Urban)	-	2	2
Secondary Rural	-	2	2
Local Urban	-	2	2
Total	9	10	19

All weighing and classification data is collected during the summer months using temporary employees in survey crews.

The program is conducted separate from enforcement activities.

Approximately 20,000 trucks are weighed during the program and 60,000 vehicles are classified.

Iowa was one of nine states participating in the 1980-1981 FHWA sponsored truck weight and vehicle classification case studies. Motor vehicle weight and classification data was collected for one full year including weekends at 12 weighing sites and 31 classification sites. We weighed 52,000 trucks during 192 8-hour shifts and classified vehicles for 744 8-hour shifts.

Iowa is one of eight states selected for RTAP demonstration program on weigh-in-motion.

Weight and other related data on trucks are utilized by the Iowa DOT in a variety of areas including:

- Highway Needs
- Cost Allocation
- Financial Resources
- Pavement Management
- Pavement and Bridge Design
- System Preservation
- Enforcement Planning
- Research

Users range from the Office of Policy for legislative issues to the Office of Motor Vehicle Enforcement for operational planning and include the offices of: Advance Planning, Planning and Programming, Road Design, Bridge Design, and Transportation Research.

Accurate, reliable, and current truck weight data is a critical component in all of these areas.

FHWA reporting requirements are only one use of many of our data.

Strained financial resources have limited Iowa's regular weighing program to summer months only. No seasonal or weekend data is collected.

Safety to both motorist and surveyor has limited the truck weight data gathered on high volume urban and/or rural highways where portable scales are required.

The mixture of permanent and portable operations results in different data collection procedures.

Truckers have utilized the C.B. radio to bypass the weigh station to avoid time delay during surveys and/or being identified as overweight.

Trucks that have a special permit for an overweight load are not always identified in survey.

Distribution of truck weighing stations by highway system and sample obtained may not be representative of truck travel in state.

The Iowa DOT recommends several changes to the truck weight program be considered.

- The weighing program should include weekdays and weekends to get a more representative sample of truck weight.
- Results of Iowa's Truck Weight Case Study shows little variation in weights seasonally. Therefore, seasonal coverage is less essential than classification.
- Vehicle classification in conjunction with truck weight survey should be expanded to obtain seasonal variation.
- Hours of weighing should be reduced through statistical sampling techniques. This would effect both number of locations and number of vehicles weighed at each site.
- The weighing program should also include high volume urban/rural highways and low volume secondary roads.
- Efforts need to be made to improve safety related to collecting data.
- Need to streamline and simplify W-Series tables in truck weight report. Produce a summary weight survey report and make detailed data accessible to users via computer tape with appropriate software. This would also allow for interfacing weight data with other data bases.

- There should be uniform weighing and reporting to facilitate comparing weight data among states.

- There should be a coordinated relationship between survey and enforcement to maximize data use in both areas.

  - The enforcement program can provide data on overload permits, commodities hauled, level of enforcement, etc.

  - Truck weight survey data can aid in planning enforcement activities.

  - Differences in weight data due to truckers bypassing enforcement scales or waiting until they close must be considered.

- The truck weight program should be evaluated in light of increasing costs and current user needs.

  - Schedule weight program around weight and size law changes.

  - Costs need to be justified in terms of benefits received.

  - Program concept must be continually adjusted as necessary to meet changing user needs.

  - Additional data critical to monitoring truck activity such as maximum vehicle length and width, special permits, etc., should be collected.

  - Alternative data sources and data collection methods must be explored to keep program costs to a minimum.

- The FHWA should take a leading role in the truck weight program by providing both technical and financial support to the states for:

  - Developing uniform vehicle weighing and classification standards, sampling techniques and recommending sample sizes for the number of trucks weighed and classified by highway system.

  - Identifying a selected number of weighing sites to be maintained for continuity of historical data.

  - Identifying alternative resources and programs to obtain truck weight and classification data.

  - Support research and demonstration programs to lessen duplication of this effort among states.

RECOMMENDATIONS FOR IMPROVING THE FHWA TRUCK WEIGHT STUDY

MS. KAREN MOREHOUSE
ALASKA DEPARTMENT OF TRANSPORTATION
JUNEAU, ALASKA

TRUCK WEIGHING IN ALASKA

by

Karen B. Morehouse

Alaska DOT&PF

July 1983

Presented at the

National Weigh-In-Motion Conference

Denver, Colorado

TRUCK WEIGHING IN ALASKA

I appreciate this opportunity to join you in this Weigh-in-Motion (WIM) Conference. I have been asked to assist this committee in making recommendations for the Truck Weight Study. My presentation will reflect Alaska and its needs and give you an idea of what weighing trucks in Alaska is like.

A. GEOGRAPHY

To understand some of the unique features of Alaska's truck weighing system, you have to know something of its geography.

Alaska has 586,000 square miles, 375 million acres of land. It is more than twice as large as Texas. There are approximately 460,000 permanent residents of Alaska. With 0.79 persons per square mile, it is by far the least populated state in the Union. With 20 percent of the area of the remaining United States, Alaska is as long and tall as the, "lower 48". It currently covers four time zones.

Most of Alaska is in the "sub-arctic" climatic zone, with the exception of the North Slope which is arctic and the lower two-thirds of the southeast panhandle, including Juneau, the capital where I live, which is in the temperate zone. Rainfall patterns are very diverse with over 100 inches of precipitation per year in much of Southeast and less than 10 inches on the north coast.

There is much permafrost, permanently frozen ground, and glaciers. Alaska has a lot of forest; including the Chugach and Tongass Forests which, are the largest managed by the U.S. Forest Service. The mean yearly temperature ranges from +10°F on the north coast to 45°F in Ketchikan with extremes of -80°F to 100°F across the state. All the west coast north of the Aleutian Chain is icebound in winter, and, as you can imagine, State commerce in bulk goods is shipped through ice free ports. Of the 20 highest mountains in the U.S., 17 are in Alaska, which has 19 peaks over 14,000 feet.

The sea is a major factor in climate and resoures. Cold water holds more oxygen than hot, so the coast, washed by the cold Japanese current, teams with life of every kind. The adjacent deep Pacific and its fertile shelf provides an unparalleled fishery, a path for commerce, and awesome winter storms.

B. <u>HIGHWAY SYSTEM</u>

There are 9800 miles of highway in Alaska of which about 2600 are paved. Alaska has 93 miles of multi-lane highways in excess of 2 lanes. In 1981 the system handled an estimated total of 2.3 billion vehicle miles statewide of which 40 percent was on the 6 percent of the system in "urban" areas.

Alaska is linked to the North American highway system by the

Alaska Highway. It was built in World War II to prevent sea interdiction of supply to Alaska. 1,400 mile long, it is still gravel for most of 1,005 miles from Dawson Creek B.C. to Haines Junction, Y.T. The gravel stretch is less than 1/2 of the 2,400 mile route from Great Falls, Montana to Fairbanks or the 2,300 miles from Seattle, Washington. 1,050 miles of our Primary System are Interstate of which 1/2 is designated as part of the National Truck route network. Much of our rural road system runs through mountainous areas, of which less than 20 miles has a climbing lane for trucks.

The communities of Southeast Alaska are connected by a ferry system, the Alaska Marine Highway System some of which counts as Federal-Aid System mileage. There are also ferry routes to Prince Rupert, Canada and Seattle. The motor vessel fleet of eight ships is operated by the State and travel on it is heavily subsidized. The route is over-capacity on a seasonal basis despite winter discounts and streamlined operations.

The North Slope haul road (Dalton Highway) to Prudhoe Bay was built by the Alyeska Corporation for surface access to the oil fields and to support the construction of the trans Alaska pipeline. The truck travel on this route has always been high and is increasing. Other than commercial vehicle travel on this road is restricted by permit. Of the eight permanent scalehouses on the Alaska highways, one is located at the south end of the Haul Road. The other scalehouse locations are Ester, Fairbanks, Soldotna, Anchorage, Potter, Tok, Valdez and Haines.

C. PRESENT OPERATION

The Biennial Truck Weight Study is relatively new to Alaska. This is the second time it has been done with any consistency. We are still working out procedures.

At the present time, we are conducting the study in conjunction with the weight enforcement program at the scalehouses which are operated by the Department of Commerce and Economic Development. This operation does have drawbacks because:

1. Our location of stations for sampling is limited to existing permanent weigh stations. This does not provide data on urban routes or on lower functional class routes. The Department of Public Safety has some portable loadmeters which can be used for collection of data on these routes. However, aside from about 60 miles of divided highway, all our routes are two way routes. Without assistance from Public Safety to direct traffic, it is difficult to weigh on these routes. It is just not safe or practical to operate with the loadometers. A portable Weigh-in-Motion (WIM) system would be more feasible.

2. The Department of Commerce, who regulates the Weight Enforcement Program, limits weighing to axle groupings. At smaller scalehouses the platforms weigh one or two axle groupings. These scalehouses, at Potter, Sterling, Valdez and Haines, will be replaced with 160-foot scales, each with four electronic scales. For almost all trucks these scales weigh the entire truck and give readings on

four different axle groupings.

3. Sampling the stream of truck traffic is difficult. We have been able to gather data on every type of loaded truck that passes the scale but not data for empties. The scalehouse operators wave these trucks through, especially when traffic is heavy -- such as the Anchorage and Fox scalehouses. Collecting data requires the cooperation of scalehouse operators. This is true also for weighing pickups. Some scalehouse operators are more flexible and provide more assistance than others. Generally, I have found them helpful as long as we don't interfere with their routine or traffic does not get backed up.

D. Data Types

The Truck Weight Study in Alaska, is not a fully operational program of data gathering because of its newness. The attitude has been to get just what is needed to fulfill FHWA requirements. We have not found the FHWA "W" Tables to be useful for our purposes. The types of data for which we have the most requests are:

1. Truck types, weights and lengths for any particular location. The planners want to know what kind of trucks are on the road and how big and how heavy are they.

2. Average Truck Weights are requested from design, as well as axle percentages. (See Appendix A)

3. Percentage of empty trucks on the roads is requested by Planners. Occasionally a request is made for commodity flow.

4. Fuel type is requested occasionally by environmentalists or energy consultants. This is particularly a request from interior areas because of the ice fog phenomenon.

5. Seasonal data are requested. Most planners do not feel confident with an 8-hour sample, taken usually during the summer, every other year. Nor do they feel confident with one time class counts.

E. Alternative Programs

The Biennial Truck Weight Study does not provide all the requested data, so we are implementing our own program to collect on a seasonal basis statistically sampled 24-hour truck data and classification counts at each of the scalehouses. (See Appendix B) These data will be collected regularly for us by the Department of Commerce and we will collect the class counts. The data will be computerized and linked to other data files. This should provide up-to-date complete data in a format we can use.

F. Weigh-in-Motion (WIM)

Alaska is just beginning to consider WIM. We are installing a scale near the Anchorage scalehouse in one lane. A test of this scale is needed to determine if a WIM system can operate at temperatures to

-50° Fahrenheit. This should help Department of Transportation and Department of Commerce officials decide whether or not to install this equipment at other locations. Those of us in Alaska DOT&PF who have investigated WIM feel that it should solve the problems encountered in collection of truck data, at least on the Interstate routes.

G. Recommendations

The recommendations that I offer are tailored to Alaska's needs.

1. I urge FHWA to accept the data gathered from WIM as the study data. In Alaska, truck traffic is increasing at a rapid pace. For the information to be useful it needs to be current and include origin-destination. Another data item that we have been collecting is total trailer length. We were requested by planners to collect this on long trucks because of federal length limitations on Interstate. Height and width data may also be useful. Actually, the State currently operates by the bridge formulas and allows doubles. Our regulations are much broader than proposed federal regulations.

2. Good sample data and consistency of data gathering is important. However, to fulfill the FHWA requirements there needs to be a certain amount of flexibility. FHWA is cooperative in this respect. For example, we are experimenting by continually changing our operating procedures. Operating the Truck Weight Study with a crew from one office is not feasible. Presently, we take the interviewer/supervisor/recorder, (myself) and two axle-space measuring people from Statewide Planning. The Regional Planning people provide the classification counters and the Department of Commerce

assists with weights. To get the attention of truckers, I tried using signs that read "All Trucks and Pickups Stop 500 feet." This brought all the pickups in for a period of time and created a waiting line. I have also used a sign "Truck Weight Survey Ahead." This was okay but unnecessary and a burden to carry around. Right now we are weighing only those pickups which inadvertedly come through the scalehouse and we provide verbal explanation to truckers instead of a sign. Alaska Truckers have been receptive to the study and my crew. I prefer to keep the procedures flexible for each station.

3. Linking of truck weight data to Highway Performance Monitoring System (HPMS) would key data to sample HPMS sections. Presently there is no way to link the two data files unless each state has tailor made their own linkages. For Alaska, the scalehouse data are primarily on the Interstate routes which are 100% sample for HPMS. By addition of Commodity and Origin-destination, Commodity flow models can be developed and updated annually. Truck Weight data is also useful in models to determine effects on pavements.

H. Summary

In summary, I would like to see improvements in data sampling and new formats to provide ease in update and simplicity in reporting, and data which facilitate a wider range of modeling applications. More important in Alaska is flexibility in operating procedures.

Our Interstate is different from other states, our road system is different, our truck traffic is different. Because of extreme climate and terrain variations, certain adaptations must be made. Traveling long distances to the scalehouses poses a problem in terms of cost. Air travel is necessary and flying crew members around the state is expensive. Our current governmental administration is carefully watching travel budgets of the Departments including travel covered by HPR funding. As Alaska goes up in the learning curve of weighing trucks, I cannot emphasize enough the need for flexibility in data gathering and station locations.

KM/pp

APPENDIX A

STATE OF ALASKA

DEPARTMENT OF TRANSPORATION AND PUBLIC FACILITIES

GUIDE FOR FLEXIBLE PAVEMENT

Design and Evaluation

August, 1982

Prepared by

Division of Standards and Technical Services

Materials Section

Anchorage, Alaska

APPENDIX A

STATE OF ALASKA

DEPARTMENT OF TRANSPORATION AND PUBLIC FACILITIES

GUIDE FOR FLEXIBLE PAVEMENT

Design and Evaluation

August, 1982

Prepared by
Division of Standards and Technical Services
Materials Section
Anchorage, Alaska

SECTION ONE

TRAFFIC LOADS

Traffic Data

Structural sections are designed for the traffic imposed loadings during the design period. An Equivalent Axle Loading (EAL) is determined from project traffic volume and loading data. Separate EALs should be selected for mainline, crossroads, ramps, frontage roads, or any other appropriate portion of the project.

Planning will provide the EAL or the following data from which the EAL may be determined:

1. ADT_1, the one way average daily traffic expected during the first year of operation.
2. PTT, the percent of ADT which is heavy truck traffic.
3. W, the average gross heavy truck weight (Heavy Truck)* (lbs.)
4. r, the compounding traffic growth rate, expressed as a decimal.
5. N, the project design life in years.

Wherever the values of these parameters are not equal in both directions or not equal between sections, the parameters for each direction or section should be reported.

EXAMPLE: (This example will be used throughout this manual.)

Assume	ADT_1	=	3667
	PTT	=	6%
	W	=	35,000 lbs.
	r	=	0.06
	N	=	20

* Heavy trucks are heavy commercial vehicles, normally two-axle six-tire vehicles or larger. Pickup and light panel trucks are excluded.

Procedure

1) Determine the Number of Heavy Trucks (NHT) per day in the design lane. The design lane is the lane upon which the greatest number of equivalent 18,000-pound single-axle loads is expected.

The percent of Trucks in the Design Lane (TDL) may be estimated from Table 1. Normally, trucks operate in the outermost traffic lanes, and may be considered equally divided in both directions. Exceptions include special circumstances where heavy truck haul traffic will be in one direction, such as mining areas or between pump stations with empty trucks using the return lanes. On multilane highways, it has been found that more than 80 percent of the heavily loaded trucks are in the outside lanes.

TABLE 1 - PERCENTAGE OF TOTAL TRUCK TRAFFIC (ONE DIRECTION) IN DESIGN LANE, TDL

Number of Traffic Lanes (Two Directions)	Percentage of Trucks in Design Lane, TDL
2	100
4	90(70-96)*
6 or more	80(50-96)*

*Probable range.

The NHT may be calculated by the following:

$$NHT = (ADT_1)\ (PTT/100)\ (TDL/100)$$

EXAMPLE: NHT = 3667(6/100)(100/100) = 220

2) Establish the Initial Traffic Number (ITN), using the Traffic Analysis Chart, Fig. 1, page 3 as follows:

(a) Enter the chart with the average gross weight, W, at the proper point of line D.
(**EXAMPLE:** 35,000 lbs.)

(b) Locate the NHT, at the proper point on line C.
(**EXAMPLE:** 220)

(c) Connect the points on lines D and C with a straight line and extend it to find the pivot point on line B.

(d) Locate the proper single-axle load limit point (20,000 pounds) on line E.

(e) Connect the single-axle load limit point on the line E and pivot point on line B with a straight line and extend it to line A.

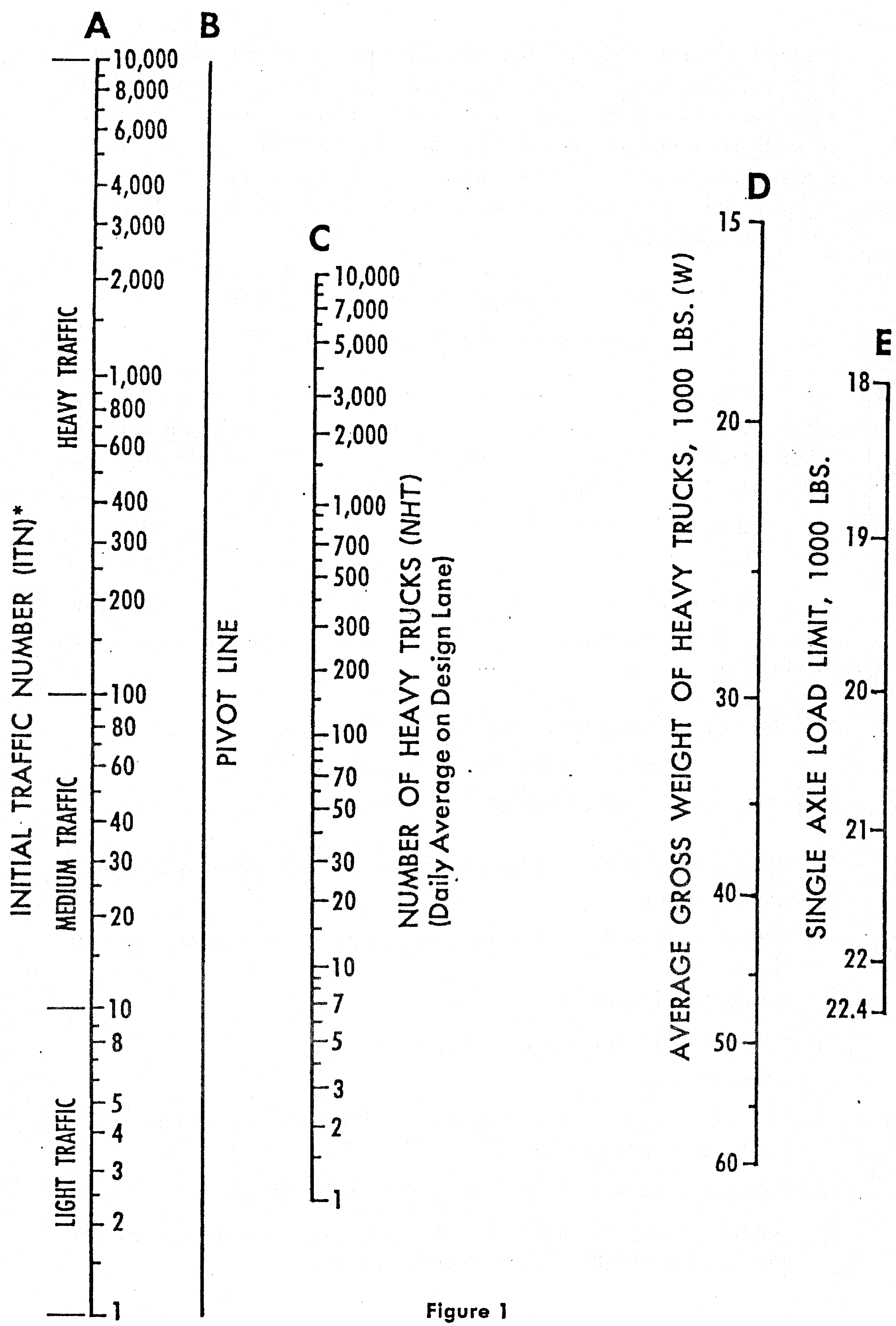

A
B
C
D
E
10,000
8,000
6,000
4,000
3,000
2,000
1,000
800
600
400
300
200
100
80
60
40
30
20
10
8
5
4
3
2
1
HEAVY TRAFFIC
MEDIUM TRAFFIC
LIGHT TRAFFIC
INITIAL TRAFFIC NUMBER (ITN)*
PIVOT LINE
10,000
7,000
5,000
3,000
2,000
1,000
700
500
300
200
100
70
50
30
20
10
7
5
3
2
1
NUMBER OF HEAVY TRUCKS (NHT)
(Daily Average on Design Lane)
15
20
30
40
50
60
AVERAGE GROSS WEIGHT OF HEAVY TRUCKS, 1000 LBS. (W)
18
19
20
21
22
22.4
SINGLE AXLE LOAD LIMIT, 1000 LBS.

Figure 1

(f) Read the ITN on line A where the extended line E-B intersects it.
NOTE: If ITN is less than 10 go on to (g) otherwise go to (3).
(**EXAMPLE:** 186 > 10 so go to (3) on page 5.)

(g) When the ITN is less than 10 and when a relatively large number of automobiles and light trucks are expected to use the roadway a correction of ITN is required. The correction is made by the use of Fig. 2, page 4 as follows:

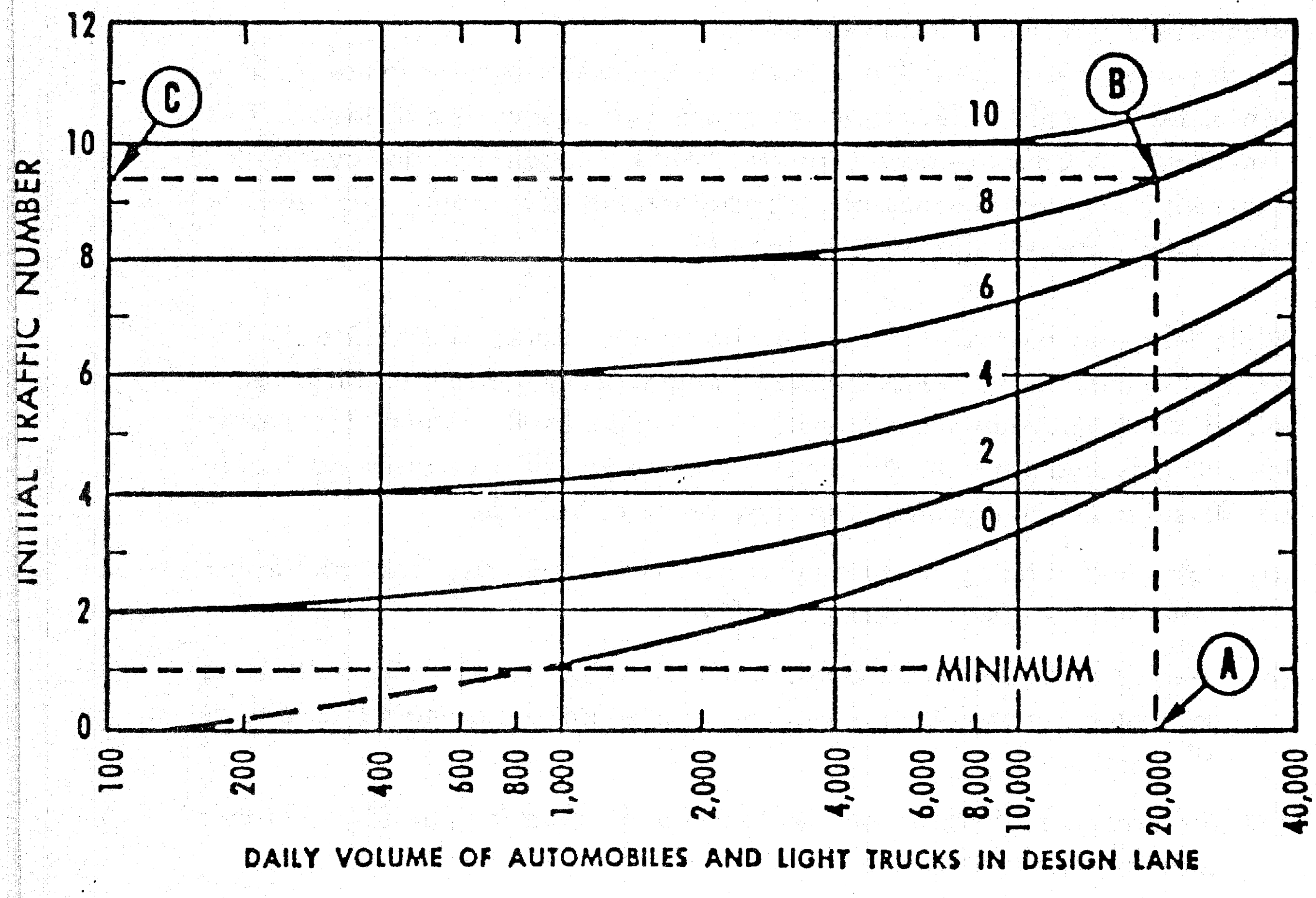


Figure 2

Chart for adjusting Initial Traffic Number (ITN)
for daily volume of automobiles and light trucks

(i) Enter Figure 2 on the horizontal scale at a point representing the Daily Volume of Automobile and Light Truck Traffic in the Design Lane which equals:

$$NHT \left(\frac{100}{PTT} - 1 \right) \qquad \text{(e.g. Point A).}$$

(ii) Move vertically to the curve representing the Initial Traffic Number (ITN) based on heavy trucks. (e.g. Point B)

(iii) Read the corrected ITN on the vertical Initial Traffic Number scale. (e.g. Point C)

3) Establish the pavement Design Period, n.

The pavement design period, n, is the number of years from the initial application of traffic until the first major resurfacing or overlay is anticipated. This term should not be confused with pavement life. By adding asphalt overlays as required, pavement life may be extended indefinitely, or until geometric or other factors make the pavement obsolete.

While Planning has determined the appropriate project design life, N this design life may not be the desirable pavement design period, n. If it is determined that the pavement design period, n, will be less than the project design life, N, coordination with Planning will be required to program additional overlays. Pavement design period considerations include:

(a) Costs and funding of overlay projects in the future, and differential maintenance costs, corrected for time.

(b) The geometric design standards to which the roadway is to be built. Some geometric designs may not warrant a pavement design period as long as 20 years.

(c) The presence of structures with functions that are impaired by overlays; curb, median islands, etc.

(d) Wear to the surface course induced by freeze-thaw, aggregate degradation, studded tires, etc.

(e) Differential settlements due to ground ice or other soil conditions.

(f) Future construction schedules for nearby projects.

EXAMPLE: Assume above considerations indicate a 14 year life for pavement before overlay.

4) Determine the Equivalent Axle Load (EAL).
Multiply the ITN by a pavement design period adjustment factor.

$$EAL = ITN \quad [((1 + r)^n - 1)/r]\ (365)$$

The Adjustment Factor $[((1 + r)^n - 1)/20\ r]$ (365) may also be taken from Table 2, page 6.

EXAMPLE: n = 14, r = .06
Adjustment Factor = 7671
∴ EAL = (7671)(186) = 1,426,806: say 1,430,000

TABLE 2 - INITIAL TRAFFIC NUMBER

ADJUSTMENT FACTORS

Design Period Years (n)	Annual Growth Rate, (r)					
	0.01	0.02	0.04	0.06	0.08	0.10
1	365	365	365	365	365	365
2	734	737	745	752	759	767
4	1,482	1,504	1,550	1,597	1,645	1,694
6	2,245	2,302	2,421	2,546	2,678	2,816
8	3,024	3,133	3,363	3,613	3,882	4,174
10	3,819	3,997	4,382	4,811	5,288	5,817
12	4,629	4,895	5,484	6,158	6,927	7,805
14	5,456	5,830	6,677	7,671	8,838	10,211
16	6,299	6,803	7,966	9,370	11,068	13,122
18	7,159	7,815	9,361	11,281	13,669	16,644
20	8,037	8,869	10,869	13,427	16,703	20,905
25	10,309	11,691	15,201	20,026	26,684	35,897
30	12,696	14,807	20,471	28,856	41,348	60,040
35	15,206	18,248	26,883	40,674	62,896	98,924

5) For more information on the procedure for determining the EAL, see pages 18 through 24 of **Asphalt Overlays and Pavement Rehabilitation** MS-17, 1977 or Chapter IV of **Thickness Design-Asphalt Pavements for Highways and Streets** MS-1, 1981 both published by the Asphalt Institute.

APPENDIX B

TRAFFIC DATA PROGRAM

OPERATIONS MANUAL

STATE OF ALASKA

DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

DIVISION OF PLANNING AND PROGRAMMING

STATEWIDE PLANNING OFFICE (SOUTHEAST REGION)

(final draft)

January, 1983

The preparation of this document was financed in part by a grant made by the United States Department of Transportation, Federal Highway Administration, with the cooperation of the Alaska Department of Transportation and Public Facilities.

			SEASON 1 July August September	SEASON 2 May June October	SEASON 3 January February March	April November December
	TOTAL TRUCKS	TOTAL CLASS.	SEASON	1	2	3
HAINES F-3-95	33	797	MADT DAYS @ mo.	790 4	758 5	458 2
VALDEZ F-3-71	165	1,280		537 10	340 14	142 6
FOX F-3-65	260	1,312		795 1	735 1	553 1
ESTER F-5-35	408	2,495		1,533 2	1,080 6	676 1
STERLING F-1-21	370	2,677		3,673 2	3,284 2	2,045 3
TOK F-1-46	196	2,839		861 13	691 13	405 8
POTTER F-4-31	312	3,657		4,852 6	4,160 5	2,645 3
FAIRBANKS F-4-62	1,051	14,416		12,435 2	11,730 2	9,248 1
ANCHORAGE F-1-42	1,563	21,783		20,556 2	20,628 2	16,749 1

6.3 DATA CLASSIFICATIONS

The level of detail by which truck weight data can be recorded varies according to the equipment at each scalehouse location. The desired classification of trucks and the manner of recording of truck weights, are as follows.

6.3.1 VEHICLE CLASSIFICATION

Trucks should be identified by the same axle-body classification codes used for the Vehicle Classification Count Program, per Chapter 4.0. Data entry terminals at the scalehouses should be equipped to facilitate the simple and error-free entry of truck descriptions according to those classifications.

At the least, each truck must be described in terms of the number of axles.

Future installation of Weigh-in-Motion equipment may result in modifications to the classification categories based on equipment capabilities.

6.3.2 WEIGHT REPORTING

The weight of loaded trucks should be reported for each axle individually. Second-best is to report the weight on each tandem-axle pair, with proper identification of the method of compensating adjustments in data processing. Still less desirable is to report the weight for each tractor or trailer unit with the number of axles on that unit, since accurate analytical compensation is not easy. Least desirable is to report only total weight and axles.

Empty trucks must be reported for the sake of sample requirements, but need not be weighed if a standard table of empty weights by classification has been assembled and provided to the Data Management Office, for insertion into the data base as default values.

6.4 EQUIPMENT

The majority of this manual's instructions assume manually operated roadside scalehouses as the method of data collection. Automated data entry terminals should be added to those installations, as budgets allow, for more efficient data entry and transmittal.

In the future, automated weigh-in-motion scales may also be installed and operated in various ways:

(A) on approach ramps to roadside scalehouses, in conjunction with weighing for enforcement purposes;

(B) on mainline highway lanes near scalehouses, in conjunction with enforcement weighing;

(C) on mainline highway lanes near scalehouses, but independently of enforcement activities; and

(D) on mainline highway lanes at other locations, independently of enforcement activities.

When such procedures are undertaken, the data collection plan should be correspondingly revised to account for the differences in driver-avoidance behavior, and different techniques of sampling which become possible, such as rotating a data collection device among several weigh-in-motion locations, at intervals determined by the sampling rate. Alternatively, with a link to the enforcement scalehouse, the measurements by the weigh-in-motion device may constitute a 100% sample, and be used as a sorting mechanism to select suspected overweight trucks for static weighing.

6.5 DATA COLLECTION

Truck weight data shall ideally consist of individual axle weights for each truck weighed, plus vehicle classification, time and date, the direction of travel, and other identifying information as determined by the Statewide Highway System Planning Office. In the absence of weights by individual axle, weights by axle-group may be collected. Weight per complete vehicle is least desirable. The numbers of loaded and unloaded trucks not weighed shall each be recorded. Classification counts of vehicles traveling on the adjacent roadway shall be collected by the Regional Traffic Data Office, for comparison and expansion.

The Statewide Data Management Office coordinates with scalehouse operators to assure that efficient, cost-effective and statistically valid methods of weighing, recording and transmitting data are employed at all scalehouses, considering the following factors:

(A) Truck weight data must be collected separately by each direction of travel.

(B) Scalehouses must operate 24 hours per day, in order to prevent the common practice of truck drivers avoiding weighing by waiting till the facility closes, then passing on.

(C) Scalehouses must operate enough consecutive days to further discourage the above behavior by truck drivers.

(D) If the sample rate is low, i.e., near 10%, then choices must be made between counting several consecutive days once per season, versus counting days at random during the season. This choice will depend on judgement as to the amount of variation within the season of daily truck volumes and the mix of truck classifications.

If it is negligible, then one counting session will suffice. If it is substantial, then several sessions would be preferable. In the latter case, however, if the variation within the defined season is significant, then the season length should be reduced and the sampling rate recalculated.

(E) There is usually some conflict of interest between the data gathering and law enforcement functions of scalehouses. To resolve this, if the sampling rate is small (meaning that a small fraction of all trucks is to be weighed during the season), then an operating procedure could be established whereby at certain widely publicized dates, enforcement would be suspended and only data collection would be performed. Publicity is helpful in this case because it encourages all drivers, including those whose trucks are overweight, to cooperate without fear of penalties. For best results, the scalehouse operation should be conducted by DOT/PF personnel instead of enforcement agency staff, to dramatize the absence of penalties.

For example, a schedule of penalty-free weighing on the first five days of every month would constitute a 16.7% sample rate, and could be expected to reflect average or slightly above-average biased truck weight conditions for each month. In this case the bias is acceptable insofar as it leads to a safety margin for design purposes.

(F) Sampling procedures in high volume locations may need to account for queueing up of trucks waiting to be weighed. To minimize this, the sample plan could consist of a random selection of trucks, rather than taking every truck as it arrives. Avoid any systematic pattern such as every second or every third truck, since the truck drivers' CB-radio network could be used to systematically fit overloaded trucks into the bypass pattern.

(G) Sampling procedures must account for empty trucks, as well as loaded trucks. In practice, the scalehouse operator must randomly select trucks for reporting without regard for loaded or empty status, then report each vehicle selected, by classification and weight. If the truck is visibly empty, it need not be weighed. Standard empty weights by classification will suffice, whether entered at the scalehouse or later in data processing. Manual classification counts at the scalehouse location can be used to check the validity of the scalehouse operator's sample selection.

RECOMMENDATIONS FOR IMPROVING THE FHWA TRUCK WEIGHT STUDY

MR. PAUL SIMMS
ARKANSAS STATE HIGHWAY AND TRANSPORTATION DEPARTMENT
LITTLE ROCK, ARKANSAS

PAPER TO BE PRESENTED AT THE NATIONAL CONFERENCE ON WEIGH-IN MOTION TECHNOLOGY AND APPLICATION (Due July 1)

Arkansas was one of the last three states in the nation to raise its truck weight limit to 80,000 pounds. As such, our enforcement activities were probably much greater than states of comparable size. Now with the passage of the weight/distance tax, the enforcement of the weight laws and the collection of truck weight data continues to be a top priority of the Department. We have used these truck weight data as a basis for revenue forecasts and cost allocation studies in addition to the obvious uses of these data for design. Therefore, Arkansas has been, and will continue to be, very interested in the FHWA truck weight studies and in the use of weigh-in-motion equipment for collecting planning data and for screening of vehicles at enforcement stations.

Arkansas is currently required to submit weight data from eight (8) portable scale operations as well as the eleven (11) permanent installations at our weigh stations. Because of the size of our staff, we now perform these weighing activities during the summer months when summer employees are available to assist in these activities. The guidelines on the number of stations and the truck weighings are acceptable to us. Our only comment is that more complete data appears to be easily obtainable with little or no increase in costs. This can be accomplished by revising the guidelines for truck weighing activities such that states are encouraged to share data and install weigh-in-motion equipment.

In regard to the selection of stations for monitoring weights, it appears that the FHWA could increase the amount of cooperation between the states in the collection of these data if special exceptions were provided to the FHWA guidelines on the numbers of stations on each system. For example, several of the stations in Arkansas, like many states, are near its borders. In these cases, the weigh stations of different states may be on the same highway and only a few miles apart. Obviously, the states could work together and share these data. However, there currently is no incentive for the states involved to share these data under the current FHWA guidelines. This would free the weighing crews of one state to weigh in another area or to apply the savings toward the purchase of weigh-in-motion equipment.

In discussing the need for urban stations, Arkansas may be at a disadvantage to the more populous states in terms of lacking suitable locations. I, along with many of my colleagues at the Department, believe that we presently have no true urban stations on our interstate and primary systems although a few stations are within the urban area and are reported as such to the FHWA. The safety of the crews and the expense associated with urban locations makes it imperative, with our existing technology, that we continue to operate at these stations which are on the fringe of the urban areas. In our case, two alternatives are apparent. The FHWA requirements should be relaxed such that these stations are accurately reported as rural stations or, if representative urban data are needed, the FHWA should assist the states in the installation of weigh-in motion equipment and special turnouts.

Seasonal variations in truck activity were determined to be significant during the course of the HPMS Case Studies. For example, we found that a much higher percentage of trucks were loaded during the winter months than any other time of year and that this was the case for every highway system. Because twenty-four hours of data were collected for the Case Studies, we were also able to determine that the percentage of loaded five axle trucks varies from a high of 86% at 3 a.m. to a low of 66% at 1 p.m. Both of these variations appear to confirm the need for more weigh in motion stations to monitor these variations. Strategically located weigh in motion stations could provide continuous data which would be used to adjust the weights recorded at the other locations during the summer.

Besides the installation of weigh-in-motion equipment and more flexible guidelines to encourage cooperation between states, another recommendation would be the development of national screenlines. One obvious screenline would be the Mississippi River. From weigh in motion stations located on or near the major bridges over this River, truck weights could be monitored and reported to FHWA on a continuous basis to provide a means of estimating cross-country truck flows.

In reference to the collection of other data, we would be interested in collecting additional data which could be used to better estimate diesel fuel usage. Because Arkansas borders a number of states which have significantly lower diesel fuel tax rates, many at the Department are concerned that Arkansas is not getting its fair share of fuel tax revenues. Based on a recent analysis of the diesel fuel consumption in the State, we estimated that consumption was significantly higher than the taxed gallonage reported. Our estimate of diesel consumption was based on total system VMT divided among several vehicle types using vehicle classification data and the average fuel usage rates of these vehicle types. We have considered refining this method in the following manner:

- Basing the fuel consumption rates on actual weight carried instead of the present larger classifications which are usually based on registration weight.

- Surveying trucks for engine size, air deflectors, etc. which would also have an effect on fuel usage.

Both of these data items are being gathered or could be gathered on the loadometer field sheets. However, first we would like to hear from any other states or FHWA officials who have attempted to develop fuel usage estimates from VMT data categorized by truck weight or vehicle classification data.

In conclusion, we at the Department are very serious about the collection of truck weight data. We fully understand the importance of these data with respect to revenue forecasts and highway damage. In the long term, it appears inevitable that weigh-in-motion equipment will be used to a greater extent because of its advantages in providing truck weight data at inconvenient urban stations as well as providing sufficient data to monitor daily and seasonal variations. However, in the short term, it is difficult to come up with the funds necessary to purchase this equipment. In Arkansas, we must justify the purchase and installation of weigh-in-motion equipment in the enforcement area either for screening purposes upstream of weigh stations or as a less conspicuous means of monitoring overweight truck activity at portable stations. Once the decision has been made to acquire the weigh-in-motion equipment, then we in Planning can begin to provide the necessary hardware to collect the truck weight data.

SUMMARY OF WORKSHOP B

USE OF WIM EQUIPMENT IN AN EFFECTIVE SIZE AND WEIGHT ENFORCEMENT PROGRAM

Summary Workshop B - Use of WIM
Equipment in an Effective Size and Weight
Enforcement Program

Rich Phillips

Washington State Patrol

Our workshop had three speakers, Mr. Paul Bowlin from the Alabama Highway Department. Paul stated that Alabama has Radian sites and one computer with a $500,000 investment. It is working very well in Alabama. They are having some of the same problems with roadway smoothness, drainage problems, but he didn't want to overemphasize the problems, because it is working well for them.

Mr. Larry Shoudel from the Illinois Department of Transportation said they currently do not have a weigh-in-motion equipment. They are planning for some. They do have 21 fixed weigh stations and six sets of semi-portable scales. One of their concerns is that 2% violation rate on the fixed scales and they are having a 16% violation on the portable scales. So truck avoidance they feel is a major problem for them.

Mr. Fred Juba from Pennsylvania said that Pennsylvania has one permanent weigh station. The costs for weigh station construction are prohibitive, so they will probably continue with portable weigh stations. They are really concerned with avoidance and they have tried using unmarked vans, all kinds of things to catch truckers by surprise. They are planning on having 11 semi-permanent stations and three mobile controlled centers. They do have congestion problems because they are using existing weigh stations to do their truck weighing.

Some ideas and recommendations that came out of the workshop. The first thing was to increase public reception of the truck weight problem. We need to capitalize on such things at the Connecticut bridge collapse. That is a real key issue and it a typical example of the deteriorating infra-structure throughout the states. Our state has passed a series of laws putting more teeth into the TWI enforcement. I think that if we could organize against deteriorating roads we might do a little better than we are now. One of the things we need to do is emphasis the costs of the damage that is caused by the trucks on the roadways.

The avoidance of weigh stations was another major concern voiced by the workshop. This emphasises the need for portable weigh-in-motion equipment as emphasized by the 1 1/2 to 2% violation rate of fixed scales and we have heard estimates from 16 to 25 and possibly even more percent at portable sites. So we don't really know what those violations are out when we are not out there working. In North Dakota, one gentlemen suggested that they use aircraft to monitor the bypass routes. If you have the resources and the manpower to do that it sounds like a good idea. To emphasize the need for low cost weigh-in-motion equipment, as we are all fixed with the same budget crunches.

Compatability of equipment was the third recommendation that the workshop felt was worth mentioning. A lot of times you buy some equipment and on the figure you are forced to accept the low bidder. The low bid may not be compatible with what you just bought. In Washington State we are having good luck interchanging scale heads and load cells on our static scales. We would like to see this happen in weigh-in-motion. We realize that some of the systems probably could never be compatible, but possibly by making such a statement the vendors would be a little more sensitive to this. I think the bottom line is that if their equipment was interchageable to a certain extent, we would have better bidding process, and would eventually sell more equipment. That is the bottom line for them. Personal computers have gone down drastically in cost but it doesn't seem that any other of the electronic equipment that weigh-in-motion requires has decreased in cost. We have wondered about that and have asked some of the vendors about it but they don't really know, but it is something that we think that with the trend in micro-computers that those costs should be going down and we would like to see some interchangeability.

The other thing was the national clearinghouse. As represented by this conference, a lot of the states have experienced some kind of technical problems or problems with getting weigh-in-motion or implementing it. With budgets the way they are, we can't afford to reinvent the wheel. We also felt by a national exchange of information such as this conference, that maybe some vendors that continue having the same problems would put a little more money into their R&D to try to get those problems alleviated.

One of the other things that we recommended was a standardization of fines. We have got the economic benefits out of running overweight trucks, stiffer fines, penalties, license suspensions and ways to increase risk of apprehension by truck drivers were things that were mentioned. We need to get the attention of the trucking industry to better regulate itself. Also possibly by that maybe some tax incentives to get them to install some loadcells on their trucks. For example, Washington logging industries are installing loadcells on their trucks. We sell the program by telling them that by having those on your trucks you can load right to the maximum limit and you are not going to have to worry about getting pinched. So those are some things that we think might help.

It was felt that the conference was generally very productive and the national information must continue.

USE OF WIM EQUIPMENT IN AN EFFECTIVE SIZE AND WEIGHT ENFORCEMENT PROGRAM

MR. PAUL BOWLIN
ASSISTANT MAINTENANCE ENGINEER
ALABAMA HIGHWAY DEPARTMENT
MONTGOMERY, ALABAMA

Use of Weigh In Motion Equipment In An Effective Size and Weight Enforcement Program

Presented at the
National Weigh In Motion Conference
July 11-15, 1983
Denver, Colorado

By Paul E. Bowlin
Assistant Maintenance Engineer
State of Alabama Highway Department

Use of Weigh In Motion Equipment In An Effective Size and Weight Enforcement Program

I have divided this presentation into several topics, the first of which is:

I. A little background and the beginning

In the summer of 1978 the State of Alabama Highway Department began working toward implementation of a weigh in motion vehicle weighing system. This followed a determination by this department that high volume weighing capability was a desirable, perhaps a necessary, addition to the State's existing vehicle weight enforcement program. Up until this time our vehicle weight enforcement program was limited to a mobile portable scale operation.

We began research on what was available in weigh in motion equipment. This research included contacting States that were using such equipment. We eventually decided upon the Radian Corporations's system. One of the primary reasons for selecting this system was the experience of other States using the system with the wheel load transducers installed in the traffic lanes of active highways. This appealed to us since we were not interested in constructing elaborate weigh stations adjacent to our highways.

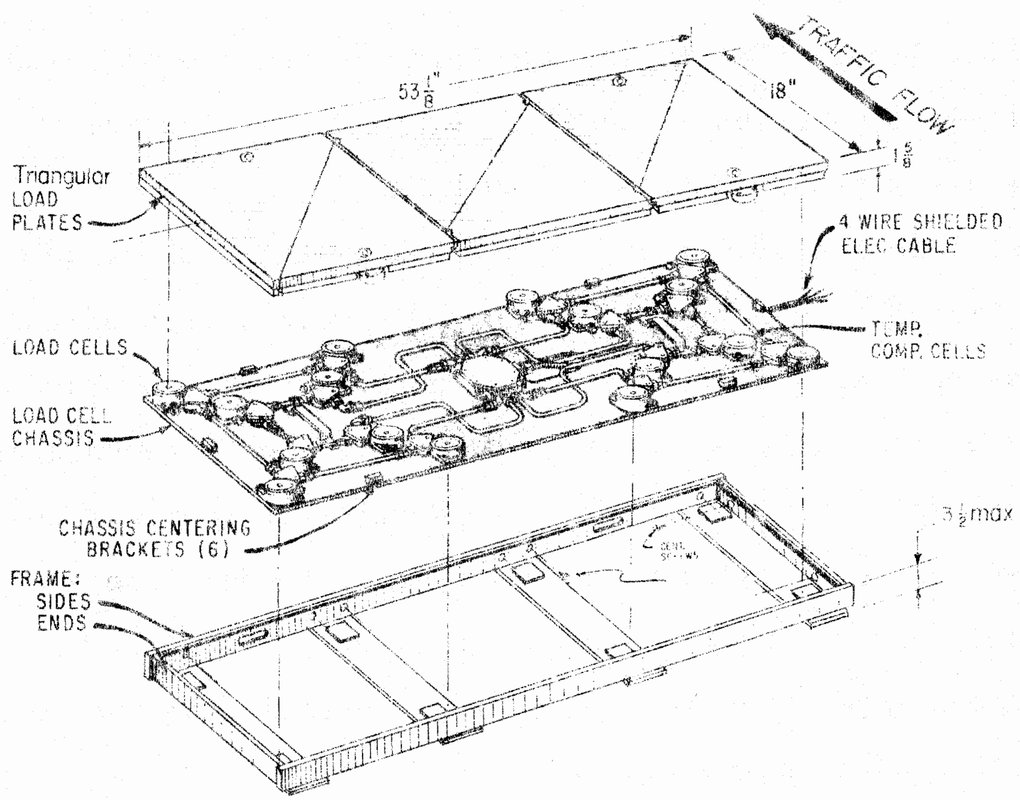
Initially, we purchased a computer (model number WIM-1E), a motor home for housing and transporting the computer and enough miscellaneous equipment and hardware for installation of three weighing sites. The total cost of this initial purchase was approximately $103,000.00.

Just before delivery of our new equipment, some of our traffic signal technicians attended a two week course on the equipment at Radian's Austin, Texas, headquarters. We had made a decision early on to use our traffic signal technicians to operate and maintain the system. We did not know at the time what a wise decision this was to prove to be. These individuals had strong backgrounds in electronics with considerable experience in programming, installation and repair of complex traffic signal controllers.

Upon delivery of the equipment, Radian sent two of their technical people to Alabama to help us install the first site and to give our technicians some on the job training.

II. The system and how it operates

We have wheel load transducers installed in all traffic lanes of the highway at each weighing site. The installation in the roadway is better described as a wheel load assembly since the transducer is only one part of the installation. See the following illustration.



It takes one of the above illustrated assemblies for each wheel path (two for each traffic lane).

Conduit and wiring connect the transducers to junction boxes mounted on guardrail adjacent to and approximately thirty feet from the roadway. These junction boxes are where the WIM-1E computer is plugged in to operate the system. An area was graded and paved adjacent to the junction boxes large enough to park the motor home that houses the computer.

The transducer portion of the wheel load assembly is only in the highway when weighing is being done at the site. When a site is not in operation wheel load "dummies" occupy the space for the transducer. When we go to a particular site to weigh we have to replace the "dummies" with the transducers and connect the computer to the junction boxes mentioned earlier.

Our system has the capability of weighing in any two traffic lanes at one time. This means we can weigh in both lanes at a two lane highway site or in any two of the four lanes at a four lane highway site.

Since we only have one computer to operate the entire network of sites that we have, the computer is moved about to the various sites. This means that only one of our sites is in operation at any one time.

III. Alabama's weigh in motion vehicle weight enforcement program

As previously stated, the weighing devices are installed in the traffic lanes of active highways rather than in specially constructed weigh stations. We do not slow down or otherwise control traffic at the weighing sites, therefore we are weighing at all normal highway speeds.

Since weigh in motion weighing has not been recognized for the purpose of making overweight violation arrests, we use the system as a screening device. We stop those trucks indicated to be overweight by the weigh in motion equipment and reweigh them on portable scales. By doing this, essentially, the only trucks detained and delayed are those that are operating illegally.

We have a two way radio in the motor home that operates on our State Trooper frequency. When the WIM operator detects an overweight truck, he radios the portable scale team waiting a short distance down the highway. He gives a description of the truck to the portable scale team who then stop and reweigh it on the portable scales. We have a very high ratio of arrests made compared to the number of trucks reweighed.

IV. Looking a little deeper

In this section I will attempt to go more in depth on various aspects of the equipment, modifications we have made and our program in general. I will not go very deep into the technical aspects of the equipment as the manufacturer has representatives at this conference who can do a much better job of that.

We did our very best to follow the manufacturer's recommendations regarding weighing site installation. We chose sites with smooth pavement and even resurfaced some sites. We choose sites where the grade was zero percent or very nearly so.

We choose sites that were not in a curved section of highway. And, we chose sites that were on open highways where vehicle braking or accelerating were unlikely. Since the divice was going to be used primarily as a vehicle weight enforcement tool, we also choose sites that did not present easy bypass capability.

We installed the first site or two exactly as the manufacturer recommended. We soon, however, realized this presented some major problems for us. Water and moisture are enemies of the system. At that time most experience with Radian's system was in Western States which have a much dryer climate than does Alabama. We found that the manufacturer's design for providing drainage was not adequate for conditions in our State. To improve this situation we enlarged the size of the conduit that runs from the wheel load assemblies to the shoulder of the highway, from 1 1/2 inches in diameter to 2 inches in diameter. We also constructed french drains where the conduit ended at the shoulder.

We were also concerned that the manufacturer's design did not provide access to the wiring that runs from the wheel load assemblies to the junction boxes where the computer plugs in. When repairs became necessary this presented quite a problem. To alleviate this situation we did two things.

One, we increased the size of the copper tubing that carries the wire from 1/4 inch in diameter to 5/8 inch in diameter. This made the wire easier to pull through the copper tube. Two, we installed junction boxes at the shoulder of the highway and at the junction boxes where the computer plugs in. This provided access to the wire at two places and made trouble shooting and repairs much easier.

We realized early on that in order to minimize down time it was going to be necessary that we acquire a spare parts inventory. We purchased some, or at least one, of almost every component that could malfunction. This has proved to be a very wise course of action. Now, when we cannot repair a component, we simply change it out and send the malfunctioned part back to the manufacturer for repair.

In the very beginning we were not tremendously successful with our new "toy". We were not very proficient in operation of the equipment and even less so in repair of same. But as I related earlier, we made a wise decision when we selected our traffic signal technicians to operate and maintain the equipment. The manufacturer also, was most helpful and cooperative during this period. Our technicians, with their background in electronics, were able to communicate with Radian's technical people by telephone to solve problems and to generally learn about the equipment. Also, I believe that our determination and persistence toward making this program work was a significant factor in our success.

Now our technicians are comfortable and confident with the equipment. They are usually able to determine the problem when malfunctions arise and if not, they understand the equipment well enough to be able to get the help they need from the manufacturer by telephone.

V. Accuracy

This will be a short section and could have been included in the last section, but I felt the subject warranted the attention that having its own title could give it.

I believe that we even surprise the manufacturer with the accuracy that we achieve. When weighing for vehicle weight enforcement we are not satisfied with more than two percent deviation from true vehicle weight.

Once construction and installation is completed on a weighing site, it must be calibrated before it is used. This is done by making adjustments to the WIM computer while passing a vehicle of known axle and gross weight over the wheel load assemblies in the highway. In addition, when we go to a site to weigh, after we put in the data from the calibration, we make further adjustments after we check a few trucks with the portable scales. Now, at the risk of further exposing my ignorance, I am going to get a little technical. The computer is calibrated by adjusting the output of the signal conditioner board. This basically means that the amount of voltage transmitted from the transducers in the highway to the antilog to digital converter in the computer is adjusted up or down to compensate for the difference in the actual weight of a vehicle and the weight displayed by the computer. By making these additional adjustments we routinally are able to calibrate the WIM to an accuracy of plus or minus two percent.

This does not mean that the weight of every vehicle that passes over the scales is determined this accurately. Occasionally, for various reasons, some of them unknown to us, we get completely erratic, unreasonable and obviously incorrect data. Some of the factors that cause this are; the vehicle bouncing as it crosses the transducers, the vehicle misses or almost misses the wheel load assembly or some other unknown reason. This is the exception, however, and rarely occurs when weighing a heavily loaded truck.

VI. Conclusion

We very definitely feel that our weigh in motion vehicle weighing program is a success. It has fulfilled our expressed goal of providing a device for high volume weighing. We often weigh more than 1,500 trucks at a site during an eight hour shift. This is more trucks than one of our portable scale teams will weigh in a month.

We now have twelve weighing sites and hope to soon add another WIM computer to our program. Our total investment to date, not including cost of operating, repair and replacement parts, is less than $500,000.00. This is less than the cost of just one Interstate Highway permanent scale weigh station.

I do not mean to indicate that everything has been perfect. We have had some problems. We have experienced a number of electronic malfunctions along with other various and sundry problems. With the experience that our technicians now have, however, these problems are annoyances rather than catastrophes.

Although the subject of this paper is vehicle weight enforcement, I would like to relate that we also use the equipment for planning purposes such as loadometer studies and for gathering data for pavement design.

USE OF WIM EQUIPMENT IN AN EFFECTIVE SIZE AND WEIGHT ENFORCEMENT PROGRAM

MR. LARRY SHOUDEL
ILLINOIS DEPARTMENT OF TRANSPORTATION
SPRINGFIELD, ILLINOIS

USE OF WIM EQUIPMENT FOR SIZE AND WEIGHT ENFORCEMENT

We do not yet have any Weigh-in-Motion (WIM) equipment in Illinois nor is our Department of Transportation responsible for enforcing size and weight limits. However, we do construct and maintain weigh stations, purchase and maintain semiportable scale equipment, and work quite closely with the State Police, who are responsible for size and weight enforcement.

The high cost of constructing new weigh stations and the need for more extensive coverage of the State highway system have spurred our interest in WIM, especially the high-speed type that can be used in the through traffic lanes. During this fiscal year, we intend to award contracts for one low-speed and three high-speed WIM installations.

Before discussing our plans for the WIM equipment, a brief description of the current enforcement program would probably be useful. At the present time, we have 21 permanent weigh stations on Interstate highways and 12 on the rest of the State system. Police officers can also require the driver of a suspected overweight truck to travel to the nearest of approximately 200 privately-owned certified scales for weighing.

In addition to the weigh stations, there are six sets of LODEC semiportable scales in use. Six additional sets will be placed in operation later this summer. The State Police provide enforcement personnel for all of the semiportable scales. The Department of Transportation provides two-man crews with four of the semiportable scales to transport and set up the equipment and to assist with traffic control. The State Police operate the other two sets on their own.

During 1982, there were 5,600,000 trucks weighed on fixed scales and 45,000 on semiportable scales. As might be expected, the violation rate at the semiportable scales was much higher than at the fixed scales, with the rates being 16 percent and 2 percent respectively. Since the element of surprise usually disappears within an hour after the semiportable scales are set up, we suspect the actual violation rate is much higher than our statistics indicate. Even if the WIM equipment is not used for enforcement purposes, it would be enlightning to find out the magnitude of overloading on highways where the drivers are not concerned about being weighed.

Each of the states probably believes its weight enforcement program is reasonably effective considering the manpower and equipment limitations we all face. But, the suspected high violation rates, along with the reports we hear about typical overloadings of 100,000 pounds or more, point out the need for new strategies and equipment. In case there is any doubt about the extent of illegal overloadings, I would like to briefly discuss the subject of bootlegging. We receive applications for permits to move loads of 175,000 to 250,000 pounds or more gross weight two or three times a month. We do not automatically reject such requests, but many must be denied after the bridge analyses are completed. One might expect those shipments that are not issued permits would not be moved or would at least be transported by rail or barge. While very few of these movements are ever subjected to enforcement action, there is little doubt that most are moved by truck regardless of whether permits are issued or denied.

Some of our staff recently had the opportunity to discuss such movements with one of the bootleggers who now claims to be reformed. He confirmed that many of these loads can be and are being moved over the highways. Obviously, they do not use the Interstate highways or other main routes where we have weigh stations, and they generally move at night after the portables are shut down. If high-speed WIM scales can be strategically placed, we may begin to detect the magnitude of such shipments and, hopefully, initiate enforcement action to reduce the frequency of these movements.

Another problem confronting law enforcement officials is that the volume of traffic at some weigh stations is so heavy trucks may be forced to stop on the mainline pavement unless the scales are temporarily closed. While we have had no experience with the Federal Bridge Formula, the number of measurements required to check various axle groups will probably compound the queuing problem. Many of the states already utilize low-speed WIM equipment as a sorting device to minimize such backups. This is the type of facility that we plan to install at our new weigh station on Interstate 55 just outside of Chicago. If the Bridge Formula enforcement becomes a major time factor, it may be necessary to install low-speed WIM equipment at existing weigh stations.

A similar problem exists at many locations where the semiportable scales are used. Since all of the trucks cannot be weighed, some method of sorting has to be used. While this can be done manually, the use of high-speed WIM as a sorter appears to be an attractive alternative, and this is one of the principal uses we plan to make of this type of equipment.

The initial three installations of high-speed WIM in Illinois will be included in resurfacing contracts that are scheduled for lettings during this fiscal year. The first location will be on Interstate 270 between the Mississippi River bridge and the first interchange in Illinois. The second is on Interstate 94 as it enters from Wisconsin. The third location is on Interstate 290, also known as the Eisenhower Expressway, in Chicago. Each of these routes carries heavy volumes of truck traffic, and there are no weigh stations along them. Due to the large number of trucks on these highways and the limited space available for weighing operations, the semiportable scales have seen only limited use on Interstate 270 and none at all on the other routes. Although it would still be difficult to have a meaningful enforcement program at these locations, especially on the Eisenhower Expressway, the use of high-speed WIM as a sorter or overweight detector could allow limited use of the semiportables. We also believe having WIM on these highways will be an important planning tool for both future construction and enforcement activities.

The equipment will be recessed in the pavement with a platform that is flush with the surface. There will be a field cabinet near the right-of-way line that will contain the on-site control equipment. The central control computer, which will be located in our main office in Springfield, will collect the data from the WIM equipment using telemetric data transmission. The central computer will automatically poll the WIM site during the early hours each morning to capture the previous day's information. A standard voice-grade telephone line will be used to transmit the data. The equipment will allow real-time monitoring of the truck-weighing operation at either the field site or at the central control center. Each of the initial installations will be complete and will allow continuous monitoring.

When the high-speed WIM is used for enforcement purposes, it will be operated as a sorting device. An officer will be positioned in a van at the WIM site. He will be able to plug in a CRT terminal and printer to special outlets at the field cabinet and will be able to monitor traffic on a real-time basis. As an apparent overweight vehicle crosses the WIM platforms, he will radio ahead to the semiportable scale crew with the description of the vehicle so it can be stopped for static weighing. In addition, he will be able to provide the weigh crew with axle spacings and specific axle combinations that appear to be in violation of the Federal Bridge Formula. The on-site operation will also be available for vehicle classification by planning personnel using a similar real-time operation.

Another use of the equipment from an enforcement viewpoint would be to determine whether there are certain times of the day or days of the week when overloads are most prevalent. If we find there are a large number of overweight loads using the highways at night or on weekends, the statistical data furnished by the system could be used as justification for providing enforcement activity at those times.

The possible use of high-speed WIM as an enforcement tool may also have an impact on the future of our weigh station program. We are currently delaying the planning for any additional permanent weigh stations until the reliability and usefulness of WIM can be evaluated. Due to the expense of installing and maintaining weigh stations and the reductions in the authorized number of truck weight inspectors to operate the scales, we hope to be able to use the data from WIM installations to determine the best location for the fixed scales or whether such a facility is even needed. If WIM can successfully be used as a sorting device for the semiportable scales, it could be a much more efficient way of enforcing the weight limits. It could also be more effective, since for the cost of one weigh station, several WIM installations could be provided. This would allow us to have better coverage of our system and increase enforcement activity on those routes now used to bypass fixed scales.

As previously indicated, the first three installations will each be complete facilities with data reporting being accomplished through a central computer using telemetric transmission. These initial installations are estimated to cost $225,000 each. While the cost could be reduced substantially by utilizing one set of equipment on a rotating basis between several locations and collecting the data in the field rather than by telemetric transmission, we want to operate each of the first group of scales on a full-time basis and be able to monitor their activity from the central office. From an enforcement viewpoint, we see a distinct advantage to be gained by having the system ready for immediate operations, with the officer only needing to connect his terminal and printer to the field cabinet outlet to be ready for weighing. If a portable system is used, it would be necessary to close the lanes to install the scale components. By the time the scales were ready for operation, the truckers with overweight loads would be traveling on other roads or would have parked until the weighing was completed.

After the evaluation of the effectiveness of the initial WIM installations is complete, we will be in a better position to determine future needs for both enforcement and planning purposes. While we would prefer to have any future WIM equipment operating on a full-time basis with telemetric data transmission, the cost and effectiveness as an enforcement tool would have to be given consideration. There are obvious savings to be realized by using the scales on a portable basis between several sites, but we are reluctant to install a system that requires considerable field work to move the equipment and collect data.

We also have the following concerns and questions about WIM equipment that will hopefully be addressed during this conference.

1. The effect lightning has on the scales and field computer equipment. We have frequent severe storms in Illinois that often damage automated speed monitoring equipment. We are interested in learning whether other states are having similar problems with WIM equipment.

2. We are concerned that if WIM scales are used as an enforcement tool, truck drivers will become aware of these locations and will intentionally miss the platforms when the trucks are overloaded. If this is done when the portable scales are being used downstream from the WIM site, those who miss the platforms can be stopped for static weighing. However, if drivers do this when no enforcement action can be taken, the resulting data will be biased. If the WIM site is never used for enforcement purposes, off-scale vehicles would probably not be a problem.

3. We are curious whether truck drivers become aware of the location of WIM scales and, if so, do they begin using bypass routes as is the case with weigh stations. Perhaps this could be remedied by placing additional WIM units on the bypass routes, if they are easily identifiable.

4. Another concern is that once WIM equipment is used for enforcement purposes, it may be the target of vandalism. We now experience this problem with weigh station facilities when there is no one there.

5. Apparently, one of the critical elements in the WIM operation is the smoothness of the approach pavement. We are curious whether any states have experienced rutting problems with bituminous pavements and how frequently corrective action is needed.

6. Finally, since many of the states have had considerable experience with WIM equipment manufactured by different vendors, we are interested in any information regarding scale accuracy, especially at highway speeds, and the type of mechanical and electrical failures that have been experienced.

In conclusion, we believe that both low-speed and high-speed WIM can be very useful as a sorting device and for determining compliance with the Federal Bridge Formula. We hope to be able to use WIM in areas where we currently do not have or cannot economically install weigh stations. We look forward to learning what other states have been doing with WIM and what plans are being made for future useage.

By: Larry Shoudel
Illinois Department of Transportation

SUMMARY OF WORKSHOP C

COORDINATED WEIGHT MONITORING AND ENFORCEMENT PROGRAM USING WIM EQUIPMENT

Summary Workshop C - Coordinated Weight Monitoring and Enforcement Program Using WIM Equipment

Don Pray
Nevada Department of Transportation

Our topic was coordinate weight monitoring and enforcement program using WIM equipment. Basic questions were: Can they be? Should they be? Obviously you have to have a close working relationship between those who collect the data and those who are involved in enforcement actions. The WIM training program will benefit enforcement operations, particularly where total traffic and truck volumes are very high and enforcement weigher is restricted to accommodating only a few trucks at any given time. Although not a calibration standard, some specified measure of consistency needs to be developed that will allow nationwide use of common data collected by all states. Data collection should be able to collect on multiple lane facilities or on any single lane. As Dr. Burden stated, the WIM capabilities are not being totally utilized, referred to the coordination the WIM system with you total value needs not just enforcement needs. Some measure of cost effectiveness of WIM operations in support of enforcement programs need to be developed within the states for their own benefit. We hear the statement made that, in fact it is a conclusion that combined operations produces a bias in the planning data, but no one can say how much of a bias. They don't actually qualify what device has incidences of error and how it affects their actual planning data. One option is to establish additional WIM sites away from enforcement activities with patrol operations being informed where the hot spots are occurring.

We have basically seen the state-of-the art in equipment this week. They can meet both enforcement and providing data needs, depends upon the individual state whether they want to do them at the same time. We are going to see an improved product. The WIM applications are unlimited. The bottom line is that we need to take our contacts and our experiences from this week and go back to our states, sit down with our important people, data managers, enforcement managers. We need to determine what our needs are, looking not just at tomorrow but next year and the years thereafter, justify our needs and those needs have to be conveyed to our budget authorities and the product manaufacturers. Conferences like this are very great. After being five years in the WIM operation, Dr. Lee brought me back to the basic philosophy an idea that got us into WIM in the first place.

COORDINATED WEIGHT MONITORING AND ENFORCEMENT PROGRAM USING WIM EQUIPMENT

MR. DONALD PRAY
NEVADA DEPARTMENT OF TRANSPORTATION
CARSON CITY, NEVADA

NATIONAL WEIGH-IN-MOTION CONFERENCE

DENVER, COLORADO

JULY 1983

WORKSHOP PRESENTATION

TOPIC: COORDINATED WEIGHT MONITORING AND ENFORCEMENT PROGRAM USING WIM

SPEACKER: DON PRAY, NEVADA DEPARTMENT OF TRANSPORTATION

FROM THIS CONFERENCE IT WILL BE SEEN THAT ALL STATES ARE COLLECTING TRUCK DATA, AND PARTICULARLY WEIGHTS, FOR ENFORCEMENT AND PLANNING PURPOSES. IN AN ORGANIZATIONAL FORMAT WE COULD SET A GROUP OF COMMON GOALS, AND THE RELATED OBJECTIVES WOULD BE SIMILAR. HOWEVER, BY THE TIME WORK TASKS AND METHODOLOGIES TO ACHIEVE THE GOALS WERE PRESENTED FOR EACH STATE, WE WOULD BE WONDERING IF WE WERE ALL ADDRESSING THE SAME PROGRAM.

AT THIS WORKSHOP THREE WESTERN STATES WILL PRESENT THEIR PROGRAMS AND, ALTHOUGH WE'RE CONNECTED STATES, OUR PHILOSOPHIES AND PROGRAMS ARE VERY DIFFERENT. THIS IS AN INFORMAL WORKSHOP INTENDED TO BE A LEARNING EXPERIENCE FOR EVERYONE, AND AUDIENCE INTERACTION IS ENCOURAGED. I WILL ASK THAT INITIAL QUESTIONS BE HELD UNTIL THE CLOSE OF EACH PRESENTATION, AND THAT YOU IDENTIFY YOURSELF AND THE AGENCY REPRESENTED.

THE FIRST PRESENTATION IN THIS TYPE FORMAT OFTEN GETS SET UP AS THE WORST CASE THAT NO ONE ELSE SHOULD BE LIKE, SO I'LL BREAK THE ICE AND PRESENT NEVADA'S PROGRAM FIRST.

THE OVERRIDING QUESTION IS SHOULD A WEIGHT MONITORING AND ENFORCEMENT PROGRAM BE COORDINATED? NEVADA'S ANSWER IS "YES". A SIMPLE ANSWER, BUT FOR COMPLEX REASONS; AND AS YOU'LL SEE, A WIM SYSTEM IS TAILOR-MADE TO FIT INTO OUR PROGRAM.

THE NEVADA SETTING IS VERY IMPORTANT. WE'RE BORDERED BY FIVE STATES THAT HAVE PORTS-OF-ENTRY AND PERMANENT SCALE SITES; AND OVER HALF OF THE TRUCKS DRIVING IN NEVADA HAVE NEITHER AN ORIGIN OR DESTINATION IN OUR STATE. THAT IS, THEY ARE ON A TRIP THROUGH THE STATE. ACCORDINGLY, WE HAVE NO PERMANENT SCALE SITES, AND INSTEAD USE ROVING PATROL OPERATIONS TO ENSURE THAT TRUCKS COMPLY WITH ALL ASPECTS OF THE LAW. ENFORCEMENT IS PROVIDED BY THE MOTOR CARRIER DIVISION OF THE DEPARTMENT OF MOTOR VEHICLES.

UNTIL 1978 NEVADA WAS CONDUCTING ONLY ABOUT A THOUSAND ENFORCEMENT WEIGHINGS IN A YEAR. IN DEFENSE OF OUR MOTOR CARRIER AGENTS, THOUGH, THERE WERE FEW PROFESSIONAL AND PERSONAL INCENTIVES TO WEIGHING TRUCKS. THEY DID NOT HAVE THE

EQUIPMENT - THREE SETS OF PORTABLE SCALES AND ONE PORTABLE PLATFORM SCALE WERE ALL THEY HAD TO COVER THE ENTIRE STATE. ALSO, UNTIL 1982 THE MAXIMUM FINE WAS $500, AND AGENTS COULD PREVIOUSLY GENERATE MUCH HIGHER REVENUES BY CONCENTRATING ON PERMITS AND REGISTRATIONS. THESE LATTER FEES ARE ALSO RETURNED TO THE HIGHWY FUND TO SUPPORT OPERATIONS, WHEREAS FINES GO INTO THE STATE GENERAL FUND.

FINALLY, NEVADA'S HIGHWAYS WERE IN GREAT SHAPE, AND IT WAS DIFFICULT TO CONVINCE CARRIER AGENTS, COURT JUDGES, AND THE LEGISLATURE THAT MAJOR PROBLEMS WOULD OCCUR IF WEIGHTS WERE NOT CONTROLLED. IN PARTICULAR, THEY DID NOT COMPREHEND THE DESIGN PROCESS WHERE INTERIOR AXLE GROUPS HAD TO BE REGULATED.

WITH THIS SETTING I'LL ADMIT THAT, IN FACT, THE TRUCK WEIGHT STUDY THAT WE CONDUCTED FOR FHWA WAS ALSO A MAJOR PART OF OUR WEIGHT CERTIFICATION PROGRAM. WE SAW NOTHING WRONG WITH THIS PROCESS; HOWEVER, I NEED TO JUSTIFY OUR ACTIONS.

TO BEGIN, THERE IS NO OPPORTUNITY FOR A TRUCKER TO BYPASS WEIGHING OPERATIONS IN NEVADA. UNTIL 1982, WHEN OUR OVERWEIGHT FINE STRUCTURE CHANGED, IT WAS SUBSTANTIALLY LESS COST-EFFECTIVE TO AVOID A WEIGH SITE THAN IT WAS TO PAY A FINE. AND HONESTLY SPEAKING, WE NEEDED ALL THE WEIGHTS FOR CERTIFICATION THAT WE COULD POSSIBLY GARNER.

AN ADDITIONAL KEY JUSTIFICATION TO CLAIMING SOME MEASURE OF THESE WEIGHTS AS ENFORCEMENT WEIGHTS IS THAT, BY NEVADA LAW, AN ENFORCEMENT OFFICER MUST BE ON THE SITE IF VEHICLES ARE BEING PULLED OFF OF THE ROADWAY. THIS PRESENTED A DILEMMA WHEN NDOT WAS STATICALLY WEIGHING FOR THE FHWA TRUCK WEIGHT STUDY IN THAT AN OFFICER COULD NOT KNOWINGLY ALLOW A LAW TO BE VIOLATED.

WE SOLVED THE PROBLEM WITH AN INFORMAL POLICY WHEREBY SAFETY, OVERWEIGHT AND OVERSIZE VIOLATIONS THAT POSED AN IMMEDIATE DANGER WERE SIDELINED UNTIL CORRECTIVE ACTION WAS TAKEN. FOR MODERATE OVERLOADS OR OPERATORS THAT WERE CONSISTANTLY "THROWING ON A LITTLE EXTRA", WE WOULD RADIO AHEAD AND HAVE THOSE VEHICLES PULLED ONTO PUBLIC SCALES FOR CITATION. FOR THE LESSER OVERLOADS WE "SLAPPED THEIR HANDS" FIGUREATIVELY SPEAKING, AND SENT THEM ON THEIR WAY WITH A WARNING.

ALL OF THE HISTORY I'VE GIVEN LEADS UP TO 1978 WHEN FHWA HAULED OUR PROGRAM ONTO THE CARPET, AND RIGHTFULLY SO. NDOT PERMANENT STAFF AVAILABLE FOR WEIGHING HAD BEEN DECREASED TO MEET OVERALL MANAGEMENT OBJECTIVES, AND THE SAME NDOT SECTION RESPONSIBLE FOR WEIGHT CERTIFICATION WAS ALSO ADMINISTERING THE 55 MPH COMPLIANCE CERTIFICATION PROGRAM. IN ADDITION, STATIC WEIGH SITES HAD DETERIORATED, AND AT LEAST THREE ADDITIONAL SITES WERE NECESSARY TO PROVIDE MINIMUM STATEWIDE COVERAGE.

FROM AN ENFORCEMENT VIEW, THE MOTOR CARRIER DIVISION WAS AWARE OF THEIR SHORTCOMINGS AND INDICATED MORE OF EACH FIELD AGENT'S TIME WOULD BE DEVOTED TO WEIGHINGS; HOWEVER, THEY DID NOT FEEL THEY COULD GAIN ADDITIONAL FUNDS TO BUY STATIC SCALES AND SUPPORT EQUIPMENT NEEDED TO BOOST TOTAL WEIGHINGS TO AN ACCEPTABLE LEVEL.

FINNALY, FROM A PLANNING PERSPECIVE AT NDOT, WE WERE CONCERNED WHETHER DATA COLLECTED FOR THE FHWA TRUCK WEIGHT STUDY WAS ADEQUATE FOR PAVEMENT DESIGN AND MAINTENANCE MANAGEMENT DECISIONS WHEN THE WEIGHTS WERE TAKEN ONLY ON A WEEK DAY DURING SUMMER MONTHS, AND PRIMARILY ON THE INTERSTATE SYSTEM.

AND SO, WITH ESTIMATED COSTS IN HAND, AND PRIOR TO THE FHWA HEARING, WE PRESENTED NDOT MANAGEMENT THE ALTERNATIVES WITH THE EMPHASIS BEING THAT NDOT WOULD HAVE TO INCREASE ANNUAL WEIGHINGS FOR ENFORCEMENT OR SURELY RISK FEDERAL SANCTIONS. OUR MANAGEMENT WISELY OPTED FOR A WIM PROGRAM, AND FHWA IS THUS FAR SATISFIED WIH BOTH OUR PLANNING AND ENFORCEMENT RESULTS. I'LL POINT OUT THAT WE DO USE WIM FOR MOST OF THE FHWA TRUCK WEIGHT STUDY, BUT THAT ENFORCEMENT PERSONNEL ARE NO LONGER NECESSARY BECAUSE TRUCKS ARE NOT STOPPED.

WE STILL MAINTAIN THAT PLANNING AND ENFORCEMENT NEEDS CAN BE COORDINATED; HOWEVER, THERE ARE SOME PROVISOS. I'VE BROUGHT SOME HANDOUTS OF OUR EXPERIENCES WITH THE RADIAN WIM SYSTEM, SO I'M NOT GOING TO REGALE YOU WITH DETAILS. I MUST EMPHASIZE THE MOST IMPORTANT ASPECT OF OUR SYSTEM; HOWEVER, WHICH IS THAT OUR WIM OPERATION IS DESIGNED TO FULFILL A PLANNING NEED. AS SUCH THE DATA IS BEING COLLECTED BY NDOT PERSONNEL, AND THE WIM SYSTEM IS ALWAYS ATTENDED BY AN OPERATOR WHO IS MAINTAINING CALIBRATION.

A SIDE BENEFIT IS THAT WE ALERT CARRIER AGENTS DOWNSTREAM TO VIOLATIONS, AND THESE TRUCKS ARE PULLED ONTO ROADSIDE PULLOUTS AND WEIGHED ON PORTABLE PLATFORM SCALES. THESE CERTIFIED STATIC WEIGHTS ARE THEN RADIOED BACK TO THE WIM OPERATOR WHO MAKES IMMEDIATE ADJUSTMENTS IF NECESSARY. THE AGENTS ALSO RECORD A DUPLICATE WEIGHT SLIP WITH A WIM CONTROL SERIAL NUMBER, AND THESE WEIGHTS ARE TURNED INTO NDOT FOR AN OVERALL QUALITY CONTROL ANALYSIS OF WEIGHT DATA COLLECTED AT A LOCATION.

AS TO ACCURACY, WE EDIT OUR WIM DATA PRIOR TO PERMANENT ENTRY ON OUR COMPUTER FILES. PRIOR TO EDIT; HOWEVER, I CAN POSITIVELY STATE THAT AN AVERAGE INDIVIDUAL TRUCK TYPE WILL

SHOW AXLES AND AXLE GROUPS TO BE WITHIN TEN PERCENT OF THE COMPARABLE AVERAGE STATIC WEIGHTS, AND THE GROSS WEIGHT WILL BE WITHIN FIVE PERCENT.

HOW RELIABLE IS THE RADIAN WIM SYSTEM THAT WE USE? AS WITH ACCURACY, OUR SYSTEM IS ONLY AS RELIABLE AS THE FIELD SUPERVISOR AND TECHNICIANS RESPONSIBLE FOR OPERATIONS. ALSO INVOLVED ARE NDOT MAINTENANCE PERSONNEL IN THE OUTLYING DISTRICTS WHO ROUTINELY CHECK OUR ROADWAY INSTALLATIONS DURING PERIODS OF NON-USE.

IN THE HANDOUT THAT I'VE BROUGHT, YOU'LL READ WHERE OUR FIELD TECHNICIANS HAVE BEEN CONFRONTED WITH SITUATIONS WHERE THEY COOULD HAVE ABORTED A SCHEDULE BECAUSE THE SYSTEM WOULDN'T COME UP, OR THE SYSTEM WAS ERRATIC IN OPERATION. THESE SITUATIONS HAVE INVOLVED DEAD LOAD CELLS, WATER OR DIRT IN LINES, BROKEN WIRES; AND MOST RECENTLY, A SPIDER WEB IN AN OUTSIDE JUNCTION BOX THAT INTERFERED WITH THE VOLTAGE. OUR TECHNICIANS ARE NOT FORMALLY TRAINED IN ELECTRONICS; HOWEVER, THEY HAVE BEEN ABLE TO RESOLVE THESE MINOR PROBLEMS.

AS DESCRIBED, OUR WIM OPERATION IS SMALL BY MANY STANDARDS, AND NDOT PERSONNEL HAVE MAINTAINED A CLOSE RELATIONSHIP WITH RADIAN CORPORATION, AND THE WIM UNIT AND THE DATA COLLECTED ARE UNDER OUR DIRECT CONTROL. BY 1986 NDOT WILL HAVE CONSTRUCTED SIX

WEIGH AND INSPECTION STATIONS ON THE INTERSTATE SYSTEM. BY THEN WE PLAN TO HAVE AN ADDITIONAL WIM UNIT; HOWEVER, OUR OPERATIONAL METHODS WILL NOT CHANGE.

THE RADIAN SYSTEM HAS MULTI-LANE WEIGHING CAPABILITY; HOWEVER, IN NEVADA'S RURAL SETTING WE ARE ABLE TO DIRECT TRUCKS INTO THE RIGHT LANE WITH MINIMUM SIGNING. WE ARE ALSO SATISFIED WITH HIGHWAY SPEED WEIGHING AND THE SEMIPORTABLE OPERATION WHERE THE VAN ROTATES AMONG SITES THROUGHOUT THE YEAR.

WE HAVE HAD PROBLEMS WITH ROAD INSTALLATIONS IN REMOTE AREAS WHERE TRUCK VOLUMES ARE LOW, AND WE MAY USE THE SITE ONLY ONCE OR TWICE A YEAR. NDOT HAS DEVELOPED AN IMPROVED SUBSTITUTE TRANSDUCER THAT IS UNDER THE ROADWAY PLATES DURING PERIODS OF NON-USE; HOWEVER, MOST OF THE PROBLEM IS WITH DETERIORATING PAVEMENTS.

NOW THAT WE HAVE PORTABLE PLATFORM SCALES FOR STATIC OPERATIONS, WE ARE TAKING A SECOND LOOK AT LOW VOLUME WIM SITES. IN A STATIC OPERATION WE STILL HAVE SAFETY PROBLEMS, AN OFFICER MUST BE ON SITE, LIGHTS ARE NECESSARY FOR NIGHT WEIGHING, AND WEATHER IS A FACTOR. HOWEVER, ONLY FOUR NDOT PERSONNEL ARE NECESSARY, AND THEY CAN WEIGH OVER FIFTY TRUCKS IN AN HOUR. A WIM OPERATION WOULD STILL BE MORE COST EFFECTIVE; HOWEVER, WE FEEL THE HASSLE OF MAINTAINING THE LOW VOLUME SITES OFFSETS THE ADDITIONAL COSTS OF STATIC OPERATIONS.

ANOTHER PROBLEM NDOT STILL HAS IS THE PROCESS OF GETTING THE WIM DATA INTO A MAIN-FRAME COMPUTER. UNTIL RECENTLY NEVADA'S CENTRAL DATA PROCESSING FACILITY OFFERED A READER SERVICE WHEREBY WIM DATA WAS TAKEN FROM OUR DISKETTES AND PUT ONTO THE COMPUTER; HOWEVER, THIS SERVICE IS NO LONGER AVAILABLE. WE TRIED A DIRECT TRANSFER USING TELEPHONE MODEMS, BUT THERE WAS TOO MUCH INTERFERENCE IN THE LINES. CURRENTLY WE'RE LOOKING AT A DIRECT TRANSFER FROM WIM DISKETTE ONTO OUR FOUR-PHASE SYSTEM WHICH WILL THEN GO TO THE COMPUTER.

AS TO COST EFFECTIVENESS, THE NDOT WIM PROGRAM RUNS ABOUT $100,000 A YEAR, AND THE SAME PROGRAM USING STATIC SCALES WOULD BE AT LEAST THREE TIMES THAT AMOUNT. WE CURRENTLY WEIGH ABOUT FIFTEEN THOUSAND TRUCKS A YEAR WITH OUR WIM SYSTEM AND HALF ARE WITH ENFORCEMENT PRESENT. WE COULD SUBSTANTIALLY INCREASE THE NUMBER OF WEIGHINGS IF WE SPENT MORE TIME ON THE INTERSTATE; HOWEVER, OVER HALF THE TRUCKS ARE PROBABLY ALSO BEING WEIGHED IN ADJACENT STATES. CURRENTLY, ABOUT HALF OUR TIME IS SPENT AT THE SITES ON OTHER SYSTEMS WHERE NEVADA'S INTRA-STATE TRUCK MOVEMENTS ARE OCCURING.

I'LL CLOSE THIS PRESENTATION BY SAYING THE WIM CONCEPT IS GREAT; THE RADIAN SYSTEM HAS PERFORMED WELL FOR NDOT AND IS NOW A ROUTINE PROGRAM; AND THAT IN NEVADA'S ENVIRONMENT A COORDINATED WEIGHT MONITORING AND ENFORCEMENT PROGRAM USING WIM IS VERY DEFINITE ADVANTAGE IN MEETING STATE AND FEDERAL GOALS.

COORDINGATE WEIGHT MONITORING AND ENFORCEMENT PROGRAM USING WIM EQUIPMENT

MR. LOYD HENION, MANAGER
ECONOMICS UNIT, PLANNING SECTION, HIGHWAY DIVISION
OREGON DEPARTMENT OF TRANSPORTATION
SALEM, OREGON

WEIGH IN MOTION

NEW TECHNOLOGY TO ASSIST US IN MANAGING OUR HIGHWAY INVESTMENT

A Discussion Paper
For Presentation At The

NATIONAL
WEIGH IN MOTION
CONFERENCE

Denver, Colorado

July 11-15, 1983

by

Loyd Henion, Manager
Economics unit
Planning Section
Highway Division
Oregon Department of Transportation

WIM - NEW TECHNOLOGY TO ASSIST US IN MANAGING OUR HIGHWAY INVESTMENT

INTRODUCTION

Changing times and changing conditions have brought about changing roles and changing priorities with respect to highways as much as with other areas of our economic life. Road building has evolved into pavement management. Highway engineers are now transportation administrators. The simple task of getting people from here to there has become a complex procedure involving planners, designers, managers, inspectors, information processors, financial specialists, and a host of others.

The key element for today's administrator is information--adequate, timely, relevent information. As John Naisbitt points out in his book MEGATRENDS, in today's information society we often seem to be flooded with data but starved for knowledge. Our need is for the right information, at the right time, in the hands of the right people.

In the past--and at times even today--we have operated our highway systems with inadequate information, and the data we could gather was expensive and always untimely. Roads were often over-designed or under-designed, both of which are economically wasteful. Pavement managers lacked data to accurately predict the time of pavement failure. Weight enforcement personnel played a guessing game-- hoping that random weight checks would be conducted in the right place at the right time.

SOME HISTORY

Today everyone seems to be aware of the fact that pavement life is seriously compromised by excessive vehicle weights. Some of you may not be aware of just how long this problem has been of concern to highway administrators.

A quotation from an early biennial report of the State Highway Commissioner to the people of Oregon will illustrate the point.

> *"The protection of road surfaces and bridges against overloading is a matter which requires constant vigilance.*
>
> *One permanent twenty-ton platform scale has been installed on the Pacific Highway at Canemah to weigh up overloaded trucks, and several sets of portable scales are available for the use of traffic officers. Overloads, coupled with insufficient rubber or flat wheels, are very damaging to pavements and macadam surfaces, while overloading combined with excessive speeds set up impact stresses which are exceedingly damaging, particularly to the lighter types of paving."*

This report was written in November, 1926. Since that time, I am happy to report that we have expanded our efforts in monitoring truck weights. Let me briefly describe to you what a difference 56 years has made.

The budget for truck size and weight enforcement conducted by Highway Division Weighmasters during the 1981 - 83 biennium is about five million dollars. The Division now maintains 67 fixed platform scales, 78 portable scales, and 2 semi-portable scales. We have three ports of entry which operate on a 24 hour, 7 day a week basis. In 1981 our weighmasters conducted 1.8 million weighings resulting in 61,000 citations and over one million dollars in fines collected.

In addition to our state program, eleven counties conduct weighing programs of their own with 57 scales.

Given the current state of the art in vehicle weighing and monitoring equipment, we would be negligent not to avail ourselves of weigh-in-motion (WIM) equipment to improve our enforcement and planning efforts. Clearly, this equipment provides a win-win situation. The administrator has a tool to assist him in meeting his responsibility to enforce the law; the public protects its road investment; and the trucking industry saves the time now lost in static weighing. There is also one other subtle, but important, sense in which operators hauling at legal weights will win. Legal operators are now operating at a competitive disadvantage to the habitually overloaded operator. Several recent studies have pointed out that in most states *"it pays to overload."* The problem with today's weighing systems is that the legal operator must pay the same price in time delay as the illegal--and that simply is not fair. Forgive the pun, but WIM will help to balance the scales-- the illegal will have the delay while legal operators may go on with their business.

WIM - A MULTI-FACETED TOOL

The really exciting aspect of WIM is the diversity of its use. This *"joint product"* attribute of WIM provides opportunities in the areas of enforcement, highway management, and finance. If the equipment has an acceptable level of reliability--not more than 5% down-time for repair and maintenance--and a high level of accuracy--in the area of 1% variance--it should be useful for any of the joint product areas I have mentioned. Limiting WIM to one particular aspect would be a wasteful under-utilization of the equipment and the data produced.

In Oregon, we have for years used our static weighing data for size and weight enforcement and have provided the data to the PUC for tax collection and audit purposes. Given adequate reliability and accuracy standards, we would institute the same dual procedure for WIM data. In fact, there is no reason why this same data could not be used in highway design and pavement management studies, for speed monitoring, and for improving and refining the input data for cost responsibility studies.

The topic question for this session--*"Should weights observed for enforcement be part of the FHWA Truck Size and Weight Study?"*--is a little like asking, *"Should I use my desk-top calculator for both multiplication and division?"* The answer is fairly obvious. If we have a piece of equipment that is capable of multiple uses, and if we have need for several of those uses, simple logic and cost effectiveness considerations dictate maximum use of both the equipment and the data it provides.

There is an axiom of good management which states, *"Never let the problem-solving phase interfere with the decision-making phase."* We should decide what results we want and when we want them. If we set the goals to be achieved and the time limit within which we want them achieved, the technological skills of the industry will handle the problem-solving phase. A excellent example of this methodology was President Kennedy's statement of American purpose in the 60's. He set the goal--putting an American on the moon by the end of the decade. He didn't ask if cuttent technology could do the job, or take a survey of the obstacles--he simply set the goal and allowed the problem-solvers to overcome the obstacles.

Perhaps our goal should be a nationally integrated WIM system which can be used for any or all the joint products available. Having decided upon such a goal, the problems of equipment performance, calibration, computer compatibility, etc. will be addressed and solved by the technical experts.

OREGON'S WIM STUDY

In Oregon we see WIM as a planning and auditing tool as well as a weight screening/enforcment tool. This is the approach on which we based our WIM study grant proposal to FHWA. I am very pleased to report that our proposal has recently been accepted.

I would like to focus on one exciting potential use of WIM--how it can help us effectively administer improved taxing mechanisms. Specifically, taxing mechanisms which are practical and consistent with the results of a cost responsibility study.

It is no secret that Oregon has had, since 1947, a weight-distance tax which does accomplish the goal mentioned above. Oregon has found that the weight-distance tax is practical, proven, and can be efficiently administered (our collection and administration costs are less than 5% of revenue). WIM technology can be a significant aid, further improving the efficiency of administration.

We expect also that data from our WIM study will be useful in updating and improving our cost responsibility study. Our purpose is not merely to produce a *"better"* study, but to use the results of that study to support our legislative recommendations for tax changes that will properly and adequately capture those costs that we have identified.

SOME FUTURE PROSPECTS

The technology exists today, at least in embryo form, to fit every vehicle with a transponder which would uniquely identify that vehicle with an identification number. These transponders can be actuated and read by an *"interrogator"* unit installed at or near a WIM site. The identification data, along with the WIM data, can be fed into a computer and integrated for automatic weight, size and speed enforcement and for audit purposes.

The cost of such a transponder system would be minimal and would quickly pay for itself through reduction of overweight loads on the roads and more efficient tax administration and compliance. There are now transponders available at a cost of less than $50 per vehicle.

A strategically planned network of WIM sites, coupled with transponder identification of vehicles, would provide the basis for a national heavy vehicle tracking system. The national scope of such a system would encourage and simplify the adoption of uniform standards among states. It would assist both states and the federal government in conducting a variety of studies--traffic flow, cost responsibility, pavement management and design, weight and size, and a host of others.

Furthermore, such a transponder system could be made part of the administrative scheme for assisting in enforcing a national weight-distance tax. The relatively small additional cost per truck would be far outweighed by the gains in administrative efficiency and tax compliance it would make possible.

The information gathered by such a high-tech system would greatly improve the quality and thoroughness of tax auditing and administration.

Since each heavy truck operator would receive an identifying FIT number and be assigned a gross vehicle weight for federal tax purposes, states could easily piggyback their identification system into the federal one. This avoids the problem of differing state systems for determining gross vehicle weights--a problem particularly acute in states now taxing on unladen weights. States would also be allowed to plug into a national heavy truck data bank and be encouraged to adopt federal uniform standards for forms, recordkeeping and other administrative procedures.

Law enforcement would be greatly enhanced. Police vehicles could have on-board interrogators and receivers, identifying both speed and weight violators.

Public administrators, however, will not be the only beneficiaries from a national tracking system. Trucking firms will also reap large benefits by saving precious time through eliminating the need for much of the static scale weighing. Also trucking dispatch headquarters through accessing the data file could get valuable information on the whereabouts of each truck in their fleet. Each firm would be given a special code so that they can only keep track of their own vehicles.

WIM is a tool which provides for many improvements. The joint product nature of the technology creates a very favorable win/win environment in which both the public and the private sectors reap hugh benefits.

In summary, gentlemen, new technology is here. Lets use it to assist us in all aspects of managing our highways.

COORDINATED WEIGHT MONITORING AND ENFORCEMENT PROGRAM USING WIM EQUIPMENT

MR. WALLACE AMES
OFFICE OF PLANNING AND DESIGN
CALIFORNIA DEPARTMENT OF TRANSPORTATION
SACRAMENTO CALIFORNIA

CALIFORNIA'S COORDINATED WEIGHT MONITORING AND ENFORCEMENT PLAN USING WIM EQUIPMENT

Wallace H. Ames, P.E.
Office of Planning and Design
California Department of Transportation

Presented at the "National Conference on Weigh-in-Motion Technology and Applications" - Denver, Colorado, July 11-15, 1983

Co-sponsored by the Colorado Department of Highways and the Federal Highway Administration

Abstract/Introduction:

The California Department of Transportation (Caltrans) first became actively involved in Weigh-in-Motion (WIM) research nearly 15 years ago. We had studied the concept in the early 1950's but didn't get into the hardware stage. Our initial research study was to investigate the feasibility of screening heavy vehicles for potential truck weight law violations and thereby to improve efficiency of high traffic volume weigh stations on freeways. Since that time, the aging of our freeway facilities and accompanying deterioration of pavement and bridge structures has fostered a growing need to more objectively assess the impact of heavy vehicles on pavement and bridge deck deterioration. More specifically, we need to better relate accumulative 18-kip equivalent single axle loads (ESAL) to the rate of pavement deterioration. Continuing Caltrans WIM research evaluated two state-of-the-art systems for their potential use in enforcement screening and for truck weight monitoring.

The biennial truck weight study and other classification and census information gathering efforts provide a reasonably good system-wide picture. These efforts do not, however, provide statistically valid samples of heavy vehicle information needed to better assess the performance of given pavement designs or rehabilitation strategies. The truck weight study and other census and classification data provide only limited information on movement of commodities for use in systems planning.

Caltrans has developed a Master Plan for implementation of Weigh-in-Motion, which emphasizes the coordination of weight monitoring and enforcement. The tentative plan is to implement the installation of WIM equipment at 28 selected sites statewide. The general objectives of this plan include improving the effectiveness of weight enforcement, improving the quantity and statistical quality of truck size and weight information for pavement and bridge design and performance evaluation, and providing a better data base for estimated volume projections of heavy vehicles and corresponding goods movement trends and seasonal patterns for systems planning purposes.

The future direction of this plan is contingent on the performance of Phase I installations, which include an on-going contract to install WIM equipment in truck lanes of a freeway for pavement performance monitoring and an early contract to install WIM in an existing weigh station for truck weight enforcement screening purposes. Subsequent contracts are planned to implement the Master Plan system over the next several years.

With growing public agency and industry interest in WIM and rapidly changing state-of-the-art, it is likely that we will see a widening usage of WIM and significant changes in California's WIM Master Plan.

I. Caltrans WIM Research Studies

To our knowledge WIM goes back to the first installation of hardware by the Virginia State Highway Department in cooperation with the U.S. Bureau of Public Roads in 1955. Caltrans first WIM research project started in 1969, just before the early 70's decline in highway funding and was delayed through the lean oil embargo and subsequent years with the loss of research staff. This project, entitled "Dynamic Measurements of Commercial Highway Vehicles (Weighing-in-Motion)", is discussed in a report published by Caltrans in June 1978. The study was designed to determine the feasibility of weighing trucks in motion in a weigh station off-ramp to screen out suspected weight violators for static weighing while permitting legally loaded vehicles to bypass the static scales without stopping. Potential benefits included minimizing traffic safety hazards created by trucks queuing up onto the freeway, reducing delay to commercial vehicles, and ultimately reducing the consumer's costs of truck-transported commodities.

The WIM scales for this study were installed in a specially constructed reinforced concrete auxiliary off-ramp lane into the westbound I-80 weighing and inspection station at Cordelia, about 45 miles west of Sacramento. Figure 1 shows a layout of the converted station. Six sets of electronic WIM scales manufactured by the Rainhart Company of Austin, Texas were installed, in a randomly spaced group (as shown in Figure 2) approximately 800 feet upstream from the static platform scale and were coupled with a Caltrans assembled data acquisition system.

Actual field operational tests on this first WIM research project were made intermittently in the middle 70's. A series of tests run in 1976 proved feasibility of the WIM concept for potential screening out of overweight trucks, by predicting static weight, within an acceptable margin of accuracy, from the dynamic reactions of truck axles passing over the WIM scales.

The basic conclusions of this project were: 1. The Weigh-in-Motion concept is feasible for weight law enforcement screening; 2. Visual observation to identify suspected weight law violators through a high traffic volume weigh station operation is grossly inadequate; and, 3. The prototype WIM system revealed the need for developing a much more reliable system.

Caltrans most recent WIM research project was initiated in 1979 to determine if then commercially available WIM systems are reliable and durable to perform continuous weigh-in-motion measurements of gross vehicle weights, axle weight, axle spacing, vehicle speed, and vehicle classification from a moving truck traffic stream leading to a static weigh station. In addition, the study was designed to assess suitability of WIM systems for monitoring the same variables in a moving truck traffic stream on the open highway.

Three known-to-us off-the-shelf "turn-key" systems were available in 1979 including the following: 1. The Radian WIM System (which incorporates the previously tested Rainhart Wheel Load Transducers with some modifications); 2. The PAT Model DAW-209 WIM System; and 3. The Streeter Amet Rollweigh Model 5150 System. Another system, the International Road Dynamics System was not, to our knowledge, marketed in the United States until after we were well into the study.

Since we already had a familiarity with the basic design of the Radian WIM scale, and a number of other states had purchased later model Radian systems, we chose to test the other two relatively unknown systems.

The PAT system was tested for potential enforcement screening at a weigh station site and weight monitoring in the truck traffic stream on an open highway. Figures 3 and 4 show these two layouts. The WIM installation at a weigh station site was retrofitted into an existing plain concrete off-ramp approach to an existing weigh station. The open highway installation was retrofitted into a newly placed AC overlay.

The Streeter Amet System was similarly tested for potential weight enforcement screening only in a high-volume station at Castaic on I-5 north of Los Angeles, as shown in Figure 5. To our knowledge, the manufacturer of the Streeter Amet does not recommend its usage where traffic speeds are above 30 mph. This, in effect, would generally confine usage of the system to a weight enforcement screening operation.

Testing of the PAT System at a weigh station involved the comparison of WIM and static scale weights of 975 trucks selected at random from the traffic stream excluding only those carrying liquid and livestock payloads. Each truck was identified by an observer at the WIM scales and descriptive features were transmitted by radio to an observer-recorder located in the static scale house to assure proper data correlation. The scale house observer recorded all static weights and selectively measured and recorded axle spacings to correlate with the PAT WIM System measurements.

A similar comparison of WIM and static scale weights was made on 1,196 trucks at the I-5 Castaic Weigh Station where the Streeter Amet System was installed for testing purposes. Axle spacings were also selectively measured and compared with system data output.

Open-highway truck lane exposure of the PAT System was included in the study primarily to investigate durability and potential longevity of the WIM scales subjected to truck traffic at highway speeds. The van mounted data acquisition system was connected intermittently over a two-year period to verify continued integrity of the WIM scales.

Findings of this most recent study indicate that the PAT System, at least insofar as the WIM scale is concerned, best meets Caltrans needs for a simple, accurate, and reliable system for weight enforcement screening in weigh stations and for monitoring of truck weights on the open highway for planning and design purposes. This study also revealed that most of the WIM data acquisition system problems encountered in the first Caltrans' study have been resolved by much improved technology and systems development in the data acquisition area.

The significant problem that, to our knowledge, has not been solved, is that of providing an automated traffic management feature that will: 1. Convey the appropriate traffic directions to each trucker in spite of short headways (say no less than 25 feet) at a high volume weigh station-- (In essence to screen out the overloaded trucks and direct only them to the static scales while clearly directing legal vehicles to the bypass lane), 2. Positively track each truck through the weigh station to ensure that each had obeyed its traffic directions, 3. Positive "mating" of WIM data to the correct truck so that the weigh-master can, through the visual display, assign the proper data to a specific truck. These features are especially vital in high-volume weigh stations, especially where visual identification and follow-through is impracticable.

Although pavement type comparison for WIM scales installation was not specifically studied by Caltrans, we feel that it would be advisable to place all permanent type WIM installations in a concrete slab to minimize changes in roughness in the WIM scales approach and leave areas. A suggested distance is 200 feet in advance of and 75 feet past the WIM scales installation. Surface profile tolerances should be very stringent, even if diamond grinding is required to satisfy.

II. Caltrans' Master Plan to Implement Weigh-In-Motion:

Caltrans' four-phase Master Plan includes implementation of WIM at 28 sites statewide over the next five years. Most of these 28 sites will provide information that serves more than one purpose. Phase I includes one LTPM site and one enforcement screening site. Subsequent Phases II, III, and IV include WIM installations at 6, 10, and 10 sites respectively. Phases II and III include LTPM, enforcement screening, and planning sites with all sites considered to contribute directly or indirectly to at least two of the three functions. Phase IV includes 10 sites that are primarily for enforcement screening, but which will also contribute data that will be useful in systems planning.

This plan has been initiated with the first operational monitoring installation to be made on Interstate 80 near Sacramento in late summer of 1983. This installation, designed for LTPM purposes, is in an 8-lane urban, high traffic volume freeway, about one mile upstream from an existing weigh station, as shown in Figure 6.

The contract calls for the installation of double-threshold (two successive) WIM scales in the westbound truck lanes (No. 3 and 4) and inductive loop detectors in all four lanes, as shown in Figure 7. Most of the future planned installations will also require multilane installations.

This first of 12 WIM installations for LTPM purposes will be used to: Compare accuracy of data with a single and double-threshold WIM scales system, refine the data collection format with the computer data processing center, refine hardware installation details, assure adequacy of unattended operation for data collection, compare data communication modes, develop specifications for Phase II, and develop a WIM operations and maintenance manual.

We hope to have this installation in operation by October 1, 1983 and complete the above shakedown, evaluation, and developmental tasks by the summer of 1984.

The second installation included in Phase I is a weight enforcement screening installation at an existing high volume weigh station that is being upgraded on I-580 in Livermore, California. This is on the main Interstate route between the San Francisco Bay Area and Los Angeles. The general layout of this installation is as shown in Figure 8.

The objectives of this installation are to develop: an enforcement screening design that can be used for future installations; an effective traffic management system; a system that will continuously record all truck data; specifications for Phase II screening installations; and a manual for operation and maintenance of the WIM screening system.

It is hoped that shakedown and evaluation of this system will result in an end result type design including specifications that can be used for future installations. The development of a traffic management system is essential to effectively communicate with the vehicle operator and to clearly indicate to the weighmaster the identification of suspected violators, without the need for any visual tracking. We have developed a functional concept for a prototype traffic management system on the I-580 Livermore project. This concept will be included in a Request for Proposal (RFP) which will be advertised soon by Caltrans. We hope that the WIM vendors will be responsive to this proposal and that we will be able to buy and install such a system under an early contract to implement this WIM screening operation by early 1984.

The weigh stations in California currently record the numbers of all vehicles and the size and weight statistics on fined violators only passing through the station. They do not, however, record weight data on legal vehicles. An interim Caltrans goal is to incorporate the recording of gross and axle weights, axle spacing, bridge law conformance, vehicle classification, and speed at all weigh stations where WIM weight screening is planned. Ultimately, it is planned to provide such a recording capability at all permanent weigh stations to include all of the above data elements.

The data derived from all permanent weigh stations and from all planning and design monitoring sites should become an integral part of the FHWA Truck Size and Weight Study. In effect, it would eventually eliminate the need for most or all of the static weighing and classification counts now done biennially at 18 sites statewide.

The timing and implementation of Phase II is dependent on the evaluation of the Phase I installations and in turn Phase III will be dependent on Phase II progress. It is tentatively planned to construct Phase II in 1984 and 1985, Phase III in 1985 and 1986, and Phase IV from 1985 to 1988.

Figure 9 shows current and planned permanent weigh stations and inspection facilities on the California State Highway System. Hours of operation of these stations and facilities varies depending on truck traffic volumes. A number of the stations on busy California "port-of-entry" routes as well as high volume intra-State routes operate on a 24-hour day, seven-day week. The system shown is augmented by 54 sites where pits are provided for portable scales for use of the California Highway Patrol Mobile Road Enforcement (MRE) units in covering weight enforcement of seasonal hauling.

Figure 10 shows planned WIM weight screening sites, all of which are to be installed in existing or planned permanent weigh stations. Several of these are located in 24-hour stations that are near Long Term Pavement Monitoring (LTPM) sites and will serve for both purposes.

Figure 11 shows WIM sites that are primarily for the purpose of truck weight monitoring relative to planning and design. These are a vital part of LTPM and will provide needed information for systems planning purposes. It is also anticipated that they will provide information that is helpful to the CHP in planning weight enforcement strategies.

Figure 12 shows all the permanent planned WIM sites for all purposes. These include weight enforcement screening, gross and axle weight monitoring, axle spacing, bridge law conformance, speed monitoring, vehicle classification, and potentially the addition of systems at some sites for width and height monitoring.

Figure 13 shows a combination of all of the existing and planned permanent weighing sites. Existing truck weight study sites are indicated by the asterisks"*". All WIM sites are shown by the hexagons.

The Caltrans WIM plan does not specifically address the use of portable WIM systems. The portable systems will, however, be considered and most likely will become an essential element of a statewide system.

III. WIM System Performance:

1. Capability: A WIM System should be capable of acquiring truck axle and gross weights, axle spacing, and speed from 6 truck lanes of 10 total on a freeway. It should also be capable of acquiring speed and classification information from loop detectors in the remaining four lanes. This could be done with a separate system on each side of the freeway.

   The WIM scale(s) should essentially cover the traffic lane to minimize the percentage of trucks that are not scale borne.

   An automated traffic management system should be provided to screen for overloaded trucks and to assure positive identification of suspected violators as they pass through the screening process to the static scales.

   Capability should be provided for computerized self-calibration and recalibration of weight screening operations by an interface with the static scales.

   Data communications interface capabilities should include modem for telephone line tie to central or remote office. Provision should be made to record data on magnetic tape media and interface through compatible reader to a central computer. Microwave transmission of data should be considered a potential data transfer method. The system should be capable of generating summaries and dumping them into a portable computer or printer.

2. Accuracy: Some suggested accuracy standards or guidelines should be developed for various types of WIM installations. Accuracy standards should consider needs for weight screening, pavement monitoring, and monitoring for planning purposes.

   Required accuracy may vary between the above needs or between weigh sites, or regions, or states. For example, if a WIM weight screening facility is located in an area where gross overloads are common the accuracy required is much less than for a facility where the average magnitude of overloading is minimal. In other words, ten percent accuracy may be all right in the first case, whereas 5% or less may be required in the latter. As an example, if one had 10% accuracy and 90% of the trucks were within 5% of the legal limit, the purpose of the screening operation would essentially be defeated.

To operate an effective weight enforcement screening operation, the California Highway Patrol now feels that WIM weights must generally be within 5% of the true static load. Caltrans' 1982 research report "Evaluation of the PAT and Streeter Amet Weigh-in-Motion Systems" (Appendix M) suggests some statistically based accuracy requirements for single axle, tandem axle, and gross vehicle weights as well as for axle spacing and speed. These are not suggested as national standards and will most likely change as we get further into implementation of WIM in California.

3. Calibration: WIM equipment calibration is an area of particular concern to Caltrans. We do not feel this factor has been given enough attention. In our view it is not generally adequate to use a single or even two or three calibrated loaded vehicles for this purpose. There are just too many variables in vehicle configurations and suspensions. In addition, the WIM calibration should be made at various speeds within the speed range that the system will be used. Some WIM scales cannot be calibrated with a static load while others can. In the Caltrans' study, we found that the stationary PAT WIM System tested cannot be calibrated with a static load while the Street Amet can.

It is our recommendation that WIM equipment be calibrated using a relatively large number (100 or more) of randomly selected vehicles that truly represent the population that will be monitored or screened by the specific installation. For a weight screening installation in the off-ramp to a static weigh station, the calibration can be done quite readily by random sampling of vehicles passing through that station.

The problem of calibrating WIM scales used in the open highway are the most difficult, especially if they are in a high traffic volume area. In the case where it is simply a weight monitoring site, the accuracy required is probably less than for screening so the use of two or three calibrated loaded vehicles may be satisfactory. If traffic volumes are relatively low, it may be possible to randomly select trucks and statically weigh them at the roadside for calibration purposes.

With seasonal changes of truck mix, there may be a need for recalibration with those changes. If the static scales were interfaced with the WIM computer in a screening operation, it should be a relatively simple matter to program continual upgrading of the calibration.

Because of the many variables involved, it is doubtful that there will be a direct correlation of calibration from one WIM installation to the next. Some of the variables that must be considered are surface roughness of pavement in the immediate vicinity of the WIM, geometrics of the WIM approach, truck classification mix, truck suspensions, and the dynamic response of the WIM scales.

The coordination of WIM calibration among users or with other states is a question that needs to be answered. As long as WIM is not being used directly for enforcement, the need for coordination is not really critical. There should, however, be some minimum standard procedures or guidelines to promote uniformity in methods of calibration and to determine how accurate WIM systems really are.

4. Reliability: WIM system reliability, in Caltrans view, hinges on the durability of the WIM scale itself. The computerized data acquisition systems of all manufacturers, which are generally made up of off-the-shelf electronics and customized software, do not appear to be a problem.

Based on Caltrans' studies of three different WIM scales, it is our considered judgment that the more simple the design the higher the reliability. The WIM scale should be made of an absolute minimum number of parts, it should require an absolute minimum of physical adjustments after installation in the pavement, and it should not be susceptible to normal environmental changes.

No active electronic components should be mounted below ground level.

The longevity of a WIM scale is less critical in weigh station off-ramp screening than in an open road monitoring installation. In the weigh station removal, repair, and replacement can be done quite readily without traffic control, whereas it would be required on the open highway with attendant traffic control costs and safety hazards.

Caltrans 1982 study suggests as a goal that the WIM scale be designed to carry a minimum of 10 million truck axle loads or four years of continuous operation, whichever comes first. The WIM scales used in that study did not meet that goal, but showed some signs of signal degradation at 1.5 to 2.5 million cycles in a period of up to 2 years in service. The cause of degration of signals has not yet been determined. Conceivably, problems could have been from environmental changes affecting electrical cable lead-ins. On the other hand, the problem could be a manifestation of elemental fatigue in the WIM scale.

5. Maintenance: It is inevitable that there will be a need for maintenance repair, and replacement. As Caltrans proceeds with WIM implementation, the intent is to have spare WIM scales on hand to install while failed units are returned to the manufacturer for refurbishing at an agreed price. Initially, it is hoped that WIM scales placed in open truck lanes will last at least 2 years before removal for refurbishing. The manufacturer or supplier must, of course, assure the owner of a ready supply of parts and have service available on relatively short notice.

   The maintenance of data acquisition systems and software changes will generally be handled by Caltrans staff in the Electronics Laboratory and Computers Services areas, respectively. Traffic signal technicians in the District maintenance staffs who regularly maintain micro-computer systems will be trained to maintain, repair, or replace equipment in the field. Computer Systems staff will be involved in all WIM implementation to assure compatibility and to develop required interfacing with central computer facilities and operations.

IV. Coordinated WIM Advantages and Disadvantages

Advantages:

1. Less installations and cost to cover both monitoring and enforcement screening.
   a. Utilization of several screening installations for pavement and bridge monitoring.
   b. Record all volume and weight information in weigh stations.
2. More complete statewide truck weight information.
3. Inhibition of overloading with more complete coordinated surveillance.
4. More effective weight law enforcement.
5. Reduced delay to truckers and lower costs to consumers.
6. California Highway Patrol can use trends from monitoring sites to plan Mobile Road Enforcement and time of operation at permanent stations.
7. Better coordination of equipment calibration.

Disadvantages:

1. Could bias monitoring data by tieing it to enforcement.
2. Could encourage deliberate damage to and avoidance of monitoring equipment.
3. More sophisticated system in weigh stations requires more highly trained staff.

V. Potential Benefits vs. Costs:

The benefits of a coordinated WIM System appear to significantly outweigh the costs. Caltrans Master Plan, Appendix F, estimates a potential benefit to cost ratio range from 5:1 to 7:1. This plan stresses the complimentary nature of the truck weight information sought and the logic of a coordinated plan.

VI. Conclusions:

1. Implementation of a coordinated weight monitoring and enforcement plan utilizing WIM equipment will provide a much more complete and accurate picture of truck loads and volumes to which State highway pavements and bridges are exposed.

2. With this information, we will be able to:

    a. Do a more effective job of weight enforcement,

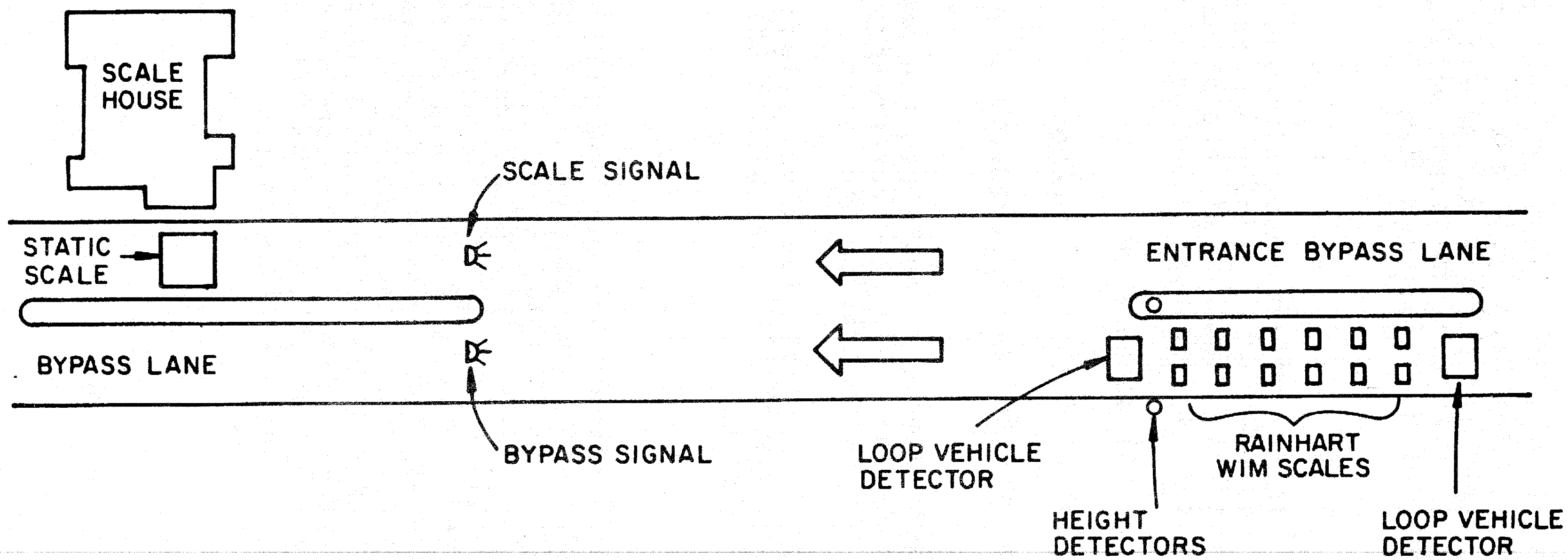
    b. More objectively plan for system improvements to handle the traffic, and

    c. More effectively assess damage to pavements and bridges to evaluate and improve the design and performance of new, rehabilitated, and reconstructed facilities.

3. Implementation of a statewide coordinated truck weight monitoring and enforcement system utilizing WIM in California will prove to be cost effective.

VII. Acknowledgements:

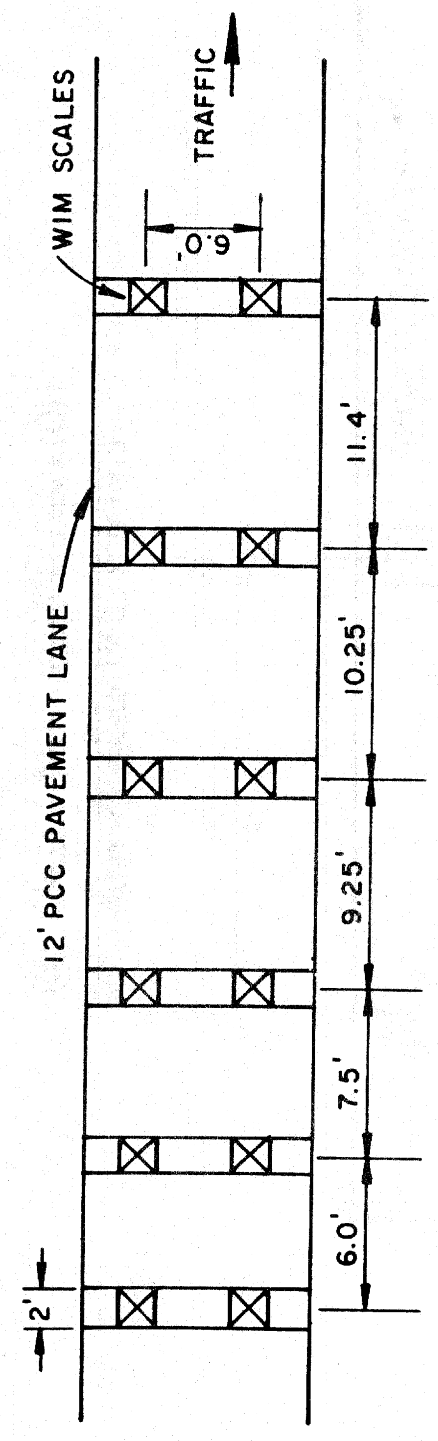
My thanks goes to William Chow, Richard Johnson, Ken Mori, Earl Rogers, Fred Boucher, Don Wingfield, and numerous other Caltrans staff members that contributed significantly to the effort in developing the Caltrans WIM Master Plan. Assistance from Captain Chuck King and Lieutenant Don Sly of the California Highway Patrol is also gratefully acknowledged. Last, but not least is the appreciated assistance and encouragement of the Federal Highway Administration at the Division, Region, and Washington, D.C. Headquarters levels. Opinions presented in the Work Plan and this paper are those of the author and do not necessarily represent the official views or policies of Caltrans, the California Highway Patrol, or the Federal Highway Administration.



I-80 WIM LAYOUT - CORDELIA WEIGH STATION

No Scale

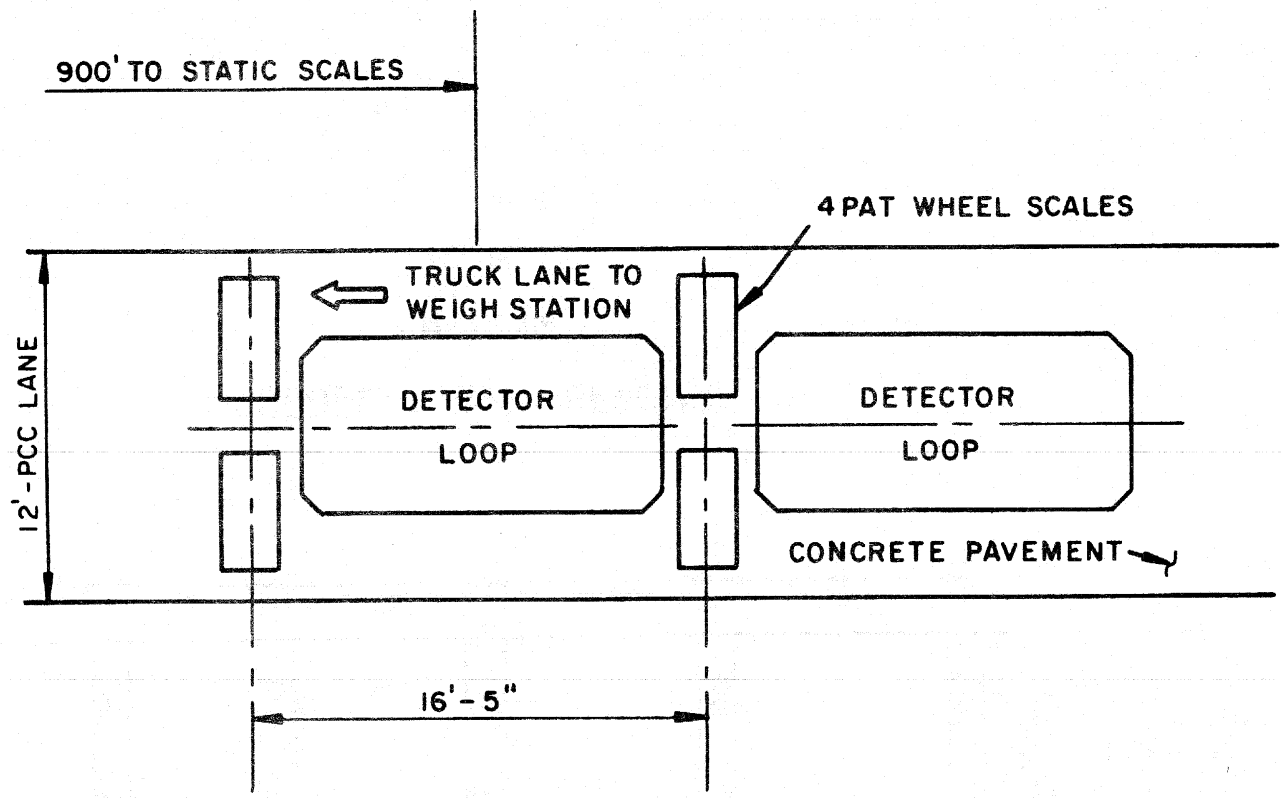
FIGURE I



CORDELIA WIM SPACING

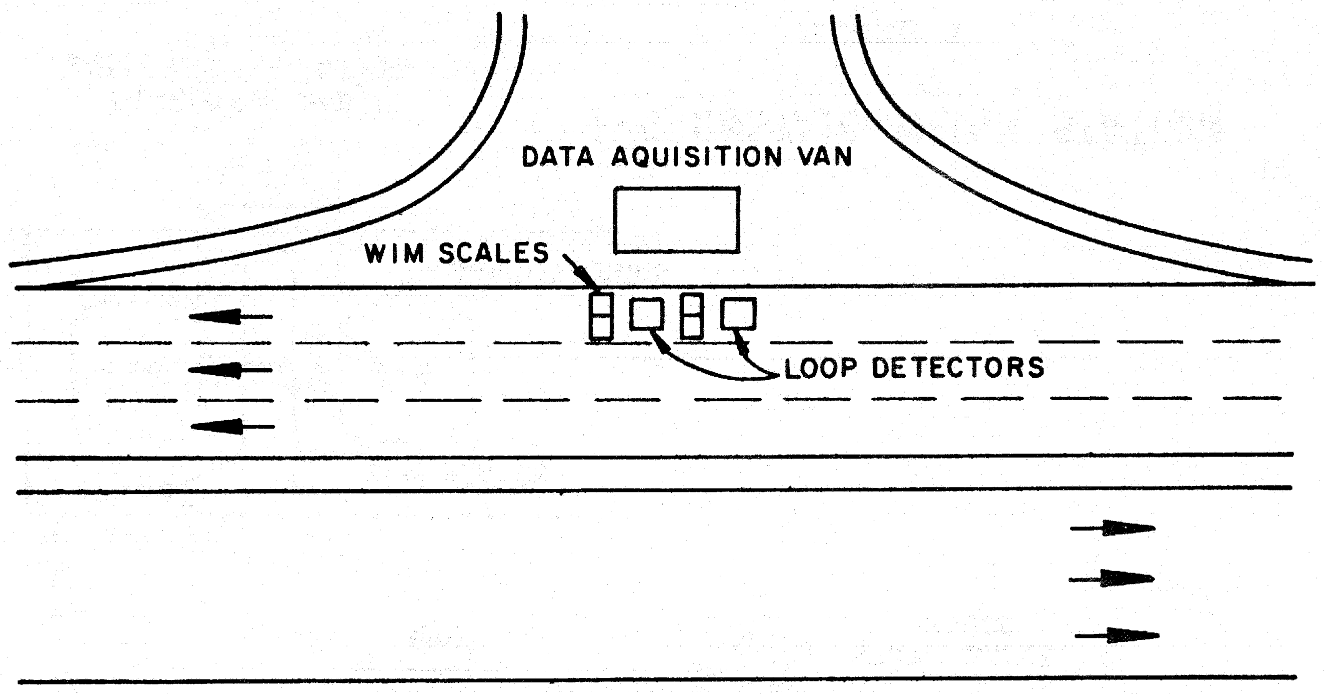
No Scale

FIGURE 2



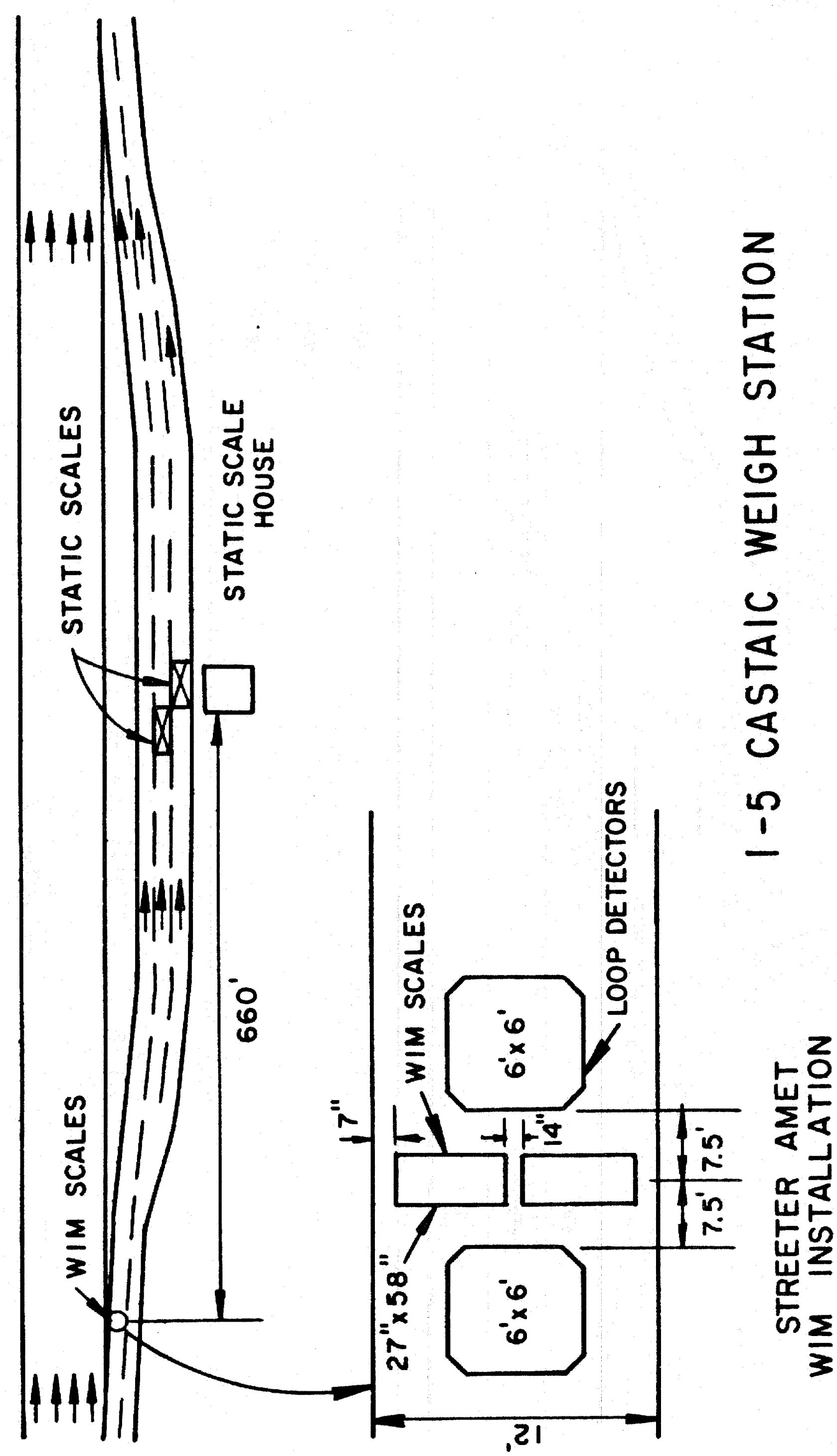
PAT WIM SCREENING LAYOUT
I-80 ANTELOPE WEIGH STATION

FIGURE 3



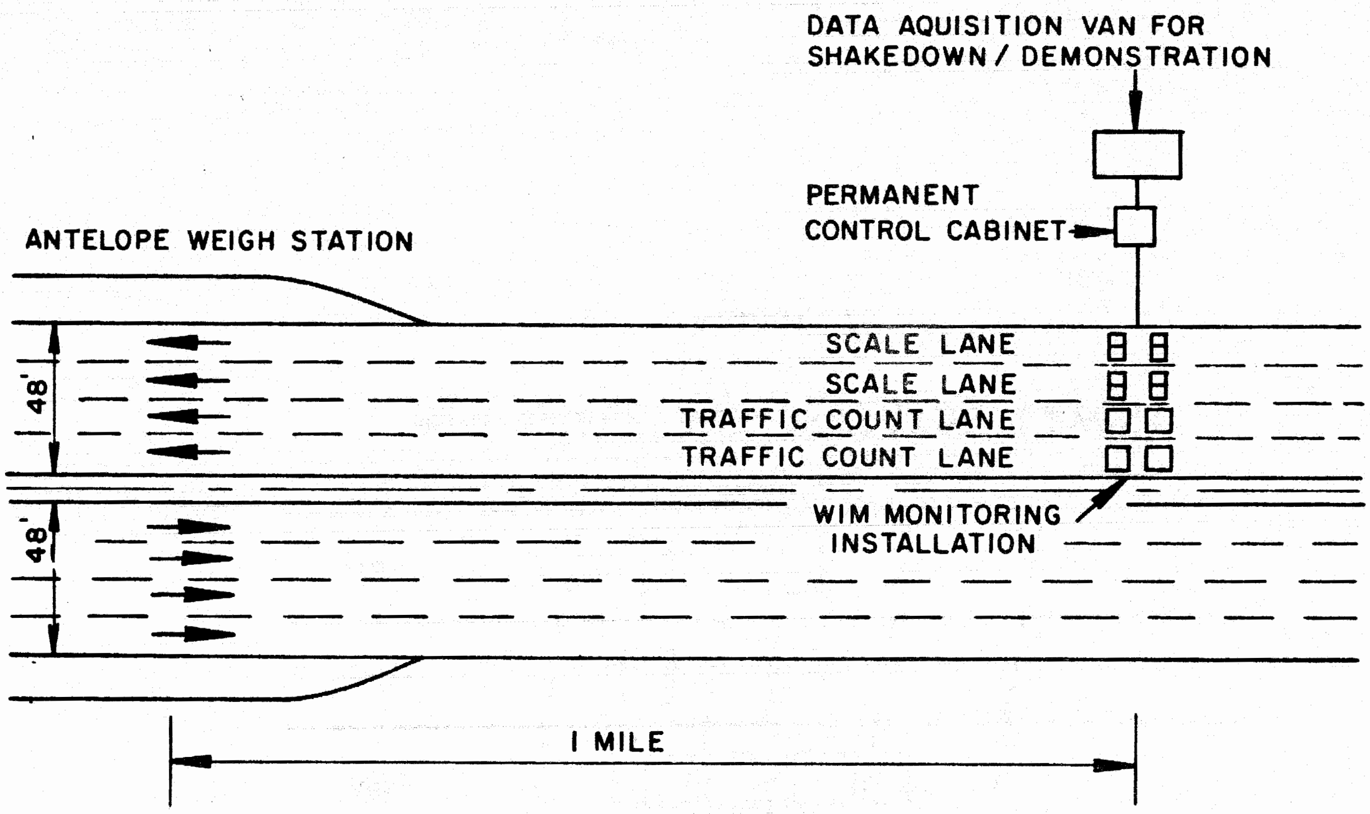
ROUTE 99 LODI WIM SITE

FIGURE 4



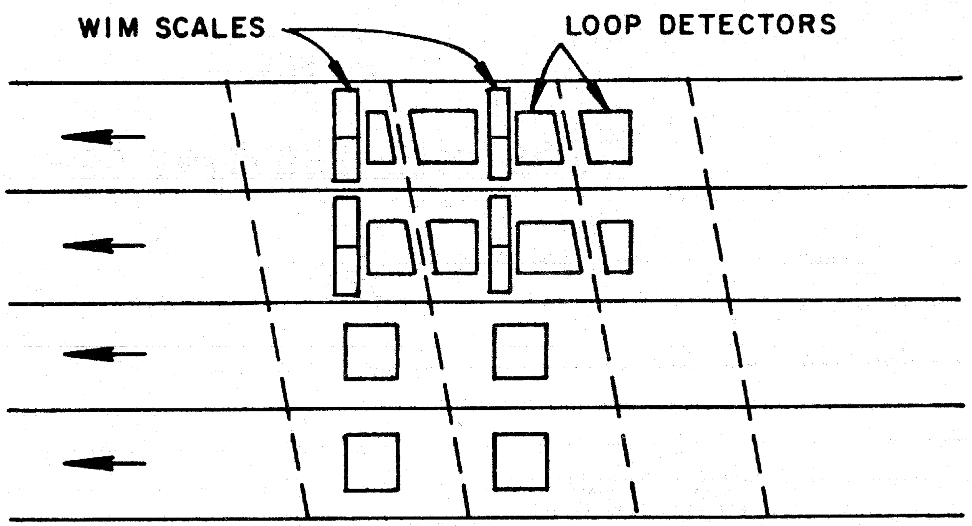
I-5 CASTAIC WEIGH STATION

FIGURE 5



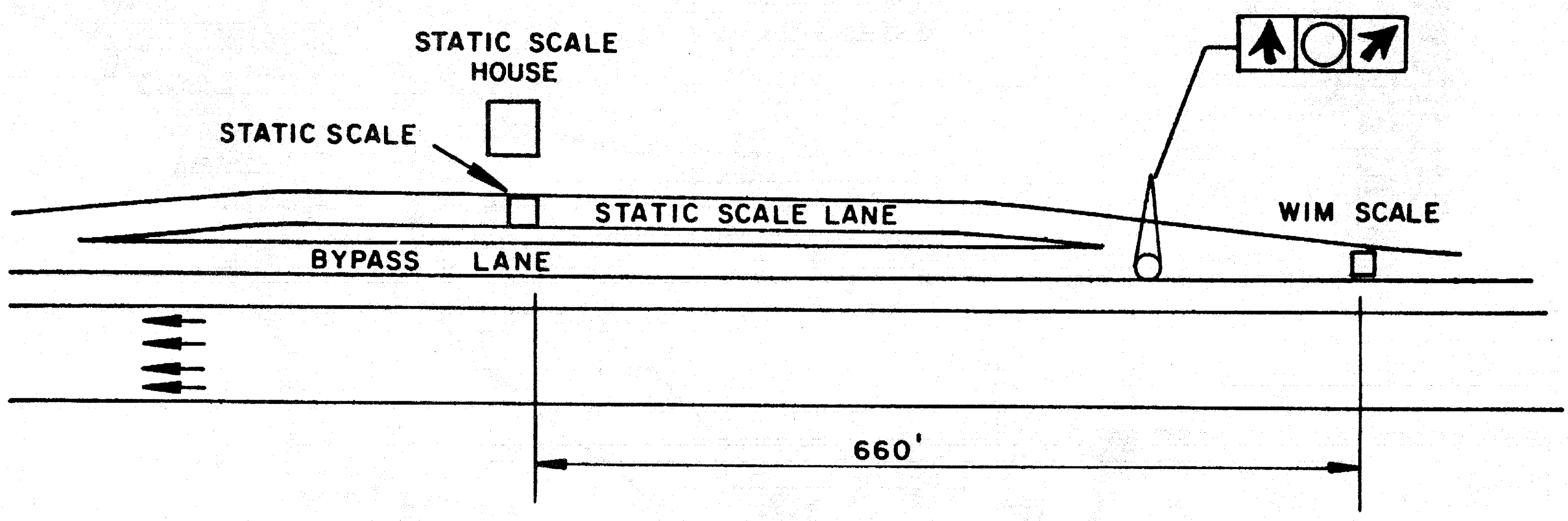
I-80 ANTELOPE WIM SITE

FIGURE 6



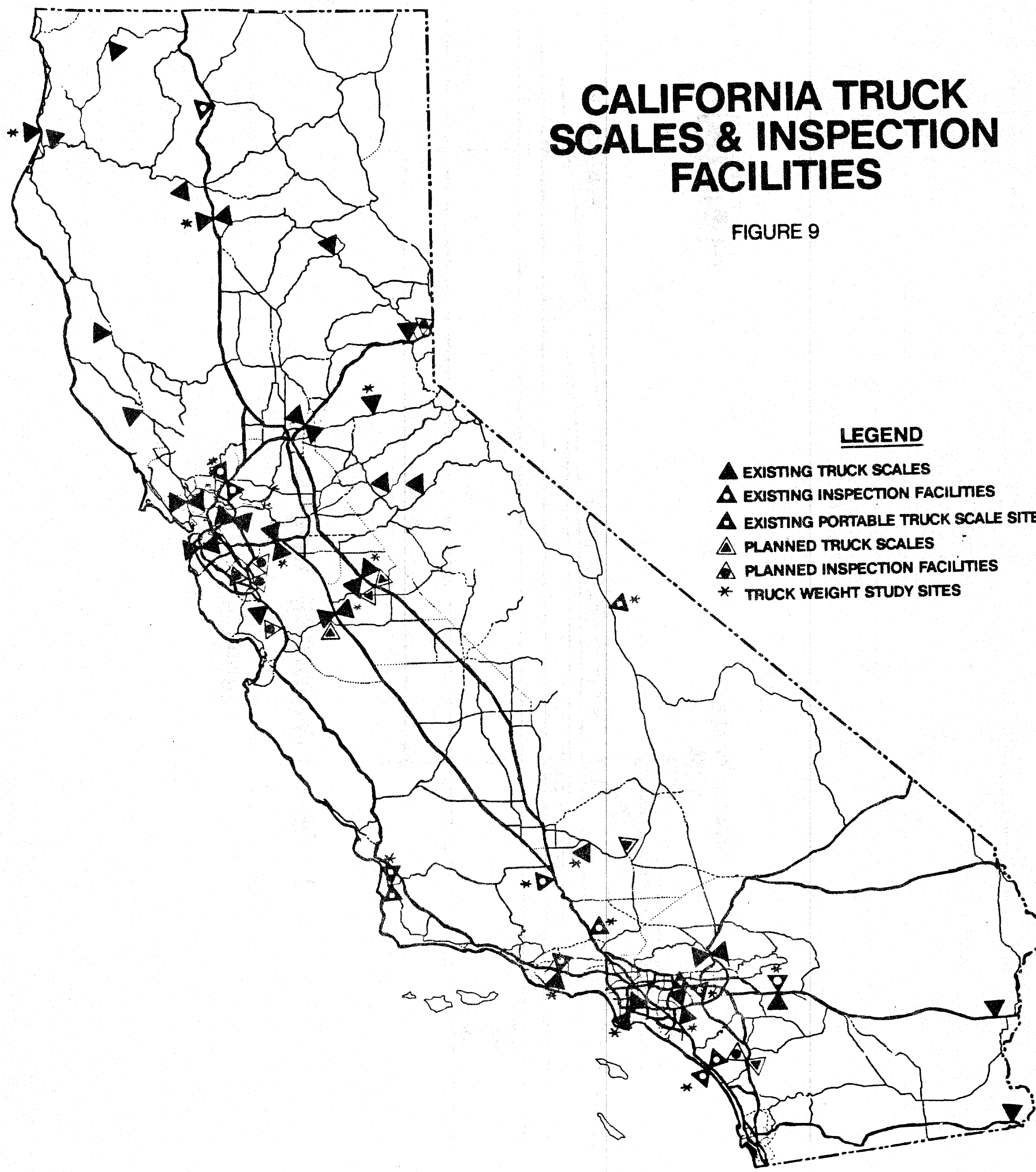
WIM SCALE AND DETECTOR LAYOUT

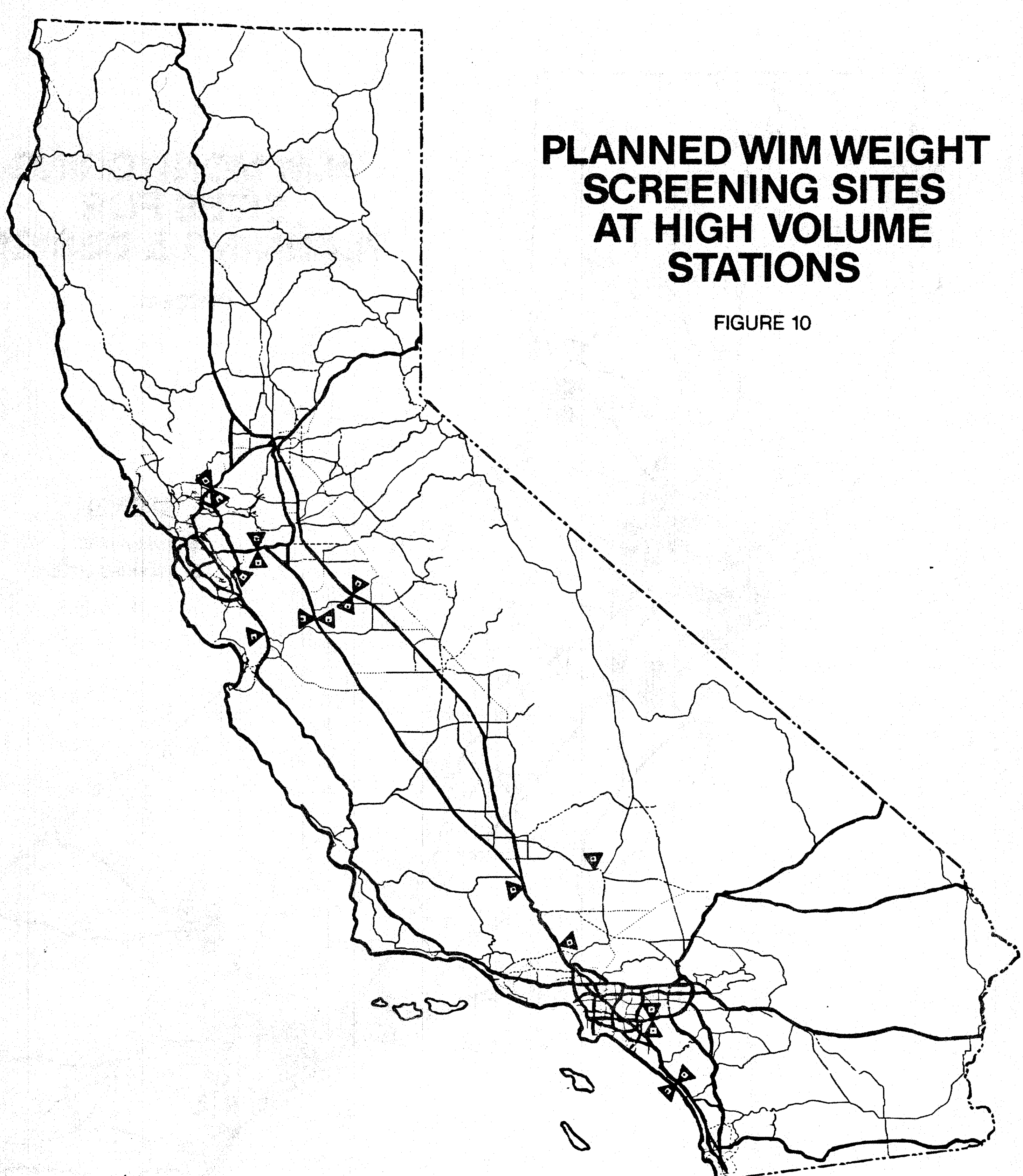
FIGURE 7



I-580 LIVERMORE WIM SITE

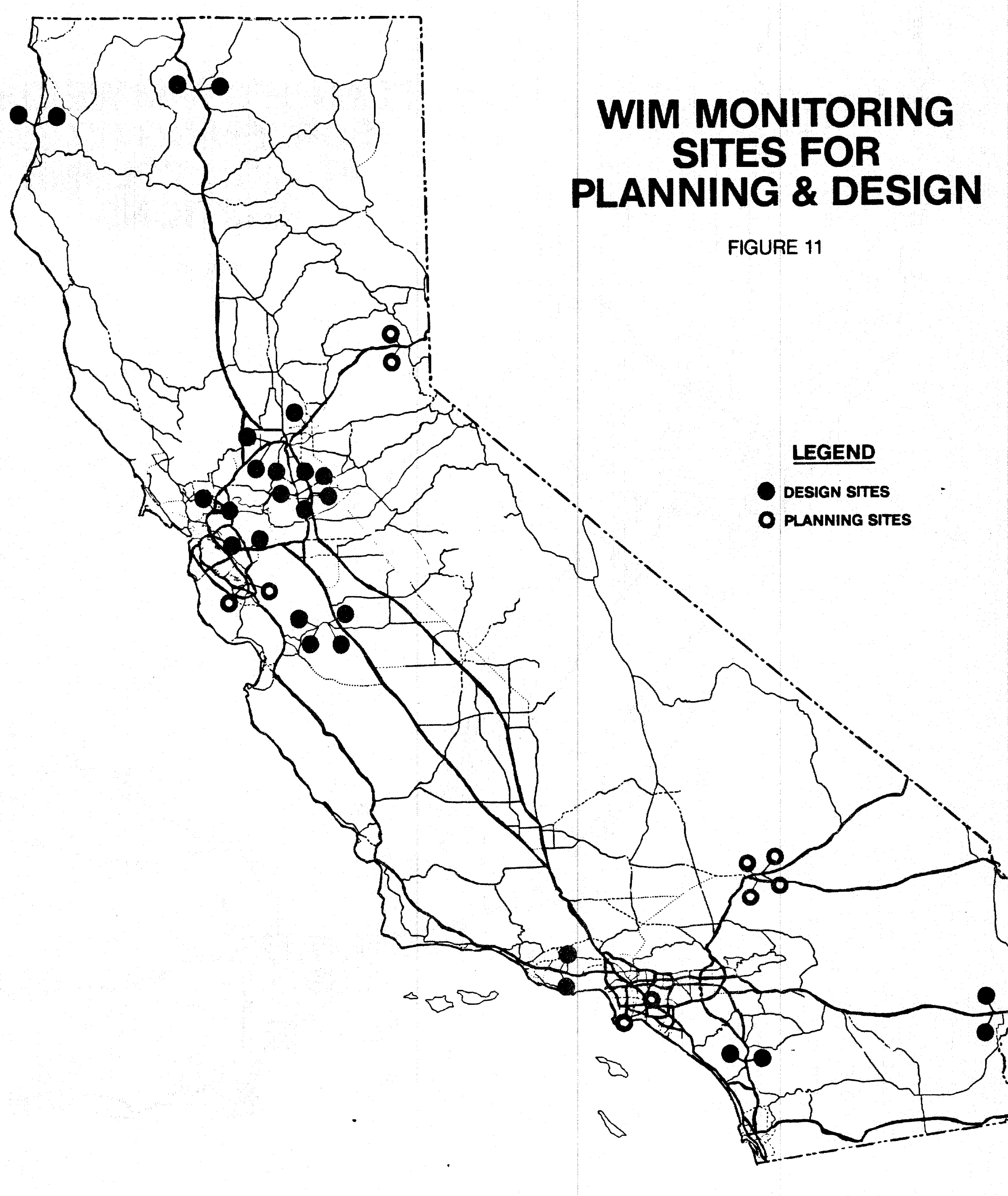
FIGURE 8


CALIFORNIA TRUCK SCALES & INSPECTION FACILITIES
FIGURE 9
LEGEND
EXISTING TRUCK SCALES
EXISTING INSPECTION FACILITIES
EXISTING PORTABLE TRUCK SCALE SITE
PLANNED TRUCK SCALES
PLANNED INSPECTION FACILITIES
TRUCK WEIGHT STUDY SITES



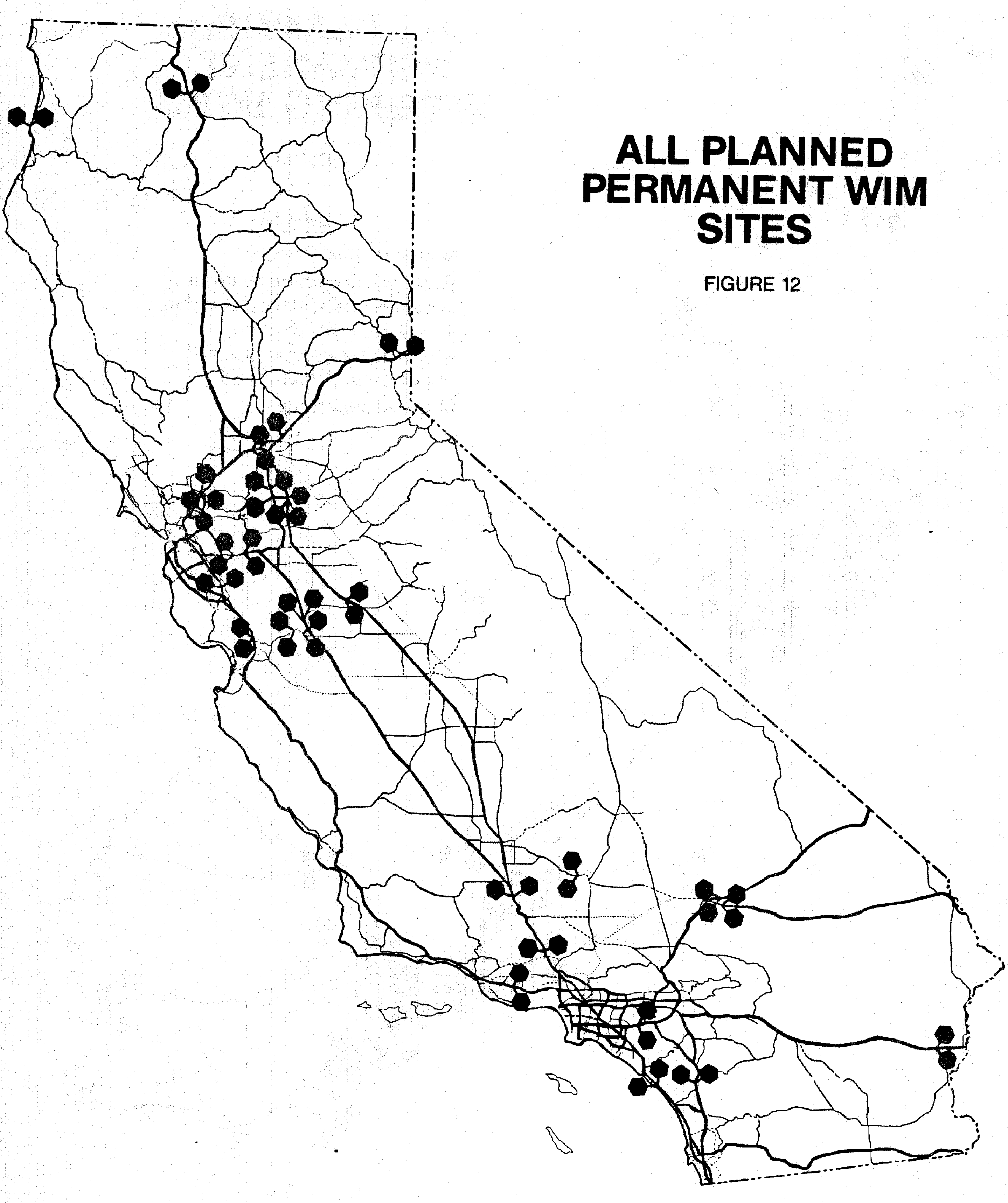
PLANNED WIM WEIGHT SCREENING SITES AT HIGH VOLUME STATIONS

FIGURE 10



WIM MONITORING SITES FOR PLANNING & DESIGN

FIGURE 11

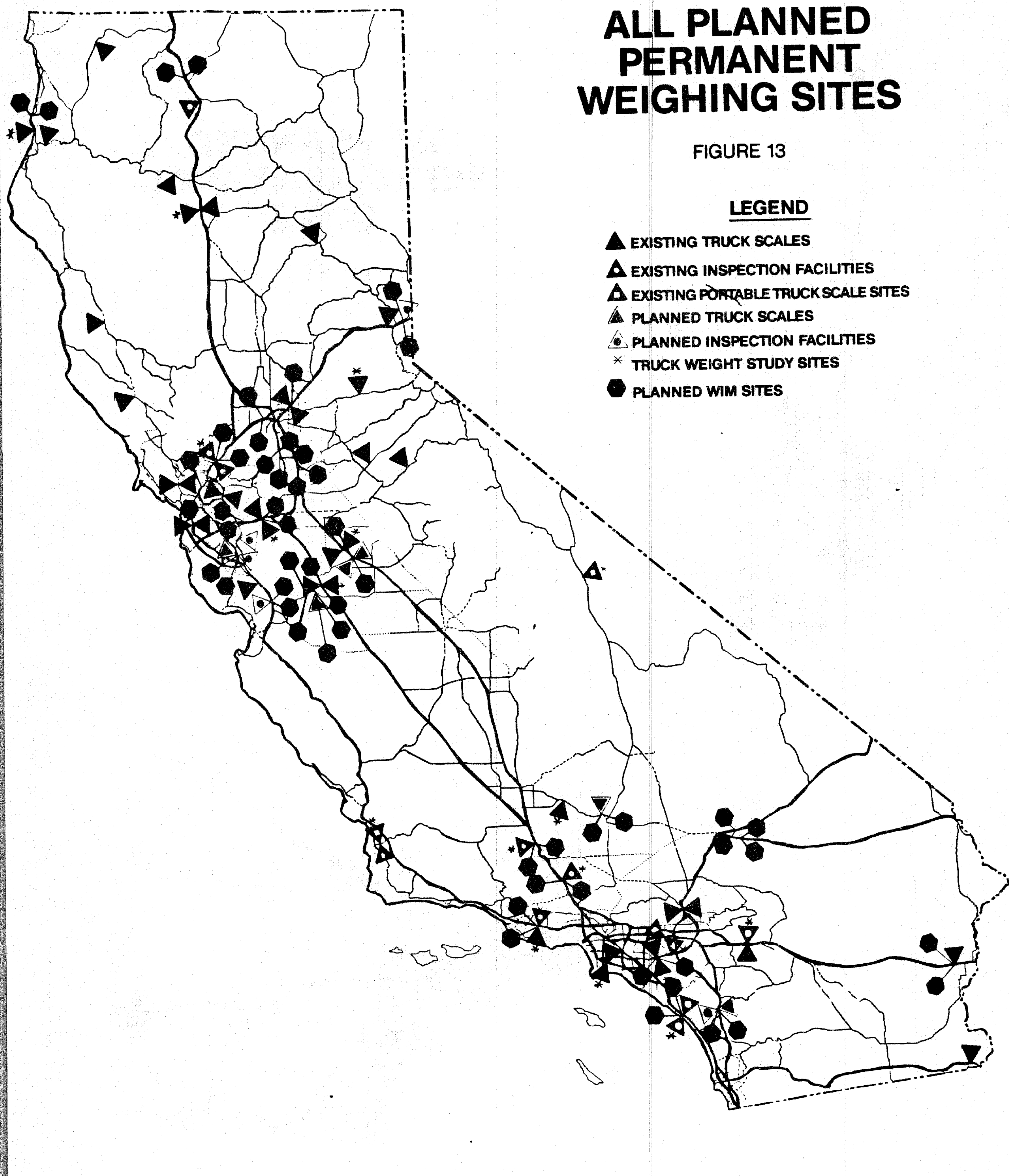


ALL PLANNED PERMANENT WIM SITES

FIGURE 12

ALL PLANNED PERMANENT WEIGHING SITES

FIGURE 13



LEGEND

- EXISTING TRUCK SCALES
- EXISTING INSPECTION FACILITIES
- EXISTING PORTABLE TRUCK SCALE SITES
- PLANNED TRUCK SCALES
- PLANNED INSPECTION FACILITIES
- TRUCK WEIGHT STUDY SITES
- PLANNED WIM SITES

COORDINATED WEIGHT MONITORING AND ENFORCEMENT PROGRAM USING WIM EQUIPMENT

CAPTAIN CHARLES KING
COMMERCIAL AND TECHNICAL SERVICES SECTION
DEPARTMENT OF CALIFORNIA HIGHWAY PATROL
SACRAMENTO, CALIFORNIA

OPERATIONAL CONCERNS/WEIGHT ENFORCEMENT

SCREENING WITH WEIGH-IN-MOTION EQUIPMENT

CHARLES E. KING, CAPTAIN
Commercial and Technical Services Section
DEPARTMENT OF CALIFORNIA HIGHWAY PATROL

Presented at the "National Conference on Weigh-In-Motion Technology and Applications" - Denver, Colorado, July 11-15, 1983.

Co-sponsored by the Colorado Department of Highways and the Federal Highway Administration.

Objectives

- o Increase effectiveness of weighing operations.
- o Reduce congestion and delay at high volumne weigh stations.
- o Increase compliance with weight laws.

Operational Requirements

The Weigh-In-Motion (WIM) system must automatically weigh all trucks crossing the WIM scale, calculate their speed, determine axle spacings, verify compliance with weight laws, detect invalid measurements, and select trucks at random for safety inspections.

Accuracy Levels

The WIM system must have an accuracy capability to weigh individual axles, axle groups, and gross vehicle weights to within $\pm$ 5 percent of actual weight. Axle spacing and vehicle wheelbase must be measured accurately to within 6 inches. These accuracy levels must be achieved at vehicle speeds of 35 - 50 mph.

Durability of Weigh Pads

Weigh pads and frames used in high speed WIM systems must be sufficiently strong to withstand a minimum of 2 years use in high volumne site locations without damage or repairs. A single 11' wide WIM pad is preferable however two pads, one for the right side and one for the left side may be used if properly spaced in vehicle wheel path area and accompanied with off pad wheel detectors. Transducers within the pads must be sealed against moisture without the use of pressurized gas.

Reliability of System

The WIM system must be operational 80 percent of the time during the first year of operation and 85 percent of the time during the remaining design life expectancy of the system.

Warranty and Service

WIM systems must be fully warranted to include all parts and labor repair costs during the first year of the operational use. Service contracts must also be provided by the manufacturers along with maintaining replacement parts availability. Replacement parts must be available on 24 hour notice in emergency situations and within three days on regular requisition.

Traffic Management System

the WIM system must include traffic management features that will direct all trucks into a static weigh station, maintain adequate spacing between vehicles, regulate vehicle speed, direct overloaded trucks to a static scale, direct legal trucks into a static scale bypass, identify vehicles which fail to follow the signal system, and include appropriate features to accomodate overload adjustment and reweighing. Legal weight trucks that inadvertently enter the static scale must be identified and trucks that fail to cross the WIM scale properly (driving to the side of the WIM pads or speeding up or slowing down) must be identified and directed to the static scale. Separate CRT display modes are required for trucks in the bypass lane, the static scale lane, and scale calibration. A reset feature must be included to allow the scale operator to restart the system with the next truck crossing the WIM scale should the system fall out of sequence for any reason. The scale operator must be able to manually override the automatic traffic signal system.

Software Program

The WIM software program must identify and calculate all weight violations on an individual vehicle or combination of vehicles regardless of where the violation(s) may be. The system must also include a CRT for continuous visual reference and a printer for permanent record. The CRT must show the trucks in the order they are directed to the static scale from the WIM scale. The largest overload must be highlighted on the CRT in a manner readily recognizable to the scale operator. Steering axles limits must be set at 12,500 pounds while other single axle limits must be set at 20,000 pounds. Axle spacing measurements must be calculated to the nearest even foot and when the measurement is determined at exactly ½ the next larger foot must be used to determine the allowed weight.

Operational Concept

The high speed WIM system used for weight enforcement screening must sort out potentially overloaded trucks from the stream at speeds of 35 - 50 mph and direct these trucks to a static scale for stop weights and enforcement action. Overloads must be adjusted and the truck reweighed before departing. As the truck reenteres the stream it must be able to do so without disruption to the ongoing weighing and screening operations or be accomplished safety and effectively will determine the degree to which WIM systems can be used as an enforcement screening tool.

DESIGN REQUIREMENTS
FOR
HIGH SPEED WIM FOR WEIGHT ENFORCEMENT SCREENING

Function

- Automatic Operation
- Manual Mode
- Traffic Management System
- Visual Display Unit
- Printer Unit
- Violation Detection
- Error Indication

Components

- Axle Scales
- Presence Transducers
- Speed Detection Components
- WIM Data Processing Unit
- Video Display/Printer/Keyboard (Enclosures)
- Traffic Management Components
- Cartridge Type Recorder
- Telephone Modem

Software Program

- Single Axle Weight Determination
- Tandem Axle Weight Determination
- Bridge Law Weight Determination
- Gross Vehicle Weight Determination
- Axle Spacing In Feet
- Overall Vehicle Wheelbase
- Vehicle Speed
- Vehicle Classification
- Program Documentation
  - Program Listing/Descriptions
  - Detailed Flow Chart
  - Functional Description of Modes
  - Revision Numbers/Dates
  - Description of Outputs Including Port Numbers and Memory Addresses

Traffic Management

- Select Out Potentially Overloaded Trucks
- Direct Overloaded Trucks to Static Scale
- Direct Legal Trucks to Bypass
- Select Trucks at Random for Safety Inspection
- Direct Trucks that Miss Pads or Change Speed to Static Scale
- Track all Trucks Through System
- Identify Failure to Obey Signal System
- Signal Weighmaster of Violations

APPENDIX M

OUTLINE REQUIREMENTS FOR A WIM SYSTEM

A weigh-in-motion (WIM) system shall automatically identify those trucks in a moving traffic stream which are in weight violation of a State's Vehicle Code as they enter the lane leading to an enforcement weigh station's static scale.

Those trucks that are not in weight violation may be directed through appropriate traffic signals to return to the highway, before they reach the station, and those that are identified as overweight shall be directed through appropriate traffic signals to the weigh station for enforcement weighing on the static scale (see Figure M-8).

The WIM system shall consist of axle scale(s) embedded flush with the pavement surface in the truck scale lane about 800 feet upstream from the weigh station and with appropriate truck presence and loop detectors.

The signals from the above components shall be routed to the weigh station and connected to the WIM instrumentation system installed therein. The system shall process the signals and communicate to the weighmaster those trucks that are in weight violation as each one crosses the WIM scale(s). In addition, the signals shall be processed by the WIM intrumentation system to generate proper outputs for use in a truck traffic management system to 1) direct overweight trucks to the static weigh scale for enforcement weighing, 2) direct non-violators to take the bypass lane back to the highway, and 3) detect violators that have entered the bypass lane.

The minimum components are shown in Figure M-1.

Figure M-2 lists a part of the performance requirements for the WIM system.

WIM Axle Scale

On the static scale approach lane, WIM axle scale(s) shall be embedded flush in the pavement lane to measure the dynamic axle forces on it and, with the associated instrumentation, to derive the (static) weight of the moving axle.

The axle scale may consist of one integral axle scale, or a left-track and a right-track wheel scale. Either one, but not more than two axle scales (in tandem) shall comprise a WIM system. If two axle scales are provided, they shall be separated by about 16.4 feet (5 meters).

The axle scale(s) shall consist of the scale proper and its foundation frame. The transducers within the scale proper shall be sealed against moisture without the use of pressurized gas.

If the axle scale consists of one integral platform, it shall be at least 132 inches wide; if it consists of a left-track and a right-track wheel scale, each scale shall be at least 66 inches wide.

WIM Accuracies

1. The WIM weight accuracy is defined in terms of percent error of the static weight as follows:

$$\% \text{ error} = \frac{\text{WIM Weight} - \text{Static Weight}}{\text{Static Weight}} \times 100.$$

2. The WIM axle spacing accuracy is defined in units of feet of error to the nearest 0.1 feet as follows:

Axle spacing error = WIM axle spacing (ft) - True axle spacing (ft)

3. The WIM speed accuracy is defined in units of miles per hour of error to the nearest 0.1 mph as follows:

Speed error = WIM speed (mph) - True speed (mph)

The required accuracies for WIM axle weights, gross weights, vehicle presence, axle spacings, and speed are set forth in Figure M-2.

Data Display

Data display shall be in two general formats (shown in Figures M-4 and M-6) and selectable by the operator. The proposed format for display shall be submitted for approval.

The WIM system shall retain in memory at least the last 20 trucks weighed and shall be available for reviewing on the CRT by forward and reverse scrolling.

Violation Signal

The WIM system shall provide output signal(s) that a weight violation has occurred. The signal will be used in the truck traffic management system to activate traffic signals to direct violators to the appropriate lane for further processing.

California Vehicle Code (CVC)

The WIM system shall incorporate the sections on "Computation of Allowable Gross Weight" of the state's CVC into the computational software program. The CVC on allowable gross weights are shown in Figure M-3. The display shall be in the general format shown in Figure M-4 to visually communicate to the operator any and all axle and/or gross weight limit violations as listed in Figure M-3.

Listed below are the general requirements for the computer program in accordance with the present CVC sections:

a. Steering (No. 1) axle limited to 12,500 lbs. in all cases.

b. Entry into lookup table (Figure M-3) based on axle spacing (ft.) as determined by Subsection (c) of that section; i.e., tenth values <0.5 ft. will truncate to the foot, and tenth values ≥ 0.5 ft. will increase lookup dimension to the next greater foot.

c. Gross vehicle weight cannot ever exceed 80,000 lbs. Axle group weight can never exceed 40,000 lbs. for the two axles, 60,000 lbs. for three axles, or 80,000 lbs. for four or more axles.

d. Tandem axles will be defined as a limit of 6 feet and Subsection (b) may override the lookup value of allowed weight.

e. Wheel weight limit of 10,500 pounds supporting one end of an axle shall be excluded in the software program.

Any violations shall be communicated to the operator via the general format of Figure M-4, with continuous CRT update display and with a keyboard entry for choice of continuous hard copy printout when desired. Only axle groups with weight violations and/or with axle combinations within a certain percentage of CVC listed weight need be displayed. The WIM system shall be programmable for threshold of 80% to 100% of axle weight limits so that it will display only WIM axle groups that weigh above 80%, 85%, 90%, 95%, or 100% of CVC listed axle weights.

The attached Figure M-4 illustrates the general format required. For example, a hypothetical truck, No. 456, is shown in Figure M-5 listing its axle spacings and axle weights. In accordance with the CVC sections, this truck is overweight for axle groups 2345, 45, and 12345 (gross weight). The overweight violations shall be displayed in the general format as shown in Figure M-4. For this particular dynamic weighing, the threshold was hypothetically set for displaying only trucks weights > 100% of CVC listed weight.

Program Documentation

The computer program shall be written and the documentation shall be sufficient so that a knowledgeable programmer can modify the coding. The WIM system shall include full program documentation as follows:

1. Program listing with detailed comments to describe operation of each module (subroutine). For assembly language, it shall include, at the minimum, complete source and object statements (code) with comments and with complete symbol and cross-reference table.

2. Detailed flow chart.

3. Functional description of each module.

4. The revision number.

5. Date of last revision.

6. An abstract - a comprehensive explanation of the purpose of each module, clearly describing all paths involved.

7. An English description of each required input, including port numbers and/or memory addresses.

8. The end result of an English description of each output, including port numbers and/or memory addresses.

Factory Performance Test

The Contractor shall factory test the WIM system to ensure its proper functional operation prior to shipment. For the tests, the Contractor, at his option, may simulate the transducer analog outputs of the scales, loop detectors and presence detectors. The factory test shall consist of 18 trucks or simulated trucks crossing the WIM scale(s) with individual truck data as listed in Figure M-7. A hard copy printout of the above factory performance test, in the general format of Figure M-4, shall be supplied to the State as evidence of a successful functional operation of the system prior to shipment.

Truck Traffic Management

Figures M-8 and M-9 are outlines of a screening and truck traffic management and identification system. Requirements for such a system are discussed in pages M-20 through M-22.

Acceptance Testing

The acceptance testing period shall be 60 consecutive calendar days. A successful acceptance test shall meet the following:

1. Meet all requirements and that listed in Figure M-2. Data will be collected to determine that the listed $\bar{x}$ and s for all measurements meet listed errors.

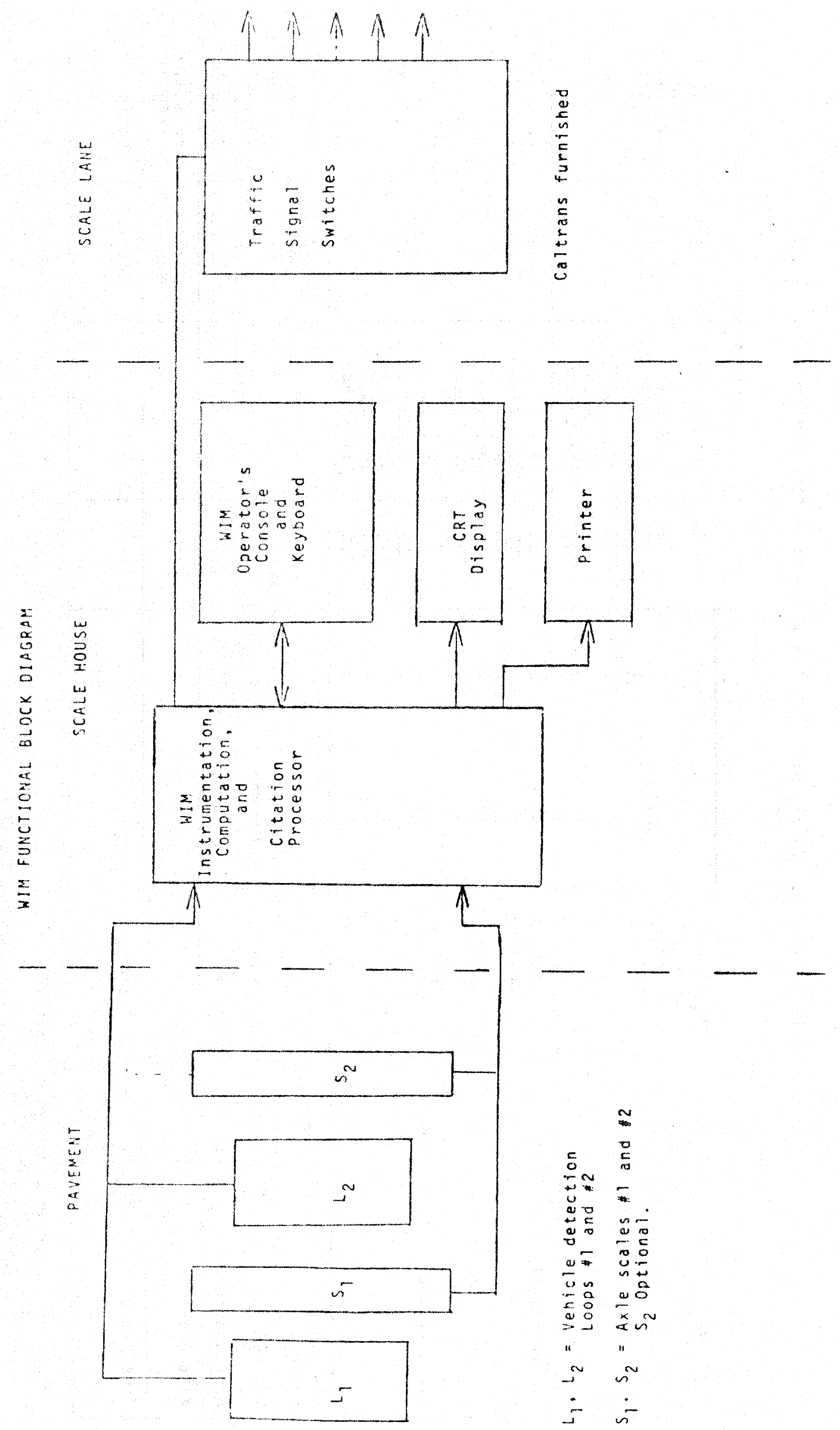
2. The WIM system shall be operational for its intended purpose at least 80% of the time the station is open for static enforcement weighing.

3. Demonstrate the system for on-line production screening and weighing as conceived.

Longevity

The embedded scales shall reliably and correctly perform its weighing function up to 10 million accumulated truck axle loadings, or four (4) years of continuous operation, whichever occurs first.

Figure M-1



WIM FUNCTIONAL BLOCK DIAGRAM
PAVEMENT
SCALE HOUSE
SCALE LANE
L1
S1
L2
S2
WIM Instrumentation, Computation, and Citation Processor
WIM Operator's Console and Keyboard
CRT Display
Printer
Traffic Signal Switches
Caltrans furnished
L1, L2 = Vehicle detection Loops #1 and #2
S1, S2 = Axle scales #1 and #2 S2 Optional.

DATA AND ACCURACY REQUIREMENTS FOR WEIGH-IN-MOTION SYSTEM

Measurand	Range	Resolution	Error $\overline{X}$	Error S	n	Speed, mph	Sensor	Signal
Single Axle Weight	20,000 pounds	100 pounds	- ±4% 4 4 4 4	1 7 7 7 7 7	30 40 160 160 40 400	Static 10 - 19.9 20 - 29.9 30 - 39.9 40 - 49.9 All Speeds	Axle Scale(s)	dc analog signal
Tandem Weight	40,000 pounds	100 pounds	±4% 4 4 4 4	5 5 5 5 5	20 80 80 20 200	10 - 19.9 20 - 29.9 30 - 39.9 40 - 49.9 All Speeds	Axle Scale(s)	dc analog signal
Gross Weight	100,000 pounds	100 pounds	±4% 4 4 4 4	4 4 4 4 4	20 80 80 20 200	10 - 19.9 20 - 29.9 30 - 39.9 40 - 49.9 All Speeds	Axle Scale(s)	dc analog signal
Vehicle Presence	Yes or No	--	-	-			Detection Loops	Logic signal (level)
Vehicle Speed	10-50 mph	0.1 mph	±0.2 mph	0.2 mph	--	--		Computed
Axle Spacing	70 ft.	0.1 ft.	±0.15 ft	0.15 ft	--	--		Computed
Axle Count	2 - 10	1	-	-	--	--	Axle Scale(s)	dc analog signal
Time, Date	24-hour clock, day, month, year	1 sec.	-	-	--	--	Digital	Logic

NOTES: $\overline{X}$ = Average error (% or unit)
S = Standard Deviation
n = Minimum sample size for calculating $\overline{X}$ and S

Reliability: The embedded scales shall correctly perform its weighing function up to 10 million truck axle loadings or four years of continuous operation, whichever occurs first.

Vehicle Speed Change: Requirements as setforth in Figure N-1 "Axle Spacing Measurement Error with Speed Change".

MAXIMUM WEIGHT ON SINGLE AXLE OR WHEELS

(a) The gross weight imposed upon the highway by the wheels on any one axle of a vehicle shall not exceed 20,000 pounds and the gross weight upon any one wheel, or wheels, supporting one end of an axle, and resting upon the roadway, shall not exceed 10,500 pounds, except that the gross weight imposed upon the highway by the wheels on any front steering axle of a motor vehicle shall not exceed 12,500 pounds.

(b) The gross weight limit provided for weight bearing upon any one wheel, or wheels, supporting one end of an axle shall not apply to vehicles the loads of which consist of livestock.

(c) The following vehicles are exempt from the front axle weight limits specified in this section:

(1) Trucks transporting vehicles.

(2) Trucks transporting livestock.

(3) Dump trucks.

(4) Cranes.

(5) Buses.

(6) Transit mix concrete or cement trucks, and trucks that mix concrete or cement at, or adjacent to, a jobsite.

(7) Motor vehicles that are not commercial vehicles.

(8) Vehicles operated by any public utility furnishing electricity, gas, water, or telephone service.

(9) Trucks or truck tractors with a front axle at least four feet to the rear of the foremost part of the truck or truck tractor, not including the front bumper.

(10) Trucks transporting garbage, rubbish, or refuse.

(11) Trucks equipped with a fifth wheel when towing a semitrailer.

(12) Tank trucks which have a cargo capacity of at least 1,000 gallons.

(13) Trucks transporting bulk grains or bulk livestock feed.

COMPUTATION OF ALLOWABLE GROSS WEIGHT

(a) Except as otherwise provided in this section or Section the total gross weight in pounds imposed on the highway by any group of two or more consecutive axles shall not exceed that given for the respective distance in the following table:

Distance in feet between the extremes of any group of 2 or more consecutive axles	2 axles	3 axles	4 axles	5 axles	6 axles
4	34,000	34,000	34,000	34,000	34,000
5	34,000	34,000	34,000	34,000	34,000
6	34,000	34,000	34,000	34,000	34,000
7	34,000	34,000	34,000	34,000	34,000
8	34,000	34,000	34,000	34,000	34,000
9	39,000	42,500	42,500	42,500	42,500
10	40,000	43,500	43,500	43,500	43,500
11	40,000	44,000	44,000	44,000	44,000
12	40,000	45,000	50,000	50,000	50,000
13	40,000	45,500	50,500	50,500	50,500
14	40,000	46,500	51,500	51,500	51,500
15	40,000	47,000	52,000	52,000	52,000
16	40,000	48,000	52,500	52,500	52,500
17	40,000	48,500	53,500	53,500	53,500
18	40,000	49,500	54,000	54,000	54,000
19	40,000	50,000	54,500	54,500	54,500
20	40,000	51,000	55,500	55,500	55,500
21	40,000	51,500	56,000	56,000	56,000
22	40,000	52,500	56,500	56,500	56,500
23	40,000	53,000	57,500	57,500	57,500
24	40,000	54,000	58,000	58,000	58,000
25	40,000	54,500	58,500	58,500	58,500
26	40,000	55,500	59,500	59,500	59,500
27	40,000	56,000	60,000	60,000	60,000
28	40,000	57,000	60,500	60,500	60,500
29	40,000	57,500	61,500	61,500	61,500
30	40,000	58,500	62,000	62,000	62,000
31	40,000	59,000	62,500	62,500	62,500
32	40,000	60,000	63,500	63,500	63,500
33	40,000	60,000	64,000	64,000	64,000
34	40,000	60,000	64,500	64,500	64,500
35	40,000	60,000	65,500	65,500	65,500
36	40,000	60,000	66,000	66,000	66,000

(CONT)

37	40,000	60,000	66,500	66,500	66,500
38	40,000	60,000	67,500	67,500	67,500
39	40,000	60,000	68,000	68,000	68,000
40	40,000	60,000	68,500	70,000	70,000
41	40,000	60,000	69,500	72,000	72,000
42	40,000	60,000	70,000	73,280	73,280
43	40,000	60,000	70,500	73,280	73,280
44	40,000	60,000	71,500	73,280	73,280
45	40,000	60,000	72,000	76,000	80,000
46	40,000	60,000	72,500	76,500	80,000
47	40,000	60,000	73,500	77,500	80,000
48	40,000	60,000	74,000	78,000	80,000
49	40,000	60,000	74,500	78,500	80,000
50	40,000	60,000	75,500	79,000	80,000
51	40,000	60,000	76,000	80,000	80,000
52	40,000	60,000	76,500	80,000	80,000
53	40,000	60,000	77,500	80,000	80,000
54	40,000	60,000	78,000	80,000	80,000
55	40,000	60,000	78,500	80,000	80,000
56	40,000	60,000	79,500	80,000	80,000
57	40,000	60,000	80,000	80,000	80,000
58	40,000	60,000	80,000	80,000	80,000
59	40,000	60,000	80,000	80,000	80,000
60	40,000	60,000	80,000	80,000	80,000

(b) In addition to the weights specified in subdivision (a), two consecutive sets of tandem axles may carry a gross weight of 34,000 pounds each if the overall distance between the first and last axles of such consecutive sets of tandem axles is 36 feet or more. The gross weight of each set of tandem axles shall not exceed 34,000 pounds and the gross weight of the two consecutive sets of tandem axles shall not exceed 68,000 pounds.

(c) The distance between axles shall be measured to the nearest whole foot. When a fraction is exactly six inches, the next larger whole foot shall be used.

(d) Nothing contained in this section shall affect the right to prohibit the use of any highway or any bridge or other structure thereon in the manner and to the extent specified in Article (commencing with Section .) and Article (commencing with Section) of this chapter.

(e) The gross weight limits expressed by this section and Section shall include all enforcement tolerances.

FIGURE M-4

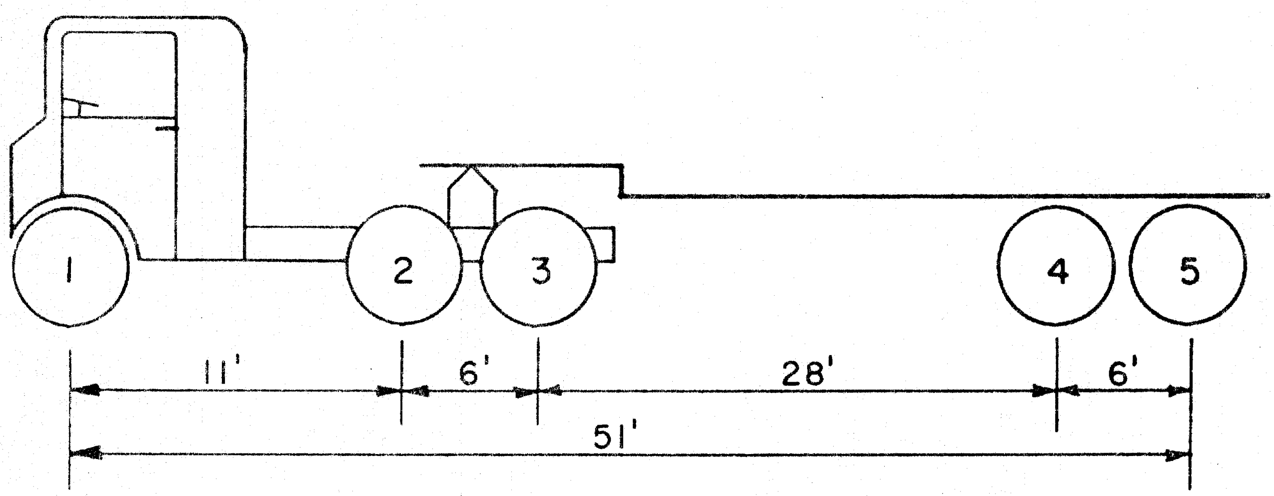
WIM SYSTEM

DISPLAY FORMAT FOR HYPOTHETICAL TRUCK CVC VIOLATION

Date	Truck No.	Axles	Axle Group	Spacing	Allowable	WIM Wt.	Diff.	Stop
5-27-81	456	4	25	40	68.5	70.0	+1.5	
5-27-81	456	2	45	6	34.0	36.0	+2.0	
5-27-81	456	5	15	51	80.0	82.5	+2.5	

FIGURE M-5

A HYPOTHETICAL TRUCK AXLE WEIGHTS AND SPACING



Axles	CVC 35550 & 35551 Weight Limit	Weight	Violation	Axle Spacing
1	12500	12500	–	-
2	20000	20000	–	-
3	20000	14000	–	-
4	20000	20000	–	-
5	20000	16000	–	-
1 2	32500	32500	–	11'
1 2 3	46500	46500	–	17'
2 3	34000	34000	–	6'
2 3 4	60000	54000	–	34'
2 3 4 5	68500	70000	+1500	40'
3 4 5	60000	50000	–	34'
4 5	34000	36000	+2000 -	6'
1 2 3 4 5	80000	82500	+2500	51'
1 2 3 4	72000	66500		45'
3 4	40000	34000		28'

1 axle limited to 12,500 pounds at all times in the software program.

There are 13 exceptions which the weighmaster will qualify in determining final compliance.

Figure M-6

0113 7-29-81-1515	SP: 12.5		GW: 27.2			TL: 57.2		AX: 5		
	AW:	8.3		6.6		6.3		2.8		3.2
	TW:				12.9				6.0	
	AS:		15.8		4.6		32.3		4.5	
0114 7-29-81-1518	SP: 10.1		GW: 11.4			TL: 16.0		AX: 3		
	AW:	5.4		3.2		2.8				
	TW:				6.0					
	AS:		11.6		4.4					
0001 7-30-81-0800	SP: 22.5		GW: 75.4			TL: 63.2		AX: 5		
	AW:	8.3		17.7		18.3		17.5		13.6
	TW:									
	AS:		14.9		15.4		17.0		15.9	

SYMBOLS

SP: Speed in miles per hour
GW: Truck gross weight in Kips (1,000 pounds)
TL: Total truck length between outer axles in feet.
AX: Number of axles
AW: Axle wieght in Kips (1,000 pounds)
TW: Tandem axle weight in Kips (1,000 pounds)
AS: Axle spacing in feet.

Figure M-7

TRUCKS WITH VARIOUS WEIGHT VIOLATIONS PER CVC 35550 AND 35551

Truck No.	Axle 1 (lbs)	S1	Axle 2 (lbs)	S2	Axle 3 (lbs)	S3	Axle 4 (lbs)	S4	Axle 5 (lbs)	S5	Axle 6 (lbs)	Axle Group Violation: Axles	Axle Group Violation: Violation (lbs)	Gross Weight
458	13,000	12.0	20,000											33,000
V	500													
459	11,500	11.5	20,000	28.0	20,500									52,000
V					500							23	500	
460	11,000	15.0	20,000	9.0	20,000									51,000
V												23	1,000	
461	13,000	11.0	19,000	30.0	22,000									54,000
V	500				2,000							23	1,000	1,500
462	9,000	30.0	20,000	4.0	20,000									49,000
V												23	6,000	2,500
463	10,000	27.0	19,000	9.0	20,000	33.0	21,000							70,000
V							1,000					34	1,000	
464	9,000	12.0	18,000	35.0	17,000	4.0	17,000							61,000
V														
465	12,500	16.0	20,000	4.5	20,000	32.0	20,000							72,500
												23	6,000	
V												123	6,000	6,000*
V												234	6,000*	
466	10,000	27.0	16,000	34.0	17,000	5.0	17,000							60,000
V														
467	12,000	9.0	18,000	27.0	20,000	10.0	20,000	20.0	20,000					90,000
V														10,000
468	13,000	24.0	19,000	12.0	20,000	34.0	15,000	5.0	15,000					82,000
V	500													2,000
469	10,000	36.0	18,000	4.0	18,000	10.0	17,000	30.0	17,000					80,000
V												23	2,000	
470	12,000	20.0	17,000	4.0	17,000	30.0	18,000	4.0	18,000					82,000
V												45	2,000	2,000
471	12,000	12.0	20,000	31.0	12,000	4.0	12,000	4.0	12,000					68,000
V												345	2,000	
472	9,000	12.0	12,000	4.0	12,000	20.0	17,000	6.0	18,000	20.0	16,000			84,000
V												45	1,000	4,000
473	8,000	20.0	13,000	4.0	13,000	9.0	21,000	23.0	12,000	4.0	12,000			79,000
V							1,000					234	1,500	
474	8,000	14.0	14,000	4.0	14,000	20.0	16,000	4.0	16,000	20.0	15,000			83,000
V														3,000
475	8,000	15.0	18,000	4.0	18,000	30.0	12,000	4.0	12,000	4.0	12,000			80,000
V												23	2,000	
												456	2,000	

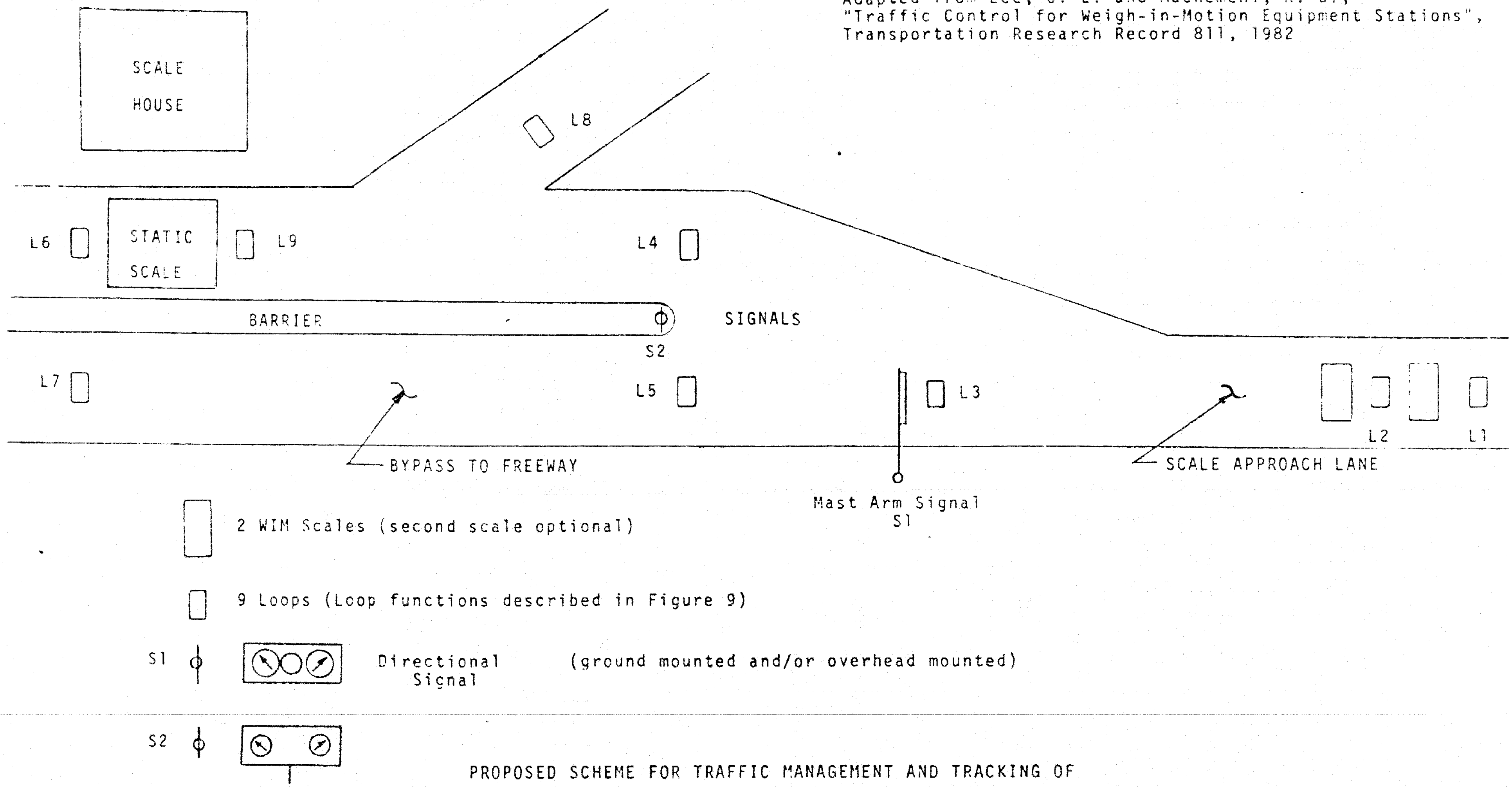
V = Axle, axle group and gross weight violation in pounds

S = Axle spacing in feet.

* = Not in computer program.

Figure M-8

Adapted from Lee, C. E. and Machemehl, R. B.,
"Traffic Control for Weigh-in-Motion Equipment Stations",
Transportation Research Record 811, 1982



PROPOSED SCHEME FOR TRAFFIC MANAGEMENT AND TRACKING OF
TRUCKS THROUGH THE CHP LIVERMORE WEIGH STATION

Scale: None

Figure M-9

PROPOSED LOOP FUNCTIONS FOR A TRAFFIC MANAGEMENT SCHEME

Loop	Function
1	Detects truck presence for WIM Scale No. 1.
2	Detects truck presence for optional WIM Scale No. 2.
3	Control directional signal to direct truck to static scale or to bypass lane. Synchronize with L4 or L5 to update directional signal. Returns S1 signal control to WIM microprocessor for next following truck.
4	Detects truck in static lane and beyond sight of directional signal. Synchronize with L3 and update directional signal for next following truck.
5	Detects truck in bypass lane and beyond sight of directional signal. Synchronize with L3 and update directional signal for next following truck. Identify violator in bypass lane.
6	Detects truck passed static scale. Update operator's WIM display for the next following truck in the scale lane.
7	Detects truck beyond scale house in the bypass lane. Update operator's WIM display for the next following truck in the scale lane.
8	Detects truck returning to static scale for reweighing.
9	Switch for delayed operator display of truck approaching static scale.

Truck Traffic Management

State of the Art Signal Systems

A state of the art method for managing truck traffic at a weigh station, where WIM scales are used for screening in advance of the static scale, calls for two overhead signals, having a red X or a green arrow under control of the WIM scale. When trucks bunch up, this type of signal system can easily be misread. Lee and Machemehl (ref 16) have suggested an improved signal system consisting of a three- section signal face (S1, Fig M-8), mast-arm mounted, and 250 feet upstream from the WIM screening scale followed by a two-section signal (S2), ground mounted, in the gore between the bypass and static scale lanes. The green ball at S1 is continuously illuminated to keep traffic moving while directional green arrows tell the drivers which lane to take.

Deficiencies

Queuing

At high-volume weigh stations, headways tend to shorten and intervals between trucks tend to close as peaking occurs. Queuing in the static scale lane will occur at peak periods when demand is greater than capacity. Two studies in California have pegged the maximum flow rate for a single static scale at 140 to 150 vehicles per hour thus averaging 24 to 26 seconds for each truck.

Current weigh-in-motion state of the art is deficient when queuing occurs because the operation cannot identify the data displayed on the video screen in the scale house with its associated truck backed up to the queue. Weight data should not be displayed in the scale house the instant a truck crosses the WIM scale. To avoid confusion, data should be held in computer memory and shown on the video screen just moments before a truck rolls up on the static scale so the operator can match the truck with its own weight data. WIM scale violation should be highlighted (blinking characters) for quick comparison with the static scale readout.

Violator Bypass

State of the art systems requires further development and refinement to alert the operator when a violator (intentionally or unintentionally) gets into the bypass lane.

Safety Inspections

The operator should have some means of randomly selecting legal vehicles from the traffic stream for safety inspections. Some weigh stations in California are fully equipped with covered inspection sheds for conducting comprehensive safety checks. At others, a critical item safety check is conducted on a routine basis.

Proposal

Figures M-8 and M-9 outline a proposal for a truck traffic management and identification system that addresses the deficiencies mentioned above.

The problem of identifying trucks in a queue can be overcome by delaying the operator display until the truck crosses loop L9.

Violators in the bypass lane can be detected by computer logic and by loops L5 and L7 causing an audio or video signal to flash in the scale house.

Random selection of trucks for safety inspections can be accomplished by computer logic and/or operator override of the signal system. In either case, a legal vehicle can be directed away from the bypass lane, across the static scale, and around back of the scale house to the inspection area.

SUMMARY OF WORKSHOP D

USES OF WIM EQUIPMENT FOR BRIDGE LOAD HISTORIES, PAVEMENT LOADING DATA, ETC.

Summary Workshop D - Uses of WIM Equipment for Bridge Load Histories, Pavement Loading Data Etc.

Kris Gupta

Washington Department of Transportation

We had the workshop on users of WIM equipment bridge load histories and pavement loading. I have come up with a slightly different format and based on premise of first finding out that everybody seems to be doing their thing, planners, designers, enforcement people, there is a big lack of coordination, very, very apparent. Based on that finding, my recommendation is let's improve communications. Let's determine the needs. What do we need to get the job done. There is an urgent need for users and collectors of data to get together and determine the type and format of data that needs to be collected. For example, future conferences of this type must include users and providers of this data. In most of the questions and answers planners say this is what we do and this is required but designers are saying we are not getting what we need. We need more sites. So that has to be defined.

Second, extensive data is presently being collected, however, there are some glaring gaps in the types of data needed by the users. So the second recommendation is develop some giant data bases. Every effort should be made to develop giant bases which can be accessed by all users. User needs based on the first recommendation will determine the type of data to be collected. We may have to modify some collection procedures if necessary. Also we may need additional site specific data, and on and on.

The third finding was that the new technology will provide us tools to get massive data at reasonable costs. From all indications it may be too detailed and too much. Again it depends on what you are doing, do you want each axle load, overweight, overlengths or whatever. So based on that finding, our third recommendation is that techniques or tools need to be developed to make use of this data that will come available in the very near future.

Finally, the fourth finding was should multi-million dollar decisions be made without any assurance that monies can be expended in cost-effective manner.

And we are talking of specifically pavement design. In the past we collected whatever FHWA wanted us to collect. But now we are changing the whole process with this state, our management states unless we use it don't collect it. That is the basic philosophy and is really being pushed hard.

So based on that finding of that recommendation, is that additional studies of research is needed in several areas to assure cost-effective use of this data for design purposes. Some of the problem areas identified were the traffic projections and design standards, like how far can we be in the percentages of trucks and still not impact the design.

Second, how could we use average data for specific sites since there is such variation between site to site. Our studies have been all been during the summer time so it is definately biased and something needs to be done about it. Also are AASHTO procedures, developed in the sixties, still valid under present conditions? Are pavement management needs are still being met with the type of data we are collecting. etc., etc.

USES OF WIM EQUIPMENT FOR BRIDGE LOAD HISTORIES, PAVEMENT LOADING DATA, ETC.

MR. KRIS GUPTA, MANAGER
TRANSPORTATION DATA OFFICE
WASHINGTON DEPARTMENT OF TRANSPORTATION
OLYMPIA, WASHINGTON

USE OF WEIGH-IN-MOTION (WIM) EQUIPMENT IN WASHINGTON STATE'S PAVEMENT MANAGEMENT PROGRAM

BY

H. K. GUPTA,

MANAGER, TRANSPORTATION DATA OFFICE

BACKGROUND

WASHINGTON STATE SIGNED A $200,000, TWO YEAR, RESEARCH CONTRACT WITH FHWA IN 1981 TO MONITOR 10 SITES AROUND THE STATE AS PART OF THE LONG-TERM PAVEMENT MONITORING STUDY (LTPMS). THE CONTRACT ALSO COMMITS THE STATE TO CONTINUE MONITORING THE SITES FOR AN ADDITIONAL EIGHT YEARS. THE CONTRACT REQUIRES THE STATE TO WEIGH TRUCKS AT THESE 10 SITES FOR A MINIMUM OF EIGHT HOURS, CLASSIFY VEHICLES AROUND THE CLOCK AT LEAST TWICE A YEAR, AND MAKE TRAFFIC COUNTS FOR A MINIMUM OF SEVEN DAYS EACH QUARTER. (NOTE: DUE TO IN-HOUSE PAVEMENT MANAGEMENT NEEDS AND TO MEET FHWA'S REGULAR TRUCK WEIGHT STUDY REQUIREMENTS, IT WAS DECIDED TO WEIGH AROUND THE CLOCK WHENEVER POSSIBLE.)

FHWA FURTHER RECOMMENDED THE USE OF WEIGH-IN-MOTION (WIM) EQUIPMENT FOR THE STUDY AND ENCOURAGED EQUIPMENT EVALUATION AS PART OF THE CONTRACT. TO FULFILL THE REQUIREMENTS, A SIEMENS WIM SYSTEM (FORMERLY PAT) WAS PURCHASED IN 1982 AND USED FOR FIELD DATA COLLECTION IN THE SPRING OF 1983. THIS PRESENTATION IS BASED ON THE EXPERIENCE OF THIS SPECIFIC EQUIPMENT IN COLLECTING TRUCK WEIGHTS. I'LL BE PRESENTING SOME SLIDES SHOWING THE

EQUIPMENT, ITS USE AT A VARIETY OF LOCATIONS, COSTS OF DATA COLLECTION AND ACCURACY LEVELS OF DATA COLLECTED. THE EQUIPMENT IS DESIGNED FOR ENFORCEMENT PURPOSES AS WELL; HOWEVER, WE HAVE NOT USED IT FOR THAT FUNCTION YET. I WILL ALSO BE DISCUSSING SOME OF THE INNOVATIVE APPROACHES WE ARE CONSIDERING IN COLLECTING ADDITIONAL TRUCK WEIGHT DATA FOR USE IN OUR STATE'S PAVEMENT MANAGEMENT (PM) PROGRAM.

- SLIDE SHOWS THE LOCATION OF THE SITES.
    - (ADD COMMENTS REGARDING HOW WE COMBINE THE FHWA'S TRUCK WEIGHT STUDY REQUIREMENTS WITH THIS STUDY.)
- EQUIPMENT SLIDES - EXPLAIN AS THEY ARE PROJECTED.
- SLIDES SHOW THE FIELD SETUP AT VARIOUS LOCATIONS (TWO LANES, FOUR LANES, REST AREA, ETC.).
- SLIDES SHOW THE FIELD DATA COLLECTION COSTS.
- SLIDES SHOW THE ACCURACY LEVELS RECEIVED AT ONE SPECIFIC SITE.

FUTURE PROGRAMS

MICROCOMPUTERS IN WEIGH STATIONS - THE DEPARTMENT OF TRANSPORTATION IN COOPERATION WITH WASHINGTON STATE PATROL IS INVESTIGATING THE POSSIBILITY OF CAPTURING TRUCK WEIGHT

DATA FROM THE STATE PATROL'S EXISTING WEIGH STATIONS. UNDER STATE LEGISLATION, THE STATE PATROL IS RESPONSIBLE FOR WEIGHT ENFORCEMENT. OF COURSE, THEIR MAIN INTEREST IS IN OVERLOADS FOR ENFORCEMENT PURPOSES; CONSEQUENTLY, THEY DO NOT MAINTAIN ANY STATISTICS AS TO THE TOTAL NUMBER OF TRUCKS, THEIR WEIGHTS OR THEIR CLASSIFICATION. IN THIS PROGRAM, WE ARE PROPOSING TO CAPTURE THE SIGNAL AT ELECTRONIC SCALES (APPROXIMATELY 16 CURRENTLY IN OPERATION), STORE IT IN MINICOMPUTERS AT THE SITE AND TELEMETER THE DATA TO DOT OFFICE AT FREQUENT INTERVALS.

- DISCUSS SLIDES SHOWING THE WASHINGTON STATE PATROL'S TRUCK WEIGHT LOCATIONS AND POINT OUT THE EXTENSIVE COVERAGE IT WILL GIVE OVER THE STATE SYSTEM.

HIGH-SPEED (35-55 MPH) WIM INSTALLATION -- DEMONSTRATION PROJECT

THE DEPARTMENT IS ALSO CONSIDERING TWO HIGH-SPEED INSTALLATIONS OVER THE NEXT TWO YEARS. THE WEIGH PADS WILL BE INSTALLED IN CONJUNCTION WITH PORT OF ENTRY LOCATIONS WHICH ARE PRESENTLY MANNED AROUND THE CLOCK BY THE STATE PATROL. IT WILL GIVE US AN OPPORTUNITY TO DEVELOP HOURLY, DAILY AND SEASONAL PATTERNS ALONG THE TWO INTERSTATE ROUTES. SINCE WIM'S COMPUTER, PRINTER AND OTHER RELATED EQUIPMENT ARE COMPATIBLE WITH HIGH-SPEED INSTALLATION, THE ONLY ADDITIONAL COST INVOLVED WILL BE THE FIELD INSTALLATION AND SOFTWARE NEEDED FOR ANALYSIS OF DATA. IT MAY BE NOTED THAT

THIS DEMONSTRATION WILL BE SUBJECT TO BUDGET APPROVAL AND IS ONLY A PROPOSAL AT THIS POINT.

VEHICLE LENGTH AT PERMANENT TRAFFIC RECORDING (PTR) LOCATIONS

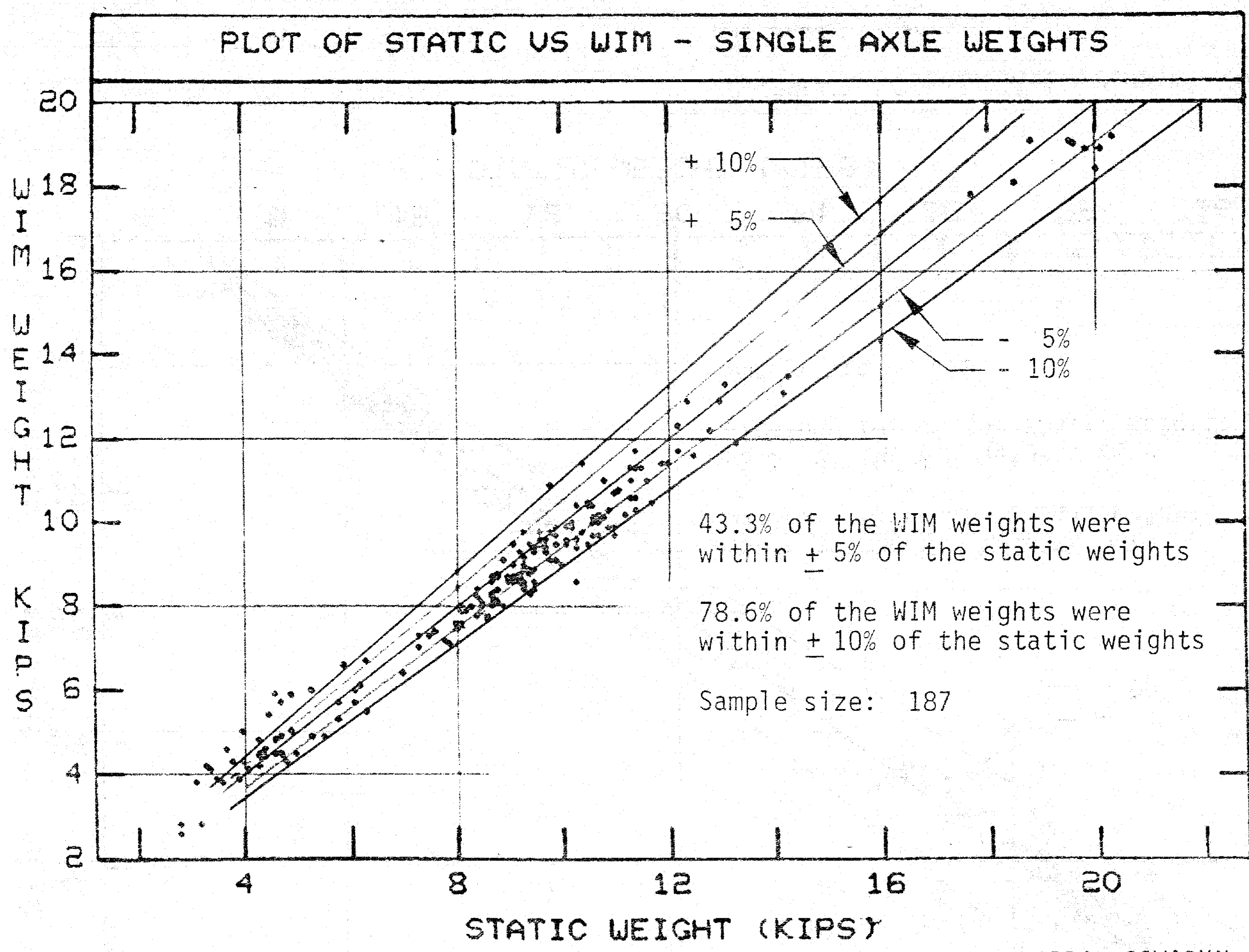
THE STATE RECENTLY PURCHASED GOLDEN RIVER TRAFFIC COUNTING EQUIPMENT FOR UPGRADING THE AGING PTR COUNTERS. PART OF THE EQUIPMENT PURCHASED HAS THE CAPABILITY OF MEASURING VEHICLE LENGTHS. WE HAVE NOT TESTED IT YET; HOWEVER, WE ARE PLANNING TO COLLECT VEHICLE LENGTH DATA IN THE FIELD USING THESE UNITS. AN ANALYSIS WILL BE MADE TO DETERMINE IF THERE IS A CORRELATION BETWEEN THE VEHICLE LENGTHS AND AXLE CONFIGURATIONS. IF CORRELATIONS DO EXIST, THIS WILL PROVIDE AUTOMATED TOOLS TO GET TRUCK CLASSIFICATION DATA AT SUBSTANTIALLY MORE LOCATIONS AT MINIMUM EXPENSE.

SUMMARY

I FEEL THAT THE COMBINATION OF PROGRAMS NOTED ABOVE WILL PROVIDE US THE NECESSARY DATA FOR EFFICIENTLY MANAGING THE LONG-TERM PAVEMENT MANAGEMENT PROGRAM.

HKG:F4/103

ATTACHMENTS



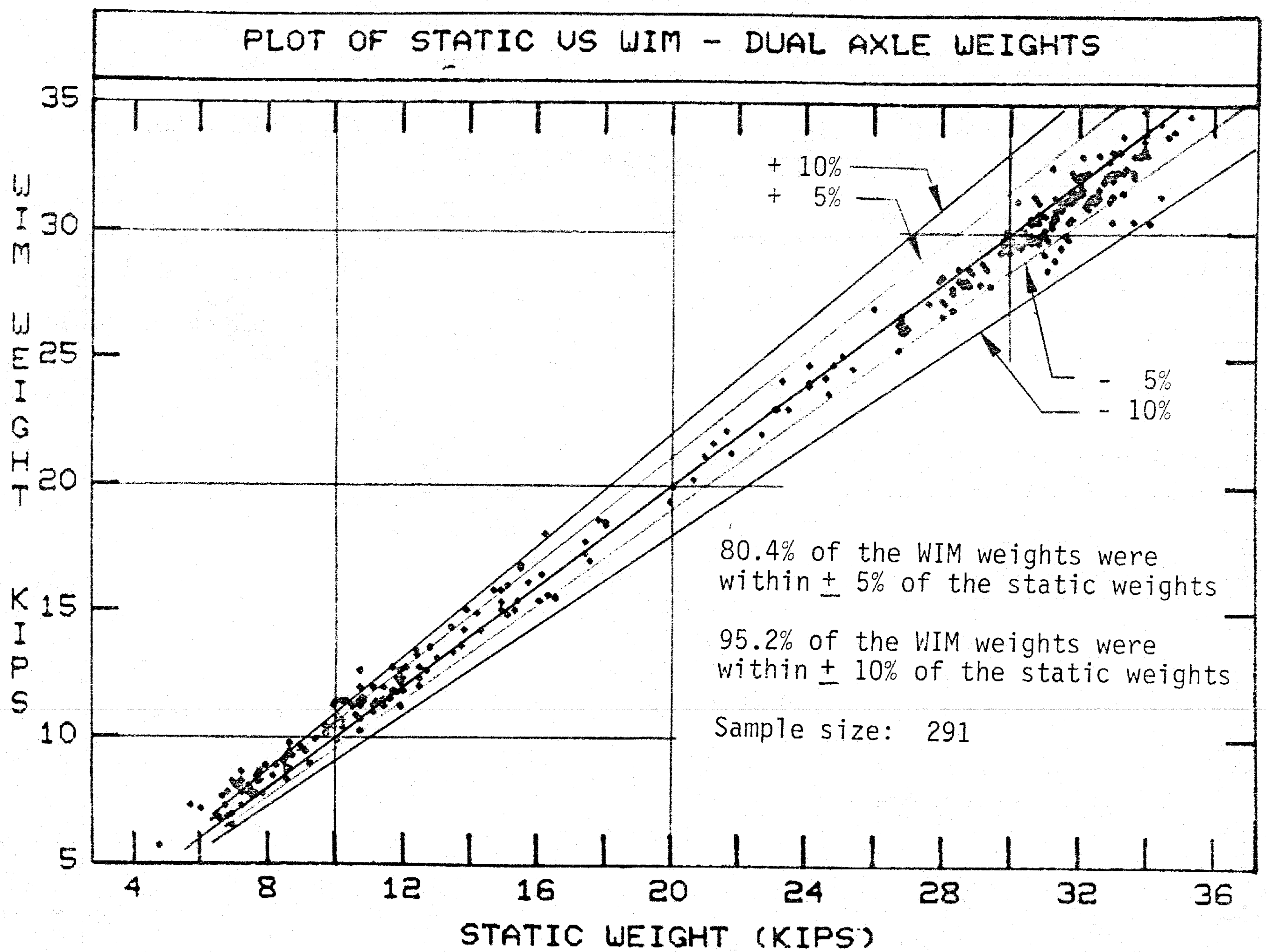
LOCATION: SR 12 (Brady)

DATE: May 23, 24, 1983

EQUIPMENT: Siemens-Allis SIWADYN 400s

RUT DEPTH: < 1/8 inch

Wash. DOT-1



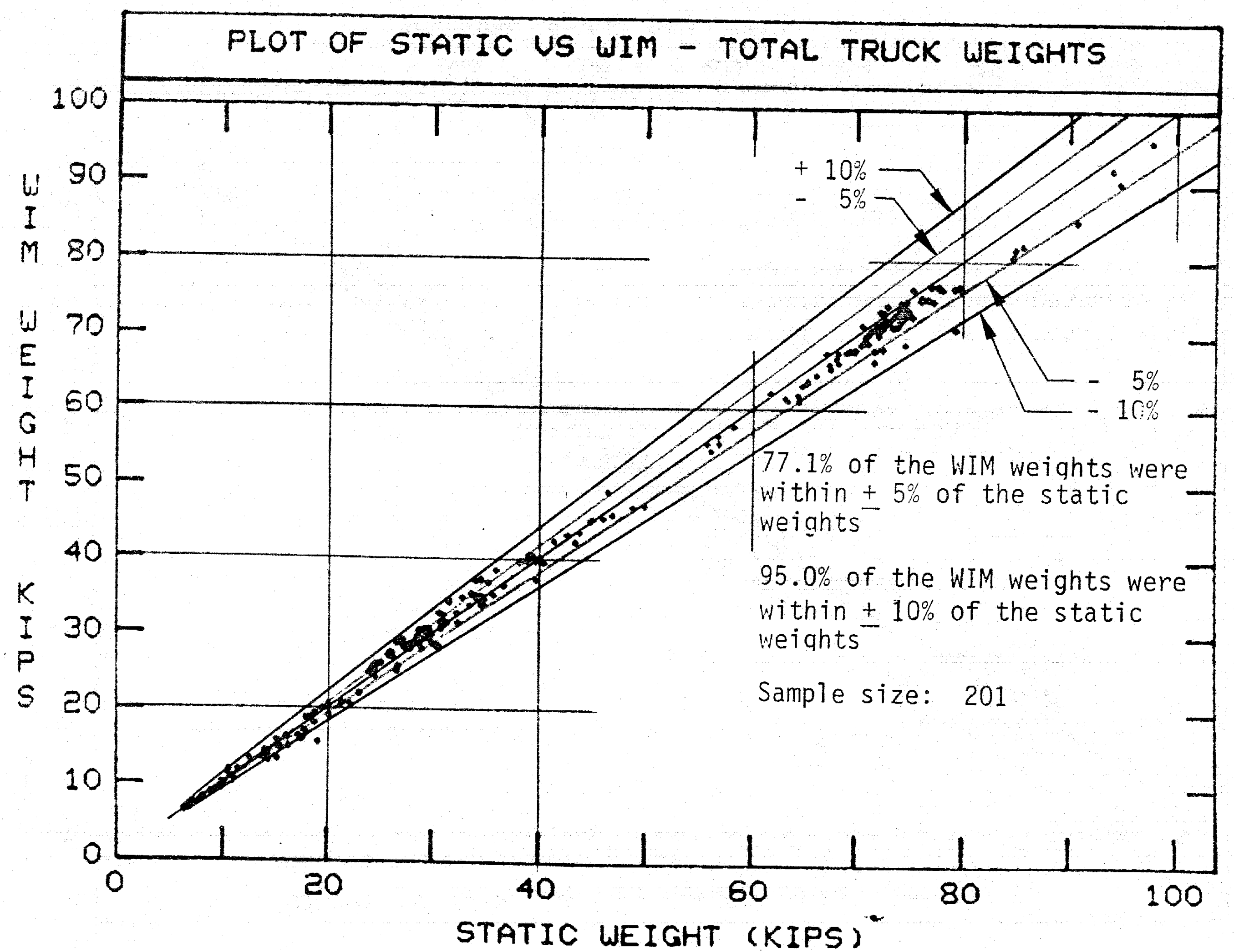
LOCATION: SR 12 (Brady)

DATE: May 23, 24, 1983

EQUIPMENT: Siemens-Allis SIWADYN 400s

RUT DEPTH: < 1/8 inch

Wash. DOT-2

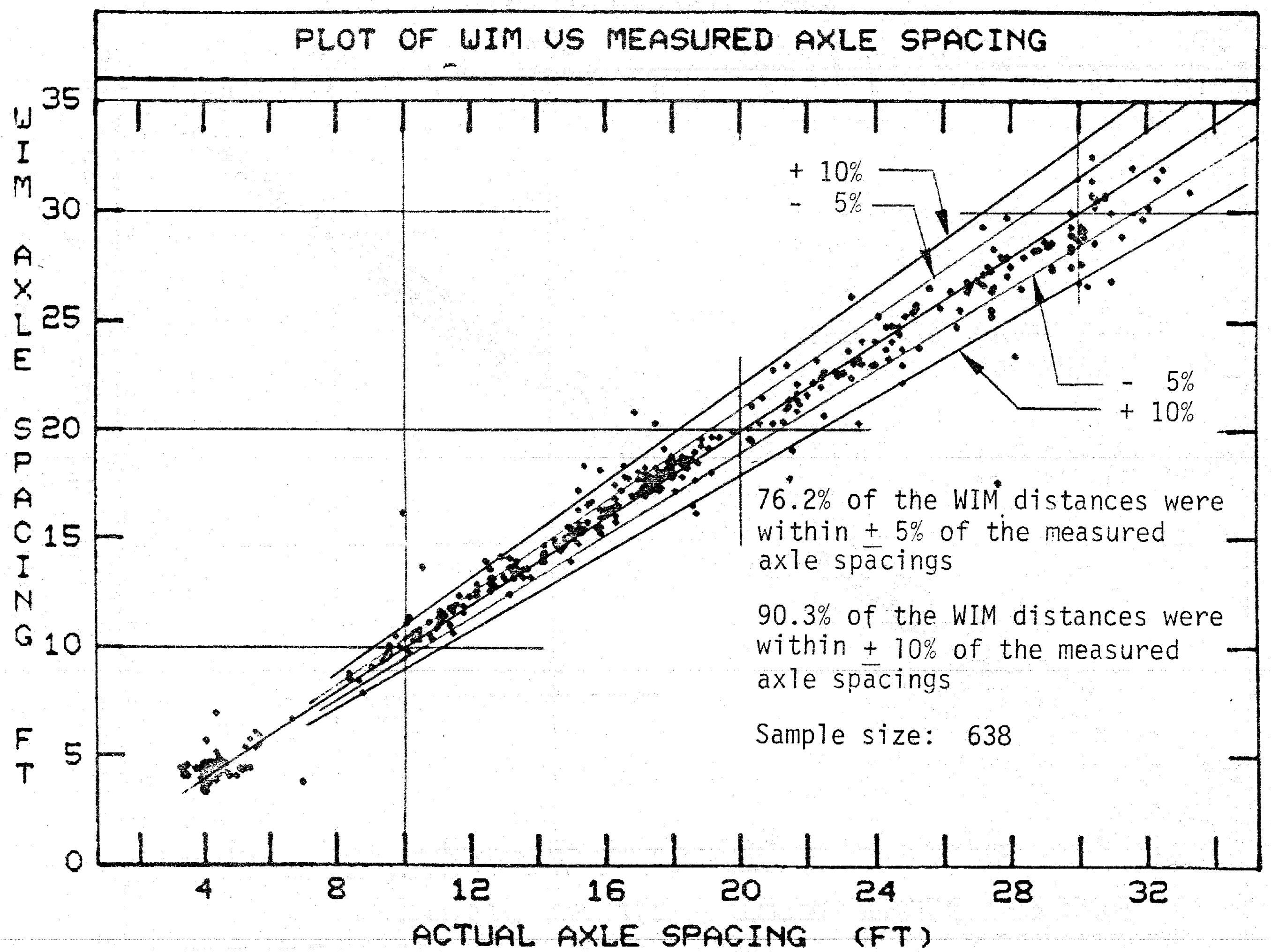


LOCATION: SR 12 (Brady)

DATE: May 23, 24, 1983

EQUIPMENT: Siemens-Allis SIWADYN 400s

RUT DEPTH: < 1/8 inch



LOCATION: SR 12 (Brady)

DATE: May 23, 24, 1983

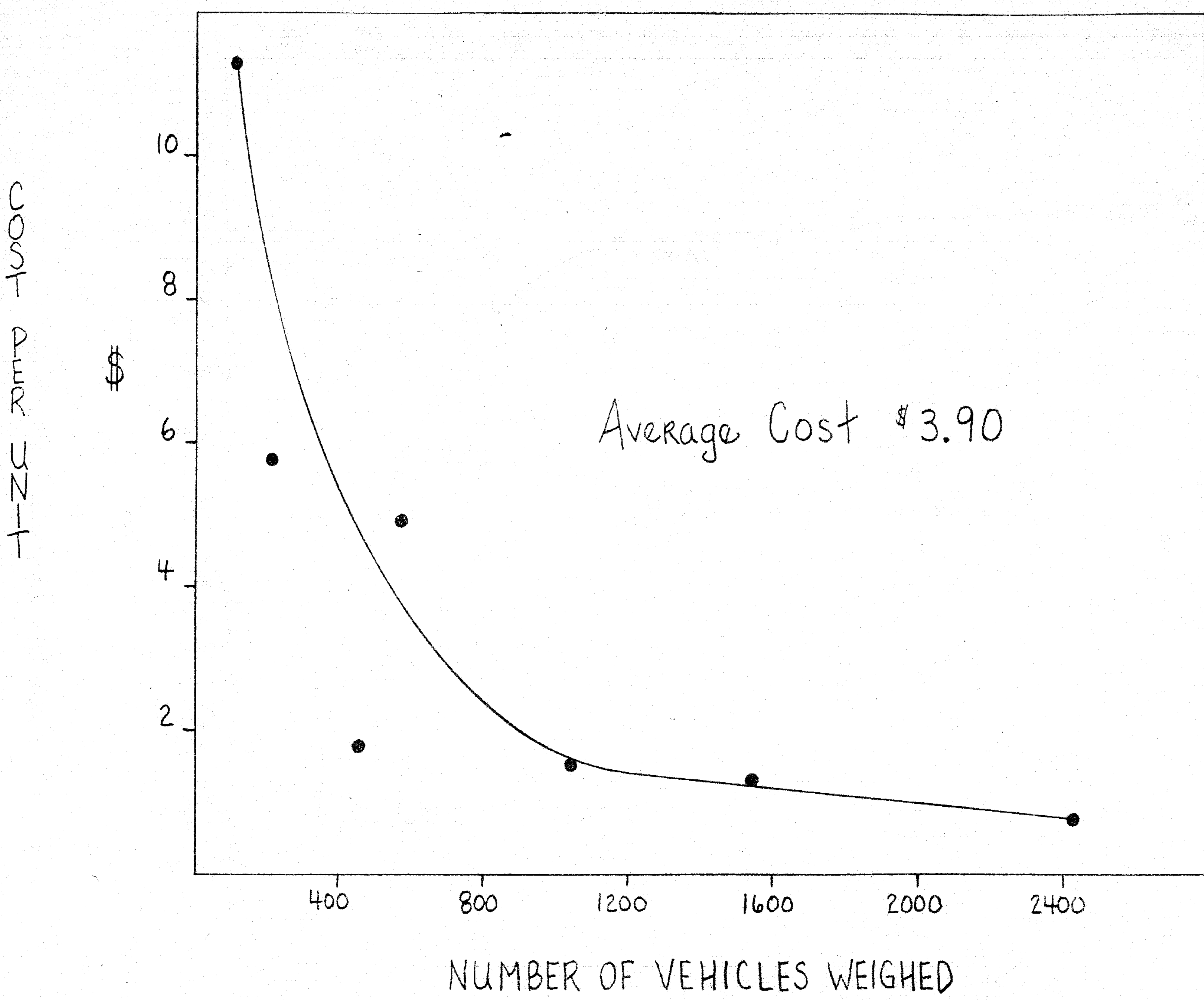
EQUIPMENT: Siemens-Allis SIWADYN 400s

RUT DEPTH: < 1/8 inch

Wash. DOT-4

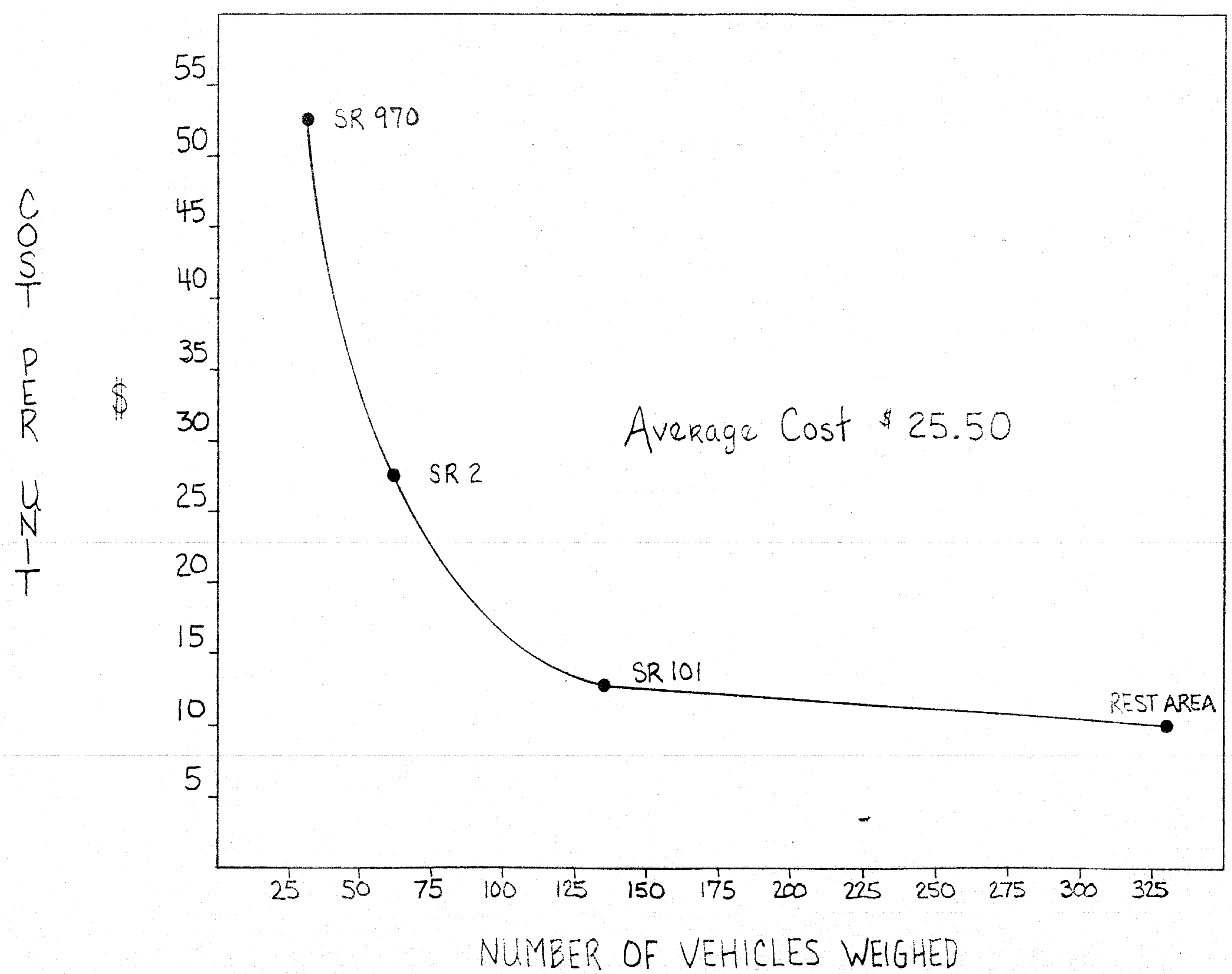
WIM - TRUCK WEIGHT STATIONS

SPRING 1983



WASH. D.O.T. 5

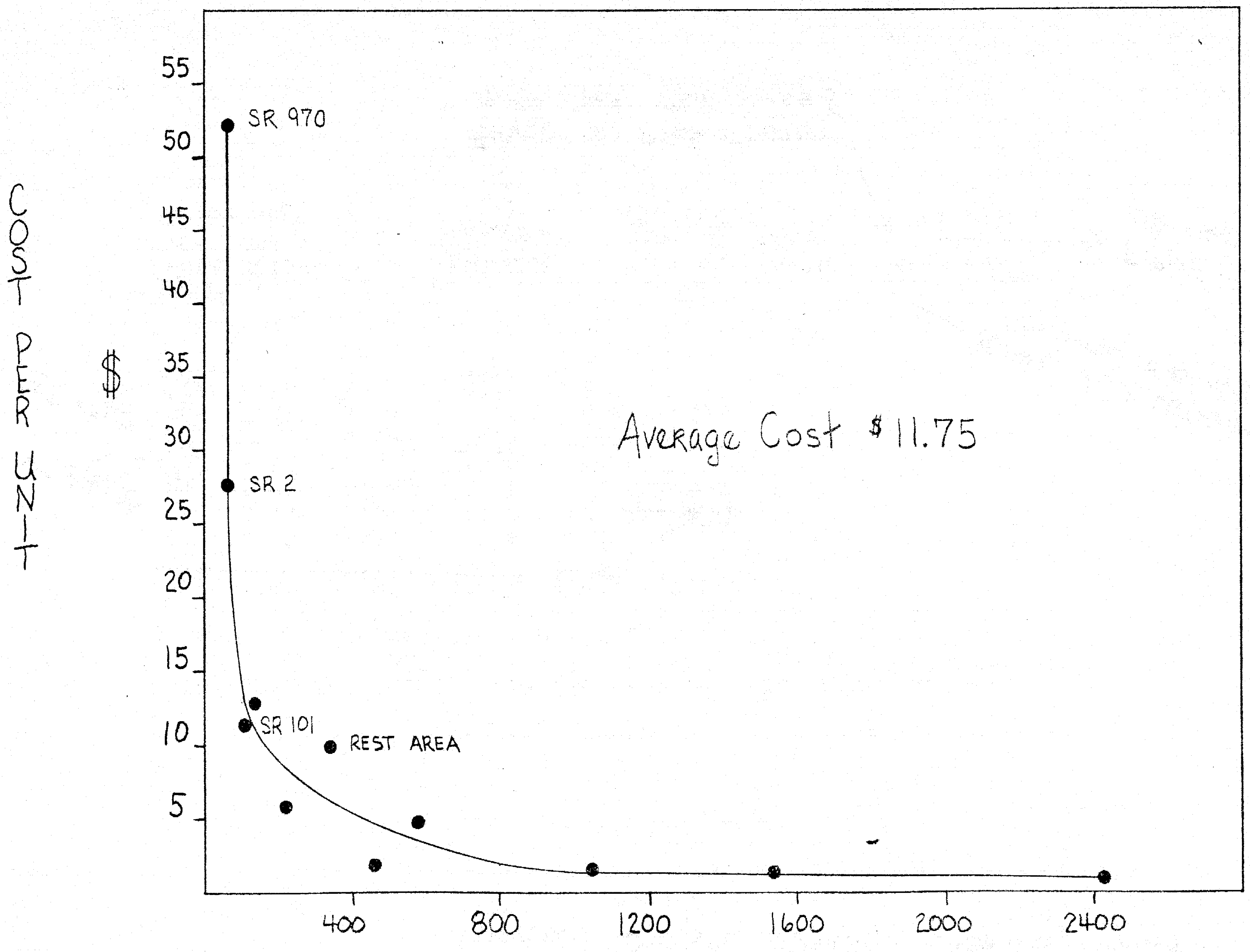
WIM - OTHER STATIONS



SPRING 1983

W.I.M.-ALL STATIONS

SPRING 1983



NUMBER OF VEHICLES WEIGHED

Typical Single Vehicle Display/Print.

```
DATE: 05/24/83   TIME: 14:01:38   STAT.:   30  BLOCK-NO:
                 METRIC   :       LINE-PRINTER :  IS READY !
MEAS-NO:   177   REGISTR.: P    H DATA-RECORDER: NO CARTRIDGE
```

AXLE	LEFT	RIGHT	WEIGHT	SPACE	OV.LOAD ERR
A1	4.80	4.84	9.6		
A2	8.44	8.51	17.0	17.9 ← 1-2	
A3	8.08	8.38	16.5	4.2 — 2-3	
23	16.52	16.89	33.4	**	
A4	8.33	8.59	16.9	22.9 — 3-4	
A5	7.81	8.38	16.2	4.2 — 4-5	
45	16.14	16.97	33.1	**	

WT. A2+A3 (→ 23)

WT. A3+A4 (→ 45)

```
GROSS WEIGHT    :   76160 LBS    VEHICLE-LENGTH :  45.6 FEET
OVER LOAD       :      00 LBS    VEHICLE-CLASS  :  53
MEASUREMENT-NO. :     177        VEHICLE-SPEED  :  3.1 MPH
```

VEHICLE-LENGTH → TOTAL VEH. LENGTH (BUMPER TO BUMPER)

VEHICLE-CLASS 53 → FIRST DIGIT = # of axles; 2ND DIGIT = axle combination

OVER LOAD / VEHICLE-CLASS → BASED ON PARAMETERS SET FOR VEH. CLASS

Typical Total Vehicle Display/Print.

Print Hourly statistical Report

Print each vehicle (IN format BELOW)

for error code (SPEED variation- etc.)

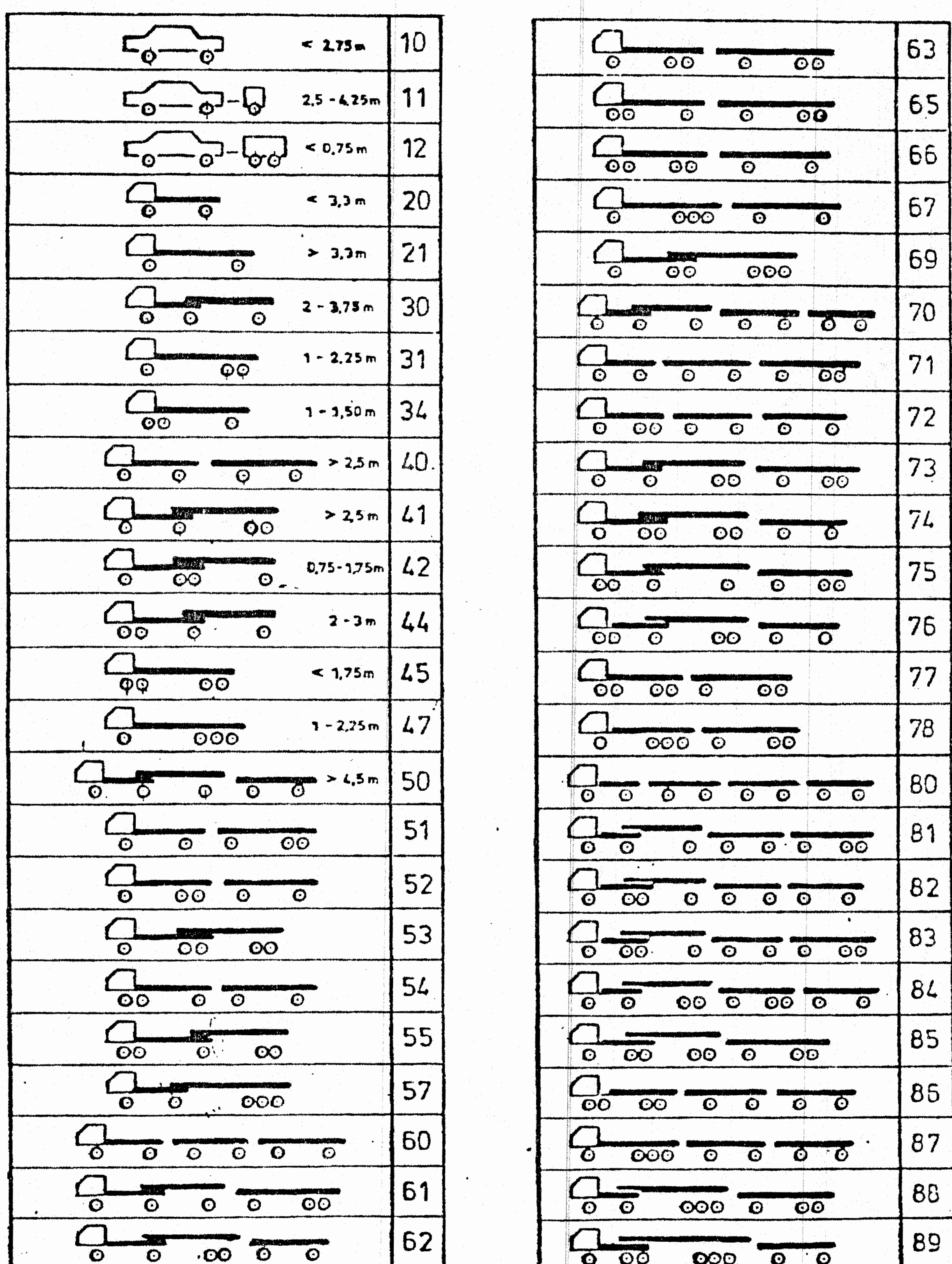
vehicle classification (352 etc)

```
DATE: 05/24/83   TIME: 14:01:56  STAT.:   30  BLOCK-NO:
                 METRIC   :      LINE-PRINTER :  IS READY !
MEAS-NO:    177  REGISTR.: P   H DATA-RECORDER: NO CARTRIDGE
----------------------------------------------------------------
```

NO.	TIME	AWT1	AWT2	AWT3	AWT4	AWT5	*	TOT.	OWT.	SPEED	CAT	M.
177	14:01	9.6	17.0	16.5	16.9	16.2	*	76.1		3.1	53	
176	14:00	2.7	4.4				*	7.0		5.6	10	
175	13:59	8.4	17.4	17.1	16.5	14.9	*	74.2		9.2	53	
174	13:57	7.9	6.0	6.5	3.0	3.3	*	26.6		11.0	53	
173	13:55	2.7	4.1				*	6.7		7.6	10	
172	13:54	4.8	7.9				*	12.7		6.0	21	

SIWADYN
Weighing-in-motion

VEHICLE CLASSIFICATION



First digit = No. of axles
Second digit = axle combination

USES OF WIM EQUIPMENT FOR GRIDGE LOAD HISTORIES, PAVEMENT LOADING DATA, ETC.

MR. WILLIAM LOFROOS
FLORIDA DEPARTMENT OF TRANSPORTATION
TALLAHASSEE, FLORIDA

PAVEMENT DESIGN

THE NEED FOR IMPROVED TRUCK WEIGHT DATA

The purpose of this presentation is to briefly describe the pavement design process and to foster discussions on how weigh-in-motion (WIM) can be utilized to provide the best possible information for the designer.

Pavement design generally deals with three relatively distinct sets of data.

1. The loadings on the pavement.
2. The pavement structure itself.
3. The underlying soils.

The soils upon which a pavement is to be constructed and the material to be utilized for the roadway are relatively well defined. Performance, histories, laboratory tests and experience provide a theoretical and logical basis for utilization of these materials in the design of the pavement structure. The most difficult information to obtain is the loading to be placed on the pavement over the design period. As a result of the AASHO road test, basic equations were developed which utilize equivalent traffic for design purposes, expressed in 18 Kip single axle loads. Procedures for converting mixed traffic to equivalent loadings have been developed.

The prediction of design traffic for new construction is most difficult and requires skilled engineering judgment. As the emphasis shifts from new construction to rehabilitation, it may be possible to increase the accuracy of the data provided to the designer. The importance of having the best possible data for design purposes cannot be over emphasized. An evaluation of the Florida 5 Year Work Program showed that a 3/8" error in the resurfacing work program over the 5 year period would produce a 60 to 70 million dollar variance. Either the roadways would be overdesigned and fewer roads rehabilitated, or the roadway could be underdesigned and require further rehabilitation at an earlier date than anticipated. Both conditions are undesirable.

The present procedure for calculating an 18 Kip single axle load involves the solution of the equation:

$$W_{t18} = \sum_{x=1}^{n} AADT_x \times T_{24} \times 365 \times D \times LF \times E_{18}$$

W_{t18} = Number of 18 kip axle loads to be designed for

AADT = Average Annual daily traffic, both ways

T_{24} = Percent heavy trucks, 24 hours

D = Directional distribution factor, normally 1.0 or 0.5

LF = Lane factor, a reduction factor for multi-lane facilities

E_{18} = 18 kip equivalency factor

x = Annual average value

Each element of the equation is equally sensitive in the sense that a doubling of any factor would double the results. The lane factor and directional distribution factor generally are not subject to any substantial variation. However, the AADT, % trucks and E_{18} equivalency factor must be calculated to represent future conditions. This is a difficult task.

In general terms, the basis for these three variables are:

AADT - Traffic Counts

T_{24} - Classification Data

E_{18} - Weigh-in-motion

The accuracy of all three of these factors is of equal concern, however, developing the E_{18} equivalency factor which most accurately represents the present and future conditions at a specific site is particularly difficult.

One procedure utilized to develop the E_{18} factor involves selecting an appropriate value from a set of tabulated data. These values represent data collected at the Weigh-in-motion (WIM) sites, published in the W-4 tables, and recalculated to reflect the impact of heavy trucks only. The engineer performing the pavement design calculations must attempt to relate his project to a similar weigh-in-motion site by inspection. The data presently tabulated for Florida varies substantially, ranging from 0.231 to 1.486, or a factor of over 6 times. Assuming extreme cases, this means that a project could be designed for either 6 times more loads or one/sixth of the load which may occur. Obviously, this is a crucial determination that must be made by the engineer and is quite subjective.

There is an alternative procedure available for performing these calculations. Two sets of information are needed, vehicle equivalency factors and classification data. Utilizing the data from the W-4 table, it is possible to derive 18 Kip equivalency factors for conventional vehicles by type. A draft copy of the data obtained for Federal Aid Interstate, Rural, 1982 is attached. This data covers 5 weigh-in-motion sites. The second set of data required is classification data at the project site under investigation.

Assuming that the project site can be related to one of the WIM stations; or that the engineer determines that the average equivalency value by vehicle type, average value plus one or two standard deviations, or some other reasonable relationship as yet to be determined can be demonstrated, a procedure for synthesizing the coefficient is available.

Essentially the classification data by standard vehicle type is obtained. Based on this information, the number of heavy vehicles within each classification per 1,000 vehicles is calculated. This data could be entered on a computation sheet. The appropriate corresponding equivalency factor by vehicle type is developed and coded on the sheet. The values by vehicle type are extended and totaled. The equivalency factor is this total value divided by 1,000.

The anticipated benefit of the latter procedure would be the development of more precise coefficients for pavement design, thus better designs. This procedure should more accurately reflect the characteristics of the specific project site if good classification data can be obtained. The anticipated problems include obtaining adequate classification data in a timely manner and statistically valid coefficients. The procedure also does not address the problem that percent trucks and the design coefficient may change over time in a manner similar to AADT.

A thorough review of these procedures and the ability to obtain data required to support them is needed. Several questions come to mind. Can it be demonstrated that one of the procedures is more precise? Are alternative methods available? Do we have statistically valid data to use as input to the computations?

In the past, much of the weigh-in-motion information has been utilized to develop trends. However, designers use this same data everyday as a basis for their designs - frequently multimillion dollar decisions.

The effective utilization of enhanced weigh-in-motion techniques can make a substantial contribution to improve designs. They also may make a substantial contribution to the continuing development of improved pavement management procedures.

An effective Pavement Management System must incorporate a number of modules that utilize truck loading data; monitoring pavement performance, pavement performance modeling, improving design procedures, developing rehabilitation programs based on models of aggregate or individual distress mechanisms, pavement performance modeling, evaluating the procedures for calculating the 18 Kip loads, scheduling maintenance, and developing procedures to optimize the utilization of resources.

Pavement performance, a key element, , is a function of both time (environmental factors) and the loads imposed on the pavement structure. Efforts to model and anticipate future pavement performance are highly dependent on our ability to develop accurate historical loadings as well as future loadings on the pavement structure. At least three sets of loading data appear to be needed, 1. Historical data to measure pavement performance and calculate design data, 2. Design data, 3. Future data (post construction) as it actually occurs in order to compare it with design data.

A sketch of Annual 18 Kip Axle Loads versus Time is attached to illustrate the type of data that could be effectively utilized. Historical data up to the date of design would be used for programming and to develop the design input data. Historical data up to "today" would be utilized to evaluate the anticipated performance of the roadway. In the attached sketch, Design Condition A would indicate a project that potentially would provide longer than anticipated service where Design Condition B would indicate an underdesigned roadway.

Under ideal conditions all of these data elements would be available for all roadway sections under consideration. This may become an overwhelming task from the standpoint of data management and alternative procedures may have to be developed. At the same time, the need for this type information is evident if Departments of Transportation are to most effectively utilize those resources that they have at hand.

W. N. Lofroos

State Pavement Design Engineer

Florida Department of Transportation

July 7, 1983

1979
EQUIVALENCY FACTORS FOR HEAVY TRUCKS
TO 18-KIP EQUIVALANT SINGLE AXLE LOADS

DESCRIPTION				PAVEMENT		
STA.	COUNTY	LOCATION		FLEXIBLE PT = 3.5 SN = 5	FLEXIBLE PT = 3.5 SN = 3	RIGID PT = 2.5 D = 9"
INTERSTATE RURAL						
1	MADISON	I-10	WEST	0.854	1.085	1.257
4	ALACHUA	I-75	NORTH	0.460	0.654	0.641
5	DUVAL	I-95	SOUTH	0.665	0.918	0.904
6	VOLUSIA	I-4	EAST	0.439	0.619	0.577
19	BREVARD	I-95	NORTH	0.380	0.563	0.514
20	SUMTER	I-75	SOUTH	0.490	0.714	0.655
AVERAGE				0.542	0.756	0.744
INTERSTATE URBAN						
14	DUVAL	I-295	NORTH	0.947	1.141	1.486
NON INTERSTATE RURAL						
3	POLK	US-27	NORTH	0.774	0.960	1.078
7	BAY	US-231	NORTH	0.515	0.667	0.736
9	LEVY	US-19	NORTH	0.426	0.565	0.579
10 *	MARION	US-301	SOUTH	0.516	0.708	0.704
13	ST. LUCIE	TURNPIKE	SOUTH	0.870	1.102	1.244
17	CHARLOTTE	US-41	SOUTH	0.445	0.577	0.619
18	HENDRY	US-27	NORTH	0.537	0.727	0.736
AVERAGE				0.643	0.829	0.901
NON INTERSTATE URBAN						
8	LEON	US-319	EAST	0.336	0.439	0.479
11	HILLSBOROUGH	SR-60	EAST	0.634	0.788	0.904
12	ORANGE	SR-436	SOUTH	0.231	0.332	0.302
16	ESCAMBIA	US-29	SOUTH	0.515	0.653	0.728
AVERAGE				0.511	0.647	0.726
ALL RURAL STATIONS				0.589	0.790	0.816
ALL URBAN STATIONS				0.738	0.903	1.121
ALL RURAL AND URBAN STATIONS				0.637	0.827	0.914

* 1978 DATA

TABLE 2

Draft

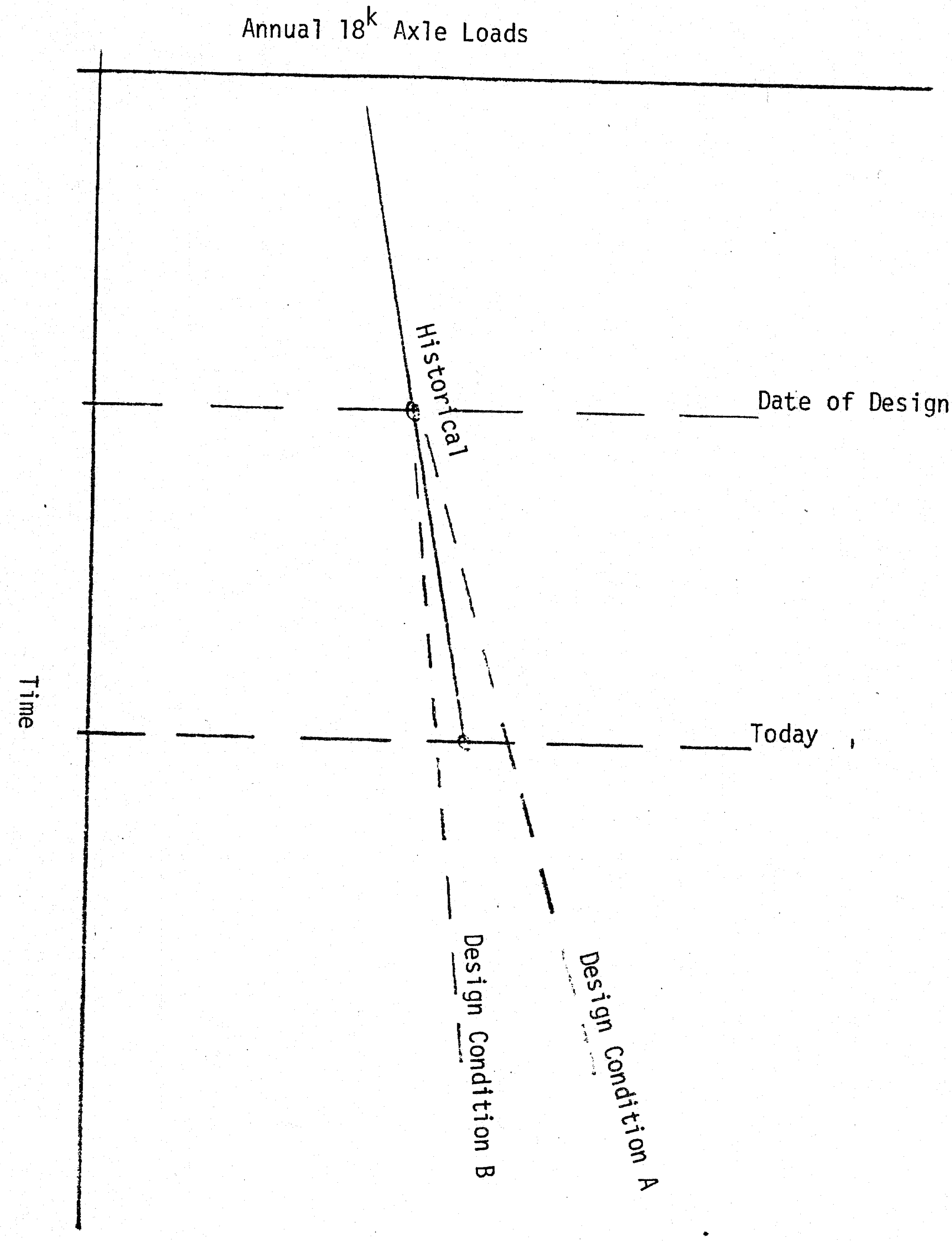
1982

18-KIP SINGLE AXLE EQUIVALENCE FACTOR RATE PER 1,000

D = 9" PT = 2.5 PI = 4.5

F.A.I., RURAL

VEHICLE TYPES				STA. 1	STA. 4	STA. 6	STA. 19	STA. 20	AVG.
SINGLE	TRUCK	Light	PP	4.7	2.6	2.4	2.8	3.4	3.2
			2x4	5.2	6.5	5.1	3.2	8.3	5.7
		Heavy	2x6	227.7	76.9	154.2	77.0	59.0	119.0
			3	1146.8	453.5	1450.5	2468.1	182.8	1140.3
				107.2	43.6	94.8	124.5	25.6	79.1
COMBINATION	TRUCK & TRAILER		3	0.6	10.2	0.0	5.4	0.0	5.4
			4	0.0	97.0	0.0	0.0	93.0	95.0
			5	0.0	3138.2	2663.5	0.0	0.0	2900.9
				0.6	1081.8	2663.5	5.4	93.0	768.9
	TRACTOR SEMI-TRAILER		3	520.1	311.8	413.8	411.3	215.2	374.4
			4	961.3	484.8	1190.5	1667.3	373.9	935.6
			5	1615.4	968.8	1407.4	460.1	784.4	1047.2
				1499.4	904.6	1329.1	770.2	698.4	1040.3
	SEMI-TRAILER TRAILER		5	1326.7	0.0	0.0	0.0	0.0	1326.7
			6	0.0	0.0	0.0	0.0	0.0	0.0
				1326.7	0.0	0.0	0.0	0.0	1326.7
E.F. ALL TRUCKS				1008.6	491.4	550.4	453.6	324.1	565.6
E.F. HEAVY TRUCKS				1312.4	720.9	965.7	681.9	637.6	863.7
NUMBER HEAVY TRUCKS				3,212	9,400	6,817	1,045	1,124	4,320
NUMBER ALL TRUCKS				4,194	13,855	12,036	1,581	1,817	6,697



Annual 18^k Axle Loads
Time
Historical
Date of Design
Today
Design Condition B
Design Condition A

USES OF WIM EQUIPMENT FOR BRIDGE LOAD HISTORIES, PAVEMENT LOADING DATA, ETC.

MR. R. A. WALSBURGER
ASSISTANT STATE HIGHWAY ENGINEER
KENTUCKY DEPARTMENT OF HIGHWAYS
FRANKFORT, KENTUCKY

Kentucky's History of Weighing Vehicles in Motion

by R. A. Walsburger
Assistant State Highway Engineer
Kentucky Department of Highways
Transportation Cabinet

Presented to the
National Weigh-in-Motion Conference
July 11-15, 1983
Denver, Colorado

It is imperative to state from the outset that the data contained in this paper was conveyed to the writer for the most part by James H. Havens, Associate Director of the University of Kentucky Transportation Research Program, and Herbert F. Southgate, Research Engineer Chief, also with the University of Kentucky Transportation Research Program. The pioneer work done by these two men in studying the weigh-in-motion concept represents most of Kentucky's history. I'm here as a representative of the Kentucky Department of Highways to communicate that history but more importantly to learn of the advancements in technology of weigh-in-motion over the past two decades.

Kentucky's experience in the early '60's can be recounted to three similar applications in the Commonwealth where weigh-in-motion installations were attempted. I am going to talk about at least two of those applications and the problems that occurred dating back to the time the Department started looking at the dynamic weigh scales in 1961.

The first installation I want to describe began in 1966 when the Department of Civil Engineering, University of Kentucky, was chosen to design, construct and install a broken-back bridge platform at a pre-selected site on the combined route of I-64/I-75 near Lexington. An electronic data collection system was designed and assembled to detect individual axles of moving vehicles and to record data in digital format on magnetic tape. The system was designed to convert both the analog signal representing axle weight and the signal representing real time to a digital form that would be compatible with available digital equipment at the University of

KENTUCKY. A RECTANGULAR PIT FOR THE SCALE WAS CONSTRUCTED ON THE OUTSIDE, EASTBOUND LANE, OF I-64/I-75 JUST EAST OF THE BRYAN STATION ROAD OVERPASS NEAR LEXINGTON, KENTUCKY. IN SELECTING THE SITE, EMPHASIS WAS PLACED ON FACTORS SUCH AS GOOD SIGHT DISTANCE, A LONG, NEARLY LEVEL TANGENT; AND THE INSTRUMENT HOUSE COULD BE CONSTRUCTED SO THAT OPERATING PERSONNEL WOULD BE SHIELDED FROM THE VIEW OF APPROACHING TRAFFIC IN A LOCATION BEHIND THE ABUTMENT FILL FOR THE OVERPASS BRIDGE OF BRYAN STATION ROAD. THE SCALE WAS INSTALLED AND COMPLETED IN JULY OF 1966 AND LATER WAS REMOVED FROM SERVICE IN 1969.

THE BROKEN BRIDGE SCALE PLATFORM WAS DESIGNED WITH THE OUTER EDGES OF THE TWO SECTIONS SUPPORTED ON HINGES AND CONTIGUOUS EDGES SUPPORTED BY TWO 20,000-LB. CAPACITY, LOAD CELLS. THE ASSEMBLED SCALE MEASURED 4'6" x 10'1½", WITH A TOTAL WEIGHT OF ABOUT 2000 LBS. COMPUTER PROCESSING OF THE FIELD DATA PRODUCED TABULAR INFORMATION ON VEHICLE SPEED, AXLE SPACING, NUMBER OF AXLES, VEHICLE CLASSIFICATION, TIME OF DAY, AND WEIGHT FOR EACH AXLE AS WELL AS VOLUMINOUS STATISTICAL DATA SUCH AS AVERAGE DAILY TRAFFIC AND EQUIVALENT AXLE-LOADS.

A "BROKEN-BACK" PLATFORM PRODUCES A TRIANGULAR OUTPUT SIGNAL FROM THE LOAD CELLS AS A LOAD TRAVERSES THE PLATFORM. THE APEX OR PEAK OF THE TRIANGULAR SIGNAL FROM THE LOAD CELL IS CALIBRATED IN WEIGHT UNITS, THUS, THE BASE LEG OF THE TRIANGLE REPRESENTS THE SPAN LENGTH; THE ADDITION OF AN INTERNAL TIMING SIGNAL PERMITS SPEED OF TRAVELERS TO BE CALCULATED; THEN, BY PRE-SETTING A PRACTICAL TIME GAP BETWEEN VEHICLES, IT IS POSSIBLE THEN TO DETERMINE THE NUMBER OF AXLES PER VEHICLE (CLASSIFICATION) AND THE SUM OF THE

AXLELOADS YIELDING A GROSS LOAD FOR EACH VEHICLE. INDEED, A SIMPLE, SHORT PLATFORM CAN ONLY SAMPLE THE LOADS (FORCES) ON THE PAVEMENT. TRUCKS (AND CARS) BOUNCE AS THEY GO ALONG; A PLATFORM MAY CATCH THEM ON THE UP- OR DOWN-SWING. THESE UNITS DO NOT MEASURE STATIC WEIGHT. AN APPARENT OVERLOAD EVENT MAY TRIGGER AN ENFORCEMENT SYSTEM.

WHEREAS, THE SCALE SYSTEM IS CAPABLE OF MEASURING THE FORCE EXERTED BY A SET OF WHEELS MOVING AT HIGH SPEEDS, THE FORCE IMPRESSED ON THE PLATFORM IS SIMPLY NOT THE STATIC WEIGHT FORCE OF THE AXLE. THE RATIO OF THE PEAK DOWNWARD FORCES TO THE STATIC WEIGHT FORCE DEFINES "IMPACT FACTOR." THIS EXPLANATION MERELY EMPHASIZES THE FACT THAT THE WEIGHING PLATFORM SENSES ONLY THE INSTANTANEOUS, DYNAMIC FORCE OF EACH TRANSIENT AXLE.

TWO MAJOR PROBLEMS WERE EXPERIENCED DURING THE PROJECT PERIOD. FIRST, THERE WAS A PROBLEM WITH MAINTAINING THE BOLTS ACROSS THE TOP EDGES OF THE SURFACE PLATES. OUR RESEARCH PERSONNEL WERE CONSTANTLY PLAGUED WITH TRYING TO REPLACE THE BROKEN AND LOOSENED BOLTS OR PROVIDE REMEDIAL MAINTENANCE METHODS FOR DIMINISHING THAT OCCURRENCE, BUT WITH THESE EXCEPTIONS IT CAN STILL BE STATED THAT THE PLATFORM SCALE OPERATED IN A SATISFACTORY MANNER FOR SEVERAL YEARS. THE OTHER MAJOR PROBLEM WAS CONSIDERED TO BE A DESIGN DEFECT WITHIN THE WEIGHING PLATFORM IN THE PAVEMENT. TIE RODS ANCHORING THE PLATFORM IN THE PIT INDUCED A PURPOSEFUL PRELOAD ON THE LOAD-SENSING ELEMENTS. THESE TIE RODS WOULD CHANGE THE PRELOAD AS THE TEMPERATURE FLUCTUATED. THUS, THE BALANCE POINT DRIFTED. THIS NOTICEABLE EFFECT CAUSED A TRIGGERING OF THE COUNTING AND WEIGHING CIRCUITS WHEN THERE WAS NO LIVE LOAD ON THE PLATFORM. SINCE THIS

WAS A SUSTAINED LOAD, THE CIRCUITRY "LOCKED IN" ON THE EXCESS PRE-LOAD. THE PRELOAD AND TIE RODS WERE INTENDED TO KEEP THE PLATFORM IN FIRM BEARING ON THE LOAD SENSING UNITS AND TO ELIMINATE RESONANCE AND FRICTION. THEREFORE, CHANGING TEMPERATURE INDUCED A PROBLEM WITHIN THE SYSTEM WHICH COULD NOT BE OVERCOME.

ABOUT THE TIME WE THOUGHT WE HAD THE BROKEN-BACK PLATFORM PERFECTED, WE WANTED TO IMPLANT UNITS IN MAJOR, BORDER BRIDGES SUCH AS THE I-75 BRIDGE CROSSING THE OHIO RIVER AT COVINGTON. WE DEBATED THE PROS AND CONS OF ON-BRIDGE AND OFF-BRIDGE LOCATIONS. FOR SECURITY PURPOSES, AN OFF-BRIDGE, DRIVE-IN VAULT BUILT INTO THE APPROACH EMBANKMENT WAS FAVORED. PRELIMINARY PLANS WERE DRAWN. THESE WERE ABANDONED WHEN THE SHALLOW, TEXAS, IN-PAVEMENT PLATFORM WAS ANNOUNCED. AS CONCEIVED THEN, FORMS COULD BE SET IN PAVEMENTS AND DUMMY SCALES INSTALLED. THE REAL SCALE(S) WOULD BE CARRIED IN A VAN ALONG WITH RECORDERS AND DATA COLLECTORS. A SIMPLE, ROVING VAN AND TEAM COULD SATISFY NEEDS FOR AN INTERIM PERIOD OF TIME. WE WERE ANXIOUS TO BUILD DATA BANKS, PROTECT BRIDGES AND PAVEMENT FROM CRITICAL OVERLOADS AND TO ANALYZE TRAFFIC AND ESTIMATE THE FATIGUE LIFE OF ALL MAJOR ROADWAY SYSTEMS AND BRIDGES.

THE SECOND ACTUAL WEIGH-IN-MOTION SCALE WAS LOCATED ON US 60 IN BOYD COUNTY IN THE NORTHEASTERN PART OF OUR STATE. IT WAS STARTED AS PART OF A RESEARCH STUDY FOR VARIOUS THICKNESSES OF FULL-DEPTH ASPHALTIC CONCRETE VARYING FROM 10-18". TRAFFIC CLASSIFICATIONS AND VOLUME COUNTS WERE ALSO MADE WHICH, WHEN COUPLED WITH THE AXLE-LOADS, ASSISTED TO MORE ACCURATELY ESTIMATE THE FATIGUE HISTORY OF THE PAVEMENTS.

THIS LATER BUT SIMILAR BOYD COUNTY INSTALLATION, A TEXAS-TYPE, ON US 60 ALSO TAUGHT US SOME INVALUABLE LESSONS. THESE LOAD CELLS

WERE DESIGNED TO TAKE UP TO A MAXIMUM OF A 30,000-LB. AXLE. UNFORTUNATELY, SOME OF THE TRUCKS TRAVELING IN THAT AREA ARE KNOWN TO CARRY AXLELOADS IN EXCESS OF 40,000 LBS. AS EVIDENCED BY SOME OF THE COAL-HAULING VEHICLES THAT WERE WEIGHED. STRAIN GAUGES BROKE, RECTANGULAR PLATES COULD NOT BE KEPT LEVEL, AND THE "BOUNCING" CREATED ERRATIC IMPACT LOADS ON THE CELLS. THESE HEAVY LOADS ALSO CAUSED SOME OF THE BEARING PADS TO SHATTER THE CONCRETE GROUT, AND THE PADS WOULD WORK LOOSE, CREATING A CHATTER OR VIBRATION OF THE ELECTRICAL SIGNAL.

IN SOME CASES THE DRIVERS WOULD INTENTIONALLY STEER THE TRUCKS SO THAT PART OR ALL THE TIRE WOULD BE OFF OF ONE END OF THE SCALES THEREBY RELAYING AN INACCURATE READING. TROUBLE WAS ALSO ENCOUNTERED IN CALIBRATING THE SCALES. IN SOME INSTANCES THE KNOWN STATIC LOAD ON THE PLATFORM MIGHT VARY AS MUCH AS 300 LBS.

DESPITE THESE PROBLEMS OUR RESEARCH PERSONNEL LEARNED A GREAT DEAL FROM THAT EXPERIENCE.

1) THE STEERING AXLE ITSELF MAY CARRY AS MUCH AS 20,000 LBS. ON SOME VEHICLES.
2) TANDEM AXLES AS A RULE DO NOT DISTRIBUTE THE LOAD EQUALLY ON THE TWO AXLES EXCEPT WHEN THEY ARE LOCATED ALMOST DIRECTLY UNDER THE CENTER OF THE TRUCKBED. AXLES WHICH CAN BE RAISED SUCH AS ON AUTO TRANSPORT TRUCKS NEVER SEEM TO CARRY THEIR PROPORTIONATE SHARE OF THE LOAD EVEN WHEN THEY ARE DOWN. SOME 34,000-LB. TANDEMS HAVE ACTUALLY SHOWN A DISTRIBUTION OF 20,000 LBS. ON THE FIXED AXLE AND 14,000 LBS. ON THE DROP AXLE.
3) THE STUDY LEFT NO DOUBT, AT LEAST IN KENTUCKY, THAT IN ORDER TO FUNCTION PROPERLY THE DYNAMIC SYSTEM WOULD HAVE

TO HAVE GREATER WEIGHING CAPACITY AND UTILIZE MORE FLEXIBLE OR PORTABLE DYNAMIC WEIGHING SYSTEM DESIGNS.

NOW LET ME DIVERT YOUR ATTENTION AWAY FROM THE RESEARCH WORK THAT WAS DONE IN THE '60'S AND FOCUS ON KENTUCKY'S TRUCK-WEIGHING PHILOSOPHY OF THE '70'S. EARLY IN 1970 OUR ENFORCEMENT PERSONNEL, KNOWN NOW AS THE DEPARTMENT OF VEHICLE REGULATION, WERE CONCERNED WITH THE LIMITED AND OVERCAPACITATED LOADOMETER STATIONS LOCATED ON KENTUCKY'S INTERSTATE ROUTES. THROUGH THEIR URGING THE DEPARTMENT OF HIGHWAYS STARTED TO DESIGN ELABORATE AND SPACIOUS TWIN LOADOMETER STATIONS ON ONE OF OUR NEWER INTERSTATES, I-24, IN THE WESTERN PART OF THE STATE NEAR PADUCAH, KENTUCKY. IT WAS PROPOSED THAT TRUCKS BE WEIGHED ON A DYNAMIC SCALE SYSTEM, BE SORTED AND DIRECTED EITHER TO THE MAINLINE TRAFFIC STREAM OR A STATIC SCALE INSTALLATION LOCATED NEAR THE CENTROID OF THE FACILITY. AFTER INTEREST WAS STIRRED IN THE EARLY 1970'S FOR SUCH A FACILITY, THE PROJECT WAS POSTPONED ONCE; AND EVENTUALLY, IN 1979, AUTHORIZATION FOR DESIGN WAS GIVEN TO AN ARCHITECTURAL FIRM AND THEY PROCEEDED TO WORK PLANS TO A 75-PERCENT STATE BEFORE BEING ORDERED TO STOP IN JUNE OF 1980. AS YOU REMEMBER, THIS WAS IN THE ERA WHEN THE WHOLE COUNTRY WAS FEELING THE PINCH OF EXPENSIVE HIGHWAY CONSTRUCTION PROJECTS AND AUSTERITY WAS NO DOUBT THE REASON WHY THIS PROJECT HAS BEEN CANCELLED WITHOUT SERIOUS THOUGHT GIVEN TO IT SINCE THAT DATE. THE ESTIMATED PRICE TAG WAS APPROXIMATELY $4 MILLION WHICH INCLUDED RIGHT-OF-WAY ACQUISITION, UTILITY RELOCATION AND ULTIMATE CONSTRUCTION FOR THE BUILDING AND SITE FACILITIES FOR BOTH LOADOMETERS.

SO UNFORTUNATELY KENTUCKY HAS NEVER GOTTEN TO THE POINT WHERE THE DATA GATHERED FROM THESE RESEARCH EXPERIENCES OR THE IMPLEMENTATION

OF A DYNAMIC LOADOMETER STATION PROVIDED INPUT FOR BRIDGE AND PAVEMENT DESIGN NOR HAVE WE USED WIM ENOUGH TO SIGNIFICANTLY ASSIST IN CLASSIFYING VEHICLES.

I WOULD LIKE TO CONCLUDE MY PRESENTATION BY FOCUSING ON THE SERIOUS QUESTION THAT THIS CONFERENCE IS ALL ABOUT AND THAT IS "HOW DO WE GET A HANDLE ON DAMAGE INCURRED TO OUR HIGHWAY SYSTEM BY OVERLOADED TRUCKS AND THE RESULTING AFFECT ON THE HIGHWAY SYSTEM?" WE IN KENTUCKY DO NOT HAVE ALL THE ANSWERS, HOWEVER, WE WOULD LIKE TO DISCUSS AN AID WHICH CAME OUT AS A RECENT RESEARCH PROJECT AT THE UNIVERSITY OF KENTUCKY. IT IS A STUDY CALLED "ALLOCATION OF TRANSPORTATION COSTS TO USERS" BY JAMES E. BLACK AND JERRY G. PIGMAN, UNIVERSITY OF KENTUCKY RESEARCHERS, WHICH IN ESSENCE MAKES A COMPARISON OF THE COST RESPONSIBILITY AND REVENUE GENERATED BY TRUCKS AS OPPOSED TO AUTOMOBILES AND PICKUPS. (I HAVE COPIES OF THIS REPORT AVAILABLE TO THOSE OF YOU WHO ARE INTERESTED.) SOME OF THE FINDINGS AND FACTS ARE: 1) AXLELOADS OF 20,000 LBS. INDUCE 1.5 TIMES THE DAMAGE OF AN 18,000-LB. AXLE, AND A 22,000-LB. AXLE (2,000 LB. OVERLOAD) WOULD BE 2.2 TIMES AS DAMAGING AS AN 18,000-LB. AXLELOAD; 2) KENTUCKY'S LEGAL WEIGHT LIMITS WHICH ARE EXCEEDED REGULARLY ARE 20,000 LBS. FOR SINGLE AXLES, 34,000 LBS. FOR TWO AXLES AND TANDEM, 50,000 LBS. FOR THREE-AXLE VEHICLES, AND 82,000 LBS. IS THE MAXIMUM GROSS WEIGHT; 3) AND THE MOST IMPORTANT CONCLUSION REVEALS THAT AUTOMOBILES AND PICKUPS PAID 157 PERCENT OF THEIR SHARE OF COST RESPONSIBILITY WHILE TRUCKS ONLY PAY 54 PERCENT OF THEIR SHARE THROUGH THE GENERATION OF REVENUE USING KENTUCKY'S PRE-1980 TAX STRUCTURE.

AS I STATED AT THE BEGINNING, WE AT THE KENTUCKY DEPARTMENT OF HIGHWAYS ARE LEARNERS, NOT EXPERTS AT INSTALLING AND USING WIM

TECHNOLOGY. I TRUST THAT I WILL BE ABLE TO TAKE BACK SOME OF THE KNOWLEDGE IMPARTED BY THE PARTICIPANTS OF THE CONFERENCE SO THAT WE IN KENTUCKY CAN MAKE MORE INTELLIGENT DECISIONS AS TO THE DIRECTION WE WANT TO TAKE IN UTILIZING NEW AND SOPHISTICATED SYSTEMS FOR THE WEIGHING AND CLASSIFICATION OF VEHICLES.

RELATED REFERENCES

1. Maggard, S.P.; "Weighing Vehicles in Motion;" M.S. Thesis, Civil Engineering, University of Kentucky; 1957.

2. Schwadered, W., and Reimund, W.; "Die Automatische Achlastwaage bei Grunback (Remstal);" Strasse und Autobahn; 1959.

3. Dearinger, J. A.; "Dynamic Weighing of Vehicles;" Public Roads; October, 1961.

4. "Weighing in Motion;" Department of Civil Engineering, University of Kentucky for the Kentucky Department of Highways (Research Report 212) in cooperation with the Bureau of Public Roads; 1964.

5. Lee, Clyde E., and Al-Rashid, Nasser, I.; "A Portable Electronic Scale for Weighing Vehicles in Motion;" Research Report 54-1P, Center for Highway Research; the University of Texas at Austin; 1968.

6. "Weighing Vehicles in Motion;" University of Kentucky Research Foundation in cooperation with the Kentucky Department of Highways (Research Report 284) and the Bureau of Public Roads; 1969.

7. Carr, Ben W., Jr., and Rizenbergs, R. L.; "Development of an Electronic Means of Weighing Vehicles in Motion;" Report 307, Division of Research, Kentucky Department of Highways; 1971.

8. Bergan, Dr. A. T., Sparks, Dr. G. A.; and Dyck, G.; "Weighing Vehicles in Motion: The University of Saskatchewan Scale;" TRR 667, Transportation Research Board, 1978 (see discussion by Jas. H. Havens).

9. Black, J. E., and Pigman, J. G.; "Allocation of Transportation Costs to Users;" UKTRP 81-22; Transportation Research Program, College of Engineering, University of Kentucky; 1982.

USES OF WIM EQUIPMENT FOR BRIDGE LOAD HISTORIES, PAVEMENT LOADING DATA, ETC.

MR. STEVE BOKUN
SPECIAL STUDIES RESEARCH GEOLOGIST
LOUISIANA DEPARTMENT OF TRANSPORTATION
BATON ROUGE, LOUISIANA

NATIONAL WIM CONFERENCE

Uses of WIM Equipment Bridge Load Histories,
Pavement Loading Data, etc.

Steve G. Bokun
Special Studies Research Geologist

Denver, Colorado
July 11 - 15, 1983

Uses of WIM Equipment Bridge Load Histories,
Pavement Loading Data, etc.

Steve G. Bokun
Special Studies Research Geologist

I. Louisiana's First Generation WIM Equipment

A. WIM - 1A Purchased from Unitech, Inc. (now Radian Corp.) of Austin, Texas in August, 1974.

B. WIM - 1A first installed on U.S. Hwy. 190 near Baton Rouge, La. in 1975

1. Short term project to perfect installation operation, and maintenance practices necessary for continued accurate and reliable operation of a computerized weigh-in-motion system

2. WIM - 1A was only capable of gathering data from one traffic lane at a time.

3. Comparative weight and speed data was gathered for a total of 173 vehicle observations.

a. Two men in WIM trailer and third man at nearby LA DOTD weight enforcement scale.

b. Two-way radio contact to tell man at enforcement scales which truck was to be checked against the WIM readings.

c. Speeds were checked at WIM site by hand held traffic radar unit at start of correlations and at the conclusion.

4. Median weight error for the 173 vehicles was 4.45 percent with a standard of deviation of 3.84 percent.

a. Only total weight of each truck was measured due to impossibility of weighing the tandem axles at the static scale.

b. Static pit scale weights used as the standard.

5. Average speed error for the vehicles measured was ±2.24 mph using the traffic radar unit as a standard.

6. It was determined that the performance of the WIM - 1A was adequate for use in gathering weight data in the Louisiana Experimental Base Study.

C. WIM - 1A installed on the Louisiana Experimental Base Study on U.S. Route 71 south of Alexandria, La. in late 1976.

1. La. Experimental Base Study (74-1G) is a research study designed to evaluate the design and performance characteristics of three types of base courses constructed on a full-scale test road, U.S. 71 south of the city of Alexandria.

2. Fourteen different test sections were constructed to evaluate the study variables, which included base course type (soil-cement, stabilized sand clay gravel, and asphalt base), design life (5, 10, and 15 years), and surface thickness (3½" and 5½" asphalt).

3. During the mid 1960's the LA DOTD adopted the design procedure established for flexible pavements at the AASHORoad Test at Ottawa, Illinois. The Department's design engineers needed to know more precisely the accuracy of their design predictions as reflected by actual performance of flexible pavements.

4. It was the purpose of this research project to (1) ascertain the accuracy of predictions concerning the performance of flexible pavements designed by Louisiana's current AASHTO design guide for various materials and design life periods and (2) determine relationships between fundamental materials properties and field performance of such flexible pavements.

5. In order to assimilate information on the response of the various pavement test sections to traffic loading through time, a scheme was developed using our semi-automated WIM - 1A system at a site just north of the northern most test section.

    a. System was operated for monitoring of both traffic weight and traffic volume for seven 24-hour days each quarter.

    b. Operation was planned so 24-hour weight and volume data would be available for a seven-day "typical week" each calendar quarter. This data can be summarized and/or separated to yield yearly, quarterly, monthly, weekly, daily, and hourly traffic information as needed. The WIM sampling plan was much less frequent (once a month and even once a quarter) in the succeeding years.

    c. Manual classification counts were conducted during day-light hours.

    d. Initial traffic projections for this project indicated an average daily traffic load (ADL) of 612 equivalent 18-Kip Axle loads for 1980, the median year for the design period. For 1978, the ADL calculated from manual counts turned out to be ADL 535. However, our WIM - 1A data gave us much lower ADL's of 122 for this same year 1978.

6. Because of the many problems we seemed to be experiencing with our WIM - 1A system it was decided to make a check of the actual truck weights with portable scales at the WIM site versus WIM data.

    a. A random check of 45 trucks at the site gave the data contained in the slide. The data indicated that the actual weights were much closer to the maximum legal axle loads than was shown by our WIM data. The WIM - 1A was not recording heavier weight vehicles.

b. The WIM - 1A had been giving many problems over the years. Electrical repairs, transducer malfunctions, bent frames, and broken roadway plates were some of the problems. Total reconstruction of the transducer pits was also necessary.

7. The WIM - 1A was discontinued in Jan. 1981. Since this equipment was about seven years old and had given many problems over the years it was to be replaced with the newer WIM - 1E.

II. Louisiana's Second Generation WIM Equipment.

A. WIM - 1E purchased from Radian Corp. in late 1981.

B. This system installed at Alexandria site in late 1981.

1. Operational problems with the wheel load transducer chassis necessitated return to manufacturer for reconditioning.

2. Entire field installation was completely removed and retrofitted with new components (frames, plates, transducers, and loops).

3. Company representative had to be called to the field site to help solve the problems.

C. System was in operation around June 1982 or about 18 months after the WIM - 1A was discontinued.

D. We have had very little problems with the new system once the installation "bugs" were worked out. System is kept under air conditioning to help relieve moisture problems with the computer.

III. WIM - 1E Data used to figure damage factor (F factor) using 1982 and 1983 figures for trucks.

A. Average F factors calculated from all WIM data for all years the system was in operation. Sum of loads divided by the number of trucks gave the average F factor for various years.

B. We took data from WIM - 1E (1982 & '83) and came up with F factors we would use prior to 1982 to refigure loads. This was done for all axle classes.

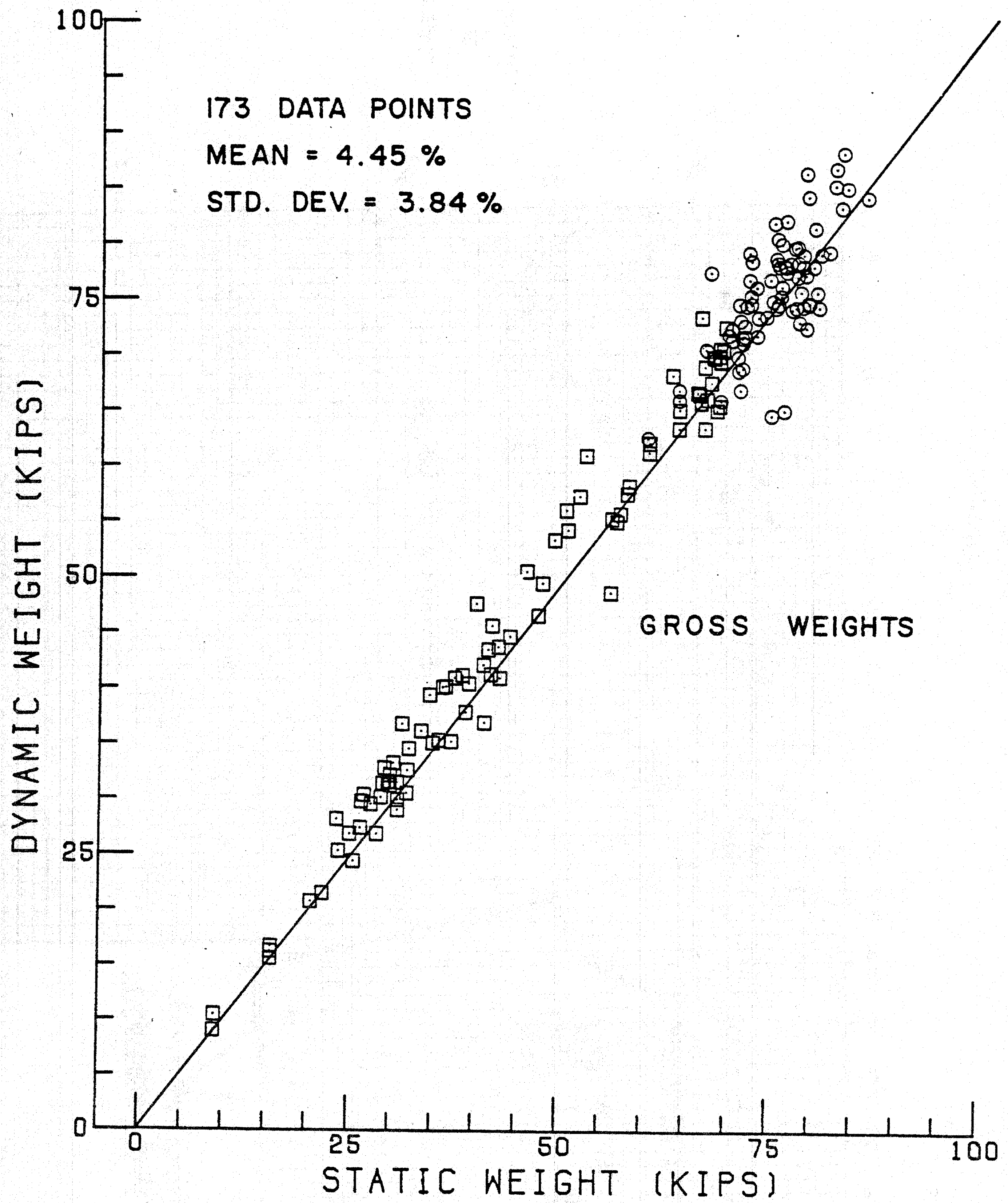
C. As an example, 1978 ADL was refigured using the new F factors and came out to be 612 Equivalent 18-Kip Axle loads.

D. This compares favorably with the 535 Equivalent 18-Kip Axle loads calculated from the loadometer (W4) design tables in conjunction with manual counts.

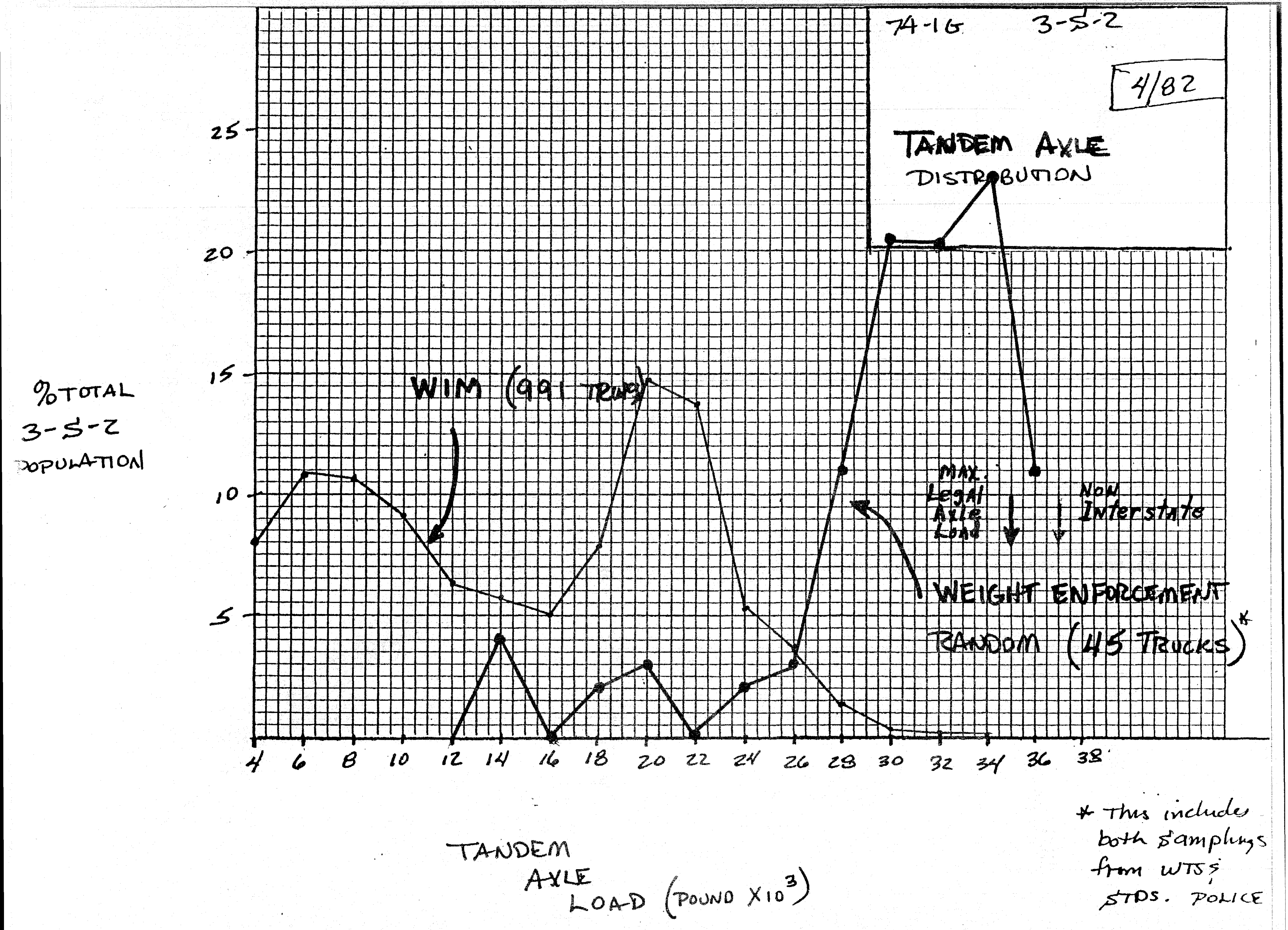
E. The last slide shows the relationship between the average daily number of heavy trucks (3-S-2) per year and the ADL yearly for all vehicles. It can be seen that the trend follows one another. The summation of loads over the years is shown at the bottom. To date the LA Experimental Base test sections have undergone approximately 1.56 million Equivalent 18-Kip

Axle Loads. Computation of pavement load factors and all associated analysis is done through appropriate software for the Department's IBM 3031 computer system.

Slide No.	Description
INTRO	LA. Experience with WIM for Pavement Loading
1.	Slide of WIM-1A control panel
2.	WIM-1A site near Baton Rouge (Port Allen) on U.S. Hwy. 190
3.	Graph of dynamic weights vs. static weights for 173 sample vehicles
4.	Begin La. Experimental Base Project near Alexandria
5.	WIM-1A site at LA. Experimental Base Sections
6.	Graph WIM data vs. Weight Enforcement
7.	Slide of WIM-1E equipment inside trailer
8.	Average F factors (3-S-2) for all WIM years
9.	F factors for 2AX, 3AX, 4AX, 5AX, >5AX for all years
10.	1978 = 612 for refigured F factors
11.	1978 = 535 from loadometer (W4) design tables
12.	Chart of Average daily # of 3-S-2; ADL; Sum of Loads



GRAPH I - STATIC VS. DYNAMIC WEIGHTS OF 173 SAMPLE VEHICLES



74-1G 3-S-2
4/82
TANDEM AXLE
DISTRIBUTION
%TOTAL
3-S-2
POPULATION
25
20
15
10
5
WIM (991 TRKS)
MAX. Legal Axle Load
Non Interstate
WEIGHT ENFORCEMENT
RANDOM (45 TRUCKS)*
4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
TANDEM
AXLE
LOAD (POUND X10³)
* This includes both samplings from WTS; STDS. POLICE

VEHICLE TYPE = 3S2

YEAR	AVERAGE F
1976	1.396
1977	0.995
1978	0.810
1979	0.847
1980	0.923
1982	1.479
1983	1.239

F factor for all years

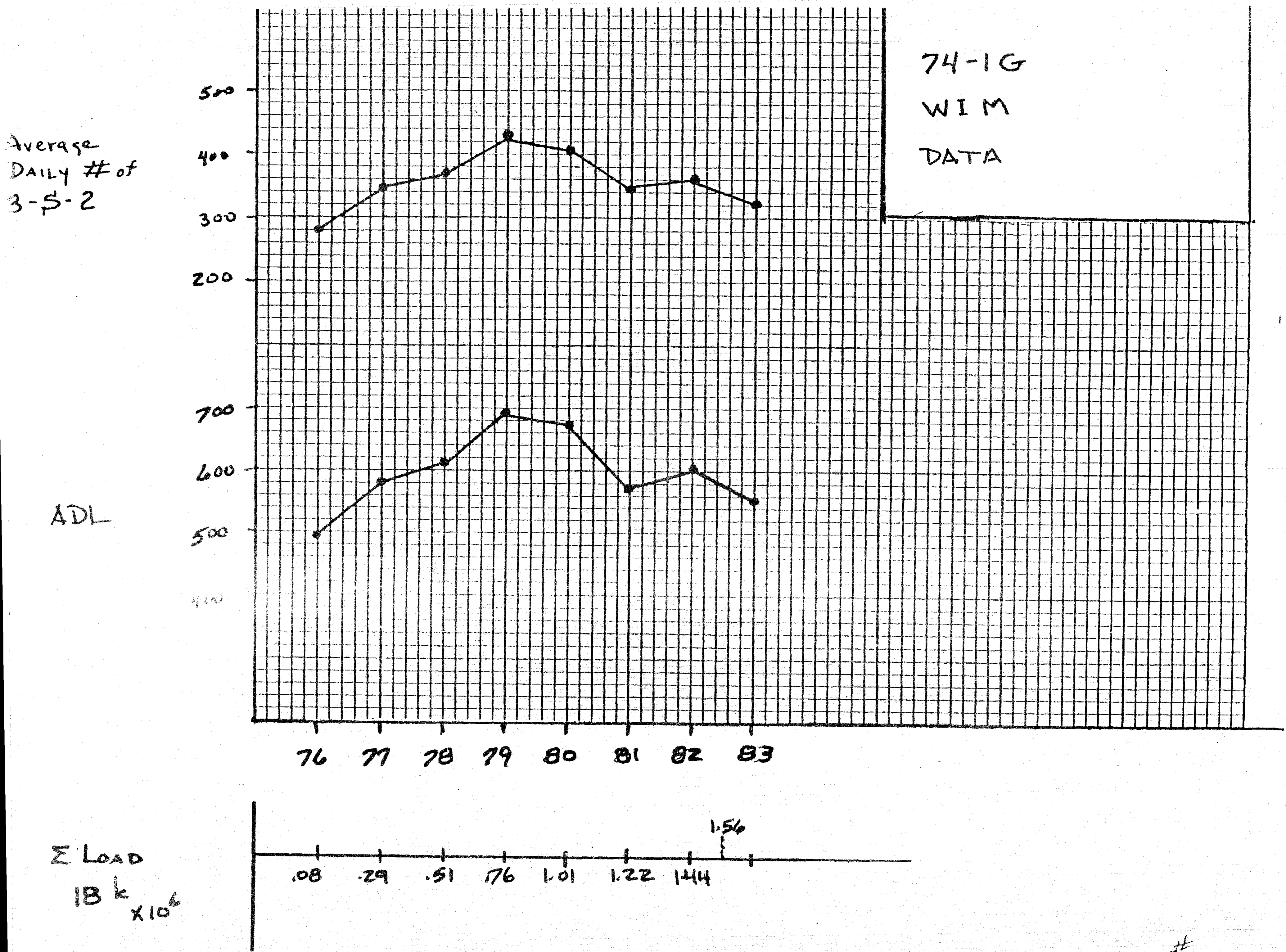
2AX	3AX	4AX	5AX	>5AX
.36	.76	.92	1.36	1.51

1978 ADL = 612 Equivalent 18 Kip Axle loads

5AX

1978 ADL = 2AX + 3AX + 4AX + 364(1.36) + >5AX

1978 ADL = 535 EAL from loadometer (W4) design tables in conjunction with manual counts


74-1G
WIM
DATA
Average
DAILY # of
3-5-2
500
400
300
200
700
600
ADL
500
76
77
78
79
80
81
82
83
Σ LOAD
18 k
x10^6
.08
.29
.51
.76
1.01
1.22
1.44
1.56

	ΣEAL	
YEAR	T&P	WIM
1976	64,481	80,000
1977	269,940	290,000
1978	513,140	510,000
1979	743,455	760,000
1980	985,487	1,010,000
1981	1,270,807	1,220,000
1982	1,321,539*	1,440,000

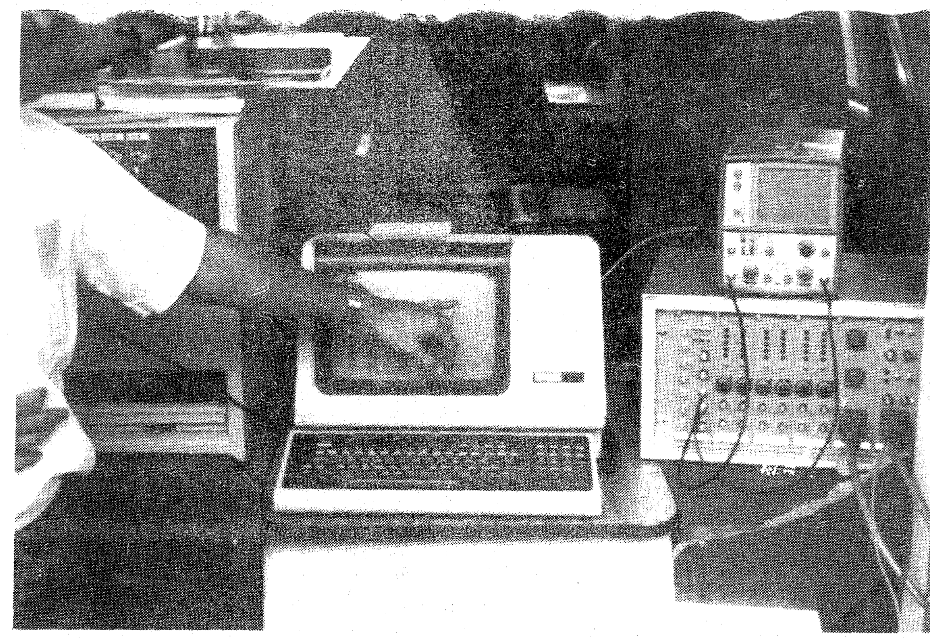
* Reflects only first 3 months of 1982.

FIELD TRIP

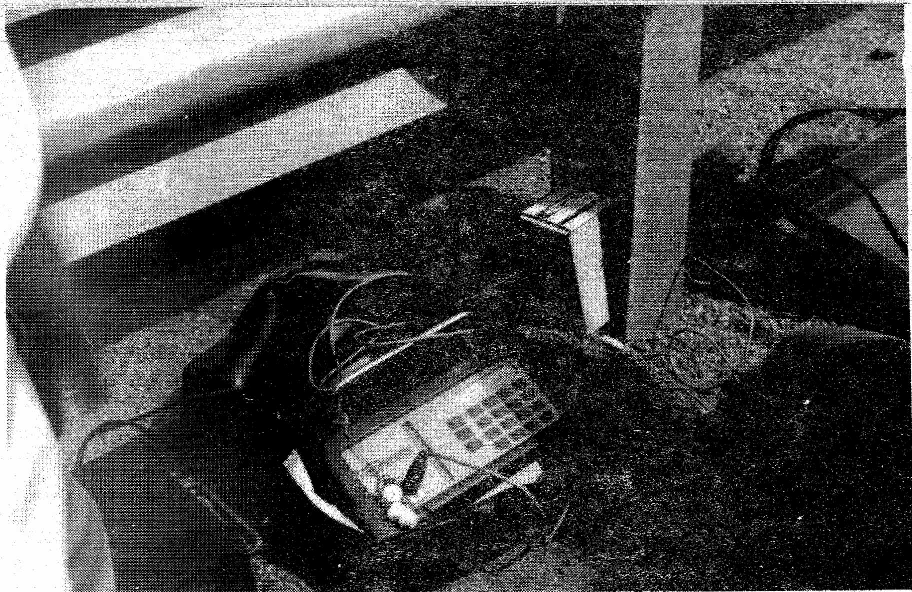
During the field trip the participants were able to view the actual operation of 5 different weigh-in-motion systems. These included:

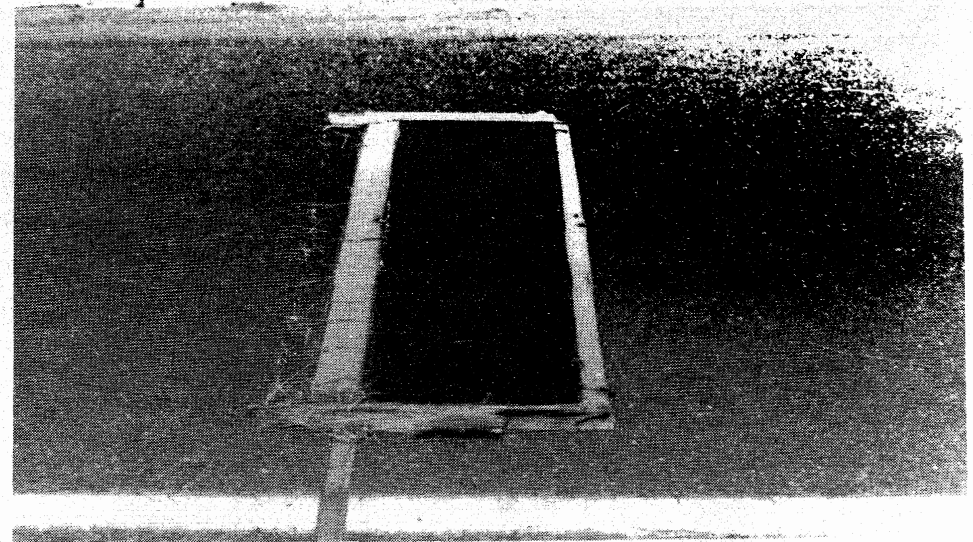
1) Bridge Weighing System
2) Golden River
3) Radian
4) Siemens-Allis
5) Weighwrite

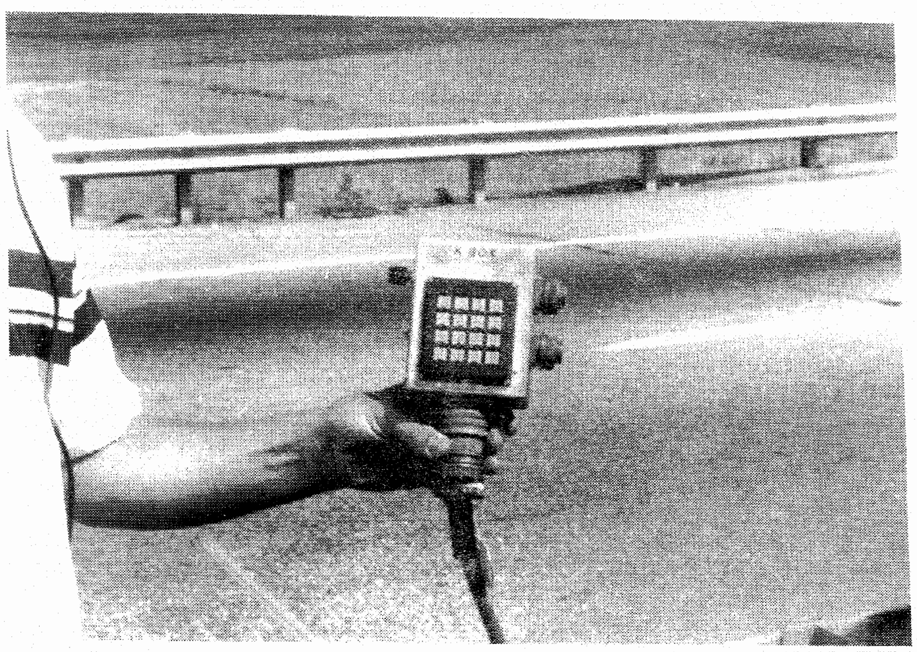
There was an attempt ot compare data from each of these systems to that received from our static scales at our Ports of Entry. This did not work as well as hoped there fore to avoid creating misleading conclusions this portion of the program will not be included in the proceedings.



BRIDGE WEIGHING SYSTEMS

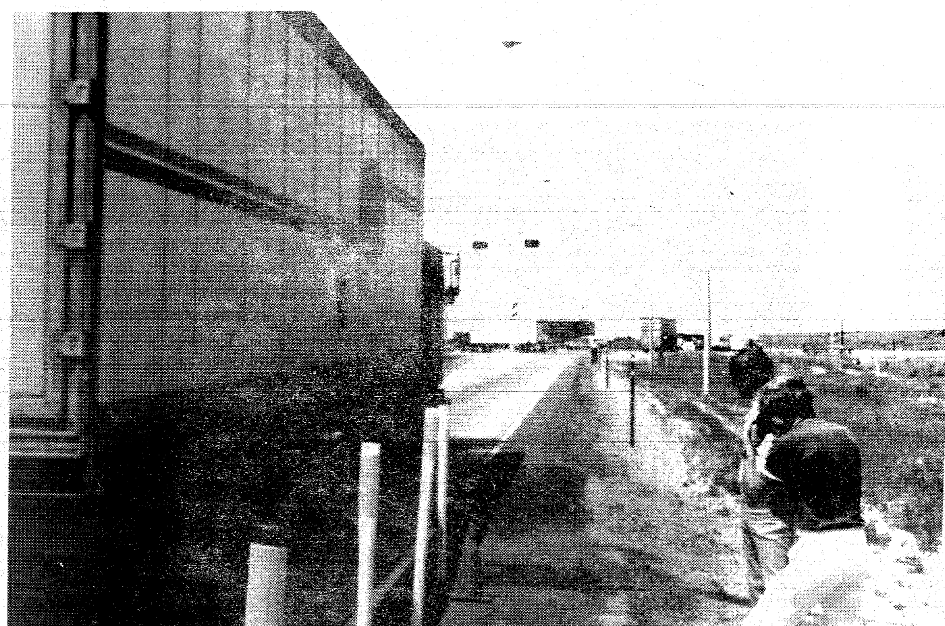


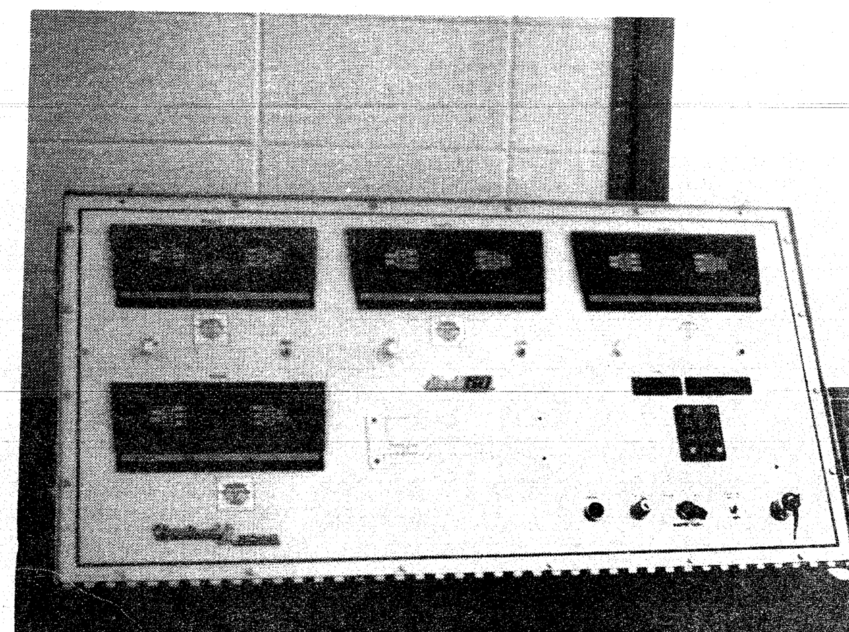




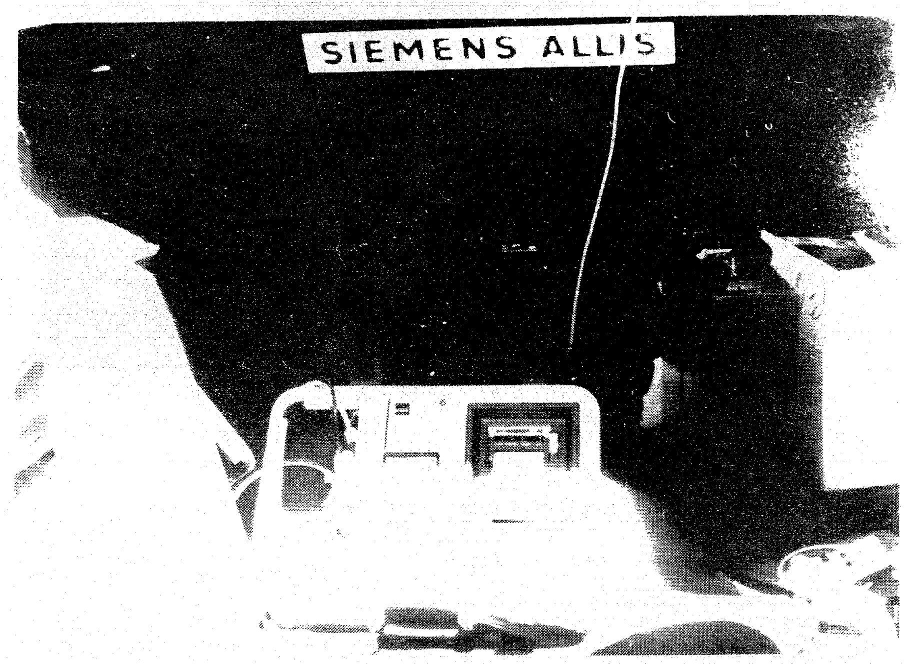
GOLDEN RIVER

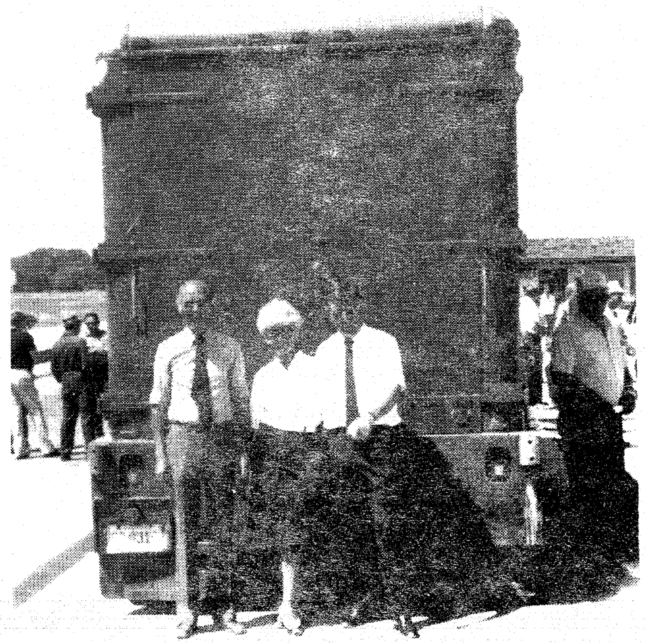
RADIAN





SIEMENS-ALLIS





WEIGHWRITE

INFLUENCE OF TRUCK SIZE AND WEIGHT ON HIGHWAY CRASHES

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

[illegible]

[illegible]

[illegible]

Insurance Institute for Highway Safety
Research Note No. 105   March 1983

Influence of Truck Size and Weight on Highway Crashes

Ian Jones

Howard Stein

Paul Zador

From time to time, researchers on the staff of or supported by the Insurance Institute for Highway Safety develop analyses, findings, and observations that require publication in formats and on schedules more flexible and timely than those provided in journals. *Research Notes* is a vehicle provided by the Institute to make such material available on a timely basis. For more information concerning *Research Notes* or other Institute publications, write to Communications Department, Insurance Institute for Highway Safety, Watergate 600, Washington, DC 20037.

The Insurance Institute for Highway Safety is an independent, nonprofit, scientific and eductional organization. It is dedicated to reducing the losses — deaths, injuries, and property damage — resulting from crashes on the nation's highways. The Institute is supported by the American Insurance Highway Safety Association, the American Insurers Highway Safety Alliance, the National Association of Independent Insurers Safety Association and several individual insurance companies.

ISSN 0732-8532

Influence of Truck Size and Weight on Highway Crashes

ntroduction

Maximum sizes and weights of trucks allowed on public roads were for many years regulated by each state. 'nder state regulations, permitted truck maximums varied considerably. Maximum gross vehicle weights ranged om 73,280 pounds in Arkansas, Illinois, and Missouri to 129,000 pounds in Nevada. All but eight states restricted ıe width of trucks to 96 inches. Twin trailers (i.e., a tractor pulling two trailers) were permitted in most western 'ates but not in most of the East.

Since passage of the "Surface Transportation Assistance Act of 1982" (P.L. 97-424), which increased the feder- tax on fuel and earmarked the proceeds for highway purposes, the maximum allowable limits on truck sizes and eights are required to be *at least:*

- 80,000 pounds gross weight, with axle loads up to 20,000 pounds for single axles and 34,000 pounds for double axles
- 102 inches in width for all trucks
- 48 feet in length for semitrailers and trailers
- 28 feet in length for each twin trailer

No state is allowed to establish limits on overall truck length. In addition, legal gross vehicle weights must satis- the limiting conditions in the bridge gross weight formula, which establishes maximum allowable weights for all oupings and spacings of axles. These provisions apply to all trucks operating on interstate and other "qualifying" !eral-aid highways. States not complying with the new regulations by October 1983 will have their federal highway ! apportionments withheld.

The basic safety question raised by the new federal provisions for truck size and weight is whether they are ely to increase the already large numbers of deaths and injuries resulting from crashes involving large trucks. In- ases could result from higher truck crash frequencies and/or greater crash severity.

agnitude of the Truck Crash Problem

In 1978, large trucks (10,000 pounds and greater) were involved in 432,000 crashes, about six percent of the itional crash total (1). In the same year, large trucks contributed to 12 percent of the national total of fatal crashes.

Trucks have a lower crash rate per mile than cars, but their fatal crash rate is significantly higher. The overall sh rate for large trucks in 1978 was 474 per hundred million vehicle miles compared to 825 for cars (1). The fatal ash rate for large trucks, however, was 5.3 per hundred million vehicle miles compared to 2.8 for cars.

Combination trucks (i.e., tractor semitrailers or tractor semitrailers plus trailers) have almost twice the crash ıe of straight trucks — 604 per hundred million vehicle miles traveled compared to 351. Combination trucks also ve a very high fatal crash rate, 8.6 per hundred million vehicle miles traveled. Thus, although on a per mile basis ;e trucks are less involved in crashes than passenger cars, large truck crashes usually are much more severe.

A principal reason for the overinvolvement of large trucks in fatal crashes is the difference in weight between :ks and other involved vehicles. In 1977, about 74 percent of fatal crashes involving large trucks also involved er vehicles, and 65 percent of these other vehicles were passenger cars (1). More than 3,000 car occupant deaths ulted from such crashes.

The proportion of all fatal crashes involving trucks has remained at 11 or 12 percent since 1977. During this period, however, the relative risk of death to occupants of passenger cars has been increasing. Table 1 shows the ratio of occupant fatalities in passenger cars to fatalities in trucks for fatal crashes involving cars and trucks. As the table indicates, the relative risk of death to passenger car occupants increased steadily between 1977 and 1980; this is most likely attributable to the increased risk of death in small cars, and these cars increased greatly in number during 1977-1980.

TABLE 1

Increased Risk of Death* for Car Occupants Relative to Truck Occupants in Fatal Crashes of Large Trucks and Cars

	1977	1978	1979	1980
TRUCK TYPE				
Single-Unit	16.7	17.8	22.9	25.6
Combination	26.0	28.9	30.8	32.9
ALL LARGE TRUCKS	22.9	25.2	28.6	30.6

Source: Eicher, J.P., Robertson, H.D., and Toth, G.R., "Large Truck Accident Causation," National Highway Traffic Safety Administration Technical Report No. DOT HS-806-300, July 1982.

*E.g., in 1977 a car occupant was 22.9 times more likely than a truck occupant to be killed in a fatal large truck-car crash; in 1980, 30.6 times more likely.

The crash involvement rate of trucks is higher in urban areas than rural areas (2), but the severity of the crashes is greater in rural areas because of higher travel speeds (3). Truck crash involvement rates on controlled access roads (freeways, etc.) are significantly lower than on other roads (4), although even on controlled roads truck involvement in fatal crashes is disproportionately high. Trucks account for 20 percent of vehicle mileage on freeways, but they are involved in 35 percent of the fatal crashes on such roads.

Influence of Truck Configuration on Crash Involvement Rates

Most truck safety studies have focused on the influence of truck configurations on crash involvement. The twin trailer configurations permitted by the fuel tax bill are the so-called "Western Doubles" (already permitted in western states), which consist of two 28-foot semitrailers hauled by a tractor unit. These are not to be confused with "Eastern" or "Turnpike Doubles," which are tractors pulling two 40- to 45-foot semitrailers.

The most recent Federal Highway Administration study has shown that "Western Doubles" have significantly higher crash involvement rates than single tractor trailors, regardless of the type of road on which they are traveling. Their crash rates (shown in Table 2) are based on accident and mileage data collected from selected road sections in California and Nevada where singles and doubles are operated under about the same conditions.

TABLE 2

Truck Crash Rates Per 100 Million Miles Singles and Doubles by Roadway Type

	RURAL		URBAN	
	Freeway	Nonfreeway	Freeway	Nonfreeway
TRUCK TYPE				
Singles	110	99	214	93
Doubles	228	468	388	428

Source: Vallette, G.R., McGee, H.W., Sanders, J.H., and Enger, D.J., "The Effect of Truck Size and Weight on Accident Experience and Traffic Operations, Volume 3: Accident Experience of Large Trucks." Federal Highway Administration Report No. FHWA/RD-80/137. Washington, D.C., July 1981, PB No. 82 139726.

Cambell and Carsten reached similar conclusions (5). Their rates — based on data from the Bureau of Motor Carrier Safety and the National Highway Traffic Safety Administration's Fatal Accident Reporting System, and exposure data over a two-year period from a random survey of truck fleets — show that doubles are overinvolved in crashes on a per mile basis (Table 3). They also show that crash involvement rates for bobtail tractors (those not pulling a semitrailer) are substantially higher than for tractors pulling either single or double trailers.

TABLE 3

Truck Crash Involvement Rates Per 100 Million Miles (Intercity Use Only)

TRAILER TYPE	FATAL (FARS 1976-78)	INJURY (BMCS 1976-78)
Singles	6.5	47.9
Doubles	9.5	126.3
Bobtails	90.0	913.5

Source: Cambell, K.L., and Carsten, O., "Fleet Evaluation of FMVSS 121," UM-HSRI-81-9, Highway Safety Research Institute, Final Report National Highway Traffic Safety Administration Contract No. DOT-HS-6-01286, August 1981.

The important feature of the studies by Vallette et al. and Cambell and Carsten, from which Tables 2 and 3 are ·awn, is that they compute crash rates on the basis of mileage and crash data from comparable trips. Other studies ıve compared the crash rates of different truck configurations, but their results have been misleading because ·ir exposure data were not comparable for the various types of trucks they studied (6,7,8,9).

ıfluence of Vehicle Load on Truck Crash Involvement Rates

The study by Vallette et al. (2) is one of the few available that has considered the effects of load. It reported that ·pty and near-empty combination trucks have substantially higher crash involvement rates — higher by at least a ·ctor of two — than loaded trucks. Empty doubles reportedly show a relationship between weight and crash experi·ce that is similar to that of singles, but for all weight classes doubles have a higher crash involvement rate than ·gles.

It should be noted that Vallette's findings about the effects of truck weight on crash involvement depend on · correct identification of both empty truck exposure and the involvement of empty trucks in crashes. A data ·view indicates that these were incorrectly estimated to different extents. Using Vallette's data and making ap·opriate adjustments to reflect more accurately the exposure and crash involvement of empty trucks, the Insurance ·stitute for Highway Safety has concluded that Vallette's findings were not justified from these data.

However, studies other than Vallette's have reported low crash involvement rates where it was known that ·ucks were traveling substantial portions of their journeys fully loaded. High crash involvement rates were reported ·ere partial or empty loads were more characteristic (9,10). In addition, engineering considerations indicate that ·pty trucks are dynamically less stable and cannot generate braking forces as large as loaded trucks. This also sug·sts higher crash rates for such trucks.

·ect of Increased Gross Vehicle Weights on Truck Braking Performance

The new federal gas tax law allows gross vehicle weights of 80,000 pounds, a higher weight limit than has been ·owed in some states. For fully loaded trucks, increasing the weight generally increases stopping distances, because ·ximum braking capability is exceeded.

Unloaded trucks usually have longer braking distances than loaded trucks. A number of studies (2,9,10) have ·ggested that empty combination or single unit trucks and "bobtails" have higher crash rates, because truck brake characteristics are biased toward loaded conditions. When trucks are unloaded, premature wheel lockup and consequent stability problems may occur.

Federal motor carrier safety regulations require large trucks (air brake-equipped) traveling at 20 mph to stop in 35-40 feet, and cars to stop in 20-25 feet. In 1974, the Federal Highway Administration tested this stopping capability for 1,200 trucks and 366 cars selected randomly from highway traffic (11). Eighty-seven percent of the cars tested met the 25-foot requirement, but high percentages of the trucks did not meet their stopping requirements; only 29 percent of the single unit trucks, 65 percent of the tractor trailers, and 44 percent of the tractors with twin trailers could stop within their required distances.

A large number of trucks in service thus are not meeting existing stopping distance requirements, even though such requirements are well within truck design capabilities. If future brake systems are designed to accommodate higher gross vehicle weights, without improved brake technology such as load proportioning or anti-lock systems, the already large difference in braking distance between cars and trucks is likely to increase. Additionally, the disparity between loaded and unloaded truck braking distances will increase, as will the inherent stability problems caused by this disparity.

Cargo Type and Truck Crash Involvement

The consensus of studies of trailer configuration and cargo type is that tanker trucks and flatbed trailers operated as doubles have much higher crash rates than those operated as singles — higher by a factor of four in the case of tankers, and by a factor of more than two for flatbeds (2,9). The crash rates for dump trucks also have been found to be consistently high, regardless of the trailer configuration (10). Again, these results indicate that trucks which operate exclusively either heavily loaded or empty have high crash involvement rates.

There is some discrepancy concerning rates for van trailer doubles. Their crash involvement rates have been found to be higher than singles in one study (2), but about the same in another study (9). However, van doubles included in the latter study had a high proportion of their crashes at night and on divided highways. This suggests a use pattern which would tend to reduce exposure to multiple vehicle crashes.

Influence of Truck Length and Width on Crash Involvement

For single trailer configurations, there is some evidence of decreasing crash rates with increasing trailer lengths (2). However, there are insufficient data to analyze crash involvement rates by individual cargo area configurations, and this may confound the results. In a comparison of 40- and 45-foot semitrailers in six states, no significant differences in crash rates were found (2).

Because trucks and trailers have almost universally been restricted to a maximum width of 96 inches, there are insufficient data to determine whether increasing overall truck widths by six inches — as provided for in the new federal gas tax bill — would affect crash rates.

Influence of Truck Dimensions on Crash Severity

Because the mass ratio between a large truck and a car weighing 3,000 pounds already is in excess of 20 to 1, there is little evidence that increasing the maximum weight of a truck to 80,000 pounds would significantly affect the already unacceptably high risk of serious or fatal injury in crashes between cars and trucks. Primary factors influencing injury in a crash include the velocity change that the car experiences, together with the protection afforded to vehicle occupants; these would not be affected appreciably by truck weight increases.

Although Herzog (12) has reported that the risk of fatality for non-truck occupants increases steadily with truck weight, the effects of road type and location were not considered. It seems probable that the apparent weight effect may have been a surrogate for increased impact speed. This view is endorsed by Hedlund (3), who has concluded that among large trucks weight is not an issue in determining fatality risk, in part because risk can be predicted from crash location (rural or urban) and road type (number of lanes), both of which are surrogates for vehicle speed.

ımmary and Conclusions

Large trucks account for six percent of the nation's highway crashes and 12 percent of all fatal crashes. On a per ıile basis, trucks are less frequently involved in crashes than cars, but trucks are involved in twice as many fatal ashes. The proportion of fatal crashes involving trucks has remained constant since 1977, while the relative risk of :ath for car occupants in crashes with large trucks has steadily increased from 23:1 to 31:1.

Combination trucks — tractor semitrailers or tractor semitrailers plus trailers — have almost twice the crash te of straight trucks, and a fatal crash involvement rate three times that of cars. Twin trailer configurations — tractor semitrailers plus trailers — have higher crash involvement rates than tractor semitrailers. However, the expoıre of different truck types varies in terms of miles traveled, kinds of highways used, and times of day operated, ıd the influence of these variations on crash rates has not been adequately quantified. Until detailed exposure data e collected, comparisons of truck crash experience by configuration will be limited.

In the near future, trucks of increased size and weight, as well as double configuration trucks, will be permitted federal law on the interstate system and other "qualifying" federal-aid highways in all states. While researchers .ve had difficulty in precisely quantifying the influence of truck size and weight on crash involvement, there is eviınce that the new legislation will almost certainly increase the magnitude of the truck crash problem.

Notes

. Eicher, J.P., Robertson, H.D., and Toth, G.R., "Large Truck Accident Causation," National Highway Traffic Safety Administration Technical Report No. DOT HS-806-300, July 1982.

. Vallette, G.R., McGee, H.W., Sanders, J.H., and Enger, D.J., "The Effect of Truck Size and Weight on Accident Experience and Traffic Operations, Volume 3: Accident Experience of Large Trucks." Federal Highway Administration Report No. FHWA/RD-80/137. Washington, D.C., July 1981, PB No. 82 139726.

. Hedlund, J., "The Severity of Large Truck Accidents," National Highway Traffic Safety Administration Report No. DOT-HS-802-332, April 1977.

ı. Meyers, W.S., "Comparison of Truck and Passenger-Car Accident Rates on Limited-Access Facilites." Transportation Research Record 808, Highway Safety: Roadway Improvements, Accident Rates, and Bicycle Programs. Transportation Research Board, Washington, D.C., 1981.

. Cambell, K.L., and Carsten, O., "Fleet Evaluation of FMVSS 121," UM-HSRI-81-9, Highway Safety Research Institute, Final Report National Highway Traffic Safety Administration Contract No. DOT-HS-6-01286, August 1981.

. Scott, R.E. and O'Day, J., "Statistical Analysis of Truck Accident Involvements," National Highway Traffic Safety Administration Report No. DOT-HS-800-627, December 1971.

. Bureau of Motor Carrier Safety "Safety Comparison of Doubles versus Single Semitrailer Operation," Federal Highway Administration, Washington D.C. November 1977.

Yoo, S.C., Reiss, M., and McGee, W.H. "Comparision of California Accident Rates for Single and Double Tractor-Trailer Combination Trucks," Federal Highway Administration Report No. FHWA-RD-78-94, March 1978.

9. Chirachavala, T. and O'Day, J., "A Comparison of Accident Characteristics and Rates for Combination Vehicles with One or Two Trailers," University of Michigan Highway Safety Research Institute (UM-HSRI-81-41, August 1981), National Technical Information Service (PB-82-209412, May 1982).

10. Heath, W.M., "California Tank Truck Accident Survey," California Highway Patrol, Enforcement Services Division. December 1981.

11. Winter, P.A., "1974 Brake Performance Levels for Trucks and Passenger Cars," Bureau of Motor Carrier Safety, Federal Highway Administration, Washington, D.C., 1975.

12. Herzog, T.N., "Injury Rate as a Function of Truck Weight in Car-Truck Accidents," National Highway Traffic Safety Administration Report No. DOT-HS-801-472, NHTSA Technical Note N43-31-7, June 1976.