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PROBABILISTIC MODELS FOR CALCULATION OF LOAD SPECTRA AND LOADEFFECT SPECTRA FOR HIGHWAY BRIDGES

PER CHRISTIANSSON

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PER CHRISTIANSSON

DEPARTMENT OF STRUCTURAL ENGINEERING
FACK S-220 07 LUND

To ULLA, LINUS and JENS

PROBABILISTIC MODELS FOR CALCULATION OF LOAD SPECTRA AND LOADEFFECT SPECTRA FOR HIGHWAY BRIDGES.

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PREFACE

The present work contains derivations and descriptions of two numerical models by which load spectra and corresponding loadeffect spectra may be estimated for highway bridges. The load spectrum model, LOSP, estimates the distributions of heavy vehicle loads which will pass over different road sections. The loadeffect spectrum model, NULESP, which uses the load spectra as input together with bridge and traffic characteristics, analyses the arising loadeffect processes for different structural points of the bridge structure and puts up resulting distributions of loadeffect range-levels, loadeffect spectra.

This work has been carried out at the Department of Structural Engineering, Division of Building Technology, Lund Institute of Technology, in close cooperation with the Bridge Development Department at The National Road Institute.

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Per Christiansson

SUMMARY.

This report describes two numerical models by which load spectra for highway sections and loadeffect spectra for highway bridges are calculated. The models use input variables of both deterministic and non-deterministic, stochastic, nature, which are chosen so that their values can be rather easily estimated. Output from the load spectrum model is used as input to the loadeffect spectrum model. Load spectra are calculated as well as typical loadeffect spectra. The models are primarily intended to be used in connection with fatigue of highway bridges. A short description of the models are listed below.

Numerical calculation of LOad SPectra

Input (LOSP):

Distribution of total weight (maximum gross weight) by registered (heavy) vehicle type. (Stochastic)

Average yearly driving distance by vehicle total weight and type. (Deterministic)

Region road length. (Deterministic)

Distribution of degree of utilized load bearing capacity, loading level, by vehicle type. (Stochastic)

Calculations (LOSP):

Numerical manipulations of input variables.
Ex. multiplication of density functions.

Output (LOSP):

Distributions of vehicle gross weights for all vehicles by type and distribution of axle gross weights, if vehicle specifications were input. The distributions are valid for each lane section of the region.

NUmerical model for calculation of LoadEffect SPectra

Input (NULESP):

Specification for each vehicle type
Weight distribution on axles. (Deterministic)
Axle distances. (Stochastic. Deterministic in overlap calculations)

Lane occurence distributions of vehicle type gross weights, load spectra (Stochastic)

Regarded time period. (Deterministic)

Lateral influence function. (Deterministic)

Distribution of lateral track. Same for all vehicles. (Stochastic)

Longitudinal influence line specifications. Three standard shapes and one optional. (Deterministic)

Traffic data
vehicle speed, equivalent time (factor to correct available time), min. max. queue length (the stochastic queue distance is uniformly distributed). Factors on meeting, overtaking and queuing probabilities. (Deterministic)

Loadeffect calculation directives. (Deterministic)
single, meeting or parallel lanes, vehicles regarded as several axle loads, one concentrated load or all axles running freely.

Distribution (one) of dynamic amplification factor. (Stochastic)

Calculations (NULESP):

Numerical multiplication of density functions. Systematic sampling performed on: type of vehicle (axle distance factor, if single vehicle passage calculations) weight class, meeting section and queue distance and overtaking section (depending on which overlap case is under calculation, lane configuration and representation of vehicle load). The sampled variable combination has a probability to come up (based upon partial vehicle type-weight class flows following Poisson processes and independent variables), giving a weight by which the counted range-levels, from the arising loadeffect process part, shall be multiplied and added to the final result.

Output (NULESP):

Besides the input data -

Distribution of equivalent loads, (gross weight lane occurence distributions modified with regard to lateral influence function and lateral track distribution).

Influence lines and vehicle type influence lines for two driving directions plus result of range-level count performed on them.

Distributions of loadeffect range-level, from different overlap cases and single vehicle passages.

Final distribution of loadeffect range-levels before and after dynamic amplification.

The LOSP program is written in Basic language for Hewlett Packard 2116C computer and the NULESP program in Nualgol for Univac 1108 computer. The programs are fully documented with input output catalogue for the NULESP program.

One or two lanes, meeting or parallel, may be specified. The overlapping loadeffects, that is from overlapping influence lines of several vehicles, originates from meetings, overtakings or queuings, or in the case of vehicles treated as concentrated loads also from queuemeetings and queue meeting queues. The predetermined combinations of types of overlap for different lane configuration and representation of vehicle load may be changed via input.

The simulated loadeffect process parts are analysed by means of a derived statistical counting routine, LECOUNT, which makes continuous eliminations of ranges and the levels they occur on.

The distribution output of stochastic variables is mostly in the form of printed or line printer plotted spectra, where a spectrum expresses probabilities (or 10-logarithm on the absolute number of events) for a variable to be greater than or equal to specific values (or two different values, range and level in a two-dimensional loadeffect spectrum). Both linear an logarithmic spectra are plotted.

Load spectra and loadeffect spectra are calculated and compared to a few measured spectra. The influence of different variables on the appearance of the loadeffect spectra is discussed.

Besides the numerical approach an analytical loadeffect spectrum analysis was performed for uniformly distributed axle weights and short triangular influence lines taking into consideration overlapping effects of meetings.

A mobile vehicle weighing station, developed by the author, is described as well as planned computer controlled field measurments of load and loadeffect spectra in Sweden.

The numerical models LOSP and NULESP, for calculation of load and loadeffect spectra for highway bridges are intended to contribute to the understanding of underlying factors which influence the appearances of the spectra and makes available predictions of such spectra.

LIST OF TERMS.

The following units have been used in the report.

Load: N (Newton)
kN kilo Newton = 1000 N
[1 kN = 0.1 Mp (Mega gram) = 100 kp (kilogram) = = 0.22 kip (kilo pound)]

Loadeffect: Pa (Pascal) = 1 N/m^2 and kN -
1 MN/m^2 (Mega Newton per square metre) = 1 MPa (Mega Pascal)
[1 MN/m^2 = 10 kp/cm^2 (kilogram per square centimetre) = = 0.1 kp/mm^2 (kilogram per square millimetre) = = 0.142ksi (kip per square inch)]

Mass: kg (kilogram)

Length: m (metre)
km (kilometre)
[1 m = 3.28 feet = 39.37 inches]
[1 km = 0.62 miles]

Time: s (second) and year

Some of the most frequently used terms in this report are described below. The corresponding Swedish terms are also mentioned in brackets.

Some terms had to be created because there were no expressions which shortly described the meaning of some variables.

Term	Explanation
calculation case	overlap case or loadeffect calculations of single vehicle passages
critical queue time (kritiskt köavstånd)	if two vehicles pass a lane section within this time they will form a queue a distance ahead with the probability 0.5

Term	Explanation
distribution (fördelning)	used alone, refers to any grouping of values
density function (frekvensfunktion)	equivalent to density function distribution, frequency function and frequency distribution. If preceded by discrete, the function is divided into classes (discrete probability mass function). If preceded by absolute the function is multiplied by the total number of events. (Relative dens. func. is equal to dens. func.)
distribution function (fördelningsfunktion)	equivalent to cumulative distribution function (the density function integrated). May be discrete, absolute (or relative) (see density function)
equivalent load (ekvivalent last)	actual vehicle load of vehicle multiplied by the lateral influence function value part of the separated two-dimensional influence function. The equivalent load becomes stochastic if it is multiplied with all lateral influence values distributed according to the lateral track density function.
equivalent overlap load	equivalent load used in overlap calculations
equivalent time (ekvivalent tid)	a factor to reduce the available time for a vehicle flow to take place
lateral track (sidläge)	the lateral position of the centre of gravity of the vehicle axle weights during bridge passage
load (last)	also stands for weight of vehicle cargo or payload

Term	Explanation
(vehicle) total load	vehicle weight regarded as concentrated load
axle load	all vehicle axles running freely
(vehicle) type load	vehicle weight regarded as coupled axles
loadeffect, l.e. (lasteffekt)	actual vehicle load multiplied by lateral and longitudinal influence values
(loadeffect) range (spänningsvidd, växling)	the amplitude of a closed excursion back to the starting value (which do not have to be the greatest or smallest of the passed through values)
loadeffect level (spänningsviddnivå, växlingsnivå)	the level that a range occurs on, here defined as the lowest value during range excursion
loading level (lastningsnivå)	by total weight = vehicle gross weight/vehicle total weight by total load = gross load/total load
log	10-logarithm (logarithm with base 10)
ℓn	natural logarithm (with base e)
meeting section (mötespunkt)	a road section where the front axles of two meeting vehicles meet (or the front axles of the first vehicles in case of meeting queues)
overlap (överlapp)	used in connection with addition of loadeffects from several vehicles
overlap case	loadeffect calculations of meetings, overtakings, queuings, queuemeetings or queue meeting queues

Term	Explanation
Vehicle weights	
tare weight (tjänstevikt)	weight of an unloaded vehicle
gross weight (bruttovikt)	actual weight of the vehicle on the road, tareweight + gross load
max. (gross) weight (max. bruttovikt)	tare weight + max. load (normally equal to total weight)
total weight (totalvikt)	tare weight + total load (max. legal gross weight)
overweight (övervikt)	tare weight + overload
max. overweight (max övervikt)	tare weight + max. overload
gross load (bruttolast)	actual weight of pay load
max. load (max.last)	normally equal to total load
total load (total last)	max. legal pay load
overload (överlast)	gross load usually greater than max. load
max. overload (max. överlast)	max. overload

Term	Explanation
queuemeeting, QM (kömöte)	queues meeting single vehicles on the bridge
queue meeting queue, QQ (kö möter kö)	queues meet other queues on the bridge
spectrum (spektrum, kollektiv)	a function expressing the relation between the probability for a stochastic variable to be greater or equal (or the 10-logarithm of the absolute number greater equal) to different values. (Equal to 1 - the distribution function for a continuous stochastic variable.)

NOTATIONS.

The notations are chosen to give an idea of what the identifiers stand stand for and furthermore these identifiers should not have to be renamed when used in a computer program. The poorest computer language, with regard to identifier names, is Basic and because some programs are written in Basic this fact brings the following possibilities to name variables, namely simple variables consisting of a capital letter or capital letter+number and subscripted variables of a capital letter. Some longer identifiers, however, are used in the computer program NULESP because it is written in Algol which permits more complex variable names.

When some formulas are deducted small letters and indexed variables are also used. In that case the meaning of these identifiers are found in the appropriate chapter.

Below are the used variables and functions listed. They are divided into three groups, L load spectrum identifiers, E loadeffect spectrum identifiers and A computing aid identifiers. A summary is made in FIG. N-1.

In the text, matrix indexes may be replaced with dots. (Example C(LØ,T1,3) becomes C(...).) The number of indexes may also differ between different programs but it should be clear from the context which ones are deleted.

The formulas are numbered concequtively within chapters N.M (for example within Chapter 6.3).

Null may either be written as 0 or as Ø. Ø is used in order to prevent null from being interpretted as the letter O.

f denotes density function and F distribution function.

	SIMPLE VARIABLE											ARRAY	FUNC-TION FN..	ALGOL expansion		
		Ø	1	2	3	4	5	6	7	8	9			SIMPLE VARIABLE	ARRAY	FUNCTION PROCEDURE
A			E	E							A	L		AX(A)	AM(E)	
B												L				
C	L		A	A	A	A	A	A	A	A		L	L		C(A)	
D					E							L	L	DIST (A)		DYNCONV(E)
E											E					
F		A	E	E	E	E			E	E	E	A		FACT (E)		FPCOUNT(A)
G												L				
H	A			A								L		HTR, HTL, HSR, HSL(A)		
I			A	A	A	A	A	A	A	A	A	E	E			INFLADD, INFLTOYQ, INITL(E)
J		E	E	E			A	A		E		E	E			
K			A	A	A	A	A	A	A	A	A	L				
L	L	E	E									L		LQ, LS, LTR, LTL, LSR, LSL(A) LØ1, LØ2	LEV (A)	LATINT, LECOUNT (E)
M					E		A	A	A	A		E		MOV (A)		ME, MOVY (E)
N	E		L	L	E		A	A	A	A	A	L				NBR (E)
O			E	E	E							E		OCC (E)	ONB (E)	
P	L		L									L	L	PR, PRT, PL, PLT (A)	PLN, PLO(A)	PRINTLSP, PRINTST (E)
Q	A		A	A	A						E	E		QQSW (E)		QM, QU, QQ (E)
R	L		L								E	E		RE(E)	RT(A), RNB(E)	RLSTORE (E), READQ (A)
S	E	E	E	E	E	E				A	A	E		SOCC(E), SRL, SRH, SLL, SLH(A), S4QM (E)	SONB (E)	SI, STLINSPCONV(E), STOQ, STOREZW(A)
T	L	E	L	L				E	E		E	A		TE(E), TRL, TRH, TLL, TLH(A)	TEXT (A)	TADDS(E),
U													A			
V	E											L		VE(E)		VAL (E)
W	E	E	E							E		E	E			
X	E	E	E	E	E			E	E	E		E	A			
Y	E	E	A	A	A	E	E	E	E	E		E		YSEC (E), YL, YH (A)		YQTOYQ, YYDISY2(E)
Z	E	E	L	L	L	L				E	E		E			

L Load spectrum identifiers

E Loadeffect spectrum identifiers

A Computing aid identifiers

FIG. N-1. Used identifiers.

Load spectrum identifiers (L)

Simple variables (L)

C weight class number

P vehicle weight

P1 weight class width (kN)

R region number (also RE)

R1 number of regions

T1 vehicle type number (negative T1 in I(...) denotes meeting vehicle type influence line)

T2 number of vehicle types

Z1 lowest weight class in all-vehicle gross weight lane occurence distribution

Z2 highest weight class in all-vehicle gross weight lane occurence distribution

Z3 lowest weight class in axle gross weight lane occurence distribution

Z4 highest weight class in axle gross weight lane occurence distribution (Z1-Z4 are incorporated in matrix C(...) in the Algol program)

T equivalent time (see also TE)

L road length (km)

N1 total number of vehicle lane occurences per year

N2 total number of axle lane occurences per year (N1-N2 incorporated in matrix K(...) in the Algol program

Subscripted variables (L)

A(T1,I1) : I1 = 1 total axle distance (m) for vehicle type T1,
: axle distance between axles, I1, I1-1, from front

B(T1,I1) : weight distribution on axles (I1) from front vehicle type T1

C(T1,1) : lowest weight class in vehicle type total weight registration distributions

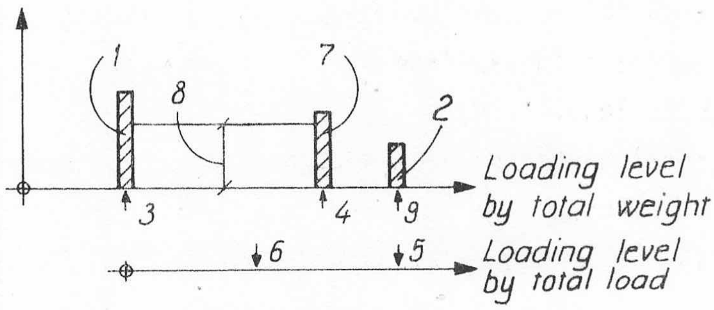
C(T1,2) : highest weight class ...

C(LØ,T1,3) : lowest weight class in vehilce type gross weight lane occurence distribution by lane LØ and type T1

C(LØ,T1,4) : highest weight class ...

C(LØ,T1,5) : lowest weight class in vehicle type equivalent

		gross weight lane occurence distribution by lane LØ and type T1
C(LØ,T1,6)	:	highest weight class ...
D(T1,1)	:	average yearly driving distance (km) per year for
D(T1,2)		lowest and highest weight class in vehicle type total weight registration distribution
G(T1,C)	:	vehicle type gross weight (also total weight in
G(LØ,T1,C)		LOSP) lane occurence distribution (absolute 1 year in LOSP or relative in NULESP)
H(T1,I1,I2)	:	axle distance factor (I1=1) and distribution (I1=2) for vehicle type T1 (number of classes, index I2, is equal to M(3,T1))
K(T1,1)	:	total number of registered vehicles of type T1
K(LØ,T1,2)	:	total number of lane occurences in lane LØ, vehicle type T1. (1 year or YØ years)
L(T1,I1)	:	coefficients of loading level distribution, vehicle type T1, see figure below.



1 tare weight/total weight portion
2 over weight/total weight portion
3 tare weight/total weight
4 max. gross weight/total weight (normally = 1)
5 overload/total load
6 mean load/total load
7 max gross weight/total weight portion

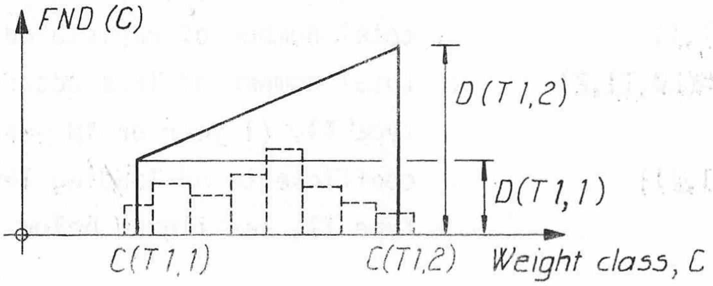
N(T1,C)	:	vehicle type total weight registration distribution (absolute 1 year)
P(1,C)	:	all-vehicle gross weight lane occurence distribution (absolute 1 year). (Also G(LØ,-1,C) lane LØ)
P(2,C)	:	axle gross weight lane occurence distribution (absolute 1 year). (Also G(LØ,Ø,C) lane LØ)
V(T1,1)	:	number of axles for vehicle type T1.

Functions (L)

FNC(P) = INT(P/P1) + 1 that is the weight class number defining loads P.
(See also function NBR(P,P1))

FNP(C) = P1·C-P1/2 that is the mean weight defining weight class C
(See also function VAL(C,P1))

FND(C) = average yearly driving distance in km for weight class C, see also figure below.



Loadeffect spectrum identifiers (E)

Simple variables (E)

A1	:	number of classes in loadeffect amplification distribution
A2	:	mean loadeffect amplification factor
D3	:	influence line displacement in vehicle type influence line calculations
E9	:	ranges that are less E9 are not counted in procedure LECOUNT
F1	:	lateral influence factor for middle track, lane 1
F2	:	lateral influence factor for middle track, lane 2
F3,F4	:	greatest positive and negative variation of middle track factors, lane 1 and 2
F8	:	factor on calculated meeting probability
F7	:	factor on calculated overtaking probability
F9	:	factor on calculated queuing probability
FACT	:	number of occurences for a certain overlap event
JØ	:	if equal -1, JØ indicates that the second lane is a meeting lane, +1 otherwise
J1	:	influence (longitudinal) line type. Negative if meeting
J2	:	number of influence line types
J8	:	number of nullreadings (less E9) to satisfy return from LECOUNT
LØ	:	lane number
L1	:	lane configuration, = 1 single lane, = 2 parallel lanes, = -2 meeting lanes
M3	:	distance between meeting sections
N	:	pointer to load or loadeffect class
N3	:	number of meeting sections
O1, O2, O3, O4	:	pointers to classes in equivalent overlap load distributions
OCC	:	overlap occurence counter
Q9	:	number of breakpoints in Q(..)
QQSW	:	if = Ø queue meets queue not calculated
RE	:	region number (also R)
R9	:	number of counted ranges in LECOUNT

SØ S1	:	shortest and longest queue distance in queue distance distribution
S2	:	mean queue distance
S3	:	queue distance increment in overlap calculations
S4,S4QM	:	number of queue distances in overlap calculations (S4QM in the queuemeeting case)
SOCC	:	overlap occurence accumulating counter
TØ	:	pointer to load distributions used in loadeffect calculations. TØ = -1 total load, = Ø axle load and = 1 type load
T6,T7	:	pointers to vehicle types
T9	:	critical queue time (sec.)
TE	:	equivalent time
VE,V	:	vehicle speed (m/s)
W	:	loadeffect range
WØ	:	loadeffect range increments
W1	:	number of classes in equivalent overlap load distributions
W8	:	highest calculated range class
X	:	coordinate along the bridge
XØ	:	length of influence line (m)
X1,X2,X3	:	influence line coordinates
X6,X7,X8	:	relations describing influence line appearance
Y	:	coordinate across the bridge (lateral)
YØ	:	loadeffect calculation period (years)
Y1	:	load distribution identification, run number
Y4	:	lateral track distribution variation width (m)
Y5,Y6	:	relations describing lateral track distribution
Y7	:	number of breakpoints (column elements) in the first and second row of matrix Y. (Y(1:2,1:Y7)).
Y8	:	number of breakpoints (column elements) in the third and fourth row of matrix Y, (Y(3:4,1:Y8))
YSEC	:	number of seconds per YØ years (including equivalent time factor)
Z	:	loadeffect level
ZØ	:	loadeffect level increments
Z8	:	highest calculated level class
Z9	:	number of negativ levels

Subscripted variables (E)

AM(I1,I2) : amplification factor (I1=1) and distribution (I1=2). Number of classes is A1.

I(T1,I1,I2) : vehicle type influence line (type T1 or -T1, meeting), I2 = breakpoint number, I1=1, 3, 5 gives X-values for axle distance factors H(T1,1,I3) (I3= =1, 2, 3). I1=2, 4,6 gives the corresponding influence values

J(J1,I1,I2) : longitudinal influence line (type J1 or -J1, meeting), I2 = breakpoint number, I1=1 gives X-values and I1=2 corresponding influence values

M(I1,I2) : number matrix
I1=1: number of breakpoints for influence line type I2
I1=2: number of breakpoints for vehicle type influence line I2
I1=3: number of axle distance factors for vehicle type I2

O(LØ,T1,I1,N) : equivalent overlap loads (I1=1) and distribution (I1=2) for vehicle type T1 and lane LØ. Number of classes (index N) is W1.

ONB(LØ,T1) : number of involved vehicles, type T1 and lane LØ, in a loadeffect calculation case

Q(I1,I2) : storage for part of loadeffect process. X-value when I1=1 and process value when I1=2. Number of breakpoints (index I2) is Q9.

R(I1,I2) : range (I1 = 1) and corresponding level (I1=2) as a result of a LECOUNT. Number of range-levels (index I2) is R9.

RNB(I1) : total number of calculated positive (I1=1) null (I1=0) and negative (I1=-1) loadeffect ranges.

S(I1,I2) : accumulated range (class I1)-level (class I2) load-effect distribution (absolute)

SONB(LØ,T1) : accumulated number of involved vehicles, type T1 and lane LØ, from different calculation cases

W(I1) : equivalent load distribution input

X(LØ,T1,N) : equivalent load (gross weight) lane occurence distribution, lane LØ, vehicle type T1

Y(I1,I2) : storage for influence lines and parts of loadeffect processes. X-value when I1=1 (or 3) and corresponding process values when I1=2 (or 4). Number of breakpoints (index I2) is Y7 (or Y8)

Functions, procedures (E)

FNI(W) = INT(W/WØ)+1 same as NBR

FNW(N) = WØ·N-WØ/2 same as VAL

FNJ(Z) used in program INFLU. Same as NBR and FNI. Used for levels Z, giving class FNJ

FNZ(N) used in program INFLU. Same as VAL and FNW, class N gives level FNZ

DYNCONV(S,SRL,SRH,SLL,SLH,A1,AM,T,TRL,TRH,TLL,TLH)
: dynamic amplification of loadeffect range distribution S(..). Result put in T(..)

INFLADD(Y,Y7,Y8,Q,Q9)
: adds loadeffect processes Y(1:2,I1) and Y(3:4,I1). Result in Q(1:2,I1)

INFLTOYQ(J,J1,AX,M1,O,JØ,LØ,YS,Y,Y78)
: moves an influence line or a vehicle type influence line, influence values multiplied with O, to Y(YS:YS+1,I1). AX denotes axle distance factor. If JØ=-1 the meeting influence line is used. That is J1 is put negative on transfer.

INIT(T) : resets variables before an overlap case calculation or single vehicle passage calculation

LATINT(Y4,Y5,Y6,YL,YH,LØ)
: calculates the integral between YL and YH of the lateral track distribution. Lane LØ

LECOUNT(Q,Q9,R,R9,JØ,E9)
: does a loadeffect count on the loadeffect process Q(2,.) and puts the result in R(..). If Q9 breakpoints are read before J8 unchanged process values are read, exit is made. Range fluctuations less than ± E9 are not considered.

ME(LA2,LA1,TØ,T) : calculates meeting or overtaking overlap cases. Result in T(..). Involved lanes LA1 and LA2.

MOVY(YS,Y,Y8,MOV) : moves Y(YS:YS+1,I1) the length unit MOV forwards in time (the vehicle arrives later)

NBR(W,WØ) : class number for load or loadeffect W if the class width is WØ

PRINTLSP(SW,LØ,PR,PL)
: load spectra (SW=1) and equivalent load spectra (SW=2) print- (PR=1) and plot- (PL=1) procedure for lane LØ. Both linear (relative) and logarithmic (absolute, for YØ years) are printed and plotted.

PRINTST(T,TRL,TRH,TLL,TLH,TØ,OCC,ONB,TEXT,PR,PL)
: print and plot procedure for loadeffect spectra. If PR=1 spectra are printed if PL is not equal Ø the procedure tries to plot PL curves "evenly" spread over the plot area. Each curve is guilty for ranges with levels greater than or equal to a specific level.

QM(LQ,LS,T) : calculates the queuemeeting overlap case. Queues in lane LQ and single vehicles in lane LS. Result in T(..).

QQ(T) : calculates the queue meeting queue overlap case. Result in T(..).

QU(LQ,TØ,T) : calculates the queue overlap case. Queues in lane LQ. Result in T(..).

RLSTORE(R,R9,FACT,T,TRL,TRH,TLL,TLH)
: store the range-levels (R9 pairs) in the temporary loadeffect distribution, T(..), (absolute) assuming that each range level has occured FACT times

SI(LS,TØ,T) : calculate loadeffects of single vehicles driving on lane LS. Result stored in T(..).

STLINSPCONV(T,TRL,TRH,TLL,TLH)
: converts a loadeffect distribution into a spectrum

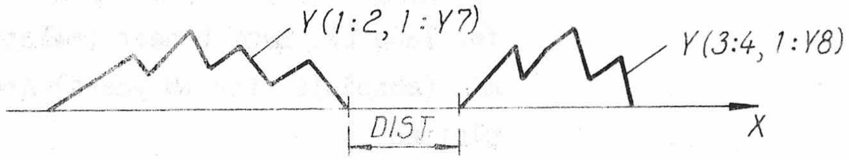
TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH)
: calculates S(..)=S(..)+T(..) and adjusts the array dimensions SRL, ... if the array S(..) becomes larger

VAL(N,WØ) : load or loadeffect value for class N if the class width is WØ

YQTOYQ(YS1,Y1,Y7,YS2,Y2,Y8)
: calculates
Y2(YS2,1:Y7)=Y1(YS1,1:Y7)
Y2(YS2+1,1:Y7)=Y1(YS1+1,1:Y7)
Y8=Y7

YYDISY2(Y,Y7,Y8,DIST)

: moves Y(3:4,1:Y8) to be situated DIST after (greater X) Y(1:2,1:Y7) see figure below.



Computing aid identifiers (A)

Simple variables (A)

A9	:	max. allowable amplification factor, due to computer array dimensions
AX	:	pointer to axle distance factor
C1-C8	:	used in subroutine boxplot
DIST	:	used in procedure YYDISY2
FØ	:	= F1 or F2 depending on regarded lane
H	:	height of lateral track distribution, procedure LATINT
H2	:	temporary storage for axle distance factors
I1-I9,N5-N9,S8-S9	:	counters and pointers
JØ1=JØ2=JØ		
J5,J6	:	min. and max. values of loadeffect process part, procedure LECOUNT
K1-K9	:	temporary storages
LØ1=LØ2=LØ		
LQ	:	pointer to queue lane
LS	:	pointer to lane with single vehicles
M5-M8	:	used to axis grading in subroutine BOXPLOT
MOV	:	used in procedure MOVY
PR,PRT	:	=1 print =Ø do not print
PL,PLT	:	=Ø do not plot =N,plot N curves
Q,Q1-Q3	:	loadeffect process values in procedure LECOUNT
Y1-Y3	:	used in LATINT to describe lateral track distribution (coordinates to breakpoints)
Y2	:	tabulator parameter
Y3	:	character size in plot routine (mm)
YL,YH	:	used in procedure LATINT
LTR,HTR,LTL,HTL LSR,HSR,LSL,HSL	:	limits of T(..) and S(..) indices L=low H=high R=range L=level T(LTR:HTR,LTL:HTL) S(LSR:HSR,LSL:HSL)
TRL,TRH,TLL,TLH SRL,SRH,SLL,SLH	:	the lowest (L) and highest (H) of the first (R=range) and second (L=level) indices of T(..) and S(..) used in calculations.

Subscripted variables (A)

C(I1) : I1=1 lin. I1=2 log. curve counter in procedure PRINTST

F(I1,I2) : convert indices I1,I2 to one index F(..). (The Basic interpreter can handle max. two-dimensional arrays)

LEV(I1,I2) : level class number for curve number I2 in lin. (I1=1) or log. (I1=2) loadeffect spectra. Used in procedure PRINTST.

PLN(T1) : remembers the spectrum value for vehicle type T1 when it has been plotted (for a certain range). If several values overlap a * is plotted.

PLO(I1) : string array containing characters to be plotted to identify different curves in loadspectra and loadeffect spectra. Used in procedures PRINTLSP and PRINTST

RT(I1,I2) : temporary R(..) matrix in procedure SI.

T(I1,I2) : temporary storage for loadeffect range (class I1) level (class I2) distributions and spectra

TEXT(I1) : contains heading for lin. and log. spectra prints and plots.

Functions, procedures (A)

FNX(T1) : =T1 if T1≥Ø, =T1+4 if T1<Ø in INFLU

FNU(I4) : =N(.,I4) if I5=1 and G(.,I4) if I5=3 in LOSP

FPCOUNT : four point count. Finds a closed loop in the loadeffect process. Used in LECOUNT

READQ : reads a new loadeffect process value in LECOUNT

STOQ : stores a loadeffect process value in matrix U(.). Used in procedure LECOUNT

STOREZW : store a loadeffect range level in R(..). Used in procedure LECOUNT

1 BACKGROUND TO THE INVESTIGATION. OBJECTIVES. PERFORMANCE.

The research object was initiated in 1972 by the National Road Administration because a theoretical model forming a background to the ongoing work on the development of the "Nordic Load regulations for Highway Bridges" was meant to be of great importance for the following reasons:

- To increase the understanding of the influence of different variables on the appearances of load and loadeffects in connection with highway bridges.
- To be a complement to and extension of field investigations.
- To give a picture of the rare but high amplitude loadeffects arising from overlap events involving several vehicles at a time.
- To estimate loadeffect spectra (stress range distributions) in connection with fatigue design.

The research objective was to put up probabilistic models by which load spectra and loadeffect spectra could be estimated by using vehicle and bridge characteristics that were as original as possible. The following sub-objectives were formulated:

- Provide a more sophisticated description of the heavy loads and the loadeffects in terms of stochastic variables, instead of using the usual deterministic description.

- Provide a theoretical model which can be used to estimate load spectra for lane sections of different regions and optional points of time.

- Provide a theoretical model which uses the load spectra as input to estimate loadeffect spectra valid for different parts of the bridge structure and optional points of time.

- Provide possibilities to get a picture of the relative and absolute influences of different variables on the appearances of the load spectra and loadeffect spectra.

Provide a method to estimate the intensities of rare but high amplitude overlap loadeffects, caused by several vehicles at a time.

Intermediate results were published in internal reports in March 1973, "Last- och påkänningsspektra för vägbroar" and in February 1975, "Underlag för bedömning av föreslagen utmattningslast för vägbroar". An introductory literature review was also published in July 1973, Christiansson /1/. The internal report, March 1973, contained a first version of the load spectrum model, LOSP, and an analytical statistical approach to determine loadeffect spectra from a loadeffect process, which is also found in Chapter 6.3 of this report. The analytical approach was abandoned in favour of a simulation solution technique, systematic sampling, which was assumed to lead to more apprehensible and general solutions with less complicated mathematical expressions and algorithms.

Because of an parallel investigation now in progress on dynamic effects, in connection with vehicles driving over coupled bridge slabs, the investigation became somewhat delayed. From autumn 1974, however, all resources were put on completion of the investigation, resulting in two complete numerical models, LOSP and NULESP, in the summer of 1975.

2 LITERATURE REVIEW.

During the past years there has been a growing interest in fatigue related problems in connection with highway bridges subjected to traffic loading especially in the form of heavy vehicles.

The research going on may be divided into three main fields: namely measurments and interpretations of loadeffect processes and the corresponding vehicle weight distributions, construction of theoretical models for calculation and prediction of load spectra and loadeffect spectra and finally, translations of the loadeffect spectra into terms of fatigue.

The author of this report wrote a report in 1973, Christiansson /1/, which gave an introductory review of related literature.

Below some of those references found in the reference list, Chapter 10, are shortly presented. Most of the references are made in Chapter 4, CALCULATED AND MEASURED LOAD SPECTRA and in Chapter 9, DISCUSSION.

A great deal of work seems to have been done in the USA concerning collection of load and loadeffect data for research purposes, see for example Cudney /2/, Christiano et al. /3/, Douglas /4/, Heins et al. /5/, McKeel et al. /6/, Galambos et al. /7/, Turner et al. /8/, Bowers /9/, Goodpasture et al. /10/, Ruhl et al. /12/ and in Great Britain Nunn et al. /11/.

The wanted characteristics, which are to be reflected in the final results, play a central role in the analysis of a loadeffect process. In connection with fatigue the variations of the loadeffect are judged to be of special interest. The variations of the loadeffect process are called loadeffect <u>ranges</u> and may be defined in many more or less useful ways. A comprehensive review of different so called statistical counting methods are found in Dijk /13/, Dowling /14/ and Mercer et al. /15/. These methods may be used through different counting devices (or manually), either direct on the process or via recordings to pick out ranges from a loadeffect process.

It is of course of great interest to have access to theoretical models which can be used to predict load spectra and loadeffect spectra and to increase the understanding of the coupling between participation variables and their influences. The spectrum of loadeffect ranges may be regarded as a final expression of a stochastic load variable which can not be further reduced to some characteristic value, before a proper consideration of the fatigue of used materials and structural detail layouts are taken, that is before a comparison to the load bearing capacity is made.

Todays efforts concerning structural safety are being directed towards greater refinements in the treatments of loads and load bearing capacities in the respect that the stochastic (non-deterministic) nature of the involved variables is considered. In this case the loadeffect spectra may be regarded as the loads which shall be compared to the design loadeffect spectra which are derived outgoing from fatigue phenomena. A lot of work is being done concerning structural safety at many places including the Division of Building Technology. For further references see for example the LITERATURE REVIEW /16/ published in 1972.

Those models found in the literature to calculate loadeffect spectra are, of course, all more or less sophisticated with regard to the following: degree of simplicity that the stochastic input data are put up with, the actual variation width of the input variables that the model will cover, the resolution of the results and how easily the model is handled.

Through regression analyses on the registered vehicle weights and the corresponding stress ranges, defined as the difference between the maximum an minimum response during vehicle passage, relations between these quantities were found for the studied objects, see for example Heins et al. /5/ and Ruhl et al. /12/.

A pure analytical approach is very hard to fulfill without farreaching simplifications. Tung /17/, /18/, calculates peak probability density functions and expected rate of threshold crossings under the assumption of Poisson or Pearson Type III distributed vehicle flows, concentrated vehicle loads and piece wise linearized influence lines. Ditlevsen /19/ introduces queues in the vehicle flows and calculates probability density functions for the bridge response. These density functions may only be transformed to loadeffect spectra under certain circumstances. It is probable that more analytical work concerning loadeffect spectra for highway bridges will come up from the field of structural response of structures to stochastic loads.

Numerical simulation models, like the one described in this report, may also be put up, which will allow more complicated input, output and model criteria to be formulated, though likely at the expense of computation times and immediate comprehensibility of the underlying casual connections.

Moses et al. /20/ uses a similar simulation technique to the one described in this report to calculate stress range histograms, for calculating bridge fatigue lives. Although that model and the one described in this report were developed completely independent of each other, they do have some characteristic features in common. They call the used solution technique a discrete convulotion or summing procedure and work with the stochastic variables truck type, truck weight, truck headway and lane occupancy. The vehicle headways were assumed to be exponentially distributed (vehicle flow described as a Poisson flow) and used both for passing and following vehicles. The stress ranges were defined as the difference between the maximum and minimum stress values during vehicle passage or overlap event. They do, however, give a somewhat different definition to be used in case of short influence lines. Fatigue lives are calculated by means of cumulative damage theory, and their sensitivity to changes in certain input variables are tested. Measured vehicle weight distributions are used as load input. No consideration is given to the lateral track distribution of the vehicles during passage and furthermore the dynamic amplification factor is supposed to be deterministic. Compability between measured and calculated stress histograms is reported though "because of the relatively small number of truck crossings reported in most measurments, comparisons of the histograms in the important high stress region due to rare heavy vehicles and multiple crossings could not be done".

Fothergehill et al. /21/ describe in four reports (of which unfortunately only two /21:2/ and /21:3/ were available to the author of this report) four stand alone computer programs which are used to simulate bridge traffic load patterns and the dynamic response to these loads of a carely specified bridge structure. The used technique seems to be a simulation of a real chain of traffic events which are stored and later used in a dynamic finite element analysis of the vehicle bridge system, during which stress maxima and minima and ranges are picked out and stored.

Finally, it shall be mentioned that in Sweden a welding regulation /22/ was published in the year 1974 which contains typical design stress spectra which are to be used in the fatigue design of welds. These spectra are defined in the same way as is done in this report namely as a curve that represents the logarithm of the number of exceedings of different stress range amplitudes. Some comments on the basis of the regulation are found in Alpsten /23/ and Jarfall /24/. Further references to fatigue are found in Moses et al. /20/ and in Fatigue of Concrete /25/.

3 THEORETICAL MODEL FOR CALCULATION OF LOAD SPECTRA.

This part of the report deals with a numerical model, LOSP, for calculation of LOad SPectra, or load density functions, valid for different road sections and time periods. The calculated load density functions will later be used as input for another theoretical model, NULESP, which analysis the arising loadeffects in different parts of a bridge structure, caused by the passing loads, vehicles.

3.1 Derivation of model

3.1.1 Introductory discussion

Through the evaluation of the model a more sophisticated expression for the loads, vehicle weights, that will drive over a road section will be achieved, than with a conventional deterministic load approach. That is the non-deterministic, stochastic, nature of the loads will be considered.

The only loads considered here are those of heavy vehicles, that is passanger cars are omitted. It is furthermore the static load, the actual vehicle weights, which are studied with no superposed time varying dynamic forces.

Beside the stochastic variable total vehicle (or axle) gross weight, a more or less complex collection of deterministic and non-deterministic variables are required to give an adequate description of the loads for a certain application. It all depends on how accurate the load transfer to the road surface has to be specified. In order to make possible calculations of axle load spectra, a deterministic distribution of the total vehicle gross weight on different axles were assumed for different vehicle types, which then are characterized by this distribution and the axle-configuration.

Once a model for the calculation of lane occurence load density functions, or load spectra, is put up, it can be used to study the influences of different variables and further, with rather easily estimated input variable values, to calculate predicted load spectra, hopefully with greater accuracy than can be made from extrapolated measured spectra.

The derived load spectrum model, LOSP, will form a part, together with the loadeffect spectrum model, NULESP, of a theoretical system to describe the load-loadeffect behaviour in a statistical manner.

The produced load density functions are not given in explicit formulas through a purely analytical solution, since such a solution was judged, at this stage, to incorporate too many assumptions about the involved density functions and to be too laborious to fulfill without fargoing simplifications. Instead a numerical technique was used in the solution thus requiring a computer to bring about reasonably short calculation times. The computer program is written in the Basic language for a Hewlett Packard 2116C computer, with 16K words of memory, belonging to the structural division.

3.1.2 Chosen input variables.

The input variables were chosen to be as simple and as easy to predict as possible. There are two fundamental variables, namely the available fleet of registered vehicles, with their basic data about loading capacity, tare weight and type of vehicle, expressed through the vehicle type total weight registration density functions and the studied "geographical" region. The region concept should be widely understood. A region can for example be constituted of all the main roads in a typical wood producing district or of the main transfer roads for heavy goods and so on.

To be able to estimate the load spectra for a certain region one also has to know to what degree the vehicles are loaded, the loading level distribution, and the average yearly driving distance for the vehicles on the roads of that region, expressed through the driving distance distribution and region road length.

These are the chosen input variables to which information about the weight distribution for the different vehicle types shall be added in order to make possible the calculations of axle load spectra.

3.1.3 Representation of results.

The final results, the output, of the load spectrum model are vehicle type (axle) gross weight lane occurence density functions. In order to make them more comprehensible, and to simplify the comparison with the later calculated loadeffect range-level distributions, the load density functions are finally transformed to load spectra, that is almost the inverse distribution function. (The spectrum expresses namely probabilities for an observation to be greater or equal and not only greater than.)

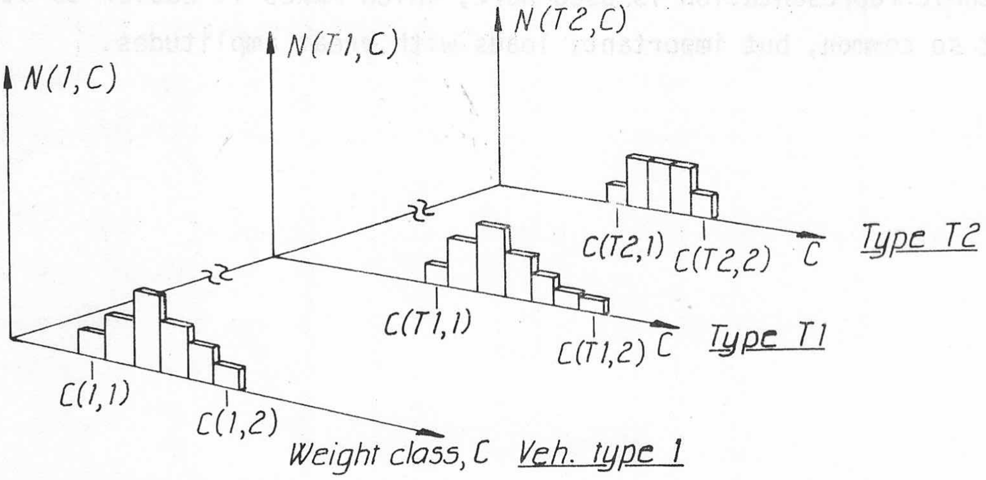
The spectra can be drawn in both linear and logarithmic scales thus emphasizing different domains, see also FIG. 6.1.3-2. In most cases the logarithmic representation is used here, which makes it easier to study the not so common, but important, loads with great amplitudes.

3.2 Description of input variables.

3.2.1 Total weight registration distribution and vehicle type characteristics.

It was judged that an estimation of the main vehicle types, with approximate total weight distributions, to appear in the future and their shares of the total fleet of vehicles, could be done with enough accuracy, to serve as input to a load spectrum model.

FIG. 3.2.1-1 shows the main elements of this part of the input section which is found in subroutine SUB 1500 called at line 240 of computer program LOSP.



T1 = vehicle type
T2 = number of vehicle types
N(T1,C) type total weight registration density function (absolute)
C(T1,1), C(T1,2) lowest, highest weight class; k_1, k_2 corresponding loads.

INPUT: k_1, k_2, $C(T1,1) - C(T1,2) + 1$ ← *For checking*
$N(T1, C(T1,1))$
:
$N(T1, C(T1,2))$

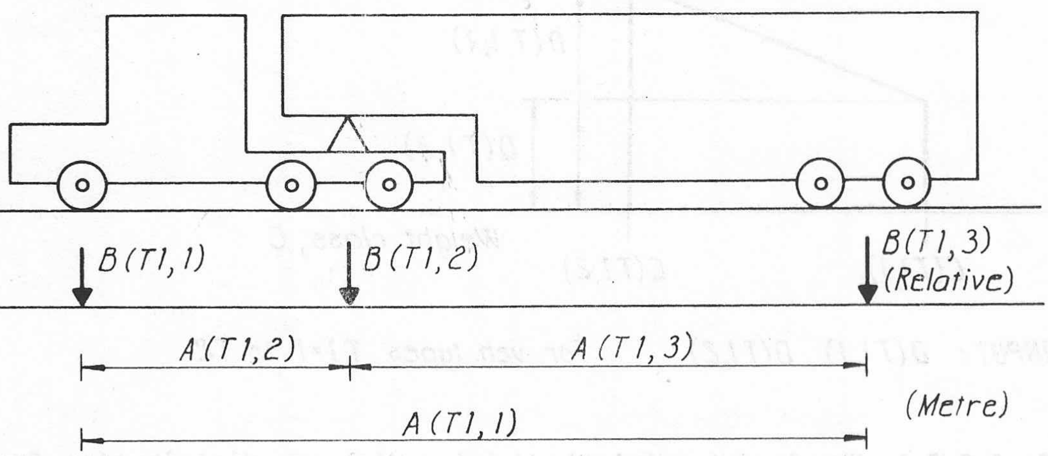
For vehicle types T1=1 to T2

FIG. 3.2.1-1. Vehicle type total weight registration density function input, LOSP.

The vehicle type input could have been limited to the deterministic weight distribution on axles for each vehicle type, but it also comprises information about the axle configuration in order to establish a closer connection to the loadeffect analyses program, where this information is used. What is said below, therefore can also be found in Chapter 6.2.1 which for clarity is partly reproduced below.

The total number of vehicle types, T2, may be max. 10 each type having max. 5 axles. The later introduced axle distance factor distributions are not used in LOSP.

The vehicle specification part is found in subroutine SUB 1000 in LOSP and is called at line 230.



INPUT: V(T1,1) number of axles
A(T1,2), A(T1,3), . . .
B(T1,1), B(T1,2), B(T1,3), . . .
For vehicle types T1=1 to T2

FIG. 3.2.1-2. Vehicle specification input, LOSP.

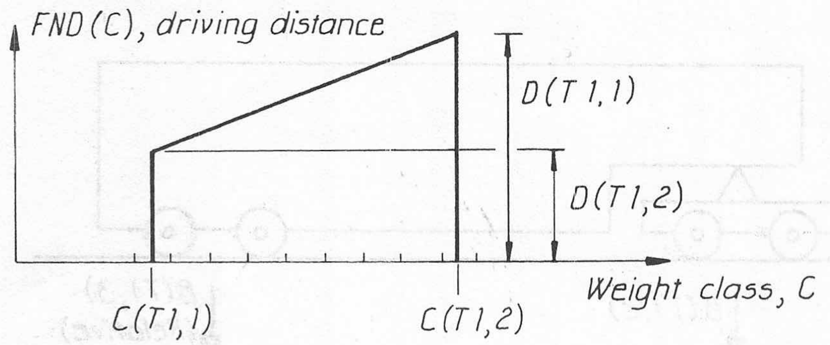
3.2.2 Average yearly driving distance distributions for the region.

It is through the driving distance distribution that it is determined how often, in average over a time period, vehicles of a certain type T1 and total weight class C will drive over a road section. It is assumed that the traffic is evenly spread in both driving directions, over the entire region road length, L.

It is also supposed that the same driving distance distribution is valid for all the vehicles of the same type, T1, and that it is the total weight of the vehicle that decides how far it will travel.

The yearly deterministic driving distance distribution for vehicle type T1 and total weight class C is defined through function FND(C, T1) according to FIG. 3.2.2-1. In this report the simpliest shape, a straight line was selected, but other arbitrary functions may be chosen. It is only the function values for integer arguments, weight class C, which are used.

The corresponding input section is found in subroutine SUB 2000 which is called at line 300 of LOSP.



INPUT: D(T1,1), D(T1,2)   For veh. types T1=1 to T2

FIG. 3.2.2-1. Yearly deterministic driving distance distribution function input, LOSP.

Both the road length L and driving distances are expressed in the unit 1000 metres = 1 km.

3.2.3 Loading level distributions for the region.

The last necessary input to do, supplies information about the degree of utilized available load bearing capacity of the regarded vehicles. A stochastic variable, the loading level, is introduced, which is a factor by which the vehicle total weight shall be multiplied, to be transformed to the actual gross weight of the vehicle running on the road.

$$\text{loading level} = \frac{\text{vehicle gross weight}}{\text{vehicle total weight}} \qquad (1)$$

In the LOSP-model each loading level density function is valid for all vehicles of the same type, which of course is a simplification among others. It is also possible to define several vehicle types which are alike, and to apply different loading level distributions on them, thus refining the calculations.

In the LIST OF TERMS are some vehicle weight related terms explained, which are used below.

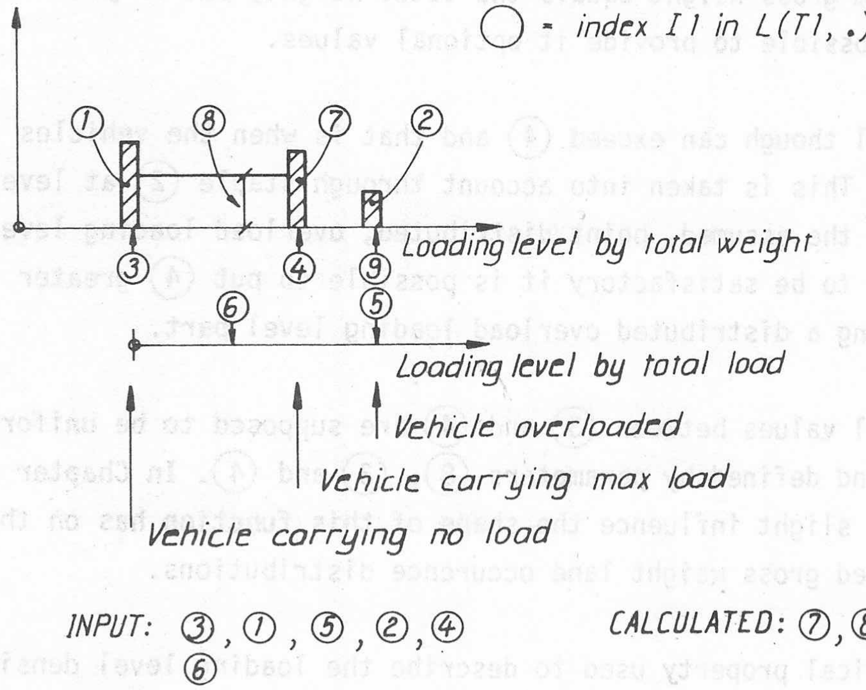


FIG. 3.2.3-1. Loading level distribution input, LOSP.

The loading level density functions consists of four main parts. Three of them are probabilities for discrete values of the loading level to occur and the fourth is a continuous function part. FIG. 3.2.3-1, which is commented below, shows the principle appearance of the function. The ringed numbers refer to index I1 in variable L(T1,I1). (See also FIG. at variable L(T1,I1) in the NOTATIONS.)

As can be seen there are two loading level axes of which the upper is the one normally referred to here. The lower axis expresses the loading level as a relation between actual load and maximum permissible load, total load. This representation of the loading level may be of interest when pure loading parameters are considered. (Here L(T1,5) and L(T1,6).)

Loading level (3) expresses the relation tare weight/total weight, valid for an unloaded vehicle. It is assumed that this loading level together with the max. gross weight/total weight level (normally equal to 1) are more specific and probable to occur, than other loading levels. Therefore the loading level continous density function is not defined in these points, in return histogram staples, representing probability values, (1) and (7), are introduced. Point (4) is normally equal to 1 since the maximum gross weight equals the total weight, but to gain flexibility it is possible to provide it optional values.

The loading level though can exceed (4) and that is when the vehicles carry overloads. This is taken into account through staple (2) at level (9) (or (5)). If the assumed, point distributed, overload loading level is not estimated to be satisfactory it is possible to put (4) greater than 1 thus adding a distributed overload loading level part.

The loading level values between (3) and (4) are supposed to be uniformly distributed and defined by parameters (8), (3) and (4). In Chapter 3.4 is shown the slight influence the shape of this function has on the finally calculated gross weight lane occurence distributions.

The only statistical property used to describe the loading level density function is the mean loading level (6) which is input together with (3), (1), (5), (2) and (4) leading to two more values to be calculated, namely areas (7) and (8), thus completely defining the function. This is done under the following conditions, the total area of the density function to be 1 and the mean value to be equal to (6). In this way the area (8) is automatically calculated, that is the probability for a vehicle to carry max. load can not be directly forecast. The input is made this way because it is judged that (1) and (2) is more easily estimated than (7) and (8).

The relations between the loading level parameters are further explained and deduced in Appendix A.

The loading level input is found in subroutine SUB 2500 which is called at line 320 in LOSP.

3.3 Description of load spectrum model, LOSP.

This chapter describes the numerical model for calculation of load spectra, LOSP, and the corresponding computer program written in BASIC (Hewlett Packard Basic) with the same name. The program listing is found in Appendix B.

First is the model described including a summary chart followed by a flow chart of the program. No examples on runs are given here, instead reference is made to Chapter 4 CALCULATED AND MEASURED LOAD SPECTRA

3.3.1 Description of the model including summary chart.

The load spectrum model, LOSP, is a numerical calculation model by which loads, particularly loads of heavy vehicles, appearing at a road section can be determined and expressed in statistical terms outgoing from parameter values possible to estimate. The load amplitudes are thus represented as distributions and not as constant values.

The following description of the program is made outgoing from the summary chart presented in FIG. 3.3.1-1.

The calculations are principally executed in two subroutines, of which the first transforms the vehicle type total weight registration absolute density functions, N(T1,.), to vehicle type total weight lane occurence absolute (one year) density functions, G(T1,.) by means of the driving distance distributions, see FIG. 3.3.1-2. The second subroutine then transformes G(..) to vehicle type gross weight lane occurence absolute density functions, by means of the loading level distributions, see FIG. 3.3.1-3.

From FIG. 3.3.1-2 it can be seen how the number of lane occurences for each vehicle type total weight class is calculated. It is assumed that all vehicles of the same class and type travel equal distances per year, FND(C), including both driving directions.

FIG. 3.3.1-3 shows how the conversion of G(T1,.) from a total weight distribution (here called G'(T1,.)), to a gross weight distribution is done. Each total weight class, I2 with weight K4, is spread and accumu-

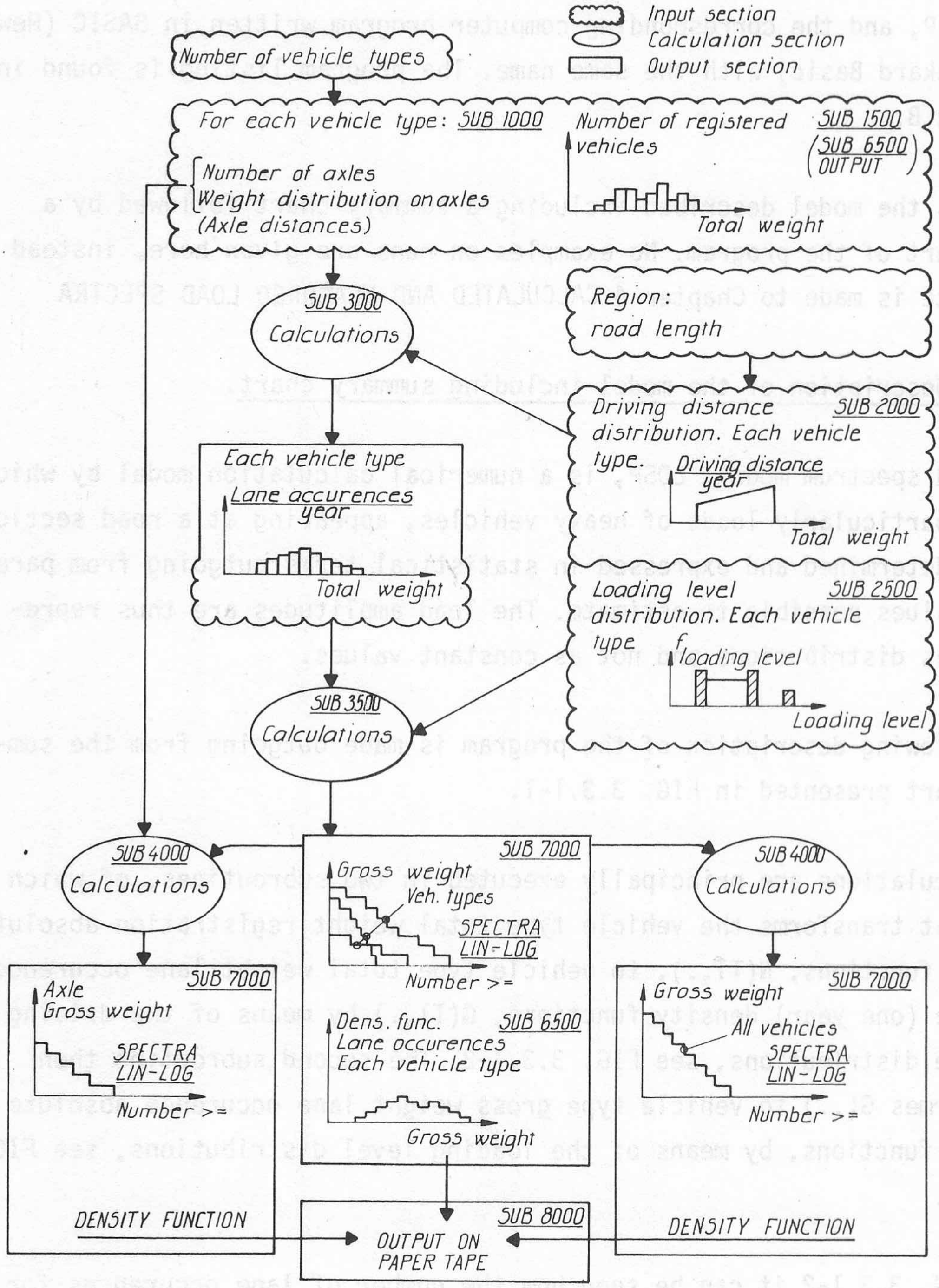


FIG. 3.3.1-1. Summary chart of LOSP. (See also flow chart FIG. 3.3.2-1.)

lated in G(T1,.), primarily in an aid matrix Y(.), according to the loading level density function.

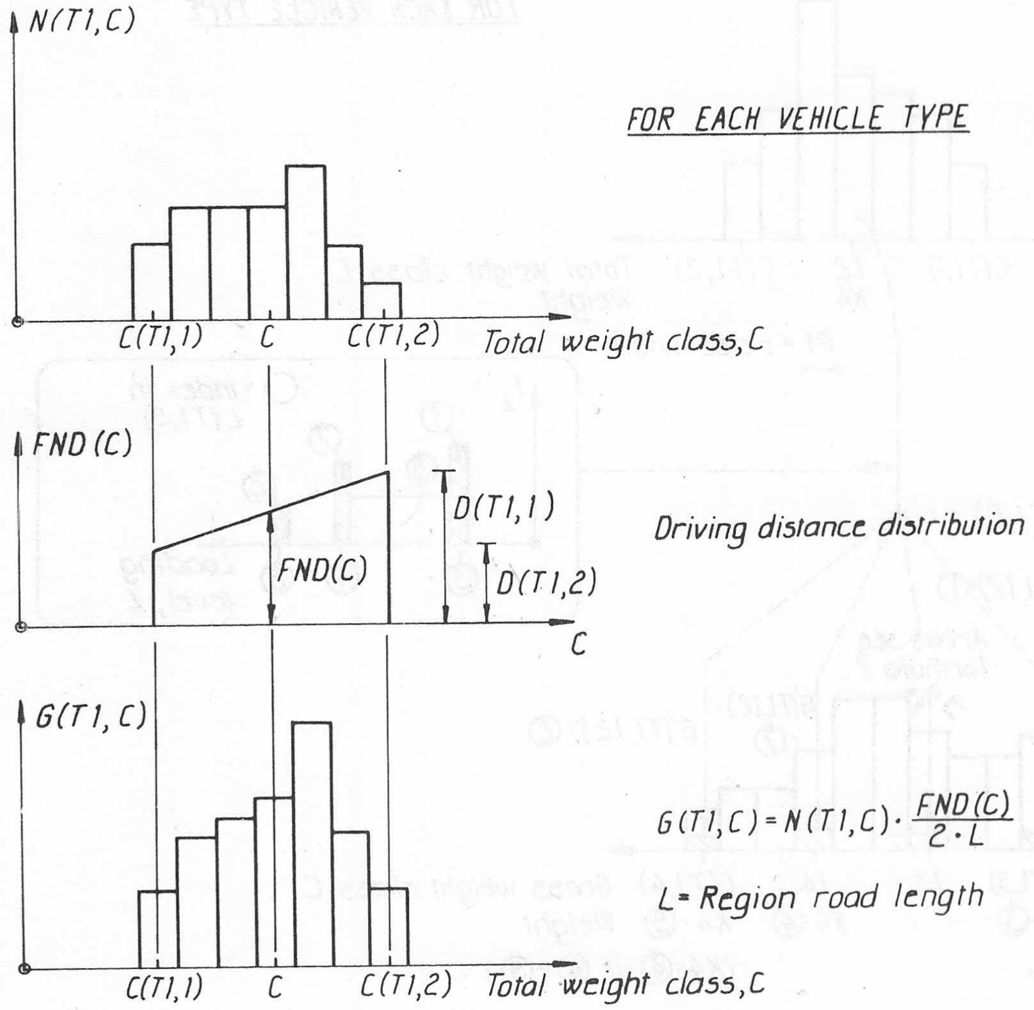


FIG. 3.3.1-2. Calculation of total weight lane occurence distributions. SUB 3000 in LOSP.

First the no load, max. load and overload loading levels of the loading level distribution are treated and then the continuous part (8). The contribution to class G(T1,I3) becomes for each I3 (I3 is incremented between the "lower I3" and I4, FIG. 3.3.1-3).

$$\text{area} = G'(T1,I2) \cdot \int_{\frac{G(T1,I3)-\frac{P1}{2}}{K4}}^{\frac{G(T1,I3)+\frac{P1}{2}}{K4}} L(T1,8) \cdot d\ell = G'(T1,I2) \cdot \frac{P1}{K4} \qquad (2)$$

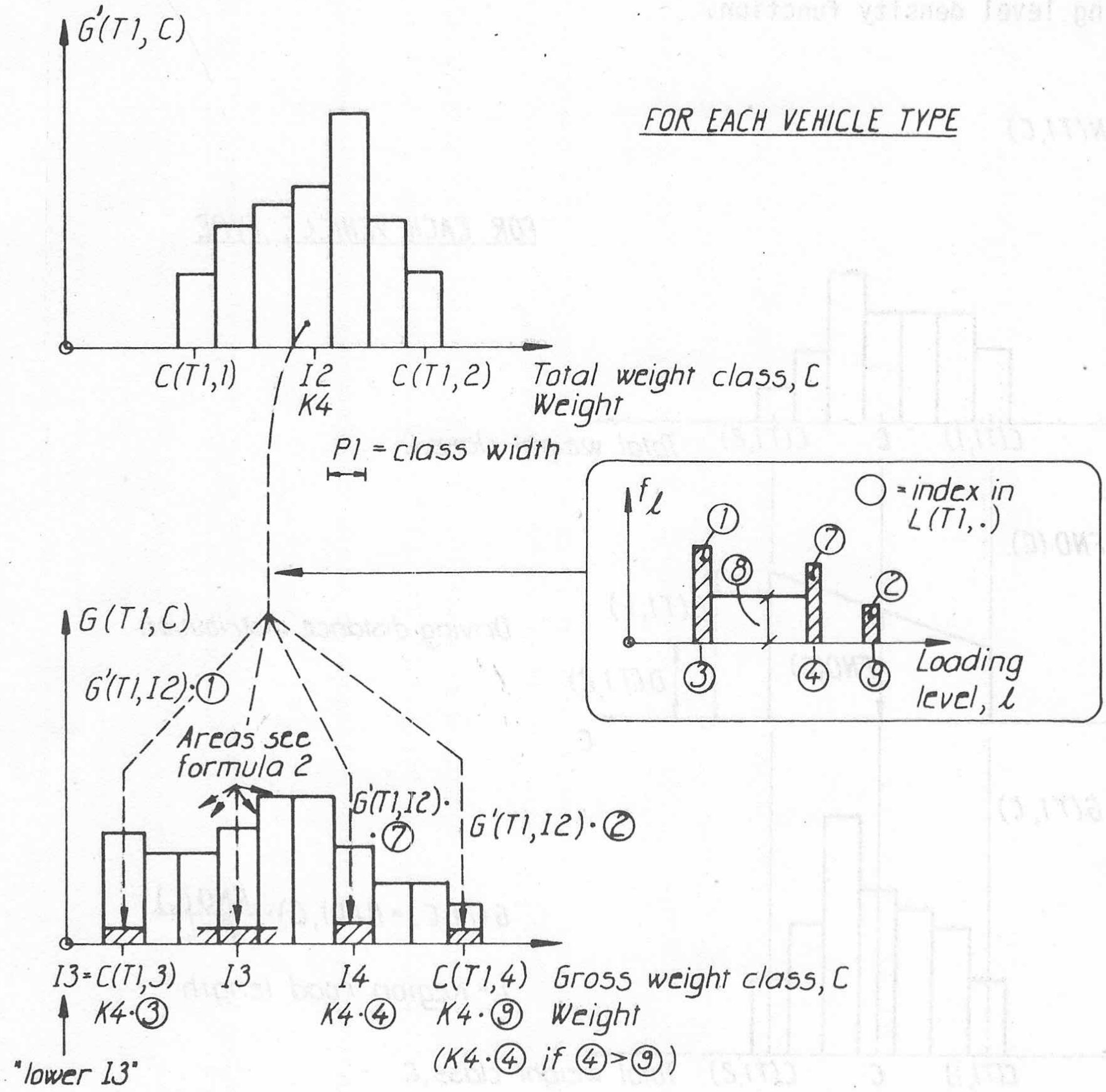


FIG. 3.3.1-3. Calculation of gross weight lane occurence distributions.
SUB 3500 in LOSP.

The main calculations are now gone through. Finally the axle gross weight lane occurence and total ("all vehicle") gross weight density functions are calculated. The former is determined by means of the weight distribution on axles information.

The following output is obtained during a RUN.

Vehicle type specifications, printed during input

Driving distance distributions, printed during input.

Loading level distributions, printed during input.

Input total weight registration distributions and gross weight lane occurence distributions plotted as density functions together with schematic vehicle type descriptions. Subroutine DENS PLOT.

Vehicle type, axle and total gross weight spectra plotted in linear and logarithmic scales. Subroutine SPECT PLOT.

Finally may the total and axle gross weight absolute (one year) density functions be punched on to papertape, if switch = 1, or, if switch = 2, the total, axle and vehicle type gross weight absolute density functions are punched. Subroutine PUNCH.
The format of the punched tape is:

run No., region No.

weight class width, lower class number, upper class number,
number of occ./year
Number of occurences lower class
:
Number of occurences upper class

:

3.3.2 <u>Computer program flow chart.</u>

Below is a flow chart presented which includes the main elements of the Basic program LOSP. As the program is interpretative no certain input-output catalogue is necessary as for the NULESP program. The program listing is found in Appendix B.

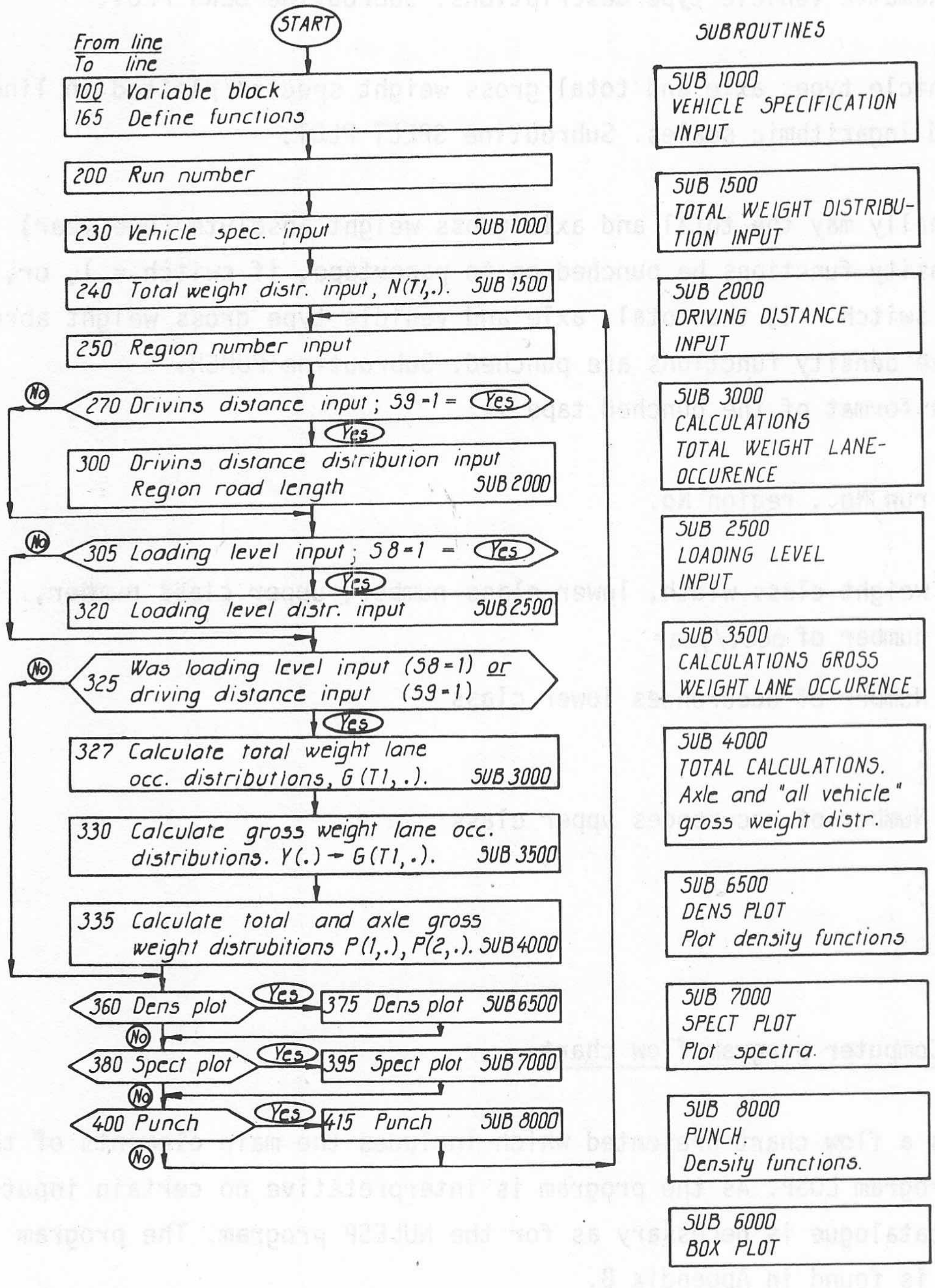
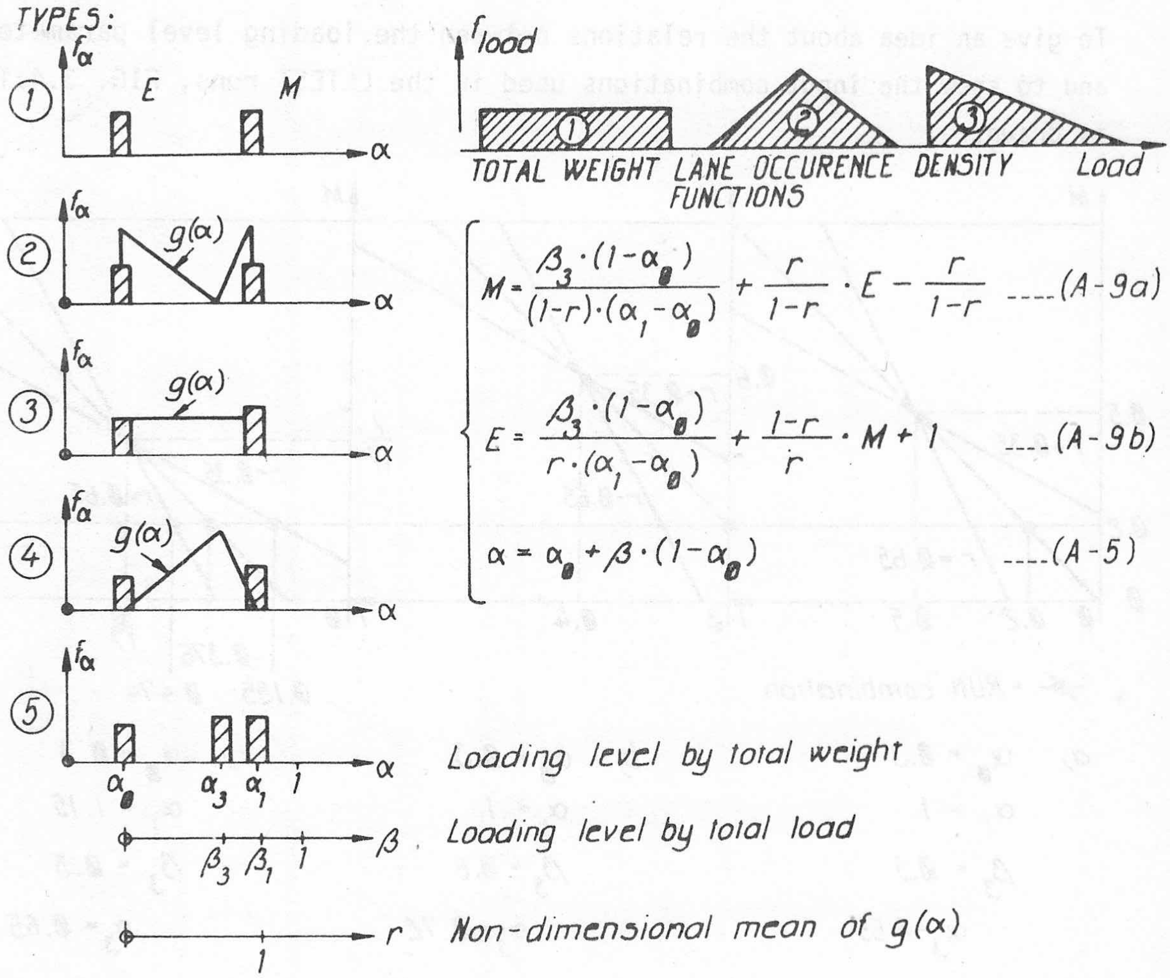


FIG. 3.3.2-1. Flow chart LOSP. (See also summary chart FIG. 3.3.1-1 and Appendix B.)

3.4 Discussion of certain variables influence on the result.

This chapter brings out an idea about the relative importance of the three main variables loading level, driving distance and input load distributions. The results are presented as spectra which are calculated and drawn by a Basic routine LLTEST. The influence of the driving distance and load distribution shapes is related in Chapter 3.4.2, which can also be looked upon as an illustration of the spectrum appearance in relation to the underlying density function. Further discussion on the influence of weight distribution on axles are held in Chapter 4, calculated spectra, and 6.5, variable influence in loadeffect spectrum model.

3.4.1 Loading level distribution influence.



$$M = \frac{\beta_3 \cdot (1-\alpha_0)}{(1-r)\cdot(\alpha_1-\alpha_0)} + \frac{r}{1-r}\cdot E - \frac{r}{1-r} \quad \text{----}(A\text{-}9a)$$

$$E = \frac{\beta_3 \cdot (1-\alpha_0)}{r\cdot(\alpha_1-\alpha_0)} + \frac{1-r}{r}\cdot M + 1 \quad \text{----}(A\text{-}9b)$$

$$\alpha = \alpha_0 + \beta\cdot(1-\alpha_0) \quad \text{----}(A\text{-}5)$$

FIG. 3.4.1-1. Five loading level distribution types and three load distribution types. Notations see Appendix A. (f_{load} = total weight lane occurence density function)

As mentioned in the LOSP description, Chapter 3.3.1, a loading level distribution of type 3, see FIG. 3.4.1-1 and Appendix A, was used in the calculations of load spectra. In order to study the influence of the loading level distribution appearance, expressions for four more distributions were deduced, Appendix A, and used on three main shapes of load distributions in a computer program LLTEST. The five types of loading level density functions and three types of load density functions are explained in FIG. 3.4.1-1, which also contains some important formulas picked from Appendix A. Notations are also explained in Appendix A.

In the test runs the overload part of the loading level distribution was not included. Instead α_1, the max. gross weight which normally is one, with its related area-probability M, is increased to show the influence of loading levels greater than one.

To give an idea about the relations between the loading level parameters and to show the input combinations used in the LLTEST runs, FIG. 3.4.1-2 is drawn.

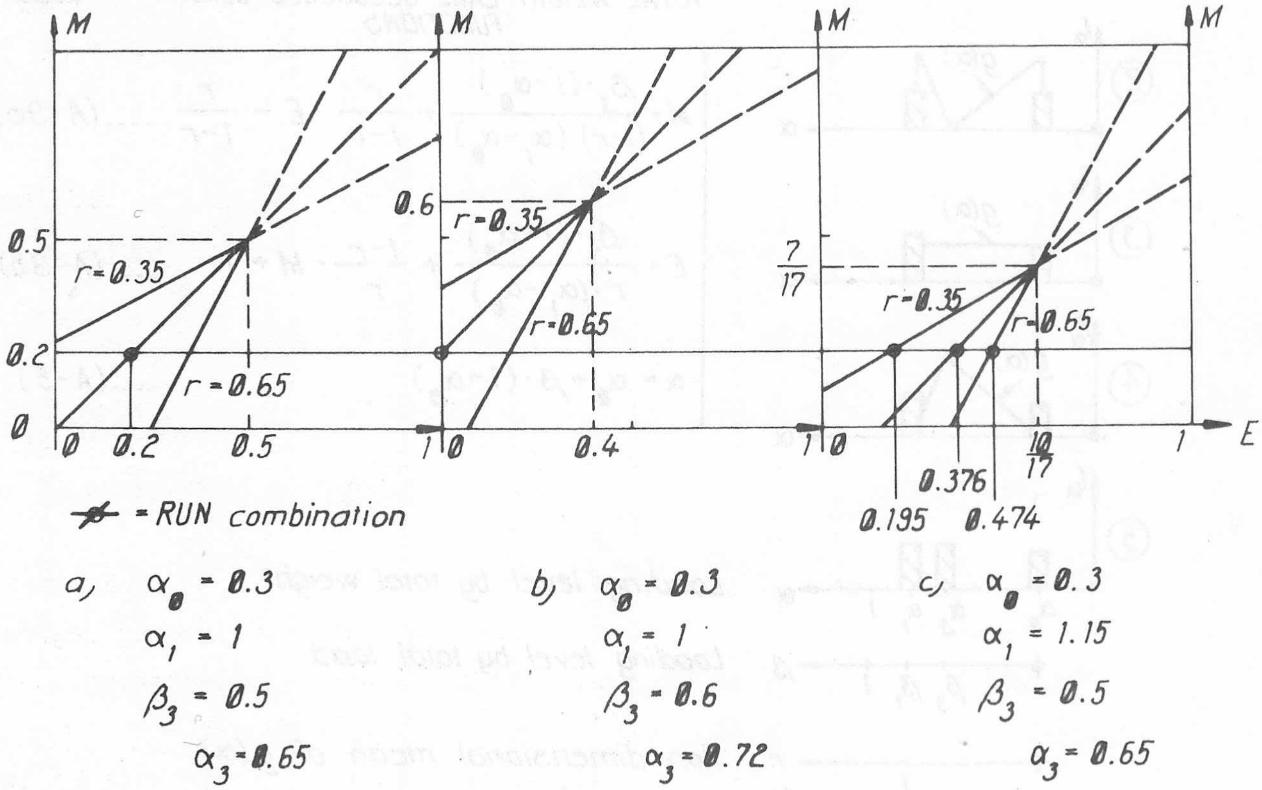


FIG. 3.4.1-2. Relation between tare/total weight portion, E, and max./total weight portion, M, for non-dimensional g(α) mean, r, equal to 0.35, 0.5 and 0.65.

The result is presented as computer plotted curves in FIGS. 3.4.1-3 to 3.4.1-5. The calculations are performed for discrete input load distributions in a similar manner as described in Chapter 3.3.1, description of LOSP. The resulting spectra are plotted under the assumption of uniform distribution of vehicle gross weights within each class, corresponding to a lower envelop of a load spectrum produced by LOSP.

FIGS. 3.4.1-3a-c — With input values according to FIG. 3.4.1-2a. The calculations are performed for the three types of input load distributions. The mean loading level, α_3, is put to 0.65.

FIG. 3.4.1-4 — With input values according to FIG. 3.4.1-2b. The calculations are performed for load type 3. The mean loading level, α_3, is increased to 0.72 and the max./total weight portion, M, retained equal to 0.2.

FIG. 3.4.1-5 — With input values according to FIG. 3.4.1-2c. Load type 3 is used. Mean loading level, α_3, is equal to 0.65. The max./total weight, α_1, is increased from 1 to 1.15.

Fixed points have been placed in the figures, coordinates (10 %, 150) and (1 %, 300), to make the comparisons between figures easier.

The main conclusions about the loading level influence are

The shape influence of $g(\alpha)$ is comparatively small even for differing $g(\alpha)$ mean, r.

A change in the total loading level distribution mean, α_3, raises or lowers the inner parts of the spectrum to a corresponding degree. The difference is more protruding in the linear representation.

It can also be seen from the figures that increasing variance of the loading level distribution raises the high load and lowers the low load parts of the spectrum. This involves a great importance to the max./total weight portion value, M.

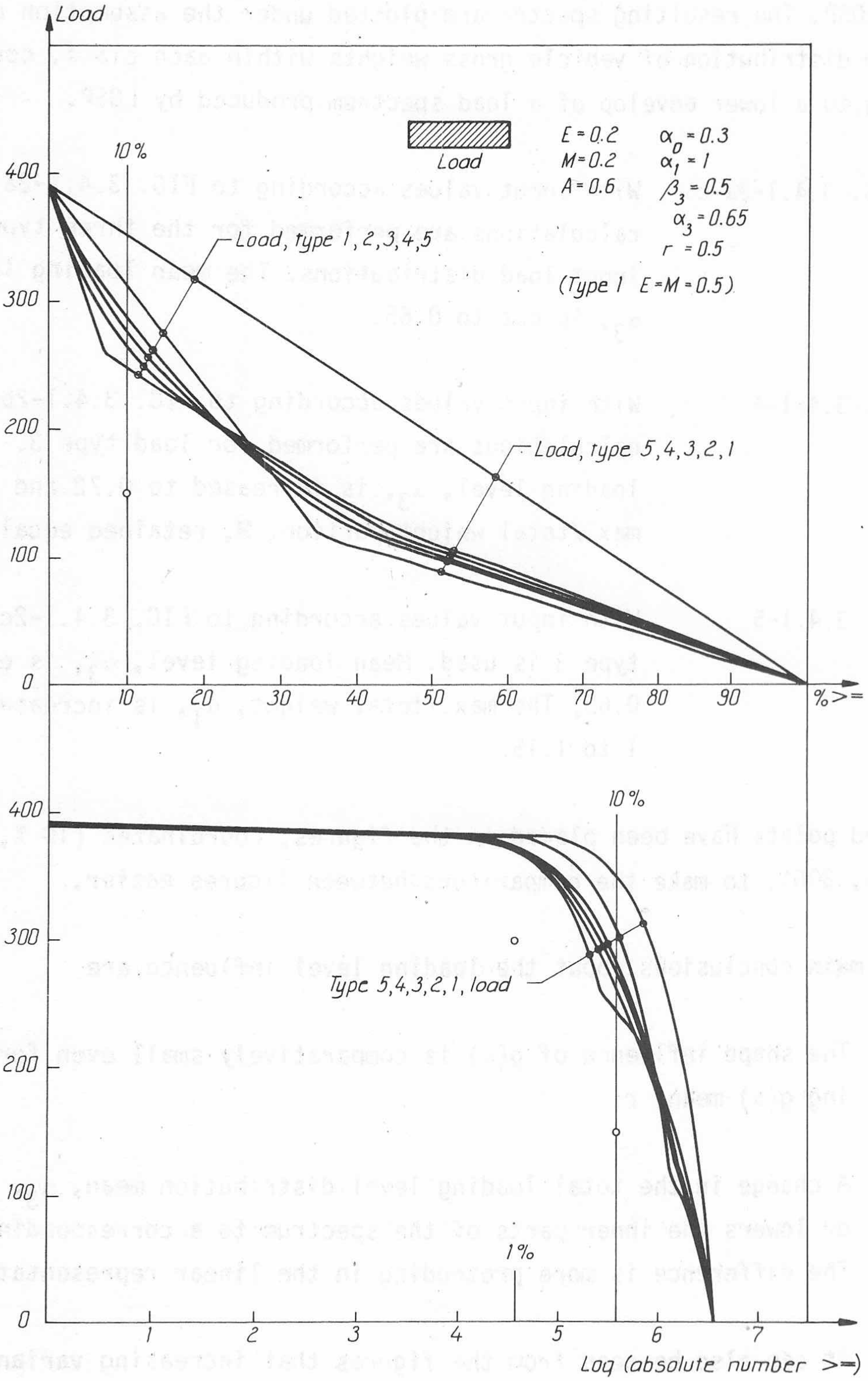

Load
10 %
Load
E = 0.2
M = 0.2
A = 0.6
α0 = 0.3
α1 = 1
β3 = 0.5
α3 = 0.65
r = 0.5
(Type 1 E = M = 0.5)
Load, type 1, 2, 3, 4, 5
Load, type 5, 4, 3, 2, 1
400
300
200
100
0
10
20
30
40
50
60
70
80
90
% >=
10 %
Type 5, 4, 3, 2, 1, load
1 %
1
2
3
4
5
6
7
Log (absolute number >=)

FIG. 3.4.1-3a

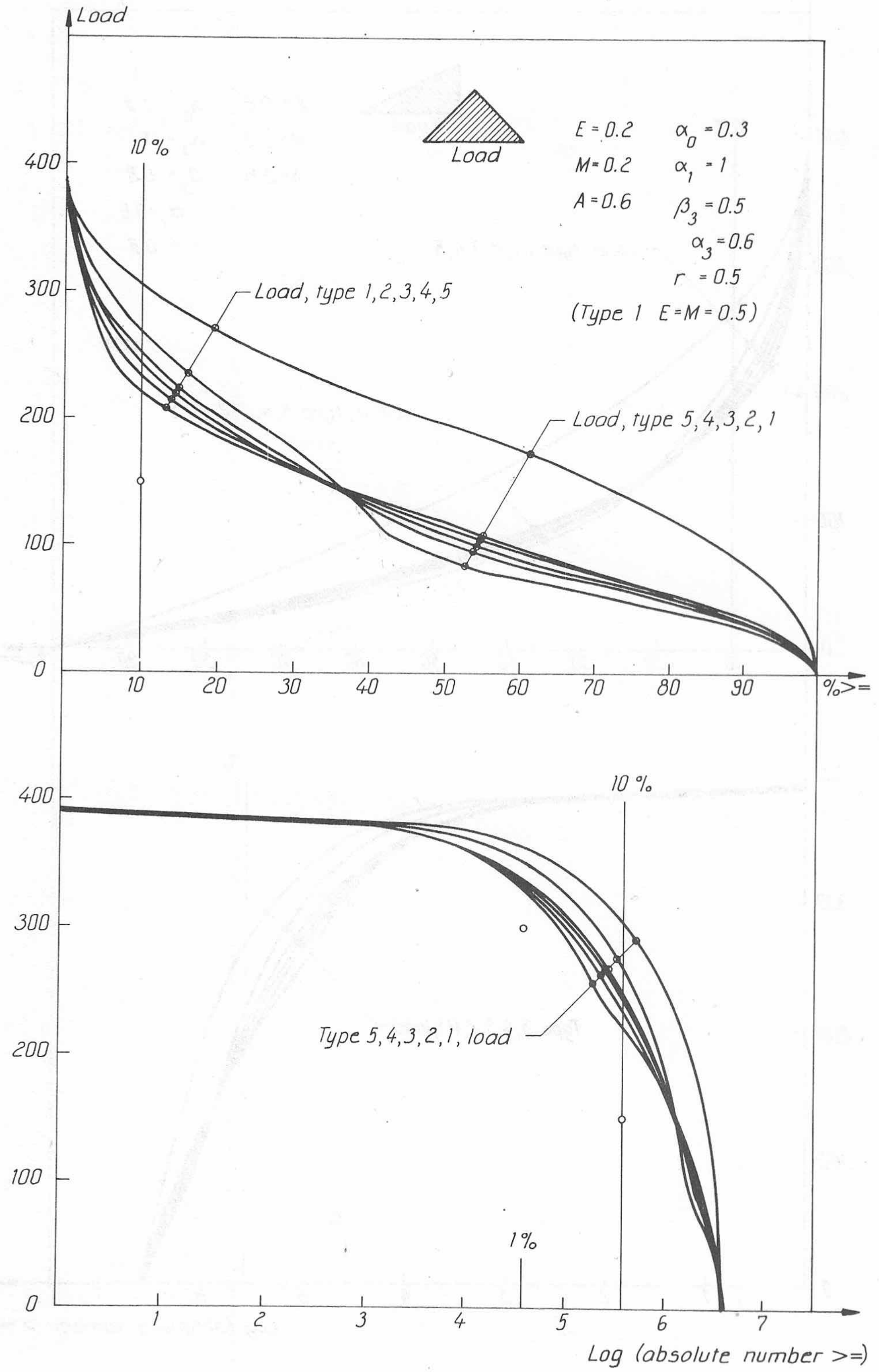

Load
400
300
200
100
0
10 %
Load
E = 0.2
M = 0.2
A = 0.6
α0 = 0.3
α1 = 1
β3 = 0.5
α3 = 0.6
r = 0.5
(Type 1 E = M = 0.5)
Load, type 1,2,3,4,5
Load, type 5,4,3,2,1
10
20
30
40
50
60
70
80
90
%>=
400
300
200
100
0
10 %
Type 5,4,3,2,1, load
1%
1
2
3
4
5
6
7
Log (absolute number >=)

FIG. 3.4.1-3b

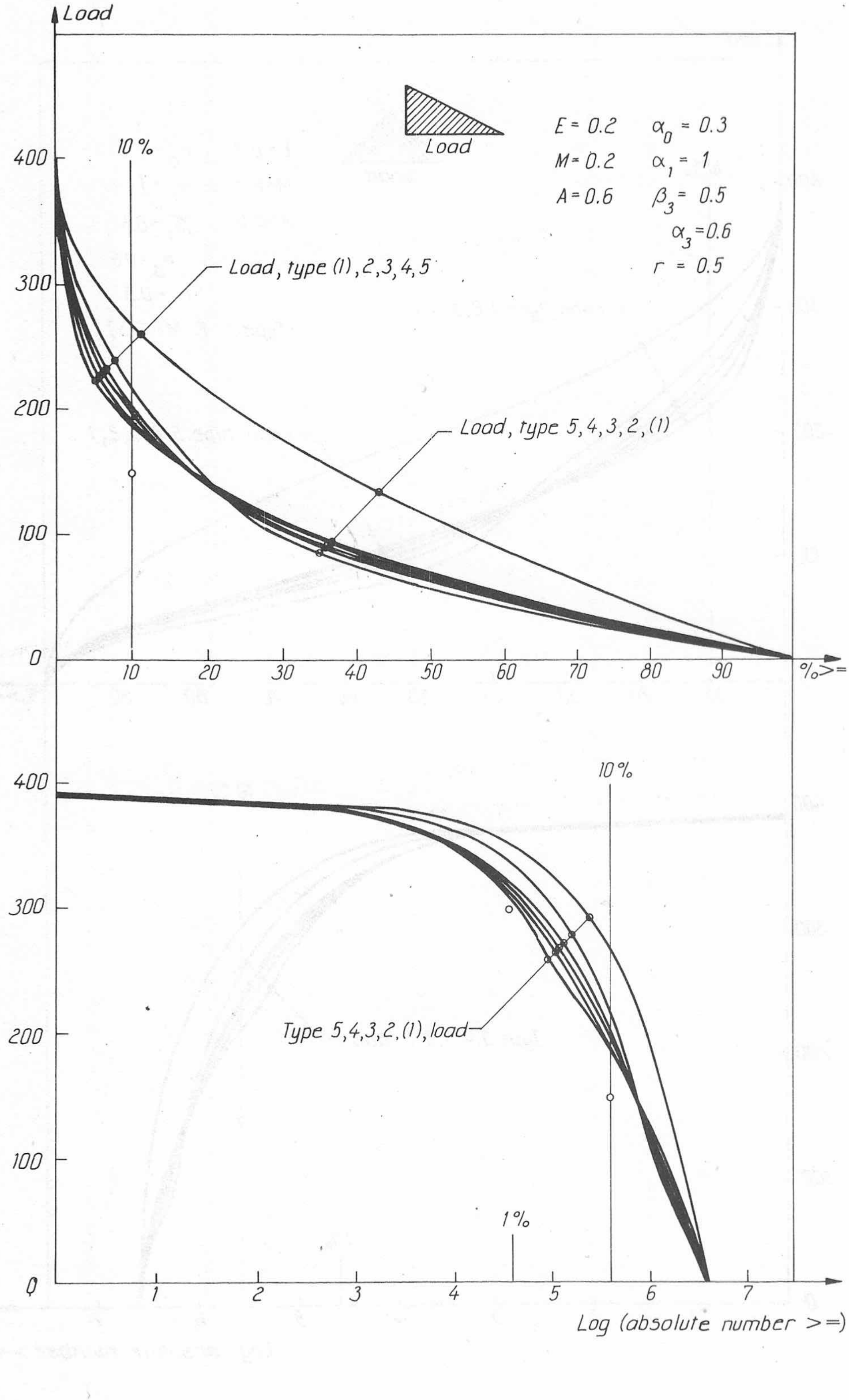
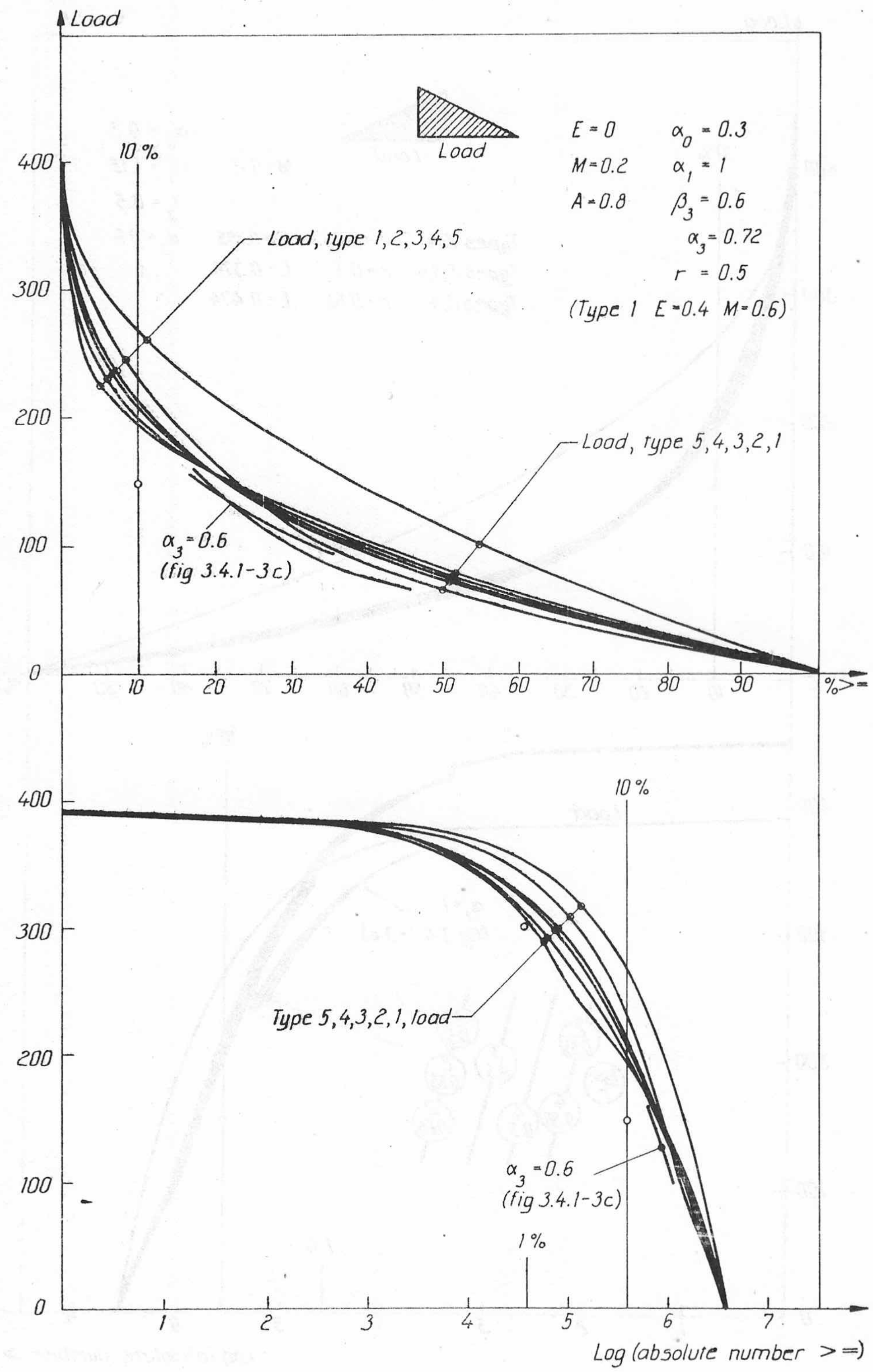
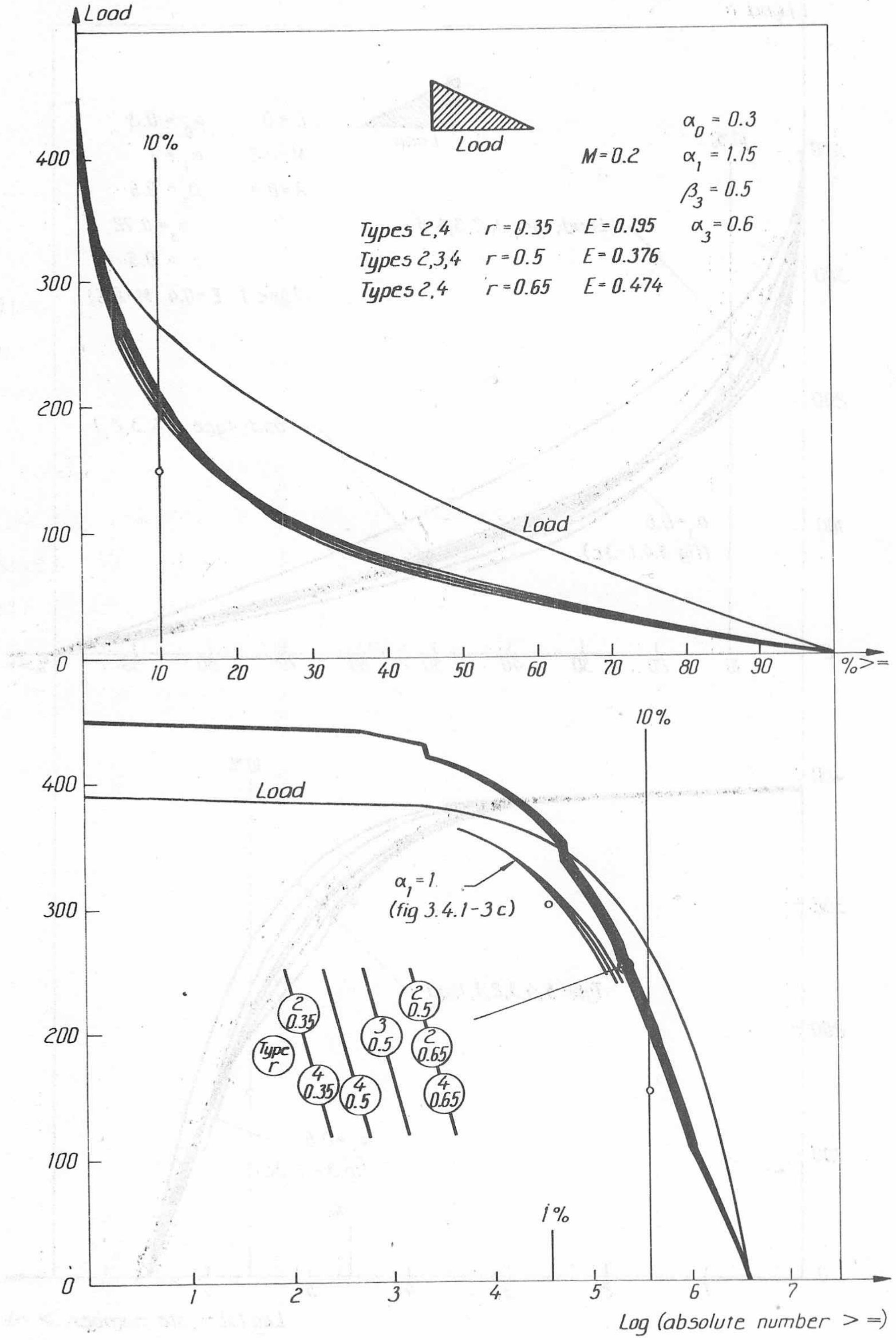

Load
Load
E = 0.2
M = 0.2
A = 0.6
α0 = 0.3
α1 = 1
β3 = 0.5
α3 = 0.6
r = 0.5
10 %
Load, type (1),2,3,4,5
Load, type 5,4,3,2,(1)
400
300
200
100
0
10
20
30
40
50
60
70
80
90
%>=
400
300
200
100
0
10 %
Type 5,4,3,2,(1), load
1 %
1
2
3
4
5
6
7
Log (absolute number >=)

FIG. 3.4.1-3c



Load
Load
E = 0
M = 0.2
A = 0.8
α_0 = 0.3
α_1 = 1
β_3 = 0.6
α_3 = 0.72
r = 0.5
(Type 1 E = 0.4 M = 0.6)
10 %
Load, type 1,2,3,4,5
Load, type 5,4,3,2,1
α_3 = 0.6
(fig 3.4.1-3c)
400
300
200
100
0
10
20
30
40
50
60
70
80
90
%>=
400
300
200
100
0
10 %
Type 5,4,3,2,1, load
α_3 = 0.6
(fig 3.4.1-3c)
1 %
1
2
3
4
5
6
7
Log (absolute number >=)

FIG. 3.4.1-4



Load
Load
10 %
M = 0.2
α0 = 0.3
α1 = 1.15
β3 = 0.5
α3 = 0.6
Types 2,4 r = 0.35 E = 0.195
Types 2,3,4 r = 0.5 E = 0.376
Types 2,4 r = 0.65 E = 0.474
400
300
200
100
0
10
20
30
40
50
60
70
80
90
%>=
Load
10 %
Load
α1 = 1
(fig 3.4.1-3 c)
Type r
2 0.35
4 0.35
3 0.5
4 0.5
2 0.5
2 0.65
4 0.65
1 %
1
2
3
4
5
6
7
Log (absolute number > =)

FIG. 3.4.1-5

The upper limit of loading level values, that is α_1 (or the overload loading level α_2), affects the spectrum appearance noticeable, at least when represented in a logarithmic scale, in that an increase of this value raises the spectrum, in the high load regions, to a corresponding degree.

3.4.2 Driving distance distribution and registered vehicle distribution influence.

The driving distance distributions are not treated as stochastic variables but as constants, which together with the region road length transformes the vehicle total weight registration density functions, class by class, according to FIG. 3.3.1-2.

A careful analysis of the shape influences of the driving distance distribution and registration total weight density function was not considered essential to carry through in detail. Instead simple density functions were transformed to linear and logarithmic spectra to give an idea about the relations between density functions and corresponding spectra. The result is shown in FIG. 3.4.2-1. The calculations and plots are performed with a computer routine LLTEST.

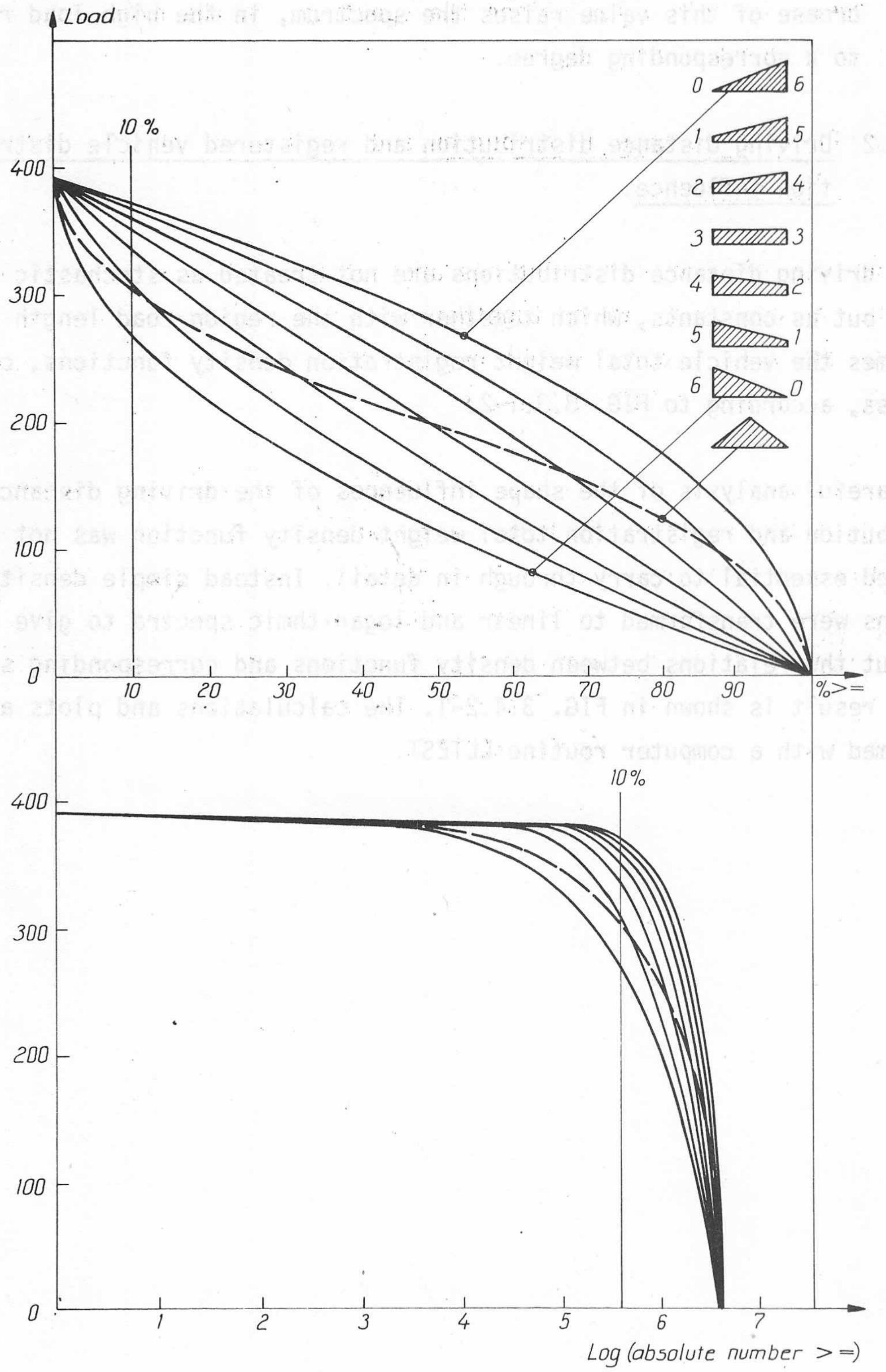

Load
10 %
400
300
200
100
0
10
20
30
40
50
60
70
80
90
%>=
0 6
1 5
2 4
3 3
4 2
5 1
6 0
400
300
200
100
0
1
2
3
4
5
6
7
10%
Log (absolute number >=)

FIG. 3.4.2-1

4 CALCULATED AND MEASURED LOAD SPECTRA

In this chapter load spectra are calculated for three different time periods, years 1965 and 1973 and for a future time period. The calculated 1965 spectra are compared with measured spectra and the calculated 1973 spectra are later used as input to calculations of loadeffect spectra, which are compared with a few measured loadeffect spectra for the same period. Finally, two predicted load spectra are calculated which are used as input to tests of the loadeffect spectrum model and to calculate predicted loadeffect spectra.

The determination of input data will of course be partly coupled to Swedish regulations about vehicle weights but will, however, show a procedure to put up the input data.

The region types are picked from the table below, FIG. 4-1, which shows a possible rough main classification of region types. See also FIG. 4-2.

RURAL	Long distance (European highway)	11
	Short distance (National main road)	12
	Special (ex. wood district)	13
URBAN	Long + short distance	21
	Short distance	22
	Special (ex. factory approach)	23

FIG. 4-1. Main classification of region types, with number codes.

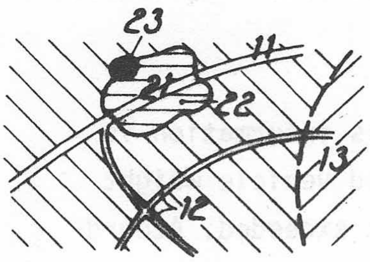


FIG. 4-2. Region types.

4.1 Comparison between measured and calculated load spectra for the year 1965.

Load spectra are calculated for two rural regions, one subjected to mainly long distance, and the other to short distance, traffic, (regions 11 and 12). The underlying data is picked from "Lastbilar och Lastbilstrafik" /28/, "Fordonskombinationer" /29/, "Bilismen i Sverige" /30/ and Jonsson /31/. The input is determined with guidance from this literature and does of course not claim to exactly describe the state of things in 1965.

The calculated spectra are compared to measured spectra from the 1965 loadometer study in Sweden.These results were picked from Brinck /32/. The 1965 loadometer study was the latest performed in Sweden of that extent.

A finer validation of the model may hopefully be made during the planned field investigations which are mentioned in Chapter 7.

4.1.1 Values of input variables, 1965.

In Sweden the maximum permissible axle/tandem weights at that time were, and still are, 8/12 and 10/16 Mp (≈ 80/120 and 100/160 kN) with maximum permissible gross weights, also related to the total axle distance, equal to 37.5 and 41.5 Mp respectively (≈ 375 and 415 kN). The vehicle total weight registration density functions per the first of January 1966 were found in "Lastbilar ..." /28/ divided on lorries, trailers and semitrailers. On the basis of these density functions, maximum axle/tandem weighs 100/160 and maximum gross weight 415 kN vehicle types according to FIG. 4.1.1-1 were defined.

The axle distances are not specified here because this information is not used in the load spectrum calculations. The ringed vehicle weight distribution is such that permissible weights are not exceeded. According to Jonsson /31/ axle overweights, besides those achieved with an overweight loading level, were common among the heavy vehicle types. This fact was regarded by a complementary set of weight distributions for types 3 to 5, within squares in FIG. 4.1.1-1, calculated under the assumption, that the heaviest axle, inner if possible, has got 20 % overweight which is transferred from the other axles. The weight relations between the remaining axles are retained.

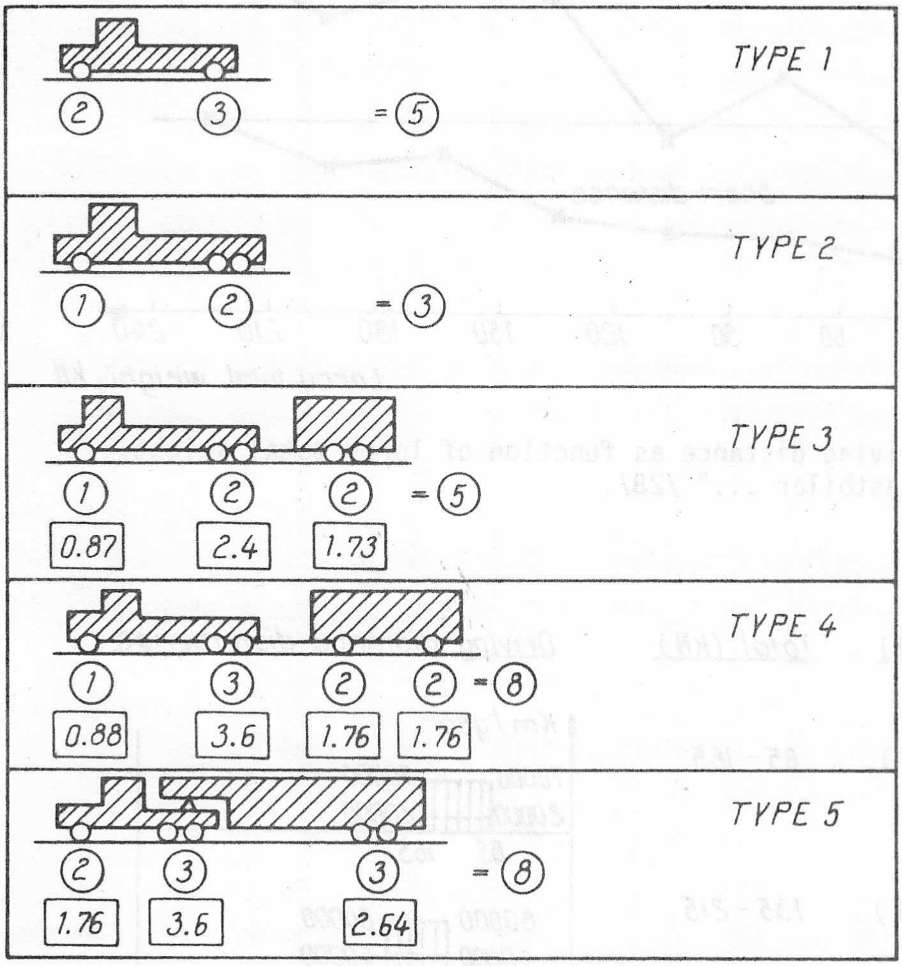


FIG. 4.1.1-1. Vehicle types for the year 1965. Weight distribution on axles ringed, with 20 % overweight on one axle squared.

The total weight registration distributions are not listed. Instead they are found in the plot output from the LOSP runs, see next chapter, FIG. 4.1.2-2. As the distributions were originally divided on lorries and trailers a pairing off according to the vehicle type specifications had to be made. Thereby it was assumed that all the trailers were always attached to a lorry, which according to "Lastbilar ..." /28/ is fairly true (94 % of the lorry driving distance) for at least trailers with more than two axles. The density functions were truncated for low total weights so that the lowest axle total weight multiplied by the lowest loading level (tare/total weight, specified later) became greater than 12.5 kN as this was the lowest axle weights registered in the loadometer study.

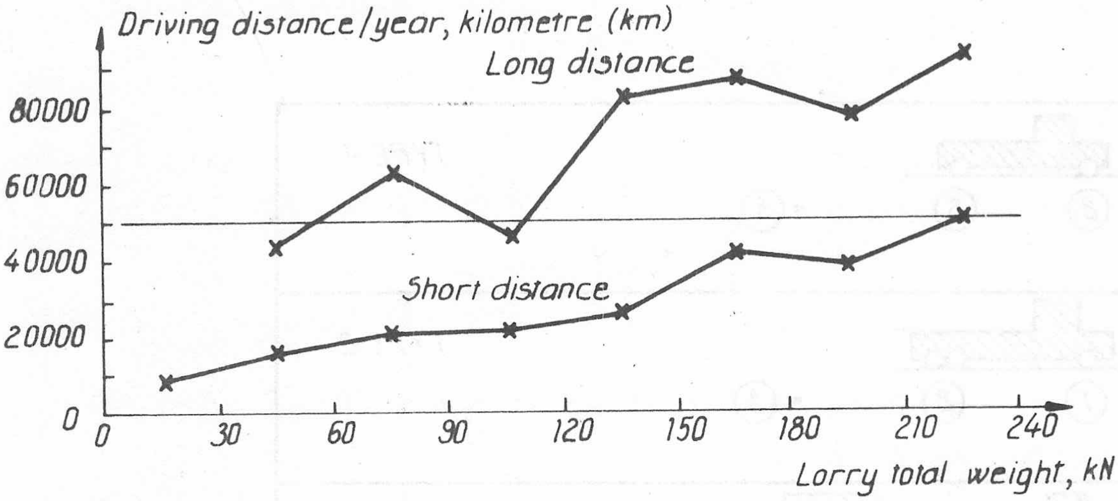


FIG. 4.1.1-2. Driving distance as function of lorry total weight. "Lastbilar ..." /28/.

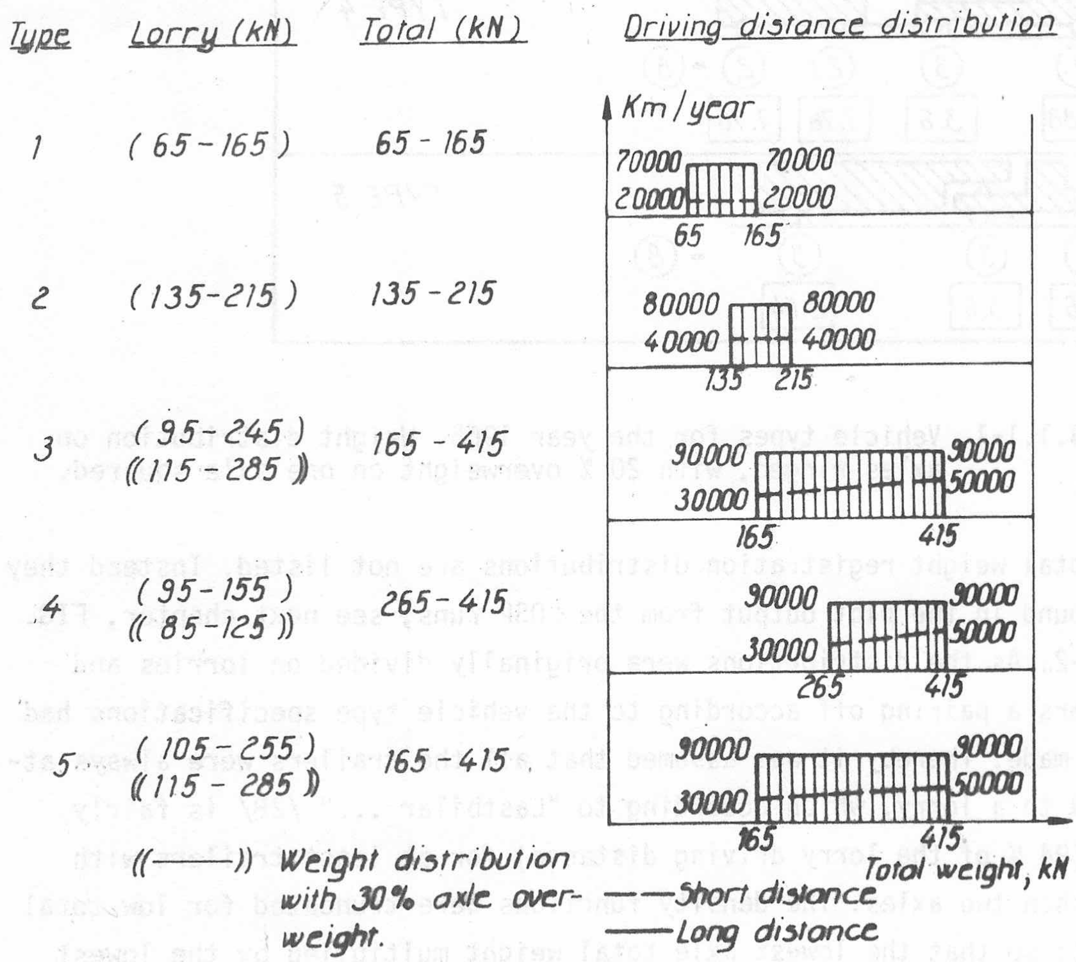


FIG. 4.1.1-3. Driving distance distributions for long distance and short distance regions related to vehicle total weight, 1965.

From the same source was FIG. 4.1.1-2 constructed giving an idea about the driving distances as a function of vehicle total weights. These curves served as guidance when the driving distance distributions for long and short distance regions were put up. See FIG. 4.1.1-3.

The same loading level distribution was used for all vehicle types. The mean loading level by total load, picked from "Lastbilar ..." /28/, was put to 0.65 and 0.55 for the two regions.

The tare/total weight share was found to be approximately 0.45, from "Lastbilar..." /28/, with somewhat higher values for light lorries and lower for trailers. The probability for a vehicle to drive without load was estimated from "Bilismen ..." /30/ to 15 % (25 %) and the over/total load share and portion 1.2 and 20 % respectively from Jonsson /31/.

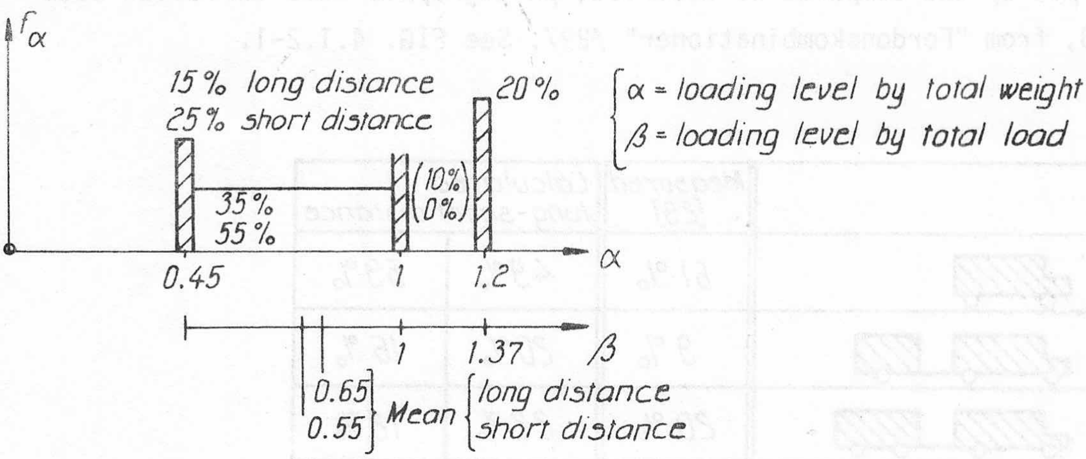


FIG. 4.1.1-4. Loading level input 1965.

For the rural long distance region it was supposed that only a fraction, here put to 0.5 of the available amount of single lorries, type 1 and 2, were running on these roads. This is accomplished by reducing the driving distances, according to FIG. 4.1.1-3 to a corresponding degree. The reason for this reduction is that it is assumed that many single lorries of the urban regions seldom make long distance travels on rural roads.

It was assumed that the total road length of both regions were 10000 kilometres, based on the fact that the total main road length with paving at that time were 10000 kilometres.

4.1.2 Calculated and measured load spectra, 1965.

The calculated spectra for regions rural long distance and rural short distance are compared with corresponding measured spectra on the following pages.

The measured vehicle gross weight spectra are rather summarily presented in Brinck /32/, but it was not considered that essential for the author of this report to make a further evaluation of the source material. The measured axle gross weight spectrum for region long distance was prepared by Bo Eriksson-Vanke, The National Road Administration, in a memo on fatigue in highway bridges 1972.

From the calculated vehicle type gross weight lane occurence density functions, see FIG. 4.1.2-2, figures for vehicle type lane occurences are put up and compared to observed, photographic data collected 1962-1963, from "Fordonskombinationer" /29/. See FIG. 4.1.2-1.

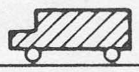
	Measured [29]	Calculated long-short distance	
	61 %	49%	59%
	9 %	20 %	16 %
	20 %	22 %	18 %
	8 %	9 %	7 %
REST	2 %	—	—

FIG. 4.1.2-1. Vehicle type lane occurences. Measured (European highway + national main road) and calculated.

FIG. 4.1.2-3 shows calculated spectra for rural long distance region and FIG. 4.1.2-4 for rural short distance. The dashed curves represents the measured spectra. A second axle gross weight spectrum was calculated for the long distance region using the original (circeld in FIG. 4.1.1-1) weight on axles distribution.

As can be seen the agreement between measured and calculated spectra is fairly good, especially for the axle spectra. The discrepancy between vehicle gross weight spectra is more pronounced in the linear than in the logarithmic scale. The measured logarithmic spectrum was calculated outgoing from the linear spectrum with the same total vehicle flow as calculated. No information is available about measured spectra above the 400 kN level other than the upper limit lays around 500 kN. Jonsson /31/.

In FIG. 4.1.2-3, rural long distance region, are also sketched parts of a linear vehicle gross weight spectrum and a logarithmic axle gross weight spectrum calculated by means of a loading level distribution with tare/total weight portion equal to 40 % and max./total weight portion equal to 35 %, (see the dotted curves). This increase of the variance of the loading level density function moves, as expected, the calculated spectrum towards the measured in the upper sectrum region. An increase in mean load/total load to 0.7 (from 0.65) has approximately the same effect, but without the lowering effect for low loads.

As mentioned a better agreement could be achieved between calculated and measured spectra. It was though considered more essential here to show that it is possible to get rather close to real spectra through treatment of simple underlying data.

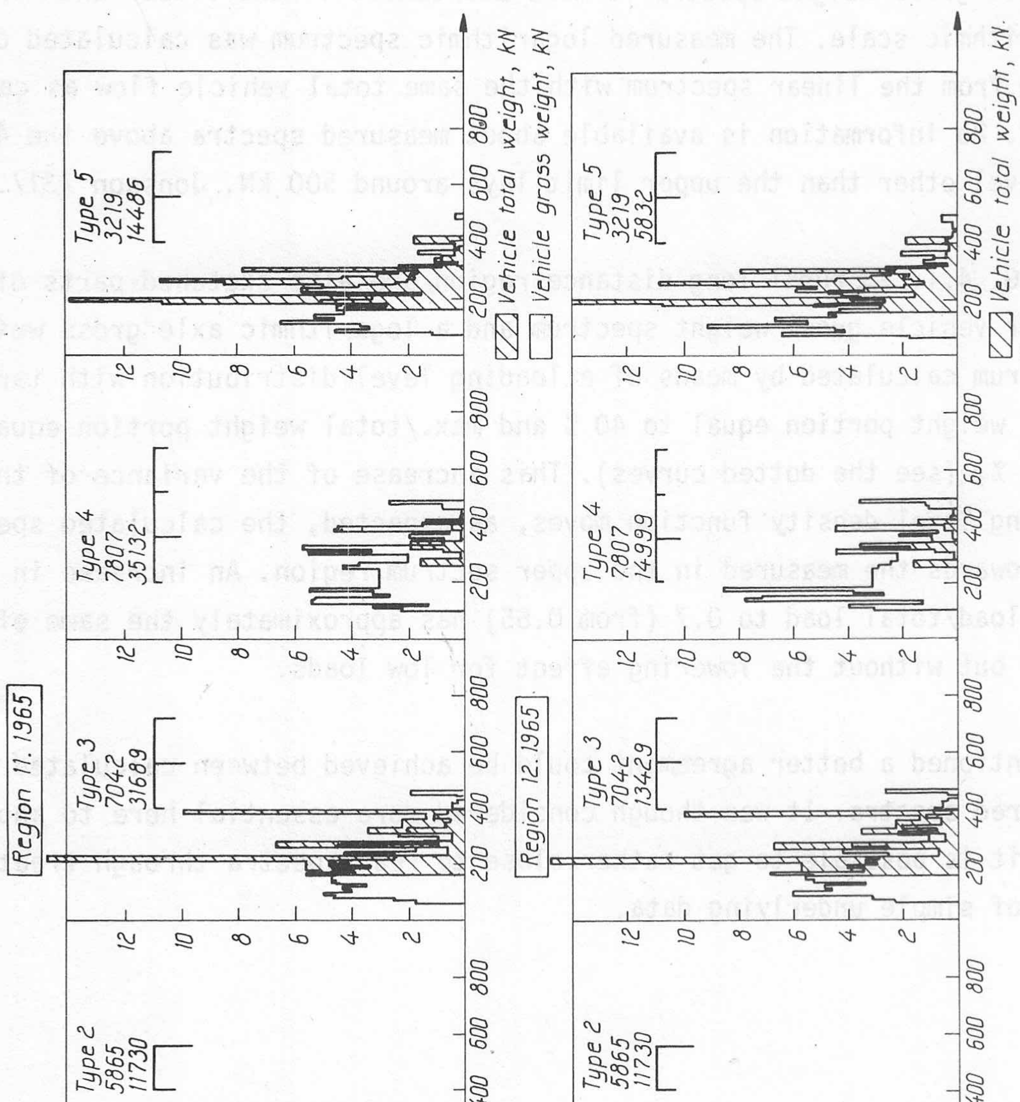


FIG. 4.1.2-2. Total weight registration distributions (hatched) and gross weight lane occurence distributions, 1965.

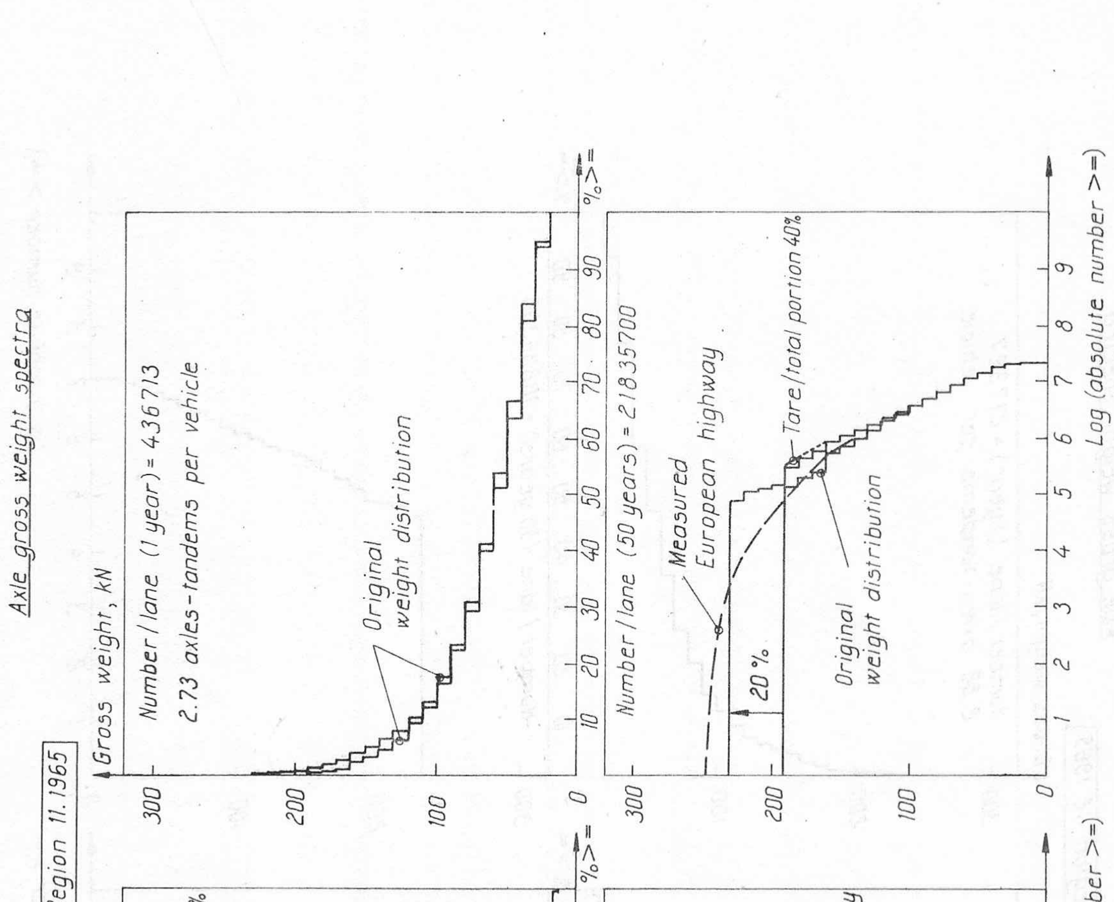


FIG. 4.1.2-3. Load Spectra, 1965. Rural long distance region.

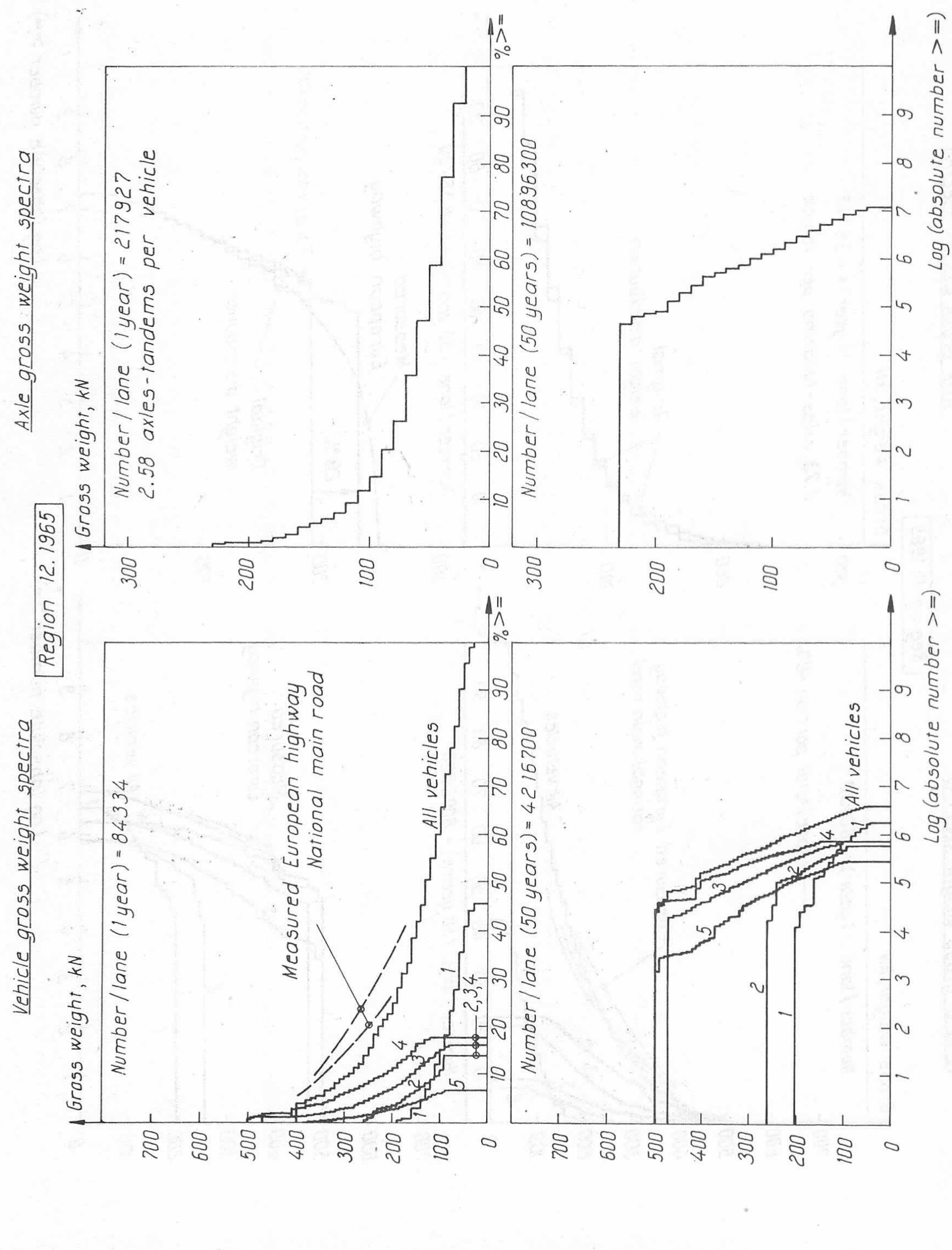


FIG. 4.1.2-4. Load Spectra, 1965. Rural short distance region.

4.2 Calculated load spectra for the year 1973.

In this chapter load spectra are calculated for the rural long distance (11) and rural short distance (12) regions. The load spectra are intended to be representative for the European highway south of Stockholm, highway bridge across Södertälje canal, and the other for main road 45 at Köpmannebro in Västergötland. These load spectra will later be used as input to calculations of loadeffect spectra, Chapter 8.1, which are compared to two loadeffect spectra collected from the highway bridges at these sites.

The input data are mainly picked from "Statistiska meddelanden NR T 1974:47" /33/, "Bilismen i Sverige" 1971 and 1973 /30/, "Lastbilar och lastbilstrafik" /28/ and a memo on fatigue of highway bridges 1975 by the author where load spectra are put up with somewhat different input values. Considerations are also given on the input sources used and results obtained, of the preceding chapter, load spectra for the year 1965, since information about the 1973 conditions is scanty.

4.2.1 Values of input variables, 1973.

The maximum permissible axle/tandem weights in Sweden were and are 80/120 and 100/160 kN. The corresponding maximum gross weights as function of total axle distance are found in FIG. 4.2.1-1.

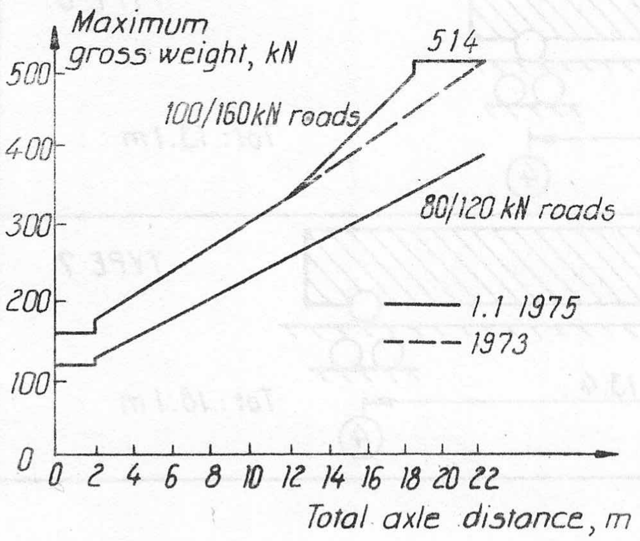


FIG. 4.2.1-1. Maximum permissible vehicle gross weight as function of total axle distance.

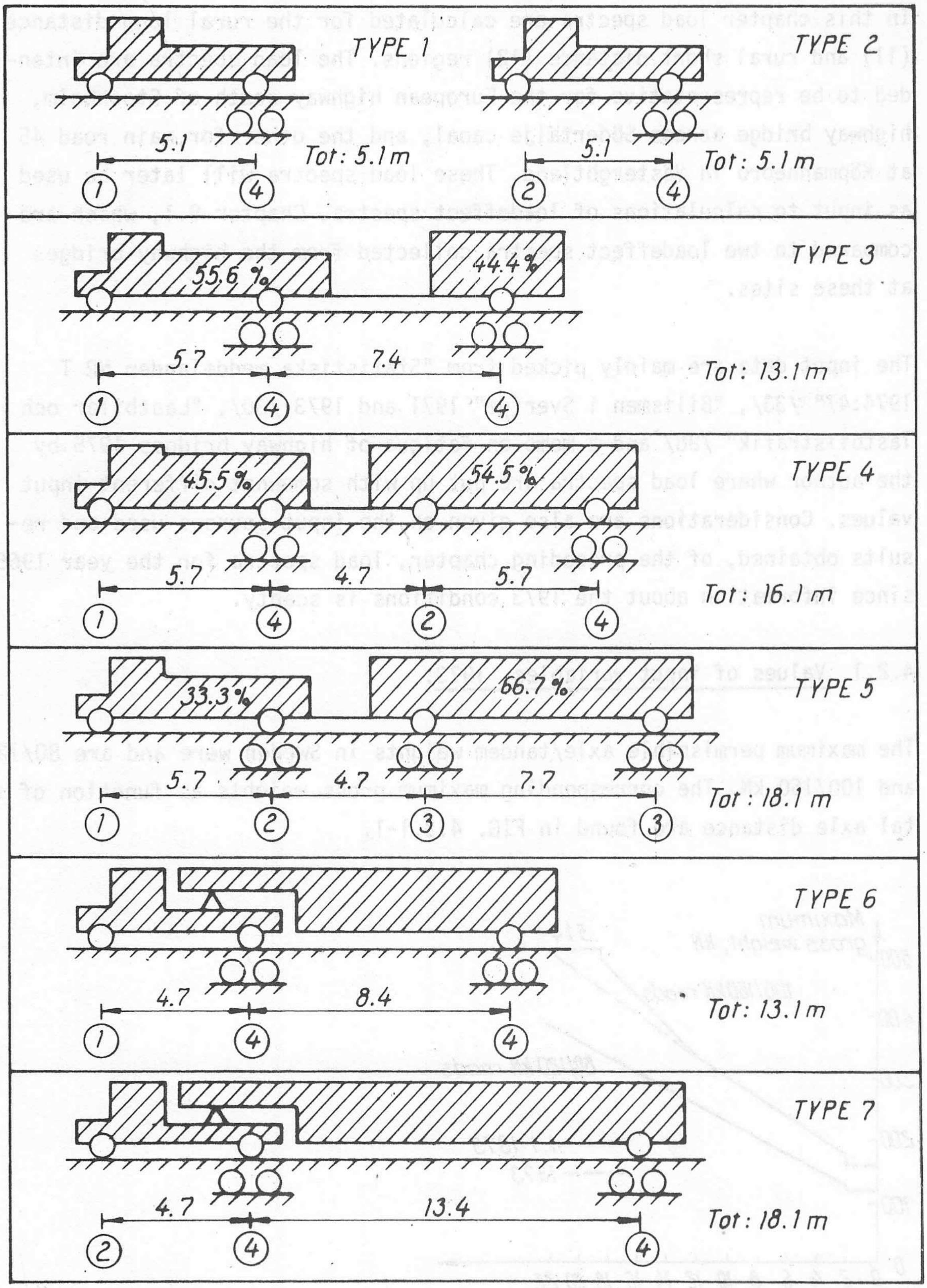


FIG. 4.2.1-2. Vehicle type specification for the year 1973. Weight distribution on axles ringed.

for highway bridges will come up from the field of structural response of structures to stochastic loads.

Numerical simulation models, like the one described in this report, may also be put up, which will allow more complicated input, output and model criteria to be formulated, though likely at the expense of computation times and immediate comprehensibility of the underlying casual connections.

Moses et al. /20/ uses a similar simulation technique to the one described in this report to calculate stress range histograms, for calculating bridge fatigue lives. Although that model and the one described in this report were developed completely independent of each other, they do have some characteristic features in common. They call the used solution technique a discrete convulotion or summing procedure and work with the stochastic variables truck type, truck weight, truck headway and lane occupancy. The vehicle headways were assumed to be exponentially distributed (vehicle flow described as a Poisson flow) and used both for passing and following vehicles. The stress ranges were defined as the difference between the maximum and minimum stress values during vehicle passage or overlap event. They do, however, give a somewhat different definition to be used in case of short influence lines. Fatigue lives are calculated by means of cumulative damage theory, and their sensitivity to changes in certain input variables are tested. Measured vehicle weight distributions are used as load input. No consideration is given to the lateral track distribution of the vehicles during passage and furthermore the dynamic amplification factor is supposed to be deterministic. Compability between measured and calculated stress histograms is reported though "because of the relatively small number of truck crossings reported in most measurments, comparisons of the histograms in the important high stress region due to rare heavy vehicles and multiple crossings could not be done".

Fothergehill et al. /21/ describe in four reports (of which unfortunately only two /21:2/ and /21:3/ were available to the author of this report) four stand alone computer programs which are used to simulate bridge traffic load patterns and the dynamic response to these loads of a carely specified bridge structure. The used technique seems to be a simulation of a real chain of traffic events which are stored and later used in a dynamic finite element analysis of the vehicle bridge system, during which stress maxima and minima and ranges are picked out and stored.

Finally, it shall be mentioned that in Sweden a welding regulation /22/ was published in the year 1974 which contains typical design stress spectra which are to be used in the fatigue design of welds. These spectra are defined in the same way as is done in this report namely as a curve that represents the logarithm of the number of exceedings of different stress range amplitudes. Some comments on the basis of the regulation are found in Alpsten /23/ and Jarfall /24/. Further references to fatigue are found in Moses et al. /20/ and in Fatigue of Concrete /25/.

3 THEORETICAL MODEL FOR CALCULATION OF LOAD SPECTRA.

This part of the report deals with a numerical model, LOSP, for calculation of LOad SPectra, or load density functions, valid for different road sections and time periods. The calculated load density functions will later be used as input for another theoretical model, NULESP, which analysis the arising loadeffects in different parts of a bridge structure, caused by the passing loads, vehicles.

3.1 Derivation of model

3.1.1 Introductory discussion

Through the evaluation of the model a more sophisticated expression for the loads, vehicle weights, that will drive over a road section will be achieved, than with a conventional deterministic load approach. That is the non-deterministic, stochastic, nature of the loads will be considered.

The only loads considered here are those of heavy vehicles, that is passanger cars are omitted. It is furthermore the static load, the actual vehicle weights, which are studied with no superposed time varying dynamic forces.

Beside the stochastic variable total vehicle (or axle) gross weight, a more or less complex collection of deterministic and non-deterministic variables are required to give an adequate description of the loads for a certain application. It all depends on how accurate the load transfer to the road surface has to be specified. In order to make possible calculations of axle load spectra, a deterministic distribution of the total vehicle gross weight on different axles were assumed for different vehicle types, which then are characterized by this distribution and the axle-configuration.

Once a model for the calculation of lane occurence load density functions, or load spectra, is put up, it can be used to study the influences of different variables and further, with rather easily estimated input variable values, to calculate predicted load spectra, hopefully with greater accuracy than can be made from extrapolated measured spectra.

The derived load spectrum model, LOSP, will form a part, together with the loadeffect spectrum model, NULESP, of a theoretical system to describe the load-loadeffect behaviour in a statistical manner.

The produced load density functions are not given in explicit formulas through a purely analytical solution, since such a solution was judged, at this stage, to incorporate too many assumptions about the involved density functions and to be too laborious to fulfill without fargoing simplifications. Instead a numerical technique was used in the solution thus requiring a computer to bring about reasonably short calculation times. The computer program is written in the Basic language for a Hewlett Packard 2116C computer, with 16K words of memory, belonging to the structural division.

3.1.2 Chosen input variables.

The input variables were chosen to be as simple and as easy to predict as possible. There are two fundamental variables, namely the available fleet of registered vehicles, with their basic data about loading capacity, tare weight and type of vehicle, expressed through the vehicle type total weight registration density functions and the studied "geographical" region. The region concept should be widely understood. A region can for example be constituted of all the main roads in a typical wood producing district or of the main transfer roads for heavy goods and so on.

To be able to estimate the load spectra for a certain region one also has to know to what degree the vehicles are loaded, the loading level distribution, and the average yearly driving distance for the vehicles on the roads of that region, expressed through the driving distance distribution and region road length.

These are the chosen input variables to which information about the weight distribution for the different vehicle types shall be added in order to make possible the calculations of axle load spectra.

3.1.3 Representation of results.

The final results, the output, of the load spectrum model are vehicle type (axle) gross weight lane occurence density functions. In order to make them more comprehensible, and to simplify the comparison with the later calculated loadeffect range-level distributions, the load density functions are finally transformed to load spectra, that is almost the inverse distribution function. (The spectrum expresses namely probabilities for an observation to be greater or equal and not only greater than.)

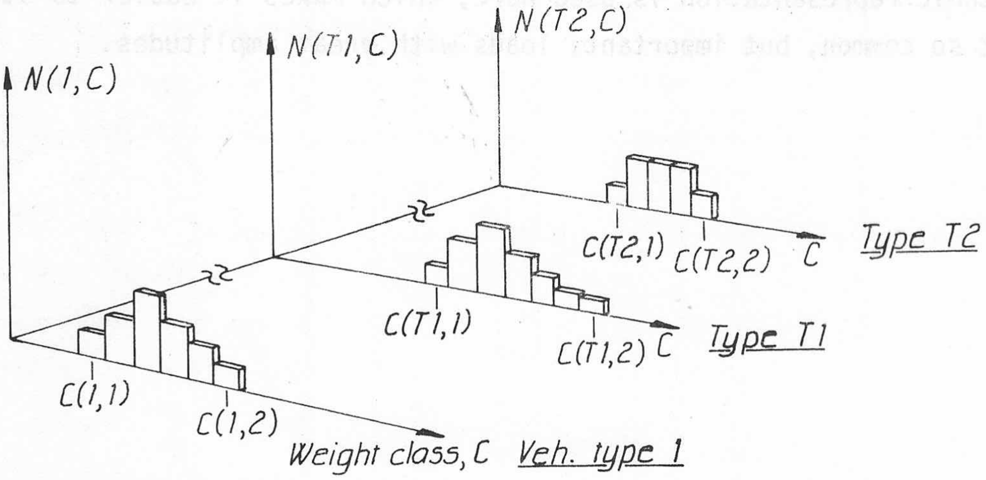
The spectra can be drawn in both linear and logarithmic scales thus emphasizing different domains, see also FIG. 6.1.3-2. In most cases the logarithmic representation is used here, which makes it easier to study the not so common, but important, loads with great amplitudes.

3.2 Description of input variables.

3.2.1 Total weight registration distribution and vehicle type characteristics.

It was judged that an estimation of the main vehicle types, with approximate total weight distributions, to appear in the future and their shares of the total fleet of vehicles, could be done with enough accuracy, to serve as input to a load spectrum model.

FIG. 3.2.1-1 shows the main elements of this part of the input section which is found in subroutine SUB 1500 called at line 240 of computer program LOSP.



T1 = vehicle type
T2 = number of vehicle types
N (T1,C) type total weight registration density function (absolute)
C(T1,1), C(T1,2) lowest, highest weight class; k_1, k_2 corresponding loads.

INPUT: k_1, k_2, C(T1,1) − C(T1,2) + 1 ← For checking
N(T1, C(T1,1))
:
N(T1, C(T1,2))

} For vehicle types T1=1 to T2

FIG. 3.2.1-1. Vehicle type total weight registration density function input, LOSP.

The vehicle type input could have been limited to the deterministic weight distribution on axles for each vehicle type, but it also comprises information about the axle configuration in order to establish a closer connection to the loadeffect analyses program, where this information is used. What is said below, therefore can also be found in Chapter 6.2.1 which for clarity is partly reproduced below.

The total number of vehicle types, T2, may be max. 10 each type having max. 5 axles. The later introduced axle distance factor distributions are not used in LOSP.

The vehicle specification part is found in subroutine SUB 1000 in LOSP and is called at line 230.

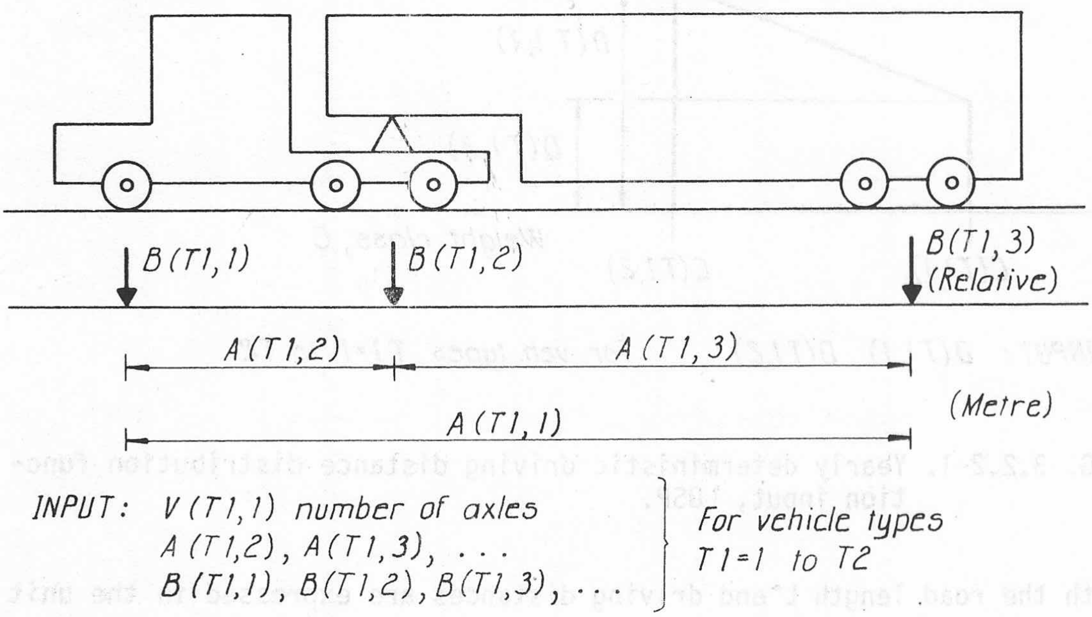


FIG. 3.2.1-2. Vehicle specification input, LOSP.

3.2.2 Average yearly driving distance distributions for the region.

It is through the driving distance distribution that it is determined how often, in average over a time period, vehicles of a certain type T1 and total weight class C will drive over a road section. It is assumed that the traffic is evenly spread in both driving directions, over the entire region road length, L.

It is also supposed that the same driving distance distribution is valid for all the vehicles of the same type, T1, and that it is the total weight of the vehicle that decides how far it will travel.

The yearly deterministic driving distance distribution for vehicle type T1 and total weight class C is defined through function FND(C, T1) according to FIG. 3.2.2-1. In this report the simpliest shape, a straight line was selected, but other arbitrary functions may be chosen. It is only the function values for integer arguments, weight class C, which are used.

The corresponding input section is found in subroutine SUB 2000 which is called at line 300 of LOSP.

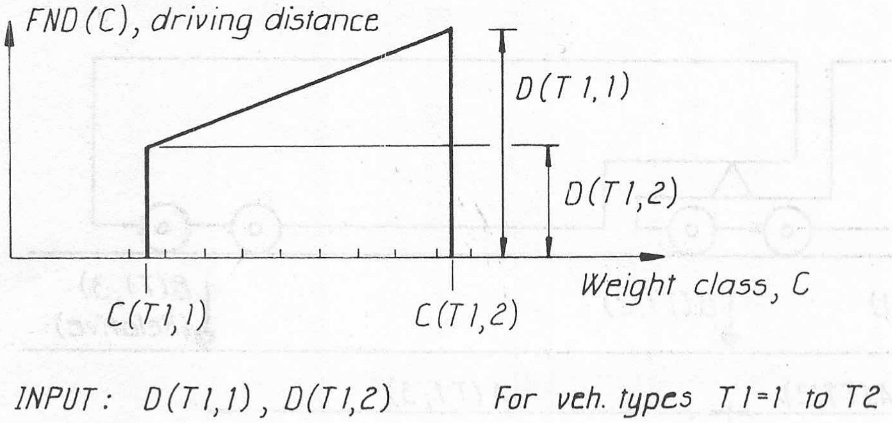


FIG. 3.2.2-1. Yearly deterministic driving distance distribution function input, LOSP.

Both the road length L and driving distances are expressed in the unit 1000 metres = 1 km.

3.2.3 Loading level distributions for the region.

The last necessary input to do, supplies information about the degree of utilized available load bearing capacity of the regarded vehicles. A stochastic variable, the loading level, is introduced, which is a factor by which the vehicle total weight shall be multiplied, to be transformed to the actual gross weight of the vehicle running on the road.

$$\text{loading level} = \frac{\text{vehicle gross weight}}{\text{vehicle total weight}} \qquad (1)$$

In the LOSP-model each loading level density function is valid for all vehicles of the same type, which of course is a simplification among others. It is also possible to define several vehicle types which are alike, and to apply different loading level distributions on them, thus refining the calculations.

In the LIST OF TERMS are some vehicle weight related terms explained, which are used below.

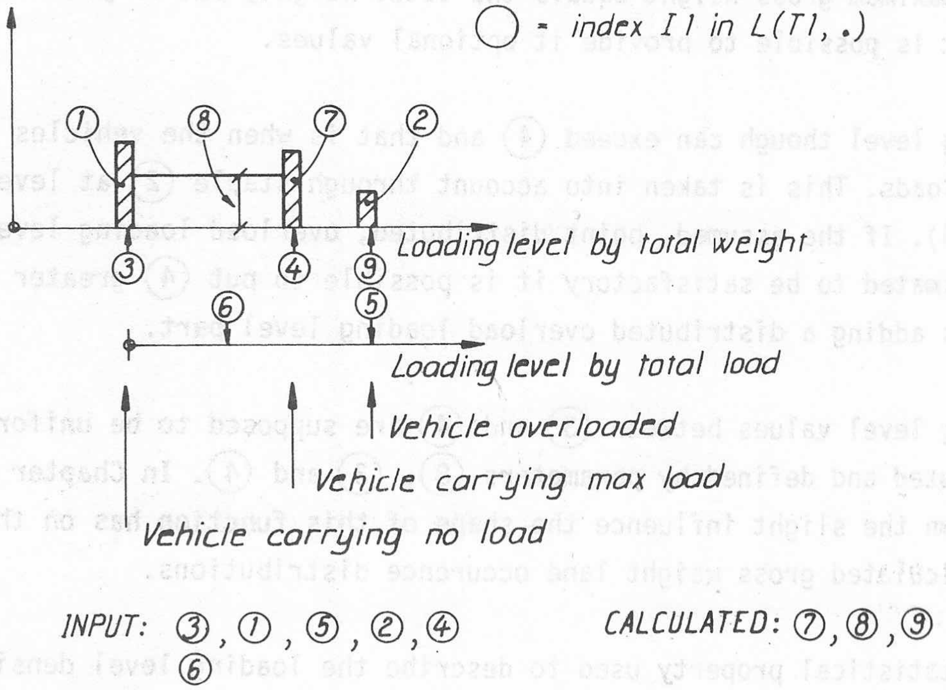


FIG. 3.2.3-1. Loading level distribution input, LOSP.

The loading level density functions consists of four main parts. Three of them are probabilities for discrete values of the loading level to occur and the fourth is a continuous function part. FIG. 3.2.3-1, which is commented below, shows the principle appearance of the function. The ringed numbers refer to index I1 in variable L(T1,I1). (See also FIG. at variable L(T1,I1) in the NOTATIONS.)

As can be seen there are two loading level axes of which the upper is the one normally referred to here. The lower axis expresses the loading level as a relation between actual load and maximum permissible load, total load. This representation of the loading level may be of interest when pure loading parameters are considered. (Here L(T1,5) and L(T1,6).)

Loading level ③ expresses the relation tare weight/total weight, valid for an unloaded vehicle. It is assumed that this loading level together with the max. gross weight/total weight level (normally equal to 1) are more specific and probable to occur, than other loading levels. Therefore the loading level continous density function is not defined in these points, in return histogram staples, representing probability values, ① and ⑦, are introduced. Point ④ is normally equal to 1 since the maximum gross weight equals the total weight, but to gain flexibility it is possible to provide it optional values.

The loading level though can exceed ④ and that is when the vehicles carry overloads. This is taken into account through staple ② at level ⑨ (or ⑤). If the assumed, point distributed, overload loading level is not estimated to be satisfactory it is possible to put ④ greater than 1 thus adding a distributed overload loading level part.

The loading level values between ③ and ④ are supposed to be uniformly distributed and defined by parameters ⑧, ③ and ④. In Chapter 3.4 is shown the slight influence the shape of this function has on the finally calculated gross weight lane occurence distributions.

The only statistical property used to describe the loading level density function is the mean loading level ⑥ which is input together with ③, ①, ⑤, ② and ④ leading to two more values to be calculated, namely areas ⑦ and ⑧, thus completely defining the function. This is done under the following conditions, the total area of the density function to be 1 and the mean value to be equal to ⑥. In this way the area ⑧ is automatically calculated, that is the probability for a vehicle to carry max. load can not be directly forecast. The input is made this way because it is judged that ① and ② is more easily estimated than ⑦ and ⑧.

The relations between the loading level parameters are further explained and deduced in Appendix A.

The loading level input is found in subroutine SUB 2500 which is called at line 320 in LOSP.

3.3 Description of load spectrum model, LOSP.

This chapter describes the numerical model for calculation of load spectra, LOSP, and the corresponding computer program written in BASIC (Hewlett Packard Basic) with the same name. The program listing is found in Appendix B.

First is the model described including a summary chart followed by a flow chart of the program. No examples on runs are given here, instead reference is made to Chapter 4 CALCULATED AND MEASURED LOAD SPECTRA

3.3.1 Description of the model including summary chart.

The load spectrum model, LOSP, is a numerical calculation model by which loads, particularly loads of heavy vehicles, appearing at a road section can be determined and expressed in statistical terms outgoing from parameter values possible to estimate. The load amplitudes are thus represented as distributions and not as constant values.

The following description of the program is made outgoing from the summary chart presented in FIG. 3.3.1-1.

The calculations are principally executed in two subroutines, of which the first transforms the vehicle type total weight registration absolute density functions, N(T1,.), to vehicle type total weight lane occurence absolute (one year) density functions, G(T1,.) by means of the driving distance distributions, see FIG. 3.3.1-2. The second subroutine then transformes G(..) to vehicle type gross weight lane occurence absolute density functions, by means of the loading level distributions, see FIG. 3.3.1-3.

From FIG. 3.3.1-2 it can be seen how the number of lane occurences for each vehicle type total weight class is calculated. It is assumed that all vehicles of the same class and type travel equal distances per year, FND(C), including both driving directions.

FIG. 3.3.1-3 shows how the conversion of G(T1,.) from a total weight distribution (here called G'(T1,.)), to a gross weight distribution is done. Each total weight class, I2 with weight K4, is spread and accumu-

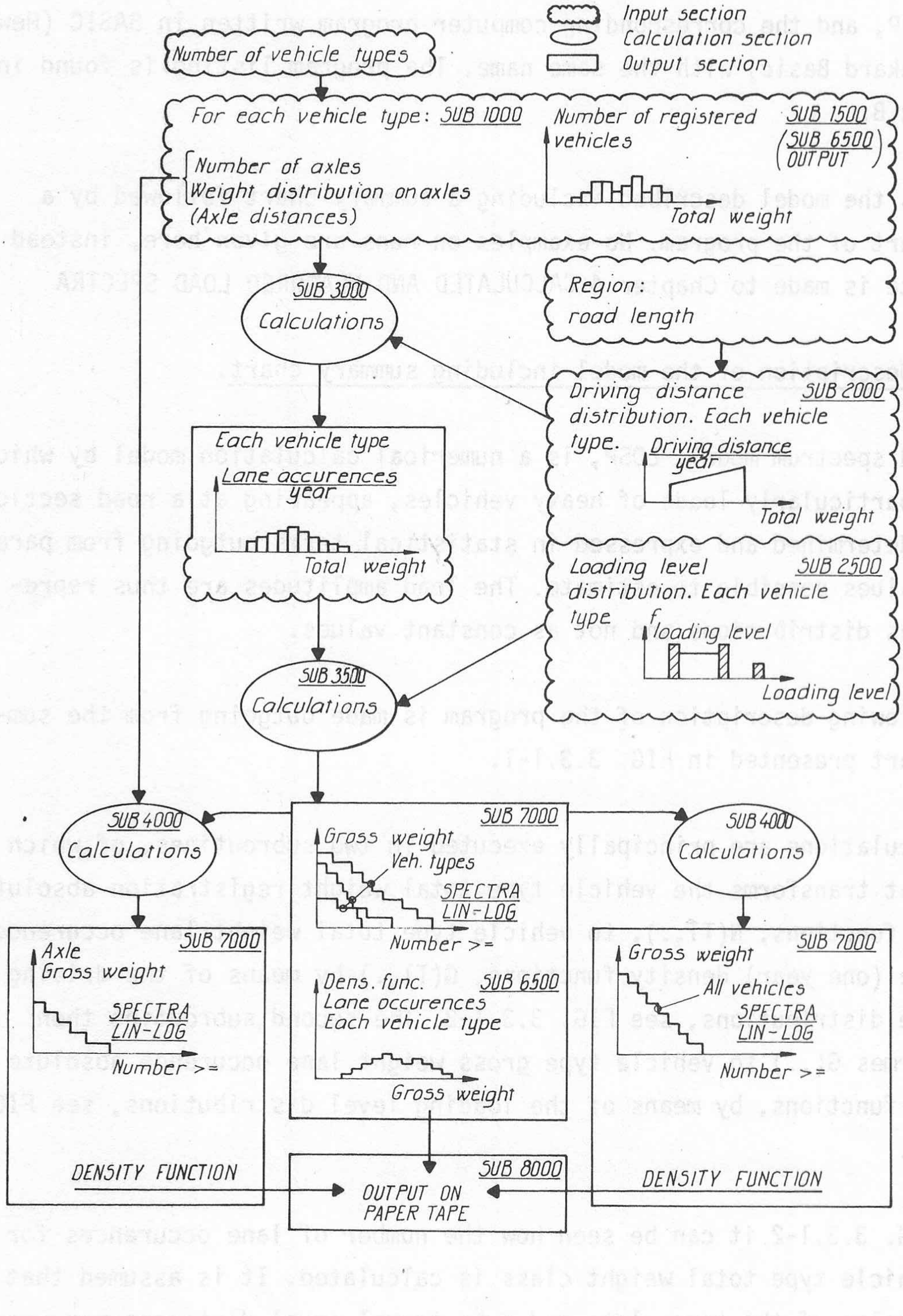


FIG. 3.3.1-1. Summary chart of LOSP. (See also flow chart FIG. 3.3.2-1.)

lated in G(T1,.), primarily in an aid matrix Y(.), according to the loading level density function.

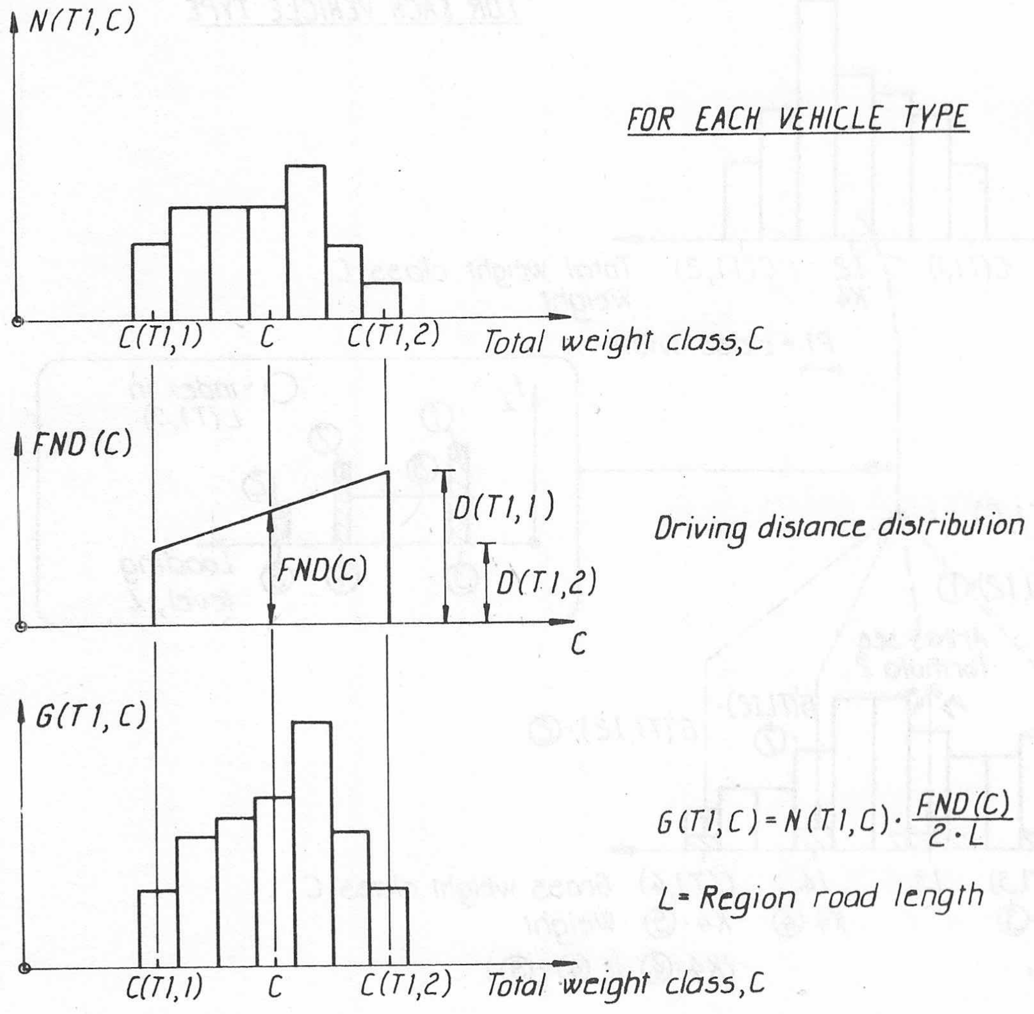


FIG. 3.3.1-2. Calculation of total weight lane occurence distributions. SUB 3000 in LOSP.

First the no load, max. load and overload loading levels of the loading level distribution are treated and then the continuous part (8). The contribution to class G(T1,I3) becomes for each I3 (I3 is incremented between the "lower I3" and I4, FIG. 3.3.1-3).

$$\text{area} = G'(T1,I2) \cdot \int_{\frac{G(T1,I3)-\frac{P1}{2}}{K4}}^{\frac{G(T1,I3)+\frac{P1}{2}}{K4}} L(T1,8) \cdot d\ell = G'(T1,I2) \cdot \frac{P1}{K4} \qquad (2)$$

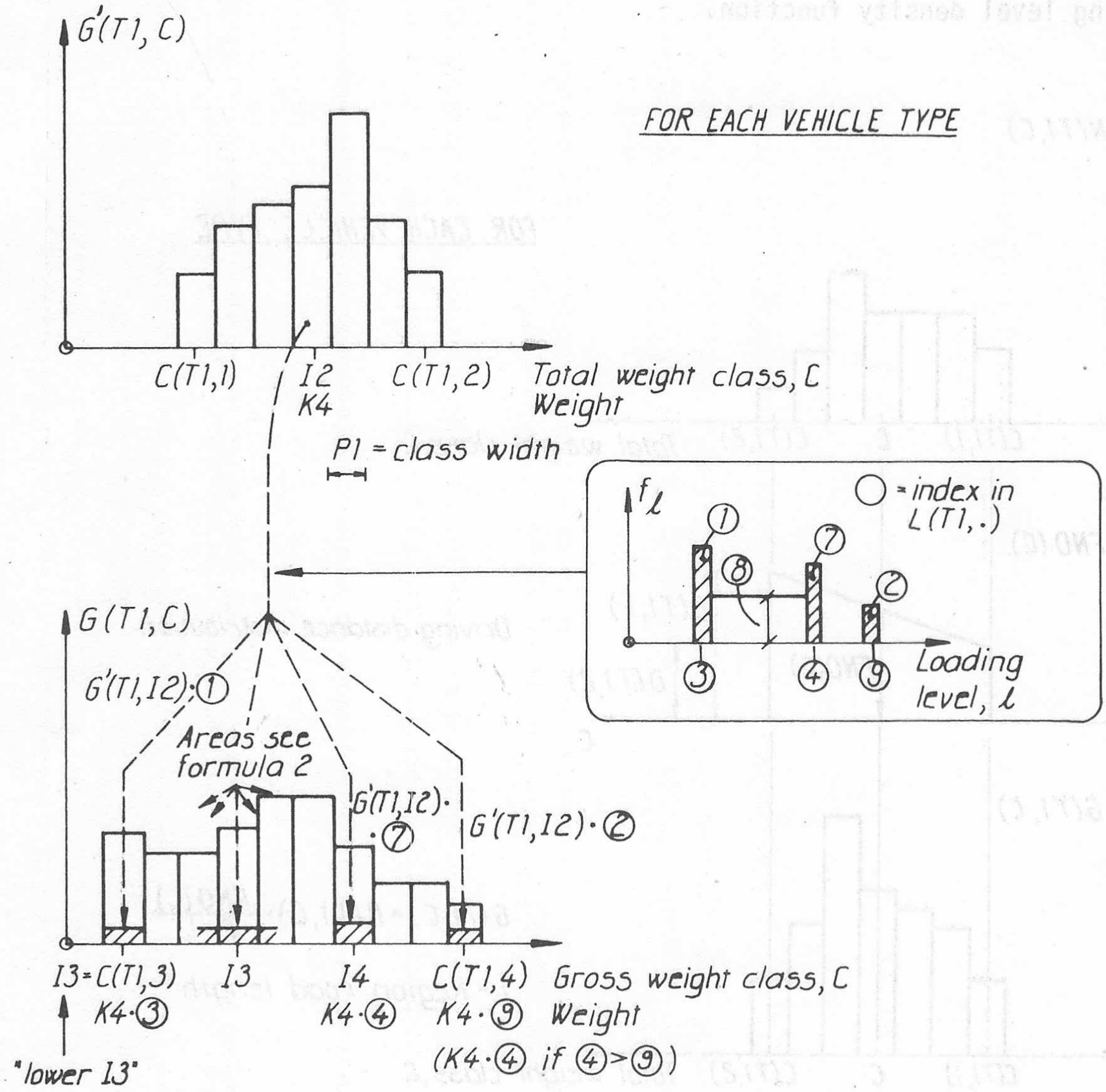


FIG. 3.3.1-3. Calculation of gross weight lane occurence distributions. SUB 3500 in LOSP.

The main calculations are now gone through. Finally the axle gross weight lane occurence and total ("all vehicle") gross weight density functions are calculated. The former is determined by means of the weight distribution on axles information.

The following output is obtained during a RUN.

Vehicle type specifications, printed during input

Driving distance distributions, printed during input.

Loading level distributions, printed during input.

Input total weight registration distributions and gross weight lane occurence distributions plotted as density functions together with schematic vehicle type descriptions. Subroutine DENS PLOT.

Vehicle type, axle and total gross weight spectra plotted in linear and logarithmic scales. Subroutine SPECT PLOT.

Finally may the total and axle gross weight absolute (one year) density functions be punched on to papertape, if switch = 1, or, if switch = 2, the total, axle and vehicle type gross weight absolute density functions are punched. Subroutine PUNCH.
The format of the punched tape is:

run No., region No.

weight class width, lower class number, upper class number, number of occ./year
Number of occurences lower class
:
Number of occurences upper class

:

3.3.2 Computer program flow chart.

Below is a flow chart presented which includes the main elements of the Basic program LOSP. As the program is interpretative no certain input-output catalogue is necessary as for the NULESP program. The program listing is found in Appendix B.

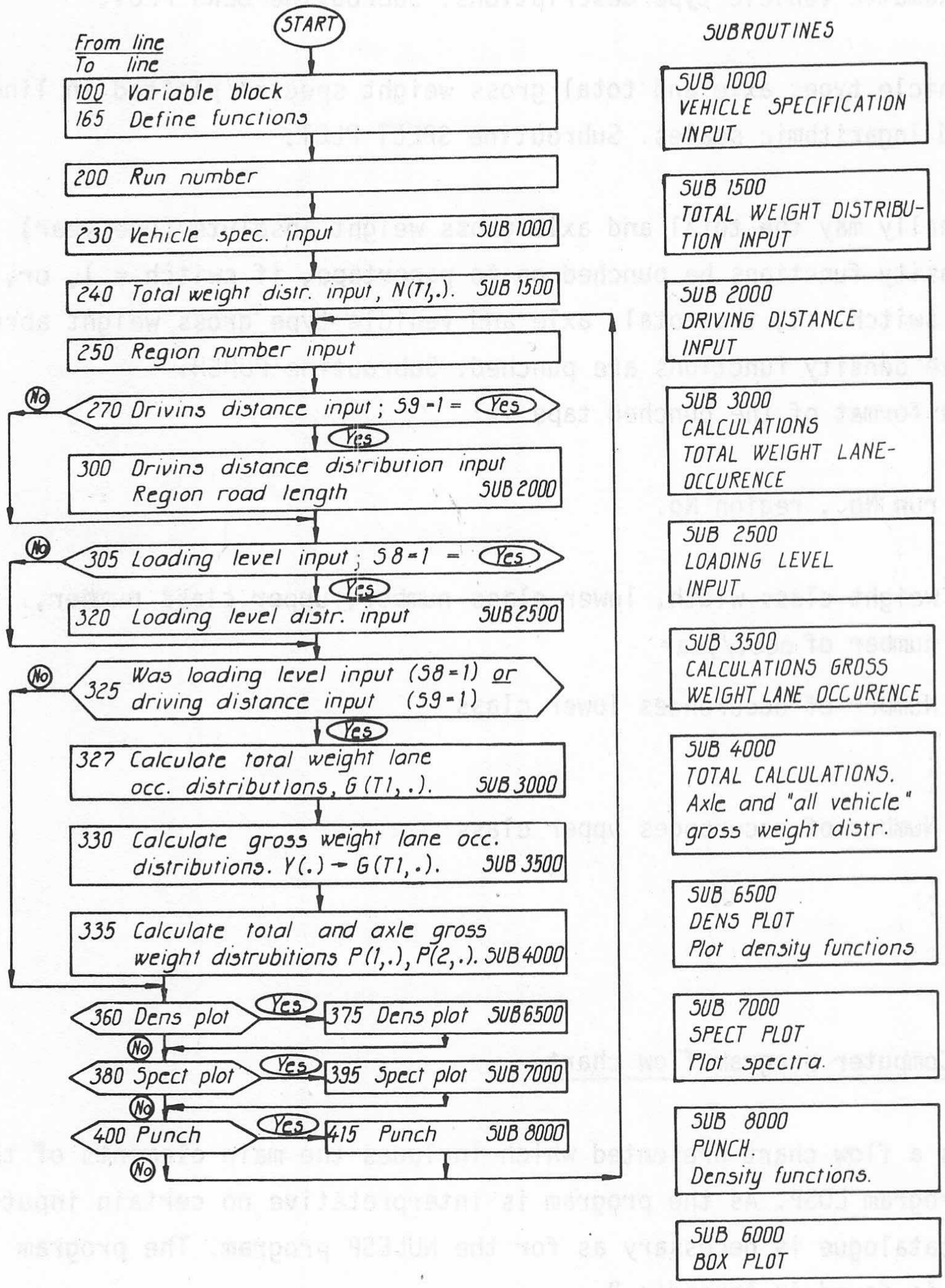
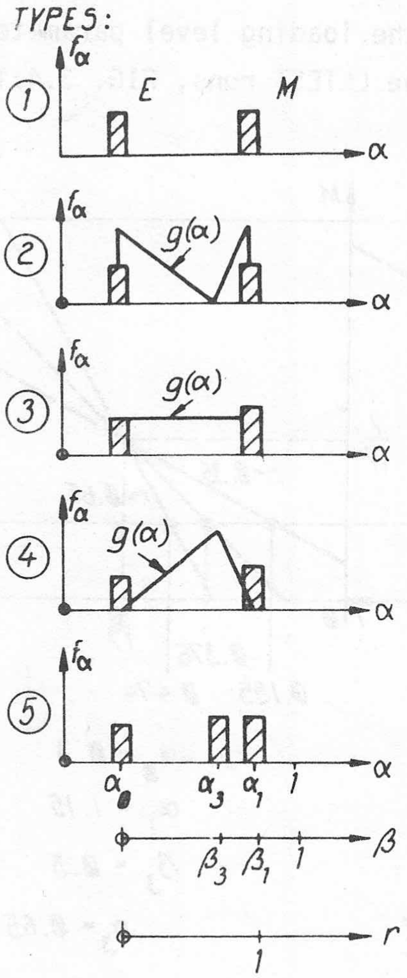


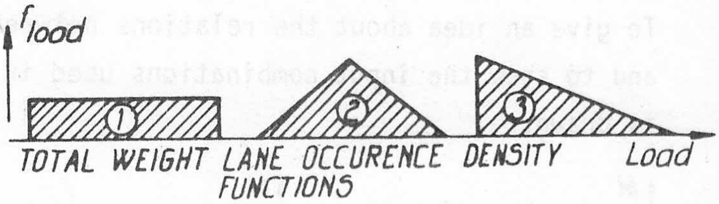
FIG. 3.3.2-1. Flow chart LOSP. (See also summary chart FIG. 3.3.1-1 and Appendix B.)

3.4 Discussion of certain variables influence on the result.

This chapter brings out an idea about the relative importance of the three main variables loading level, driving distance and input load distributions. The results are presented as spectra which are calculated and drawn by a Basic routine LLTEST. The influence of the driving distance and load distribution shapes is related in Chapter 3.4.2, which can also be looked upon as an illustration of the spectrum appearance in relation to the underlying density function. Further discussion on the influence of weight distribution on axles are held in Chapter 4, calculated spectra, and 6.5, variable influence in loadeffect spectrum model.

3.4.1 Loading level distribution influence.





$$M = \frac{\beta_3 \cdot (1-\alpha_0)}{(1-r)\cdot(\alpha_1-\alpha_0)} + \frac{r}{1-r} \cdot E - \frac{r}{1-r} \quad \text{----}(A\text{-}9a)$$

$$E = \frac{\beta_3 \cdot (1-\alpha_0)}{r\cdot(\alpha_1-\alpha_0)} + \frac{1-r}{r} \cdot M + 1 \quad \text{----}(A\text{-}9b)$$

$$\alpha = \alpha_0 + \beta \cdot (1-\alpha_0) \quad \text{----}(A\text{-}5)$$

Loading level by total weight

Loading level by total load

Non-dimensional mean of $g(\alpha)$

FIG. 3.4.1-1. Five loading level distribution types and three load distribution types. Notations see Appendix A. (f_{load} = total weight lane occurence density function)

As mentioned in the LOSP description, Chapter 3.3.1, a loading level distribution of type 3, see FIG. 3.4.1-1 and Appendix A, was used in the calculations of load spectra. In order to study the influence of the loading level distribution appearance, expressions for four more distributions were deduced, Appendix A, and used on three main shapes of load distributions in a computer program LLTEST. The five types of loading level density functions and three types of load density functions are explained in FIG. 3.4.1-1, which also contains some important formulas picked from Appendix A. Notations are also explained in Appendix A.

In the test runs the overload part of the loading level distribution was not included. Instead α_1, the max. gross weight which normally is one, with its related area-probability M, is increased to show the influence of loading levels greater than one.

To give an idea about the relations between the loading level parameters and to show the input combinations used in the LLTEST runs, FIG. 3.4.1-2 is drawn.

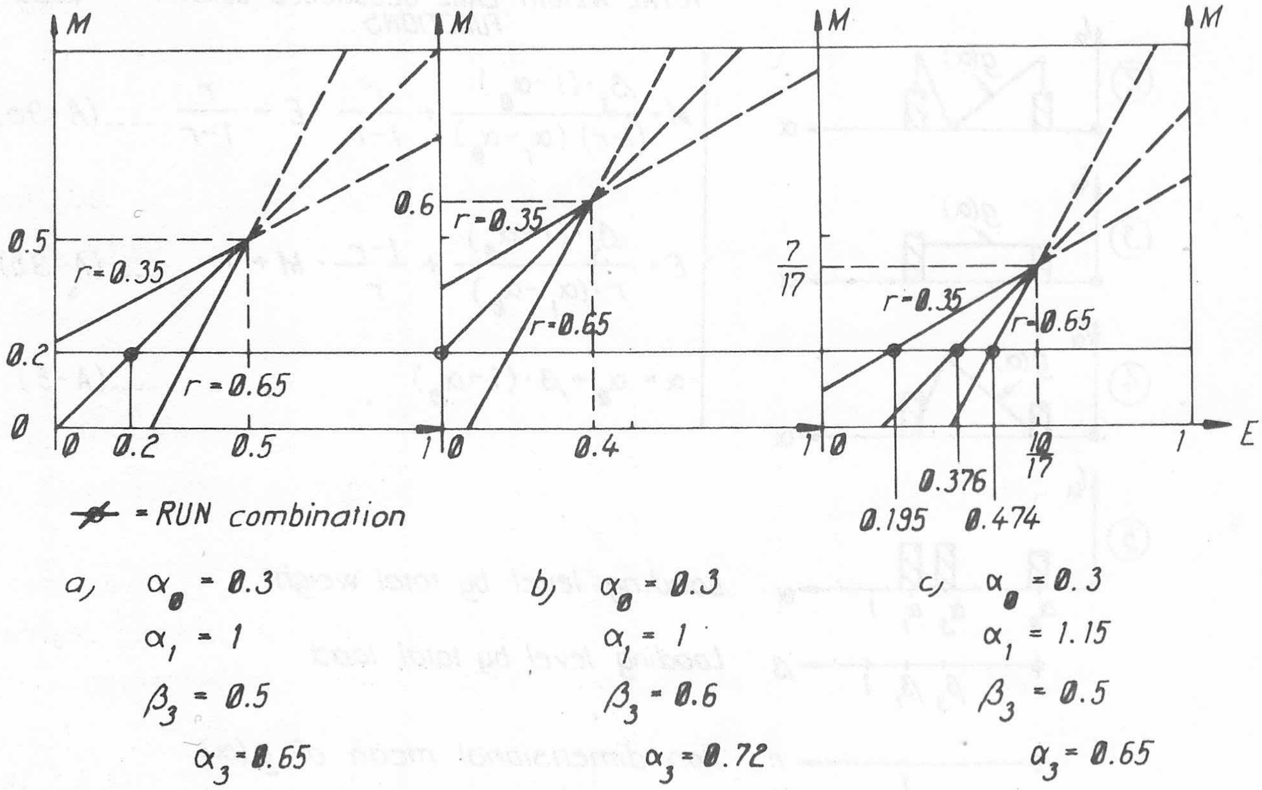


FIG. 3.4.1-2. Relation between tare/total weight portion, E, and max./total weight portion, M, for non-dimensional g(α) mean, r, equal to 0.35, 0.5 and 0.65.

The result is presented as computer plotted curves in FIGS. 3.4.1-3 to 3.4.1-5. The calculations are performed for discrete input load distributions in a similar manner as described in Chapter 3.3.1, description of LOSP. The resulting spectra are plotted under the assumption of uniform distribution of vehicle gross weights within each class, corresponding to a lower envelop of a load spectrum produced by LOSP.

FIGS. 3.4.1-3a-c — With input values according to FIG. 3.4.1-2a. The calculations are performed for the three types of input load distributions. The mean loading level, α_3, is put to 0.65.

FIG. 3.4.1-4 — With input values according to FIG. 3.4.1-2b. The calculations are performed for load type 3. The mean loading level, α_3, is increased to 0.72 and the max./total weight portion, M, retained equal to 0.2.

FIG. 3.4.1-5 — With input values according to FIG. 3.4.1-2c. Load type 3 is used. Mean loading level, α_3, is equal to 0.65. The max./total weight, α_1, is increased from 1 to 1.15.

Fixed points have been placed in the figures, coordinates (10 %, 150) and (1 %, 300), to make the comparisons between figures easier.

The main conclusions about the loading level influence are

The shape influence of $g(\alpha)$ is comparatively small even for differing $g(\alpha)$ mean, r.

A change in the total loading level distribution mean, α_3, raises or lowers the inner parts of the spectrum to a corresponding degree. The difference is more protruding in the linear representation.

It can also be seen from the figures that increasing variance of the loading level distribution raises the high load and lowers the low load parts of the spectrum. This involves a great importance to the max./total weight portion value, M.

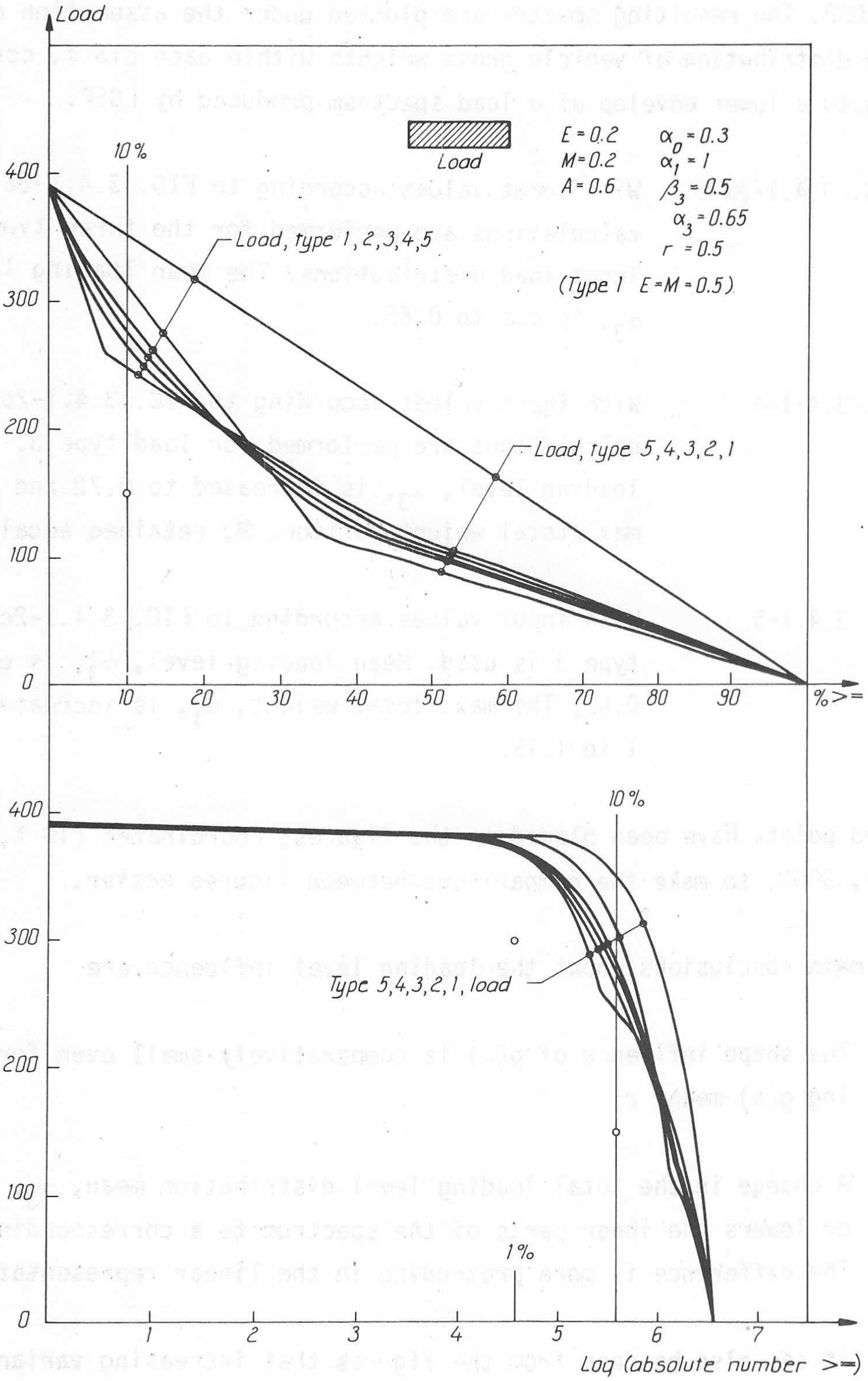
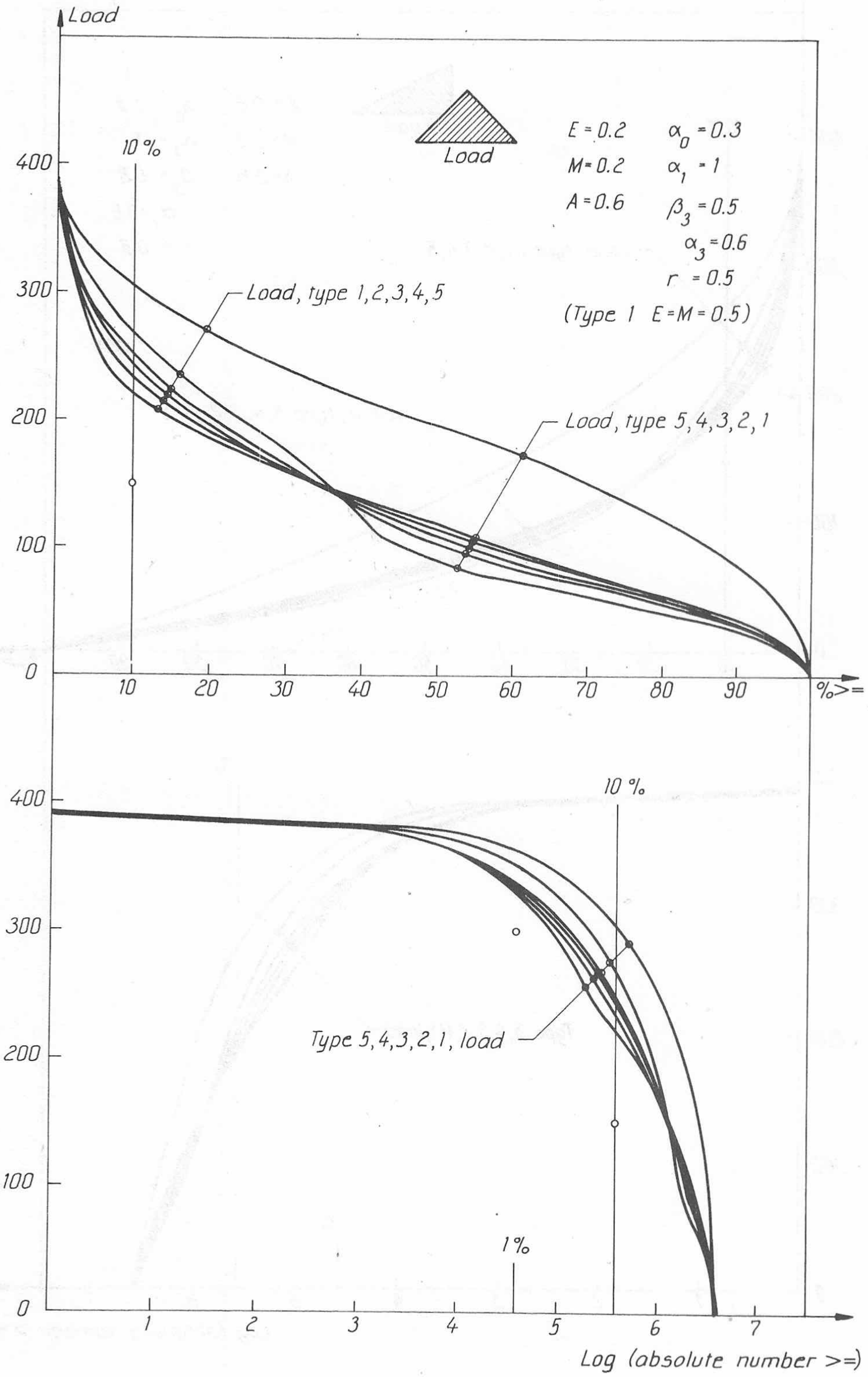

Load
10%
Load
E = 0.2
M = 0.2
A = 0.6
α0 = 0.3
α1 = 1
β3 = 0.5
α3 = 0.65
r = 0.5
(Type 1 E = M = 0.5)
Load, type 1,2,3,4,5
Load, type 5,4,3,2,1
400
300
200
100
0
10
20
30
40
50
60
70
80
90
% >=
10%
Type 5,4,3,2,1, load
1%
1
2
3
4
5
6
7
Log (absolute number >=)

FIG. 3.4.1-3a



Load
Load
E = 0.2
M = 0.2
A = 0.6
α_0 = 0.3
α_1 = 1
β_3 = 0.5
α_3 = 0.6
r = 0.5
(Type 1 E = M = 0.5)
10 %
Load, type 1,2,3,4,5
Load, type 5,4,3,2,1
400
300
200
100
0
10
20
30
40
50
60
70
80
90
%>=
10 %
Type 5,4,3,2,1, load
1%
1
2
3
4
5
6
7
Log (absolute number >=)

FIG. 3.4.1-3b

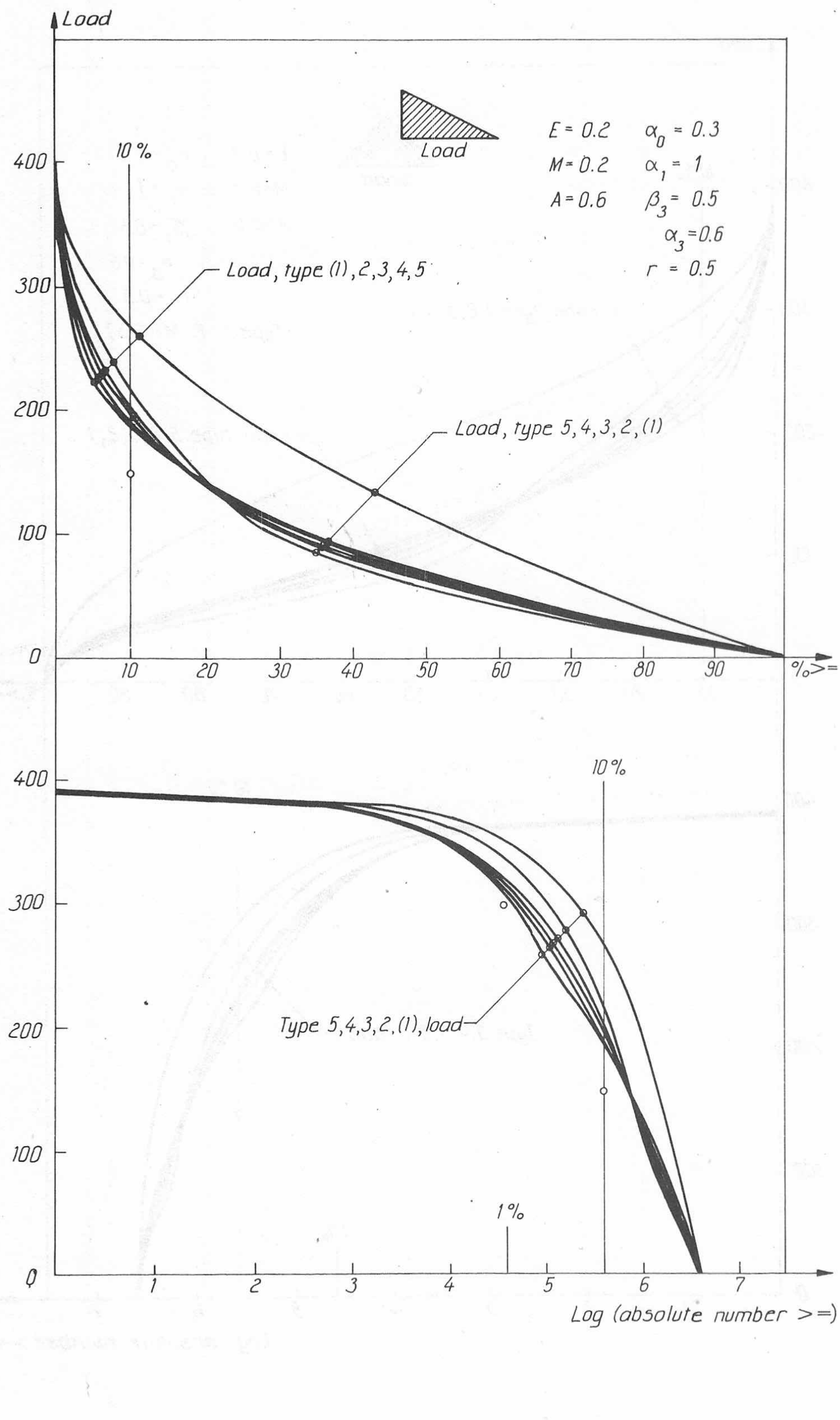
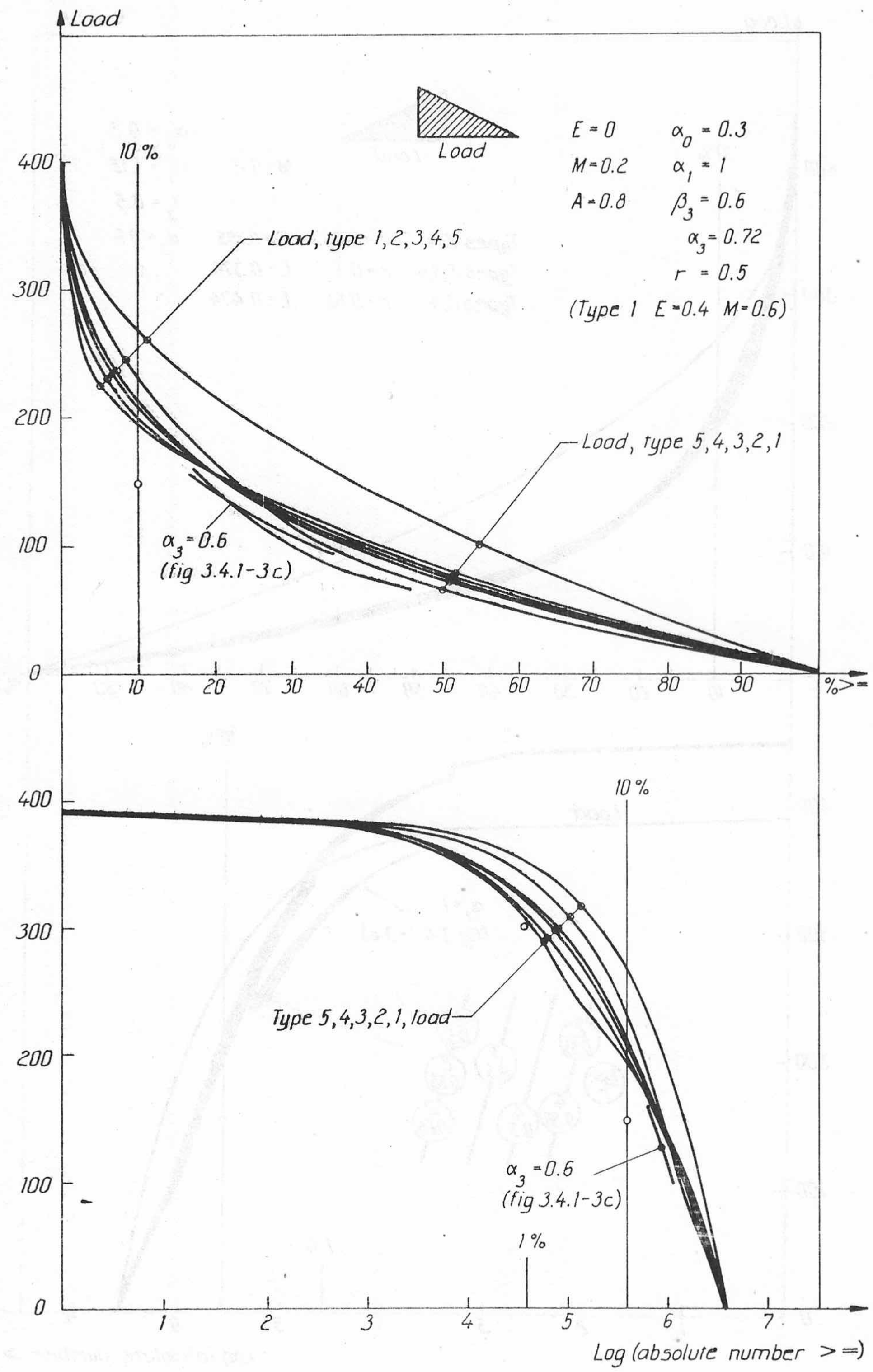

Load
Load
E = 0.2
M = 0.2
A = 0.6
α0 = 0.3
α1 = 1
β3 = 0.5
α3 = 0.6
r = 0.5
10 %
Load, type (1), 2, 3, 4, 5
Load, type 5, 4, 3, 2, (1)
400
300
200
100
0
10
20
30
40
50
60
70
80
90
%>=
10 %
Type 5, 4, 3, 2, (1), load
1 %
400
300
200
100
0
1
2
3
4
5
6
7
Log (absolute number >=)

FIG. 3.4.1-3c



Load
Load
E = 0
M = 0.2
A = 0.8
α0 = 0.3
α1 = 1
β3 = 0.6
α3 = 0.72
r = 0.5
(Type 1 E = 0.4 M = 0.6)
10 %
Load, type 1,2,3,4,5
Load, type 5,4,3,2,1
α3 = 0.6
(fig 3.4.1-3c)
400
300
200
100
0
10
20
30
40
50
60
70
80
90
% >=
10 %
Type 5,4,3,2,1, load
α3 = 0.6
(fig 3.4.1-3c)
1 %
1
2
3
4
5
6
7
Log (absolute number >=)

FIG. 3.4.1-4

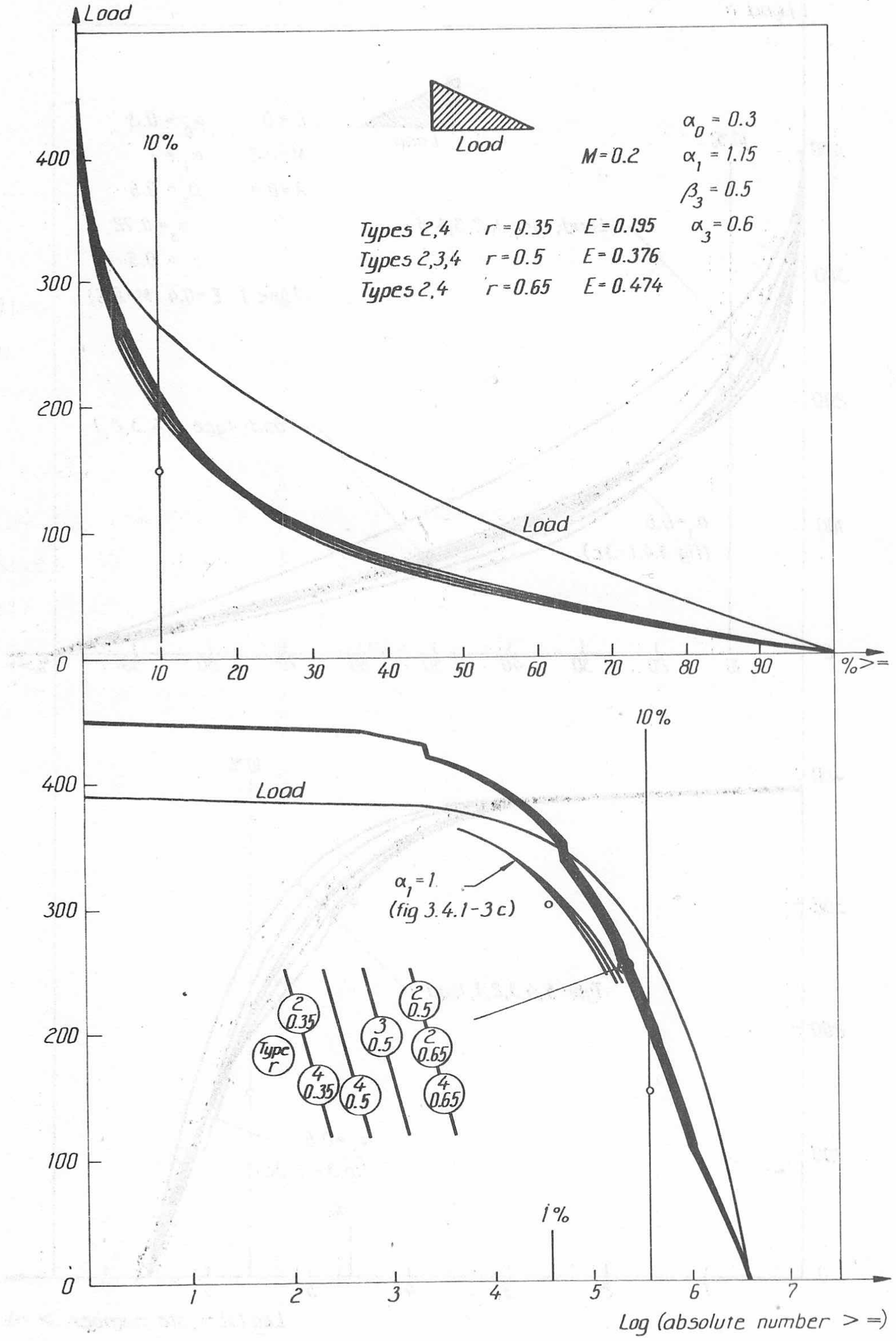

Load
10%
Load
M=0.2
α_0 = 0.3
α_1 = 1.15
β_3 = 0.5
α_3 = 0.6
Types 2,4 r = 0.35 E = 0.195
Types 2,3,4 r = 0.5 E = 0.376
Types 2,4 r = 0.65 E = 0.474
Load
400
300
200
100
0
10
20
30
40
50
60
70
80
90
%>=
10%
Load
α_1 = 1
(fig 3.4.1-3 c)
Type r
2 0.35
4 0.35
3 0.5
4 0.5
2 0.5
2 0.65
4 0.65
1%
Log (absolute number >=)

FIG. 3.4.1-5

The upper limit of loading level values, that is α_1 (or the overload loading level α_2), affects the spectrum appearance noticeable, at least when represented in a logarithmic scale, in that an increase of this value raises the spectrum, in the high load regions, to a corresponding degree.

3.4.2 Driving distance distribution and registered vehicle distribution influence.

The driving distance distributions are not treated as stochastic variables but as constants, which together with the region road length transformes the vehicle total weight registration density functions, class by class, according to FIG. 3.3.1-2.

A careful analysis of the shape influences of the driving distance distribution and registration total weight density function was not considered essential to carry through in detail. Instead simple density functions were transformed to linear and logarithmic spectra to give an idea about the relations between density functions and corresponding spectra. The result is shown in FIG. 3.4.2-1. The calculations and plots are performed with a computer routine LLTEST.

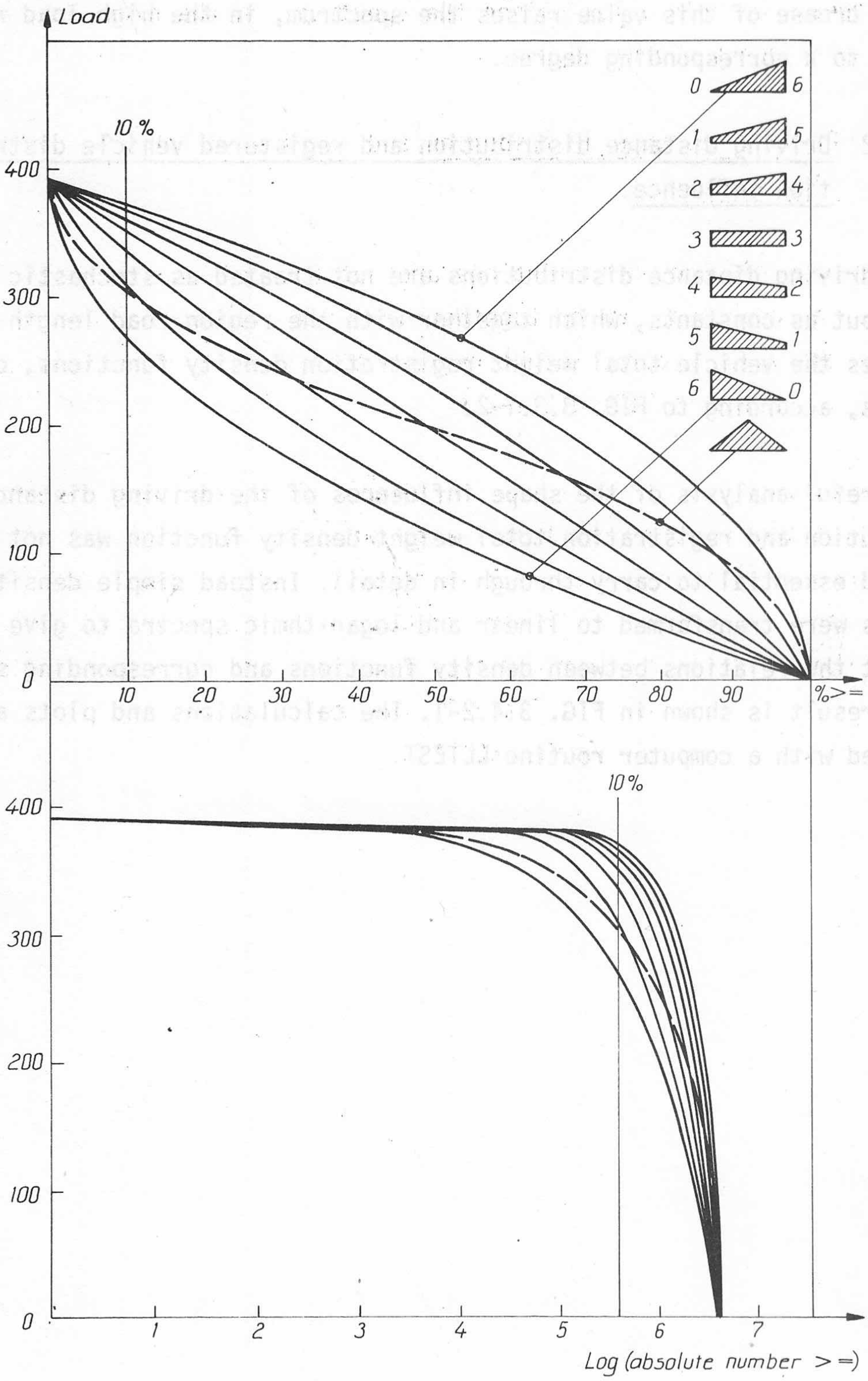

Load
10 %
400
300
200
100
0
10 20 30 40 50 60 70 80 90 %>=
0 6
1 5
2 4
3 3
4 2
5 1
6 0
10%
400
300
200
100
0
1 2 3 4 5 6 7
Log (absolute number >=)

FIG. 3.4.2-1

4 CALCULATED AND MEASURED LOAD SPECTRA

In this chapter load spectra are calculated for three different time periods, years 1965 and 1973 and for a future time period. The calculated 1965 spectra are compared with measured spectra and the calculated 1973 spectra are later used as input to calculations of loadeffect spectra, which are compared with a few measured loadeffect spectra for the same period. Finally, two predicted load spectra are calculated which are used as input to tests of the loadeffect spectrum model and to calculate predicted loadeffect spectra.

The determination of input data will of course be partly coupled to Swedish regulations about vehicle weights but will, however, show a procedure to put up the input data.

The region types are picked from the table below, FIG. 4-1, which shows a possible rough main classification of region types. See also FIG. 4-2.

RURAL	Long distance (European highway)	11
	Short distance (National main road)	12
	Special (ex. wood district)	13
URBAN	Long + short distance	21
	Short distance	22
	Special (ex. factory approach)	23

FIG. 4-1. Main classification of region types, with number codes.

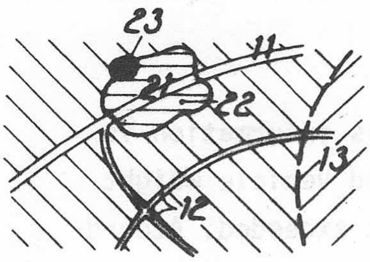


FIG. 4-2. Region types.

4.1 Comparison between measured and calculated load spectra for the year 1965.

Load spectra are calculated for two rural regions, one subjected to mainly long distance, and the other to short distance, traffic, (regions 11 and 12). The underlying data is picked from "Lastbilar och Lastbilstrafik" /28/, "Fordonskombinationer" /29/, "Bilismen i Sverige" /30/ and Jonsson /31/. The input is determined with guidance from this literature and does of course not claim to exactly describe the state of things in 1965.

The calculated spectra are compared to measured spectra from the 1965 loadometer study in Sweden.These results were picked from Brinck /32/. The 1965 loadometer study was the latest performed in Sweden of that extent.

A finer validation of the model may hopefully be made during the planned field investigations which are mentioned in Chapter 7.

4.1.1 Values of input variables, 1965.

In Sweden the maximum permissible axle/tandem weights at that time were, and still are, 8/12 and 10/16 Mp (≈ 80/120 and 100/160 kN) with maximum permissible gross weights, also related to the total axle distance, equal to 37.5 and 41.5 Mp respectively (≈ 375 and 415 kN). The vehicle total weight registration density functions per the first of January 1966 were found in "Lastbilar ..." /28/ divided on lorries, trailers and semitrailers. On the basis of these density functions, maximum axle/tandem weighs 100/160 and maximum gross weight 415 kN vehicle types according to FIG. 4.1.1-1 were defined.

The axle distances are not specified here because this information is not used in the load spectrum calculations. The ringed vehicle weight distribution is such that permissible weights are not exceeded. According to Jonsson /31/ axle overweights, besides those achieved with an overweight loading level, were common among the heavy vehicle types. This fact was regarded by a complementary set of weight distributions for types 3 to 5, within squares in FIG. 4.1.1-1, calculated under the assumption, that the heaviest axle, inner if possible, has got 20 % overweight which is transferred from the other axles. The weight relations between the remaining axles are retained.

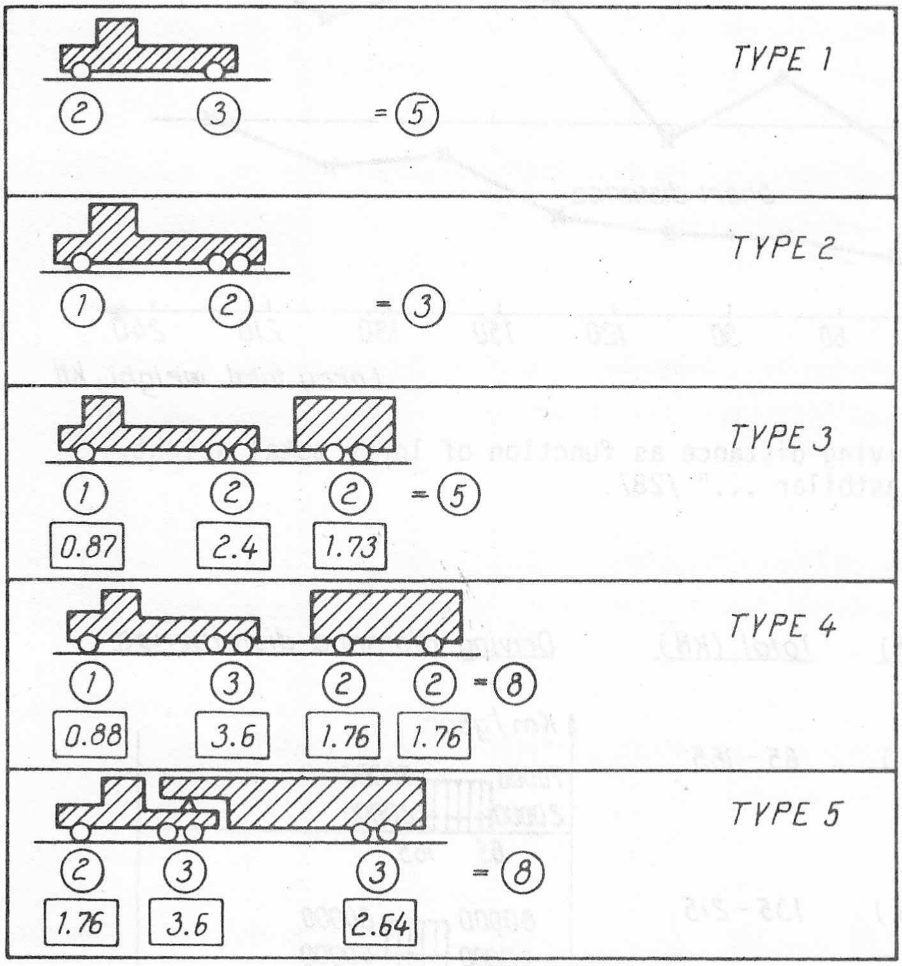


FIG. 4.1.1-1. Vehicle types for the year 1965. Weight distribution on axles ringed, with 20 % overweight on one axle squared.

The total weight registration distributions are not listed. Instead they are found in the plot output from the LOSP runs, see next chapter, FIG. 4.1.2-2. As the distributions were originally divided on lorries and trailers a pairing off according to the vehicle type specifications had to be made. Thereby it was assumed that all the trailers were always attached to a lorry, which according to "Lastbilar ..." /28/ is fairly true (94 % of the lorry driving distance) for at least trailers with more than two axles. The density functions were truncated for low total weights so that the lowest axle total weight multiplied by the lowest loading level (tare/total weight, specified later) became greater than 12.5 kN as this was the lowest axle weights registered in the loadometer study.

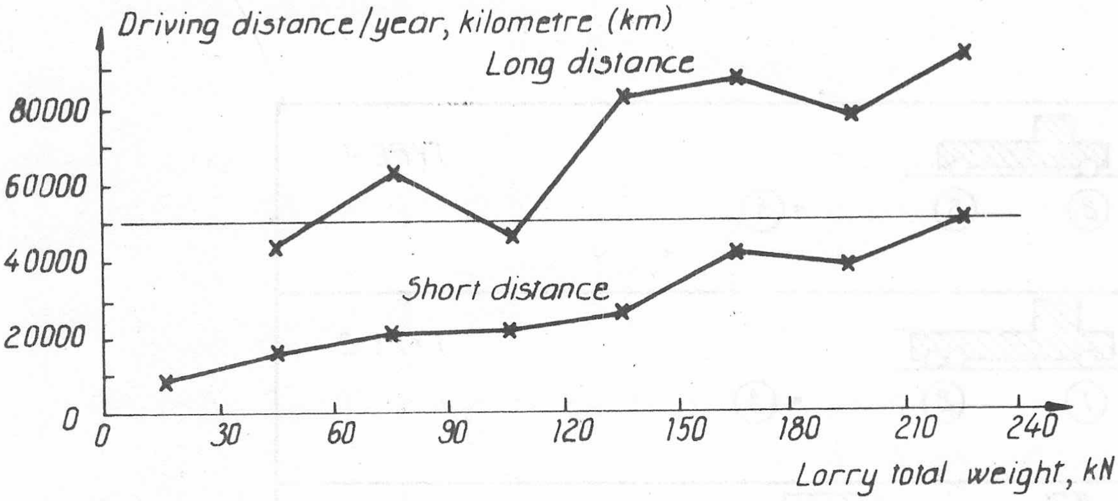


FIG. 4.1.1-2. Driving distance as function of lorry total weight. "Lastbilar ..." /28/.

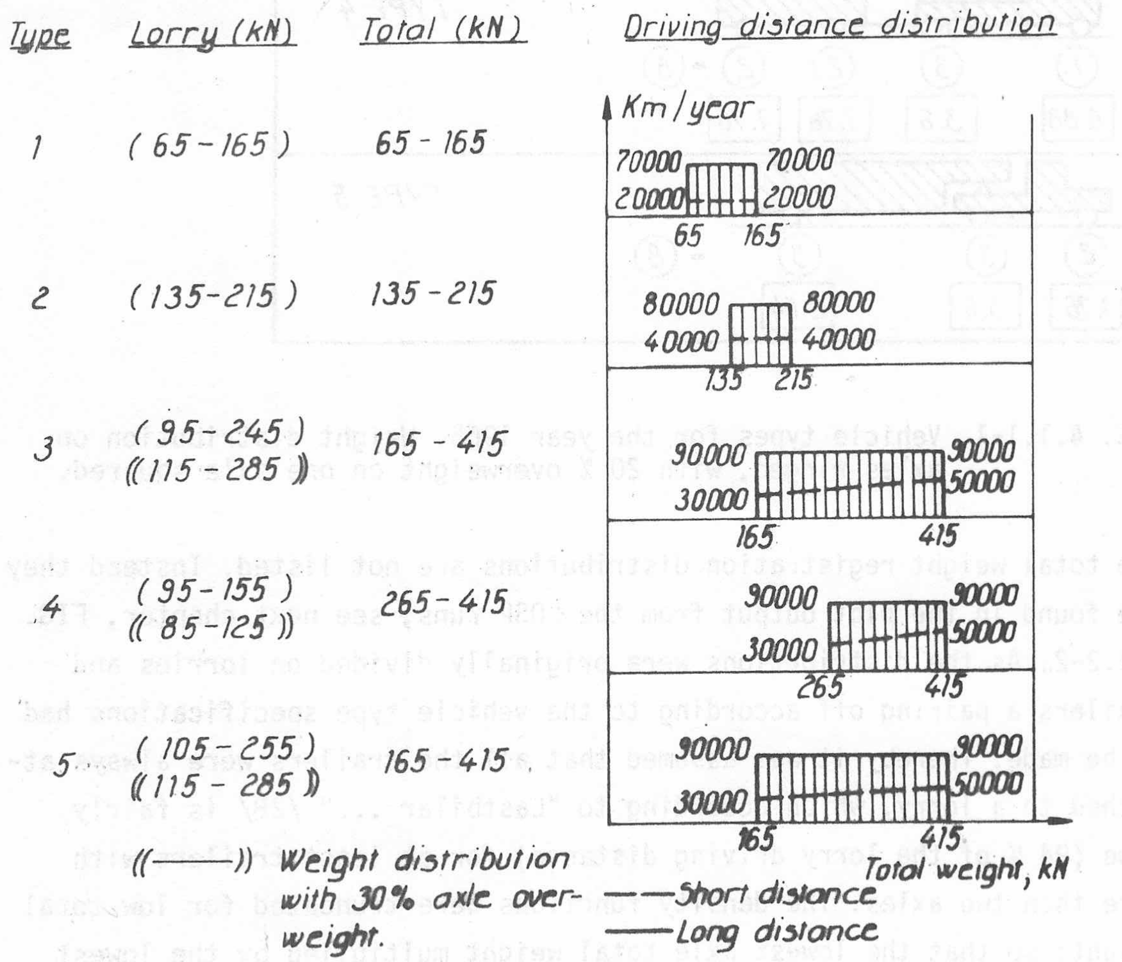


FIG. 4.1.1-3. Driving distance distributions for long distance and short distance regions related to vehicle total weight, 1965.

From the same source was FIG. 4.1.1-2 constructed giving an idea about the driving distances as a function of vehicle total weights. These curves served as guidance when the driving distance distributions for long and short distance regions were put up. See FIG. 4.1.1-3.

The same loading level distribution was used for all vehicle types. The mean loading level by total load, picked from "Lastbilar ..." /28/, was put to 0.65 and 0.55 for the two regions.

The tare/total weight share was found to be approximately 0.45, from "Lastbilar..." /28/, with somewhat higher values for light lorries and lower for trailers. The probability for a vehicle to drive without load was estimated from "Bilismen ..." /30/ to 15 % (25 %) and the over/total load share and portion 1.2 and 20 % respectively from Jonsson /31/.

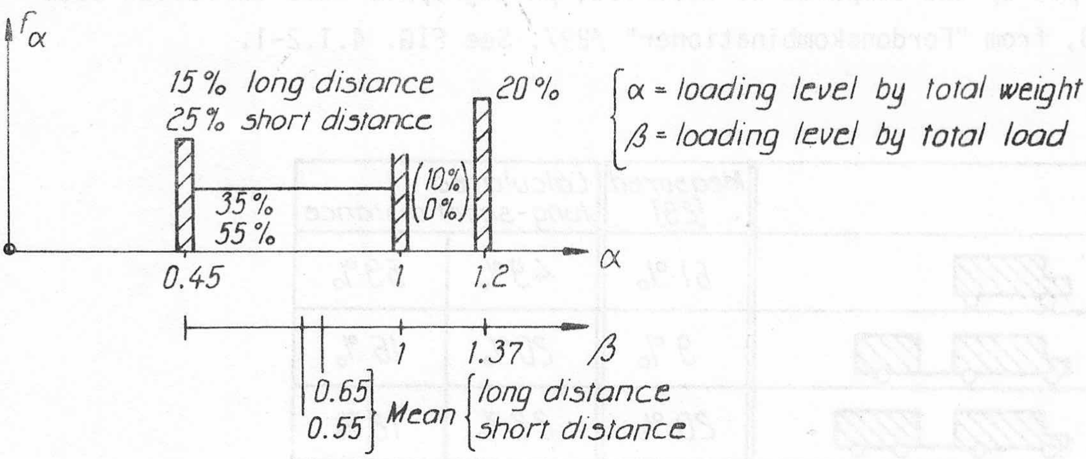


FIG. 4.1.1-4. Loading level input 1965.

For the rural long distance region it was supposed that only a fraction, here put to 0.5 of the available amount of single lorries, type 1 and 2, were running on these roads. This is accomplished by reducing the driving distances, according to FIG. 4.1.1-3 to a corresponding degree. The reason for this reduction is that it is assumed that many single lorries of the urban regions seldom make long distance travels on rural roads.

It was assumed that the total road length of both regions were 10000 kilometres, based on the fact that the total main road length with paving at that time were 10000 kilometres.

4.1.2 Calculated and measured load spectra, 1965.

The calculated spectra for regions rural long distance and rural short distance are compared with corresponding measured spectra on the following pages.

The measured vehicle gross weight spectra are rather summarily presented in Brinck /32/, but it was not considered that essential for the author of this report to make a further evaluation of the source material. The measured axle gross weight spectrum for region long distance was prepared by Bo Eriksson-Vanke, The National Road Administration, in a memo on fatigue in highway bridges 1972.

From the calculated vehicle type gross weight lane occurence density functions, see FIG. 4.1.2-2, figures for vehicle type lane occurences are put up and compared to observed, photographic data collected 1962-1963, from "Fordonskombinationer" /29/. See FIG. 4.1.2-1.

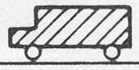
	Measured [29]	Calculated long-short	distance
	61 %	49 %	59 %
	9 %	20 %	16 %
	20 %	22 %	18 %
	8 %	9 %	7 %
REST	2 %	—	—

FIG. 4.1.2-1. Vehicle type lane occurences. Measured (European highway + national main road) and calculated.

FIG. 4.1.2-3 shows calculated spectra for rural long distance region and FIG. 4.1.2-4 for rural short distance. The dashed curves represents the measured spectra. A second axle gross weight spectrum was calculated for the long distance region using the original (circeld in FIG. 4.1.1-1) weight on axles distribution.

As can be seen the agreement between measured and calculated spectra is fairly good, especially for the axle spectra. The discrepancy between vehicle gross weight spectra is more pronounced in the linear than in the logarithmic scale. The measured logarithmic spectrum was calculated outgoing from the linear spectrum with the same total vehicle flow as calculated. No information is available about measured spectra above the 400 kN level other than the upper limit lays around 500 kN, Jonsson /31/.

In FIG. 4.1.2-3, rural long distance region, are also sketched parts of a linear vehicle gross weight spectrum and a logarithmic axle gross weight spectrum calculated by means of a loading level distribution with tare/total weight portion equal to 40 % and max./total weight portion equal to 35 %, (see the dotted curves). This increase of the variance of the loading level density function moves, as expected, the calculated spectrum towards the measured in the upper sectrum region. An increase in mean load/total load to 0.7 (from 0.65) has approximately the same effect, but without the lowering effect for low loads.

As mentioned a better agreement could be achieved between calculated and measured spectra. It was though considered more essential here to show that it is possible to get rather close to real spectra through treatment of simple underlying data.

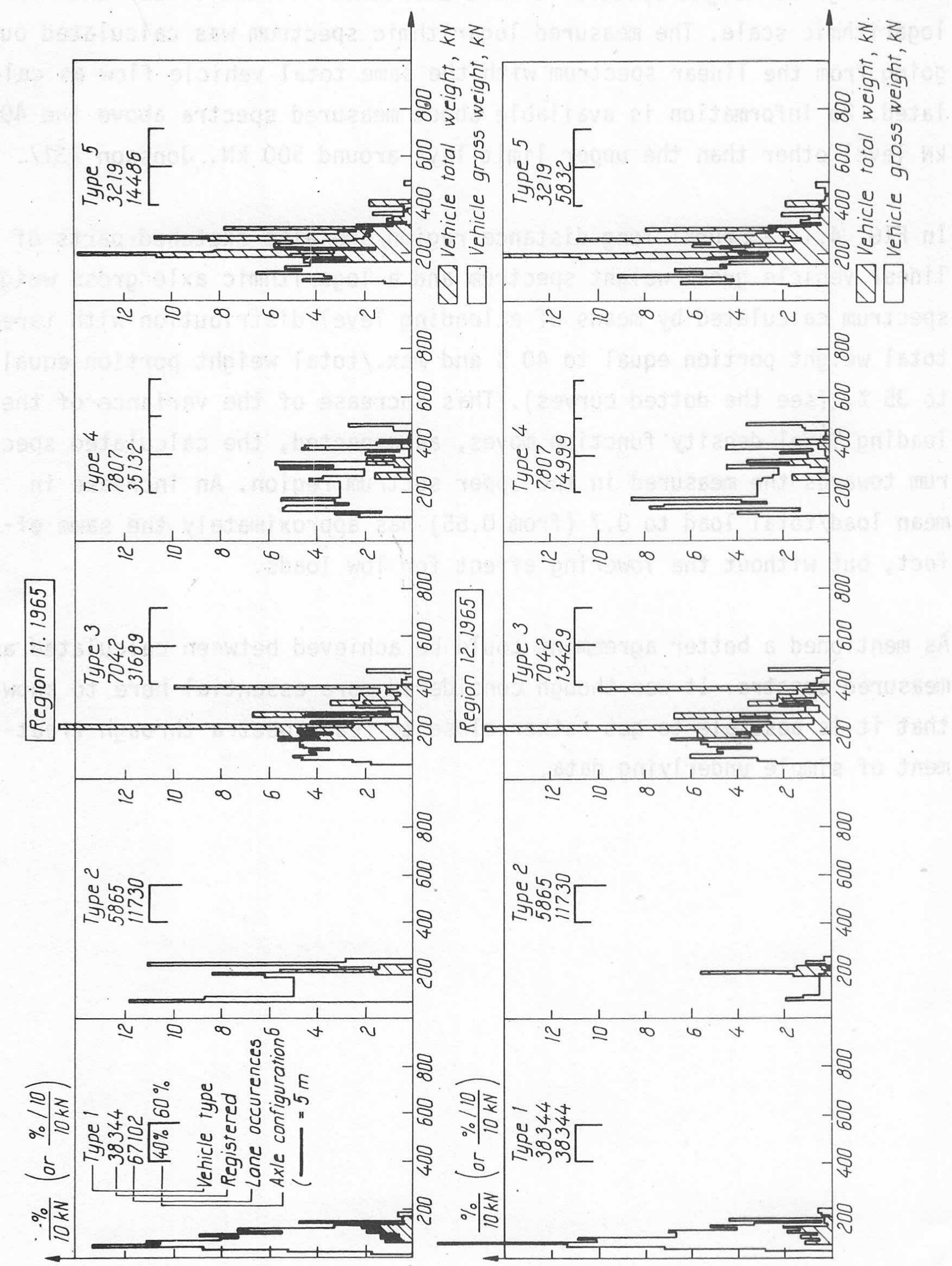


FIG. 4.1.2-2. Total weight registration distributions (hatched) and gross weight lane occurence distributions, 1965.

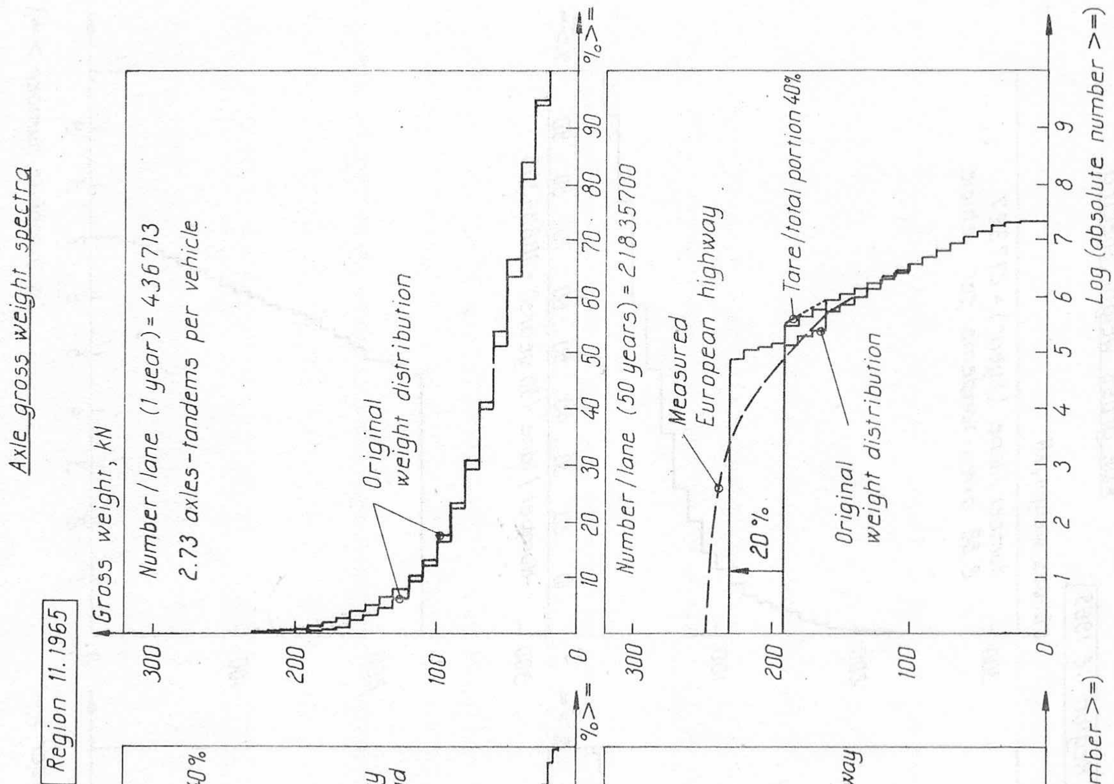


FIG. 4.1.2-3. Load Spectra, 1965. Rural long distance region.

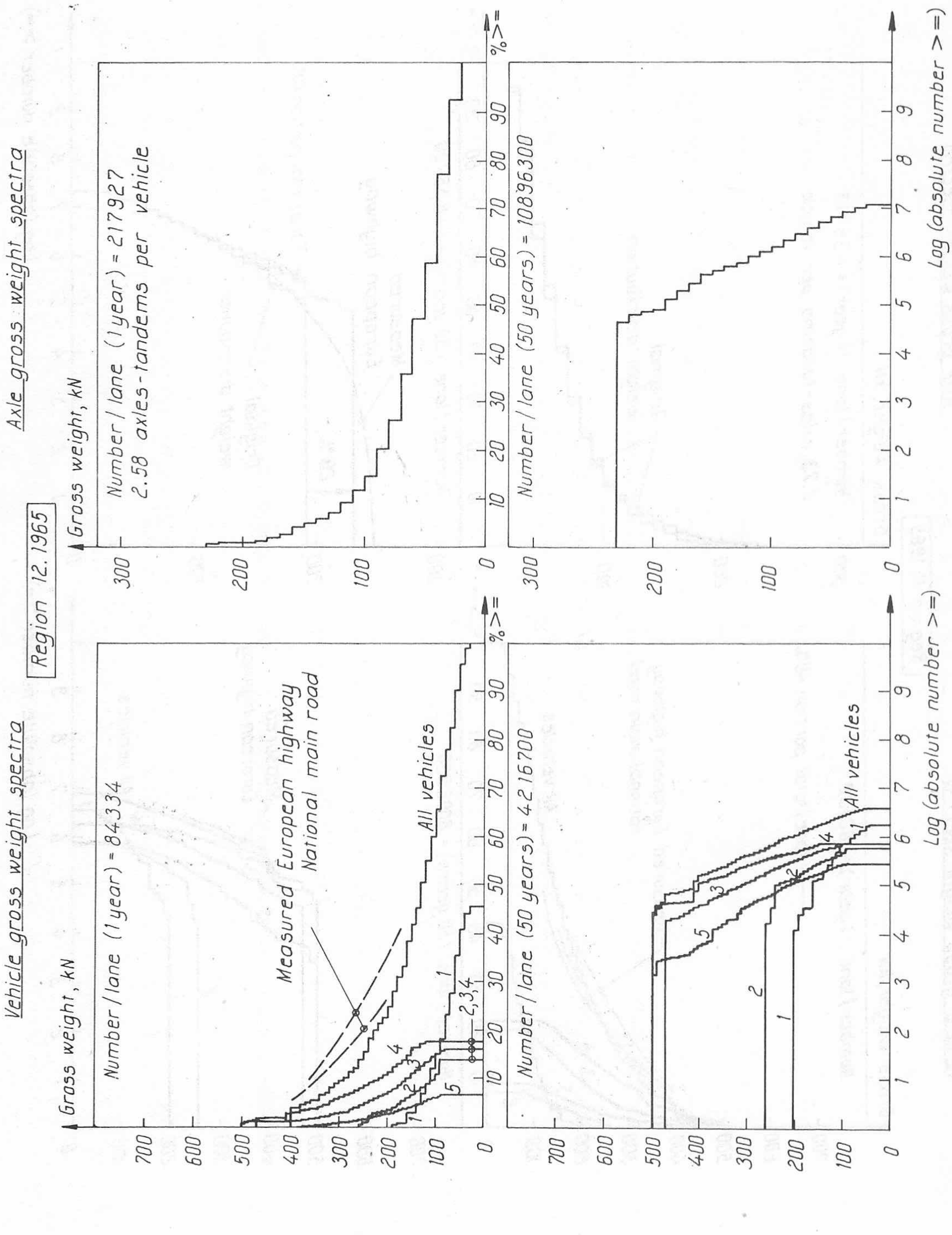


FIG. 4.1.2-4. Load Spectra, 1965. Rural short distance region.

4.2 Calculated load spectra for the year 1973.

In this chapter load spectra are calculated for the rural long distance (11) and rural short distance (12) regions. The load spectra are intended to be representative for the European highway south of Stockholm, highway bridge across Södertälje canal, and the other for main road 45 at Köpmannebro in Västergötland. These load spectra will later be used as input to calculations of loadeffect spectra, Chapter 8.1, which are compared to two loadeffect spectra collected from the highway bridges at these sites.

The input data are mainly picked from "Statistiska meddelanden NR T 1974:47" /33/, "Bilismen i Sverige" 1971 and 1973 /30/, "Lastbilar och lastbilstrafik" /28/ and a memo on fatigue of highway bridges 1975 by the author where load spectra are put up with somewhat different input values. Considerations are also given on the input sources used and results obtained, of the preceding chapter, load spectra for the year 1965, since information about the 1973 conditions is scanty.

4.2.1 Values of input variables, 1973.

The maximum permissible axle/tandem weights in Sweden were and are 80/120 and 100/160 kN. The corresponding maximum gross weights as function of total axle distance are found in FIG. 4.2.1-1.

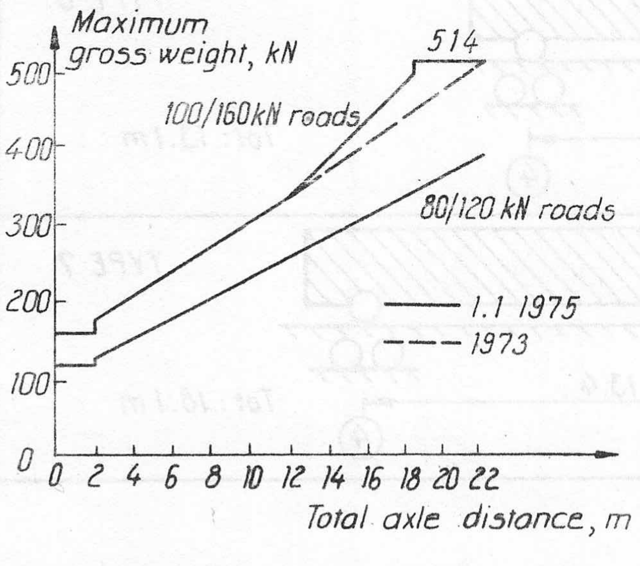


FIG. 4.2.1-1. Maximum permissible vehicle gross weight as function of total axle distance.

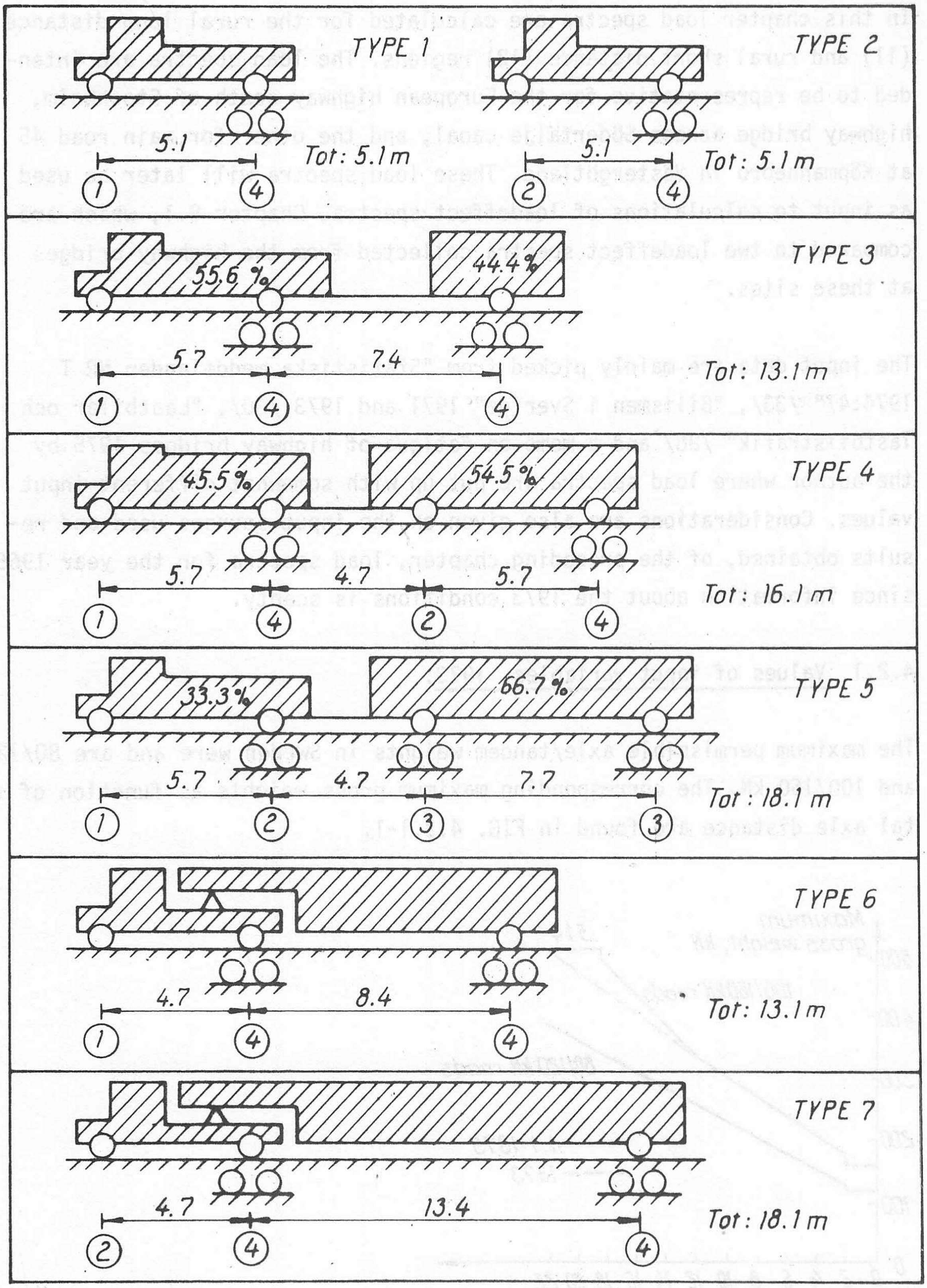


FIG. 4.2.1-2. Vehicle type specification for the year 1973. Weight distribution on axles ringed.

On the basis of the later described total weight registration distributions and the 1975 weight regulations valid for 100/160 kN roads, vehicle types according to FIG. 4.2.1-2 were put up. Only one set of weight distribution on axles was assumed. The influence of the weight distribution shape on the appearance of axle load spectra and loadeffect spectra is further studied in Chapter 6.5.3. A proper axle overweight weight distribution on axles will be chosen in Chapter 8.1 where the corresponding loadeffect spectra are calculated. The vehicle type specifications also include values on axle distances which are used in the loadeffect spectra calculations.

The total weight distributions for lorries and tractors for semitrailers were found in "Statistiska ..." /33/ as well as distributions for load capacities for semitrailers and trailers. The trailer load capacity distributions were transformed to trailer total weight distributions by assuming tare/total weight equal to 0.25 which seems to be adequate enough at least for high total weights.

A pairing off of lorries and trailers was then made assuming as before, that all the trailers were always attached to a lorry. A truncation was also made of the type 1 lorry total weight registration distribution below 70 kN, which corresponds to unloaded lorries with front and rear axle weights below $70 \cdot 0.35/5 = 4.9$ respectively 19.6 kN. Furthermore, all lorries and trailers with total weights below 30 kN were removed. The class width was put to 10 kN.

The total weight registration distributions are not listed. Instead they are found in the plot output from the LOSP runs, FIGS. 4.2.2-2 and -4.

From "Bilismen ... 1973" /30/ obtained information about driving distances did not provide anything new besides the already shown distributions used in the 1965 calculations, see FIG. 4.1.1-2. Therefore the same assumptions about driving distance distributions as function of lorry total weights were made in the 1973 calculations. The chosen values are found in FIG. 4.2.1-3.

The same loading level distribution was chosen for both regions as a result of a study of the 1965 calculations and due to lack of base data. The chosen distribution has a tare/total weight portion equal to 0.3, from

Type	Lorry (kN)	Total (kN)
1	(75-195)	75-195
2	(205-235)	205-235
3	(45-197)	75-355
4	(135-198)	305-435
5	(125-165)	365-495
6	(108-197)	195-355
7	(165-249)	275-415

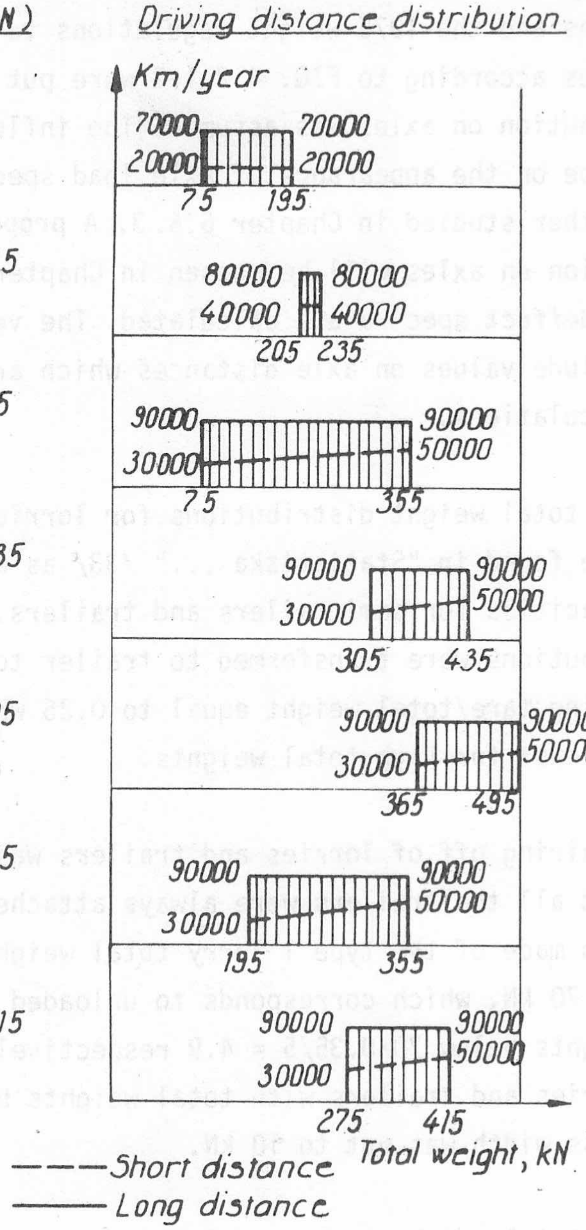


FIG. 4.2.1-3. Driving distances related to vehicle total weight, 1973. Rural long distance and short distance regions.

"Bilismen ... 1971" /30/, giving the loading level density function a relatively great variance. The tare/total weight loading level was put to 0.35 which after a study of vehicle specifications was judged to be a representative figure. The mean load/total load loading level was estimated from "Bilismen ... 1971" /30/ to 0.65. The same overweight portion, though with lower overload/total load loading level, as in the 1965 calculations was assumed, which may be an underestimation of the observance of the regulations. The assumed distribution is shown in FIG. 4.2.1-4.

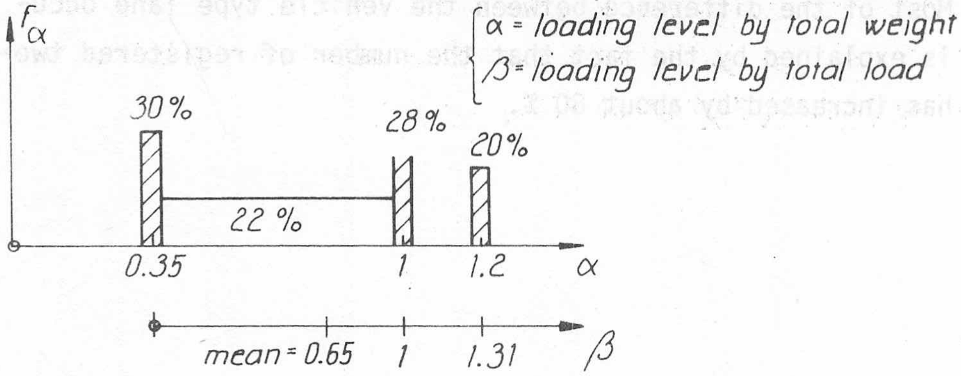


FIG. 4.2.1-4. Loading level input 1973. Rural long distance and short distance regions.

The same rather arbitrary chosen factor 0.5, as was used in the 1965 calculations, was also used here to reduce the number of single lorries involved in long distance traffic. The region road lengths were still supposed to be 10000 kilometres.

The result of the runs are shown in the next chapter with some comments made.

4.2.2 Calculated load spectra, 1973.

Below the calculated spectra for rural long distance and short distance regions are presented. In the figures dashed spectra are also drawn representing 1965 measured spectra.

FIG. 4.2.2-1 shows the calculated vehicle type lane occurences.

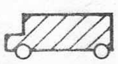
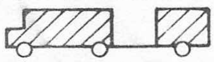
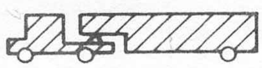
	Calculated long-short distance	
	35 %	51 %
	21 %	16 %
	34 %	26 %
	10 %	7 %

FIG. 4.2.2-1. Vehicle type lane occurences. Calculated 1973.

FIG. 4.2.2-1 may be compared to FIG. 4.1.2-1 which is valid for the 1965 calculations. Most of the difference between the vehicle type lane occurence figures is explained by the fact that the number of registered two-axle trailers has increased by about 80 %.

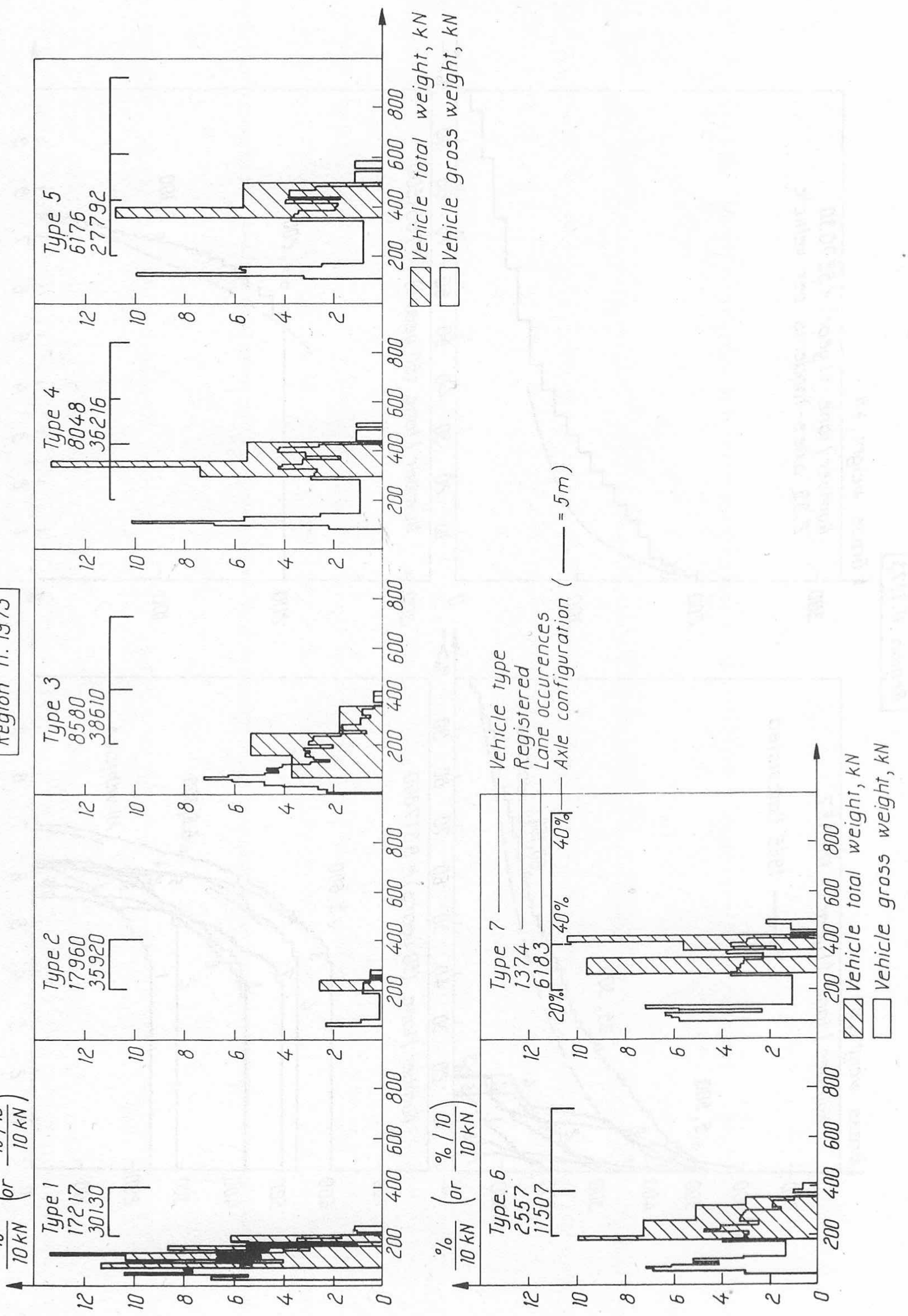


FIG. 4.2.2-2. Total weight registration distributions (hatched) and gross weight lane occurence distributions. Rural long distance region, 1973.

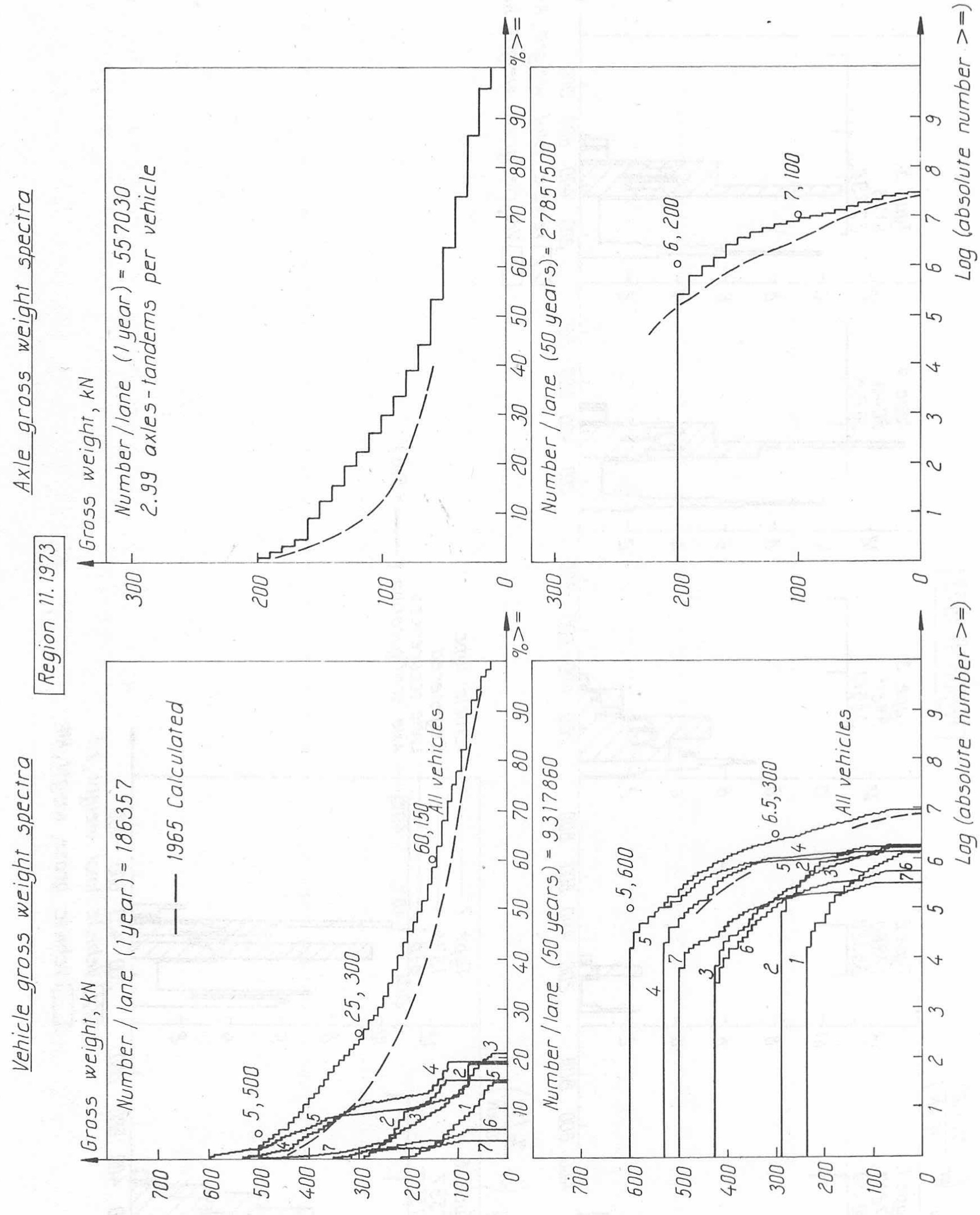


FIG. 4.2.2-3. Load Spectra, 1973. Rural long distance region.

FIG. 4.2.2-4. Total weight registration distributions and gross weight lane occurence distributions. Rural short distance region, 1973.

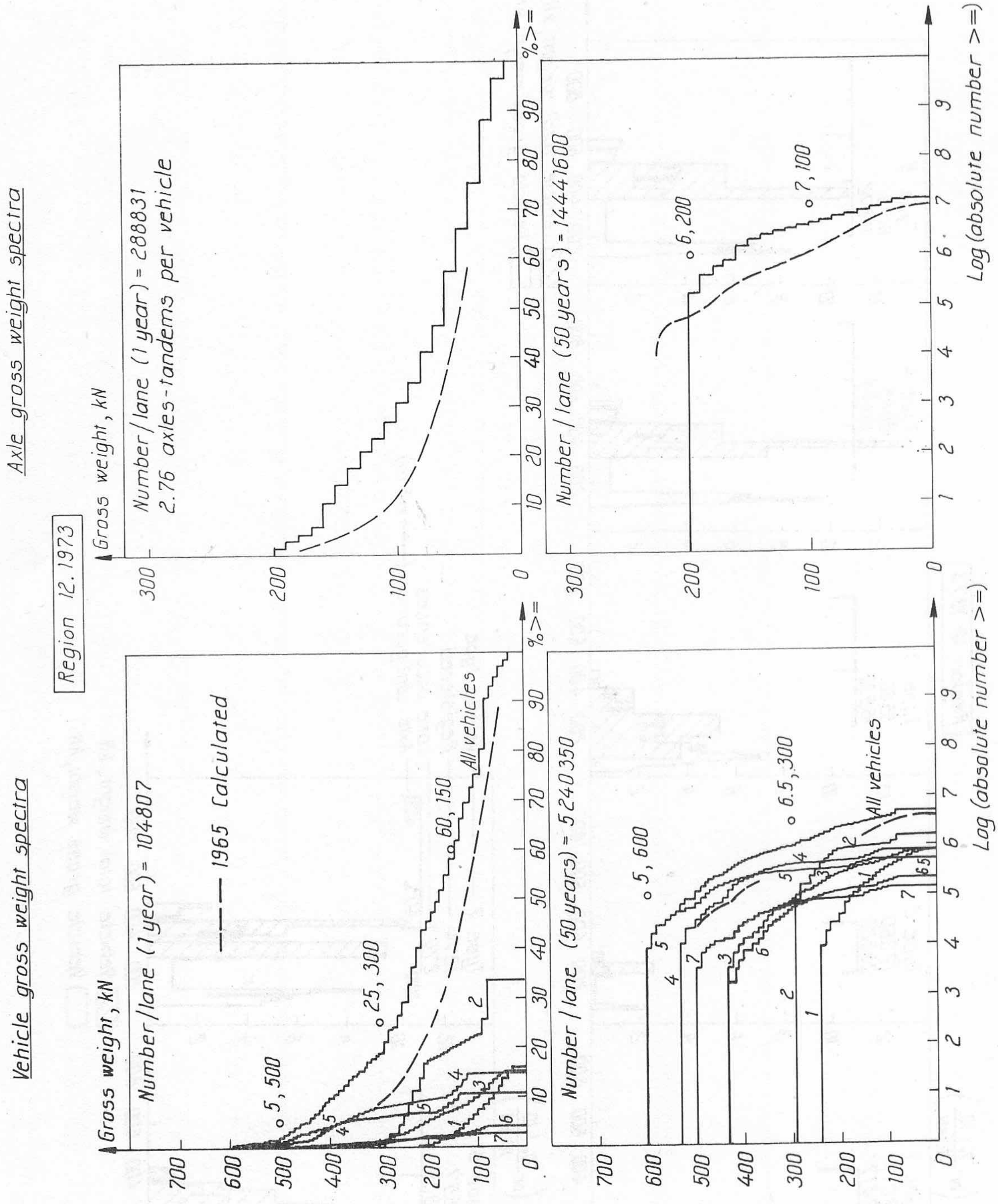


FIG. 4.2.2-5. Load spectra, 1973. Rural short distance region.

4.3 Predicted load spectra.

In this chapter efforts are made to calculate predicted load spectra. The predicted input values are not brought out from comprehensive analyses of the future and do not of course claim to give a correct picture of the future. Hopefully though comparisons to the before calculated spectra, todays spectra, can give an idea about a possible change in the spectra appearances.

The predicted spectra will be used in the analyses of different variables influence on the appearances of those loadeffect spectra calculated with the later described numerical model, NULESP.

4.3.1 Predicted values of the input variables.

In "Vägplan 70" /34/ concerning the planning of roads in Sweden and out of comments from "Preliminära nordiska lastbestämmelser för vägbroar" - "Preliminary Nordic Load Regulations for Highway Bridges", it can be found that in the future higher permitted axle/tandem loads may be expected (130/210 kN) as well as somewhat higher total weights. The maximum permissible total axle distance is now 22 metres but it is quite conceivable that this will be decreased to around 18 metres.

It is probable that a higher utilization of the load carrier will lead to more registered vehicles of type tractor-semitrailer where the tractors are not tied to specific trailers. Furthermore a more wide spread use of standardized loads, such as containers, may lead to fewer, and more exactly defined, vehicle types.

On the above mentioned circumstances the vehicle types according to FIG. 4.3.1-1 were put up. No alternative set of weight distribution on axles was made as this will be done in the loadeffect analyses. At that stage axle distance factor distributions are also introduced.

Through extrapolations of the number of registered vehicles, two-axle lorries excluded, for the years 1965 and 1973 a total of 100000 registered heavy vehicles were found to be representative for the year 1999. This time point lies in the middle of an expected bridge life time of 50 years. A similar extrapolation for vehicles with more than two-axle/tandems gave 60000 registered vehicles which were arbitrarily divided into types 2 and 3, tractor-semitrailer and lorry trailer, in the ratio of 2 to 1. That is the number of registered two-axle trailers has increased by 41 % and the number of semitrailers has increased 10 times since 1973. The corresponding figure for single lorries is 14 %.

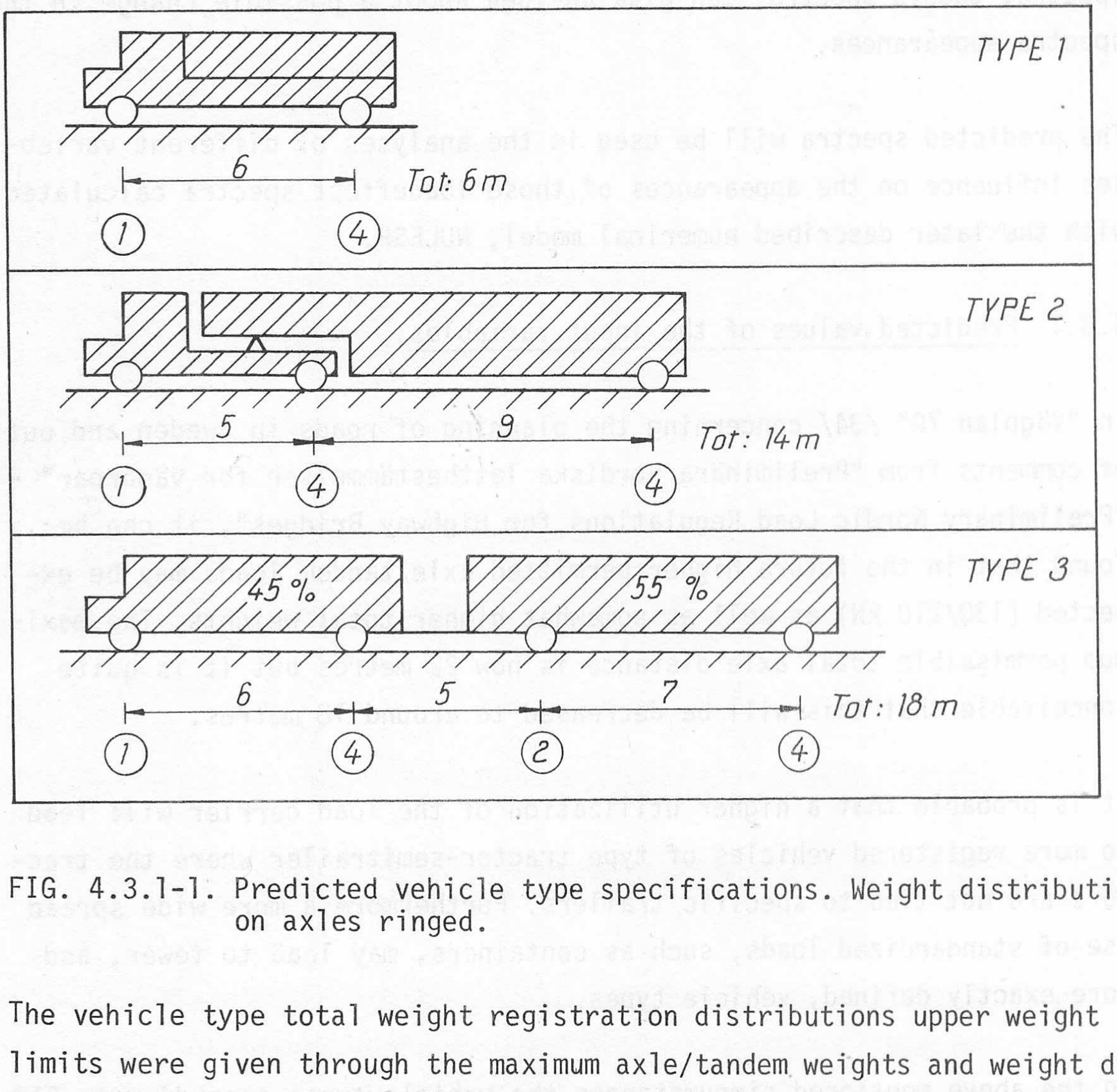


FIG. 4.3.1-1. Predicted vehicle type specifications. Weight distribution on axles ringed.

The vehicle type total weight registration distributions upper weight limits were given through the maximum axle/tandem weights and weight distribution on axles. The lower limits and the forms of the distributions were now to be chosen. The lower limits were given such values that unloaded vehicles should have axle weights greater than 12 kN, which was in accordance with the 1965 and 1973 spectra. The distributions were given rectangular forms as nothing directly perferenced any other shape. The distributions are found in the plot output from the LOSP runs, FIG. 4.3.2-2 (the hatched areas).

FIG. 4.3.1-2 shows the assumed driving distance distributions. As can be seen the vehicles are supposed to drive a longer distance per year, in the future, than they do today. However, the total road lengths of the region have increased to an estimated value of 20000 kilometres.

Type	Lorry (kN)	Total (kN)	Driving distance distribution
1	(195-265)	195 - 265	
2	(295-485)	295 - 485	
3	(175-265)	385 - 575	

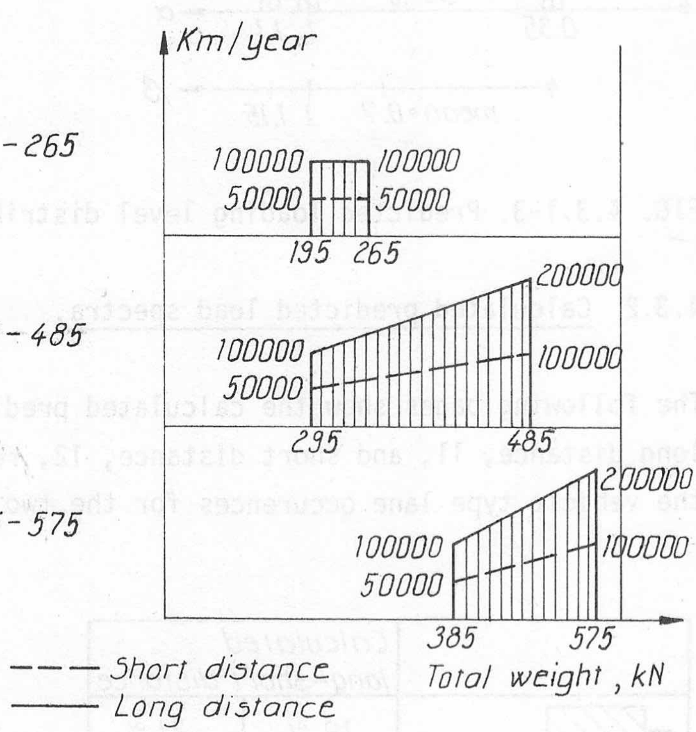


FIG. 4.3.1-2. Driving distances related to vehicle total weight, predicted values. Rural long distance and short distance regions.

The loading level distributions are supposed to be fixed for all regions and vehicle types with appearances according to FIG. 4.3.1-3. It is assumed that the probability of meeting an overloaded vehicle has decreased, compared to today, to about 10 % and so has the corresponding loading level by total weight to about 1.1. This is a consequence of higher utilization of the load bearing capacity, standardized loads and built in weighing machines in the vehicles.

In the calculations, the number of single lorries travelling in the long distance region were reduced, as before, to half of the available amount.

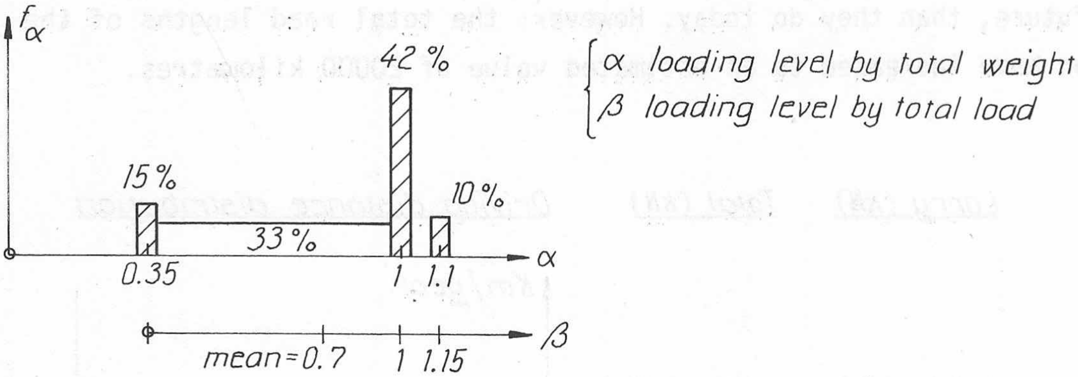


FIG. 4.3.1-3. Predicted loading level distribution.

4.3.2 Calculated predicted load spectra.

The following pages show the calculated predicted load spectra for rural long distance, 11, and short distance, 12, regions. FIG. 4.3.2-1 shows the vehicle type lane occurences for the two regions.

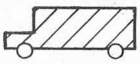
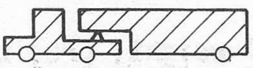
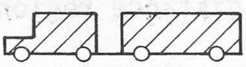
	Calculated long-short distance	
	18 %	31 %
	55 %	46 %
	27 %	23 %

FIG. 4.3.2-1. Predicted vehicle lane occurences.

In the figures are also calculated 1965 and 1973 spectra drawn for comparison.

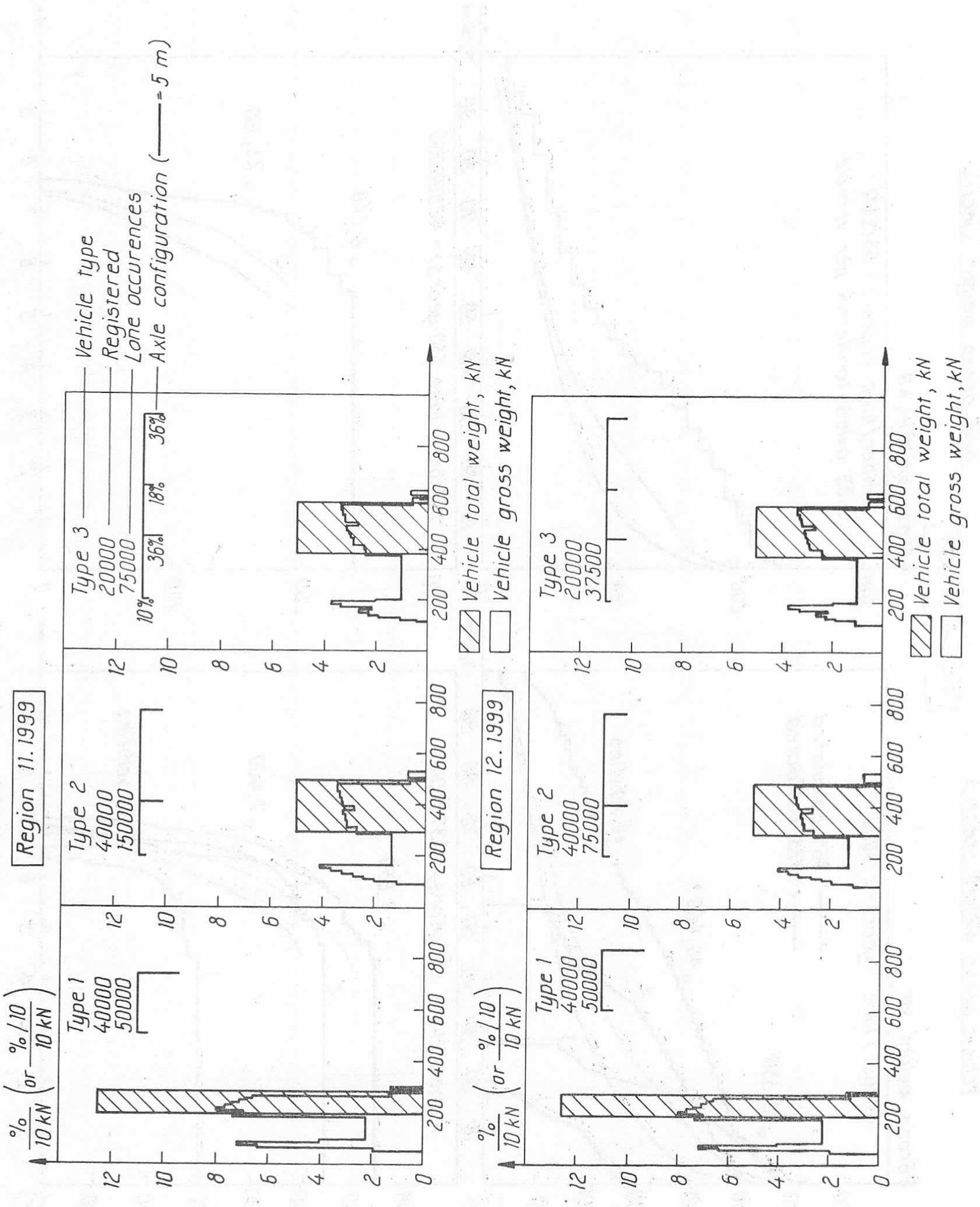


FIG. 4.3.2-2. Total weight registration distributions and gross weight lane occurence distributions. Predicted.

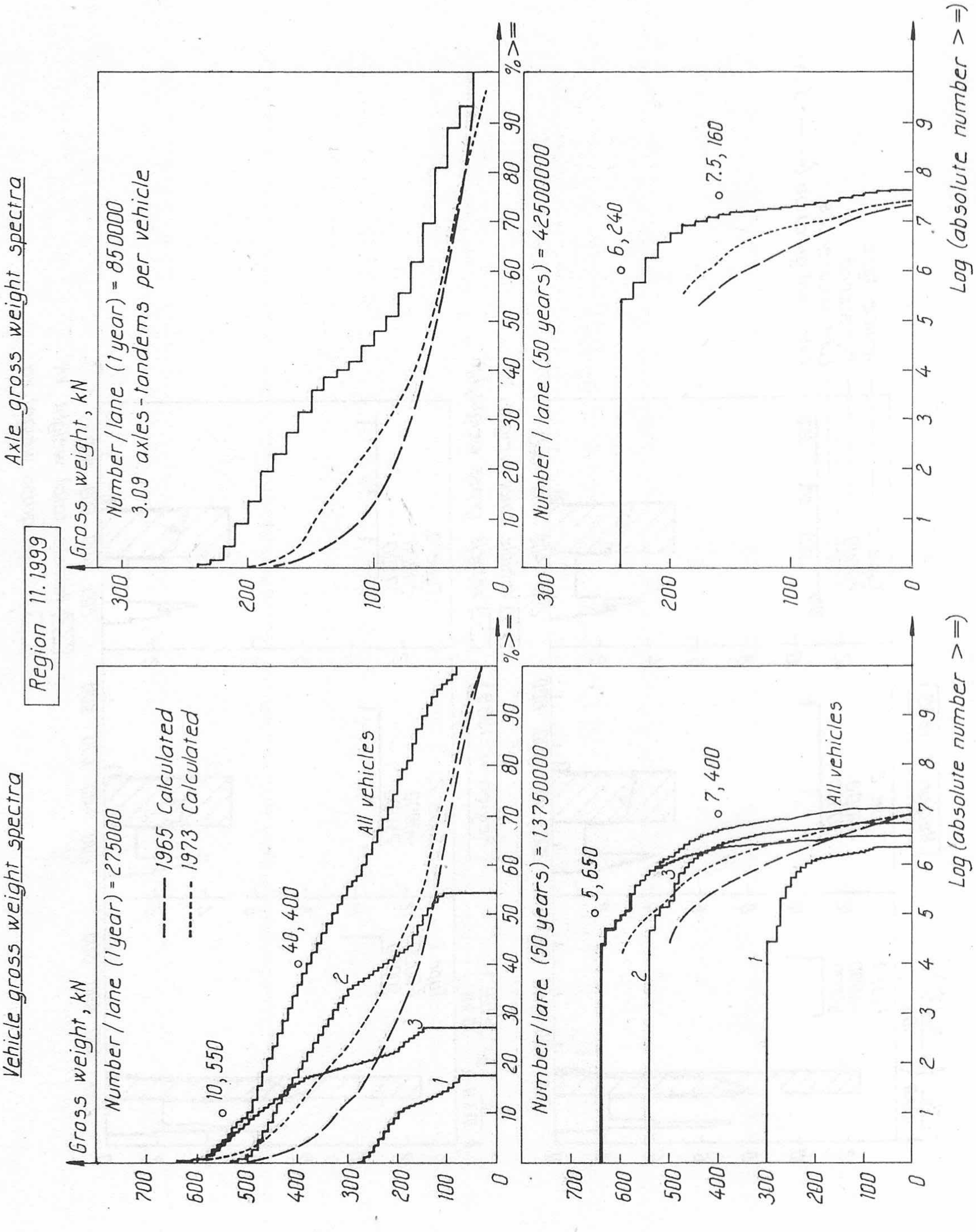


FIG. 4.3.2-3. Predicted load spectra. Rural long distance region.

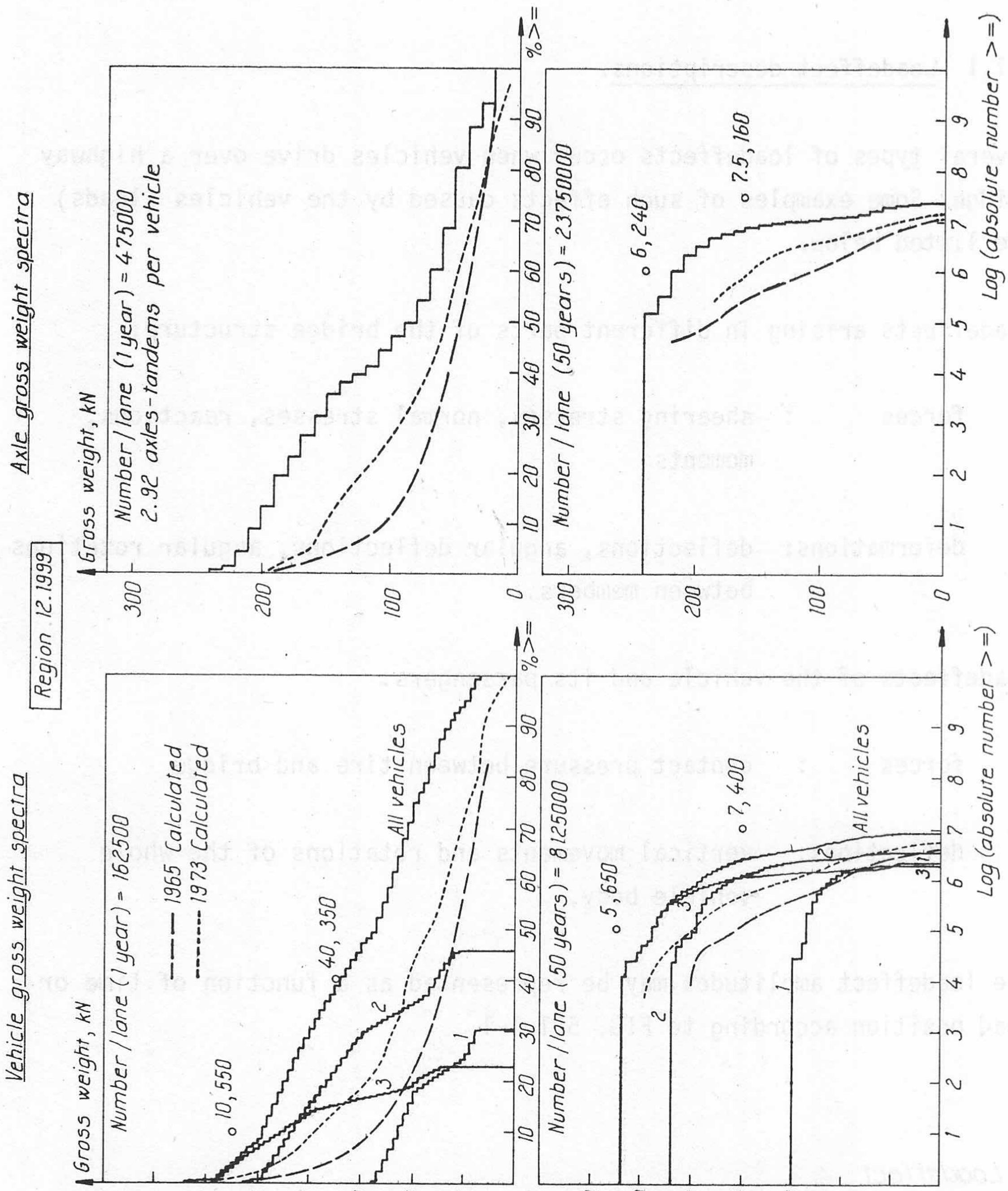


FIG. 4.3.2-4. Predicted load spectra. Rural short distance region.

5 COMMON DISCUSSION OF LOADEFFECTS.

5.1 Loadeffects in connection with vehicles driving over highway bridges.

5.1.1 Loadeffect descriptions.

Several types of loadeffects occur when vehicles drive over a highway bridge. Some examples of such effects caused by the vehicles (loads) are listed below.

Loadeffects arising in different parts of the bridge structure:

forces : shearing stresses, normal stresses, reactions, moments

deformations: deflections, angular deflections, angular rotations between members.

Loadeffects of the vehicle and its passengers:

forces : contact pressure between tire and bridge

deflections: vertical movements and rotations of the whole vehicle body.

The loadeffect amplitudes may be represented as a function of time or load position according to FIG. 5.1.1-1.

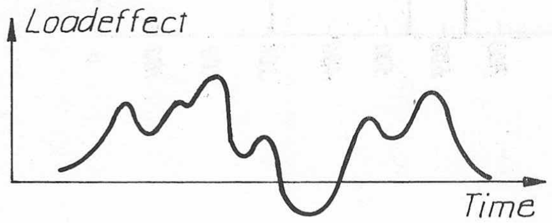


FIG. 5.1.1-1. Part of loadeffect process.

It is possible to convert a vertical deflection process of a bridge pavement to a corresponding acceleration process which may be used to express uncomfortable feelings for pedestrians. It is obvious that this acceleration could be the studied loadeffect instead.

In this report the loadeffects are expressed through superposition of influence lines multiplied with corresponding load values. The influence lines are generated by constant speed passages of single unit loads over the bridge deck. As the load is also allowed to move in a transverse direction, an influence function over an area has to be defined. This is also done but the longitudinal and transverse influences are separated which simplifies the calculations if a vehicle during passage do not make transverse moves.

If the time scale is changed in a part of a loadeffect process, the appearance of the process is usually also modified, depending on the dynamic properties of the vehicle-bridge system. A distinction between "static" and "dynamic" loadeffect processes is made in the report where the "static" process parts are caused by slowly running vehicles and entirely determined by the vehicle axle gross weights and the static properties of the bridge.

The dynamic effects may be of different kinds such as extra oscillations or dynamic amplification to a greater or lesser extent. An example of great amplification is the before mentioned vertical acceleration of a bridge pavement which in fact is non-existent in the static case. The dynamic effects are for a given vehicle bridge system dependent on the vehicle speed and lateral track and the initial conditions of the bridge and vehicle at vehicle bridge entrance.

In this report the static loadeffect process is first analysed and then a modification of the static results are performed by means of a stochastic amplification factor.

5.1.2 Analysis of loadeffect processes.

The loadeffect process itself contains too much information to serve as an apprehensible characterization of the process. Analyses performed on the stochastic process will lead to more condensed and useful properties which may be expressed in terms of stochastic or non-stochastic variables.

The processes in question can in a first stage be simplified to process parts separated by exponentially distributed time distances. This is because the flow of vehicles is supposed to follow a Poisson process.

The condensed properties may be reached in different ways which are more or less practicable depending on the complexity of the input bridge-vehicle-traffic characteristics and the wanted output.

The loadeffect process consists of effects caused by single vehicles and of overlapping effects from two or more vehicles. Small influence areas give rise to effects that are mainly dependent on vehicle axle weights and the lateral track of the vehicle. As the influence area is increased, effects will occur of several axles of the same vehicle and if the area is big enough several vehicles may influence at the same time causing overlapping effects. The vehicle characteristics as well as the traffic properties then become more important making the desired breakdown of the process more difficult to perform.

The wanted condensed loadeffect process properties are formulated from a desired field of application. In this report it is supposed that the output shall be primarily usuable in fatigue studies in practice and theory. The most important characteristics of the loadeffect process are judged to be the changes of the amplitude, in some defined way. The time dependency was dropped but can without great difficulty be regarded in the used numerical analyses model.

The changes in amplitude, from now on called loadeffect ranges, may be defined in many ways. The often very simple and unsatisfactory definitions originate from the limited possiblitities of the used stress range counters in the field tests. In FIG. 5.1.2-1 four different stress range definitions are sketched. For further references see the LITERATURE

REVIEW.

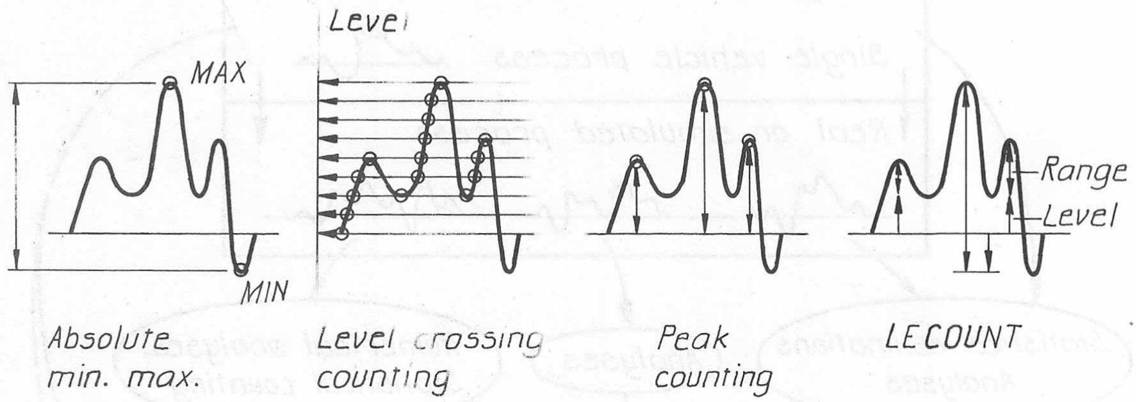


FIG. 5.1.2-1. Different stress range definitions.

The next Chapter 5.2, Counting routine LECOUNT, describes the range definition of the loadeffect process breakdown method used in this report, which continuously picks out closed range cycles and corresponding levels from the process.

The wanted output will thus be loadeffect range distributions, if possible multi-dimensional incorporating range occurence level and in second hand a time variable, as range durations.

FIG. 5.1.2-2 principally shows some ways to tackle the problem of breaking down the loadeffect process.

If the nature of the process is known or is possible to estimate, analyses may be done by means of statistical methods, depending on the complexity of the wanted condensed properties and the bridge-vehicle-traffic properties. The short description may consist of density function descriptions and characteristic qualities.

Tha analytical statistical approach is only made use of in this report in the study of short triangular shaped influence lines and loads represented by uniformly distributed axle gross weights. The statistical approach rapidly becomes laborious with complex input and output.

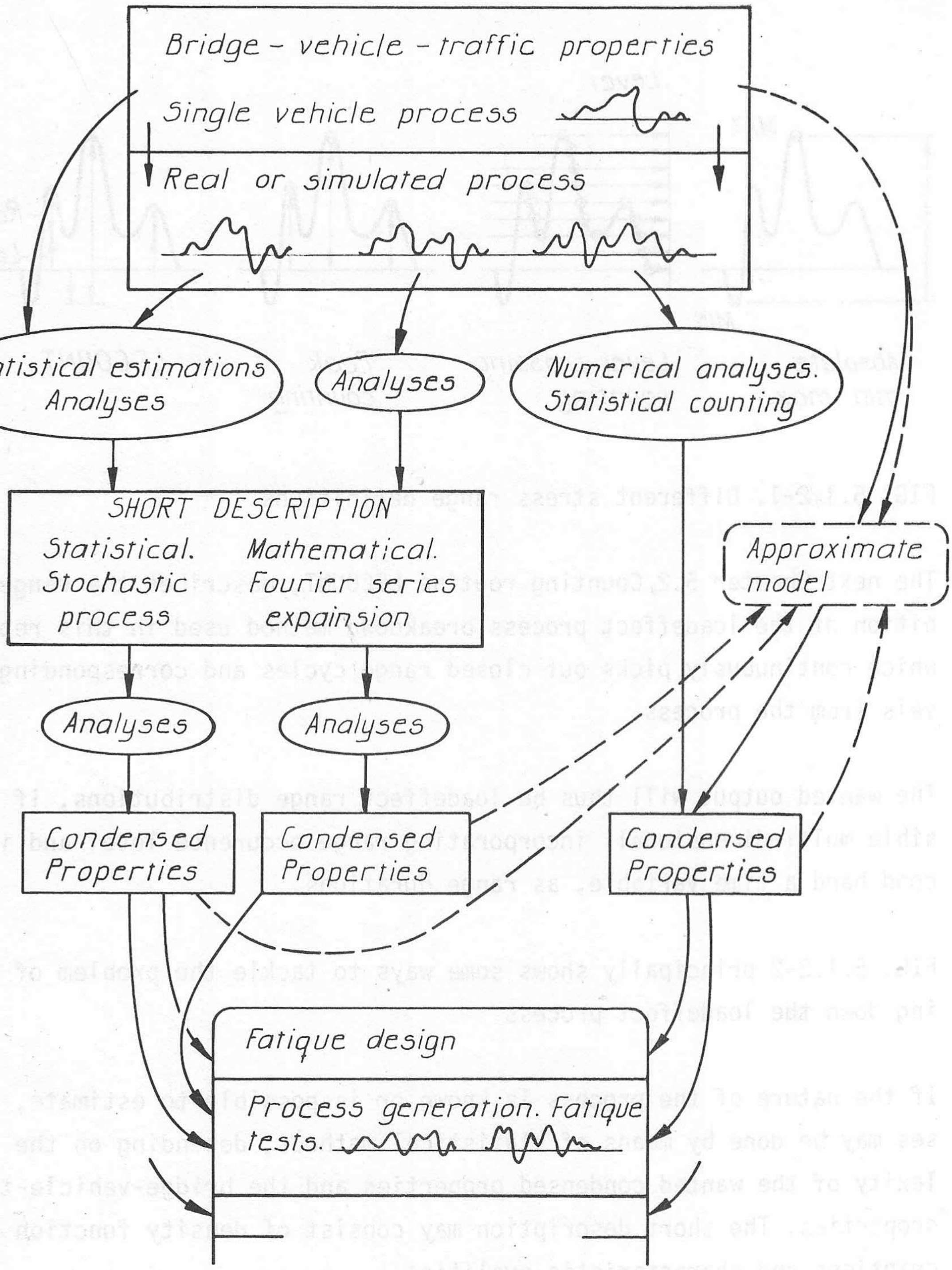


FIG. 5.1.2-2. Methods to analyse loadeffect processes.

The process may, of course, be also described purely mathematically in few terms, for example the amplitude frequency pairs of a Fourier series expansion. This short mathematical description can, as well as loadeffect range distributions, be used to generate a load process for a testing machine, or it can be used to evaluate dangerous vibration modes of the regarded system. It shall though be pointed out here that the different series of the Fourier expansion can not be directly used to put up loadeffect range distributions in the sense mentioned above, except for special cases.

The statistical counting methods provide a different solution to the problem of analysis of loadeffect processes. These methods perform a range counting on the either measured or simulated process following rules which may be more sophisticated if a computer is included in the counting device, human counting disregarded. In this work use is made of the counting routine LECOUNT, which has the ability to make rather sophisticated continuous counting, that is without having access to the whole loadeffect process part. A small portion of minima and maxima must though be remembered and this will be counted off when the process part is over.

Finally, approximate transfer models or rules may be put up, by means of evaluating the above described analyses, by which the bridge-vehicle-traffic input can be converted to output in the form of loadeffect range-level distributions.

5.2 Counting routine LECOUNT.

The counting routine used in this report is called LECOUNT and is a part of the Basic program INFLU and the Algol program NULESP. It is considered to be an essential part of the loadeffect calculation model and is therefore described separately below. It can be directly picked out and used in the analyses of a real loadeffect process originating from for example the strains of a strain gauge glued to a point in a bridge structure.

5.2.1 Description of LECOUNT.

The method was derived by the author because no suitable method was found in the literature. Later on, however, a very similar method was discovered which is used in the analyses of loadeffects arising in aircraft structures. This method is sometimes called the "rain flow counting method". See also Chapter 2, LITERATURE REVIEW.

The objective was to produce a counting routine that was able to condense the loadeffect process during a minimum of information loss. The important variables were considered to be the magnitude of the closed loadeffect ranges and the level they arise on, see FIG. 5.2.1-1. As can be seen it was assumed that no account should be given to where the closed loadeffect range loop started.

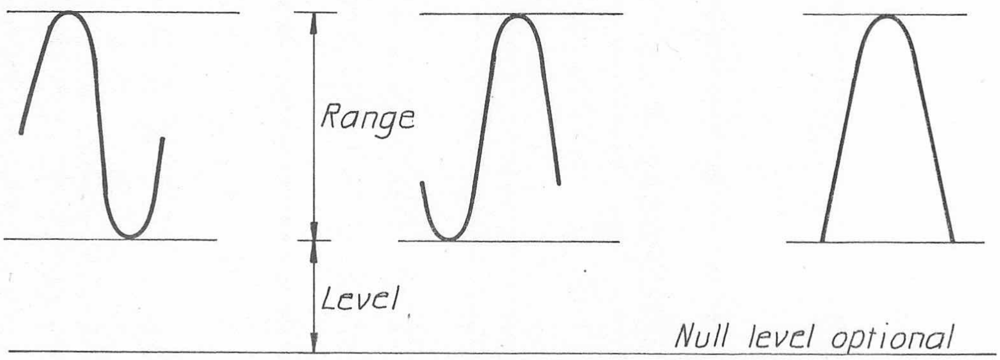


FIG. 5.2.1-1. Three examples of closed loadeffect ranges with equal magnitude and level.

The time scale was not considered that important but it is of course possible to introduce one more variable namely the frequency, the inverse time of duration, for the counted loadeffect ranges.

FIG. 5.2.1-2 shows two cases when it is possible to eliminate one closed loadeffect range loop from each example. It can be seen from the figure that the range values are given with signs. This fact is commented below.

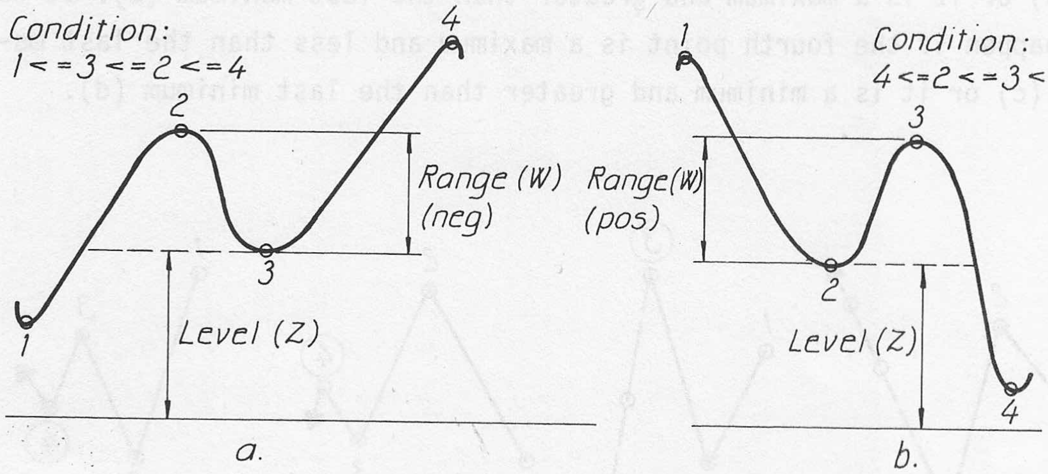


FIG. 5.2.1-2. A loadeffect range is eliminated, with the help of four point count, FPCOUNT, subroutine from an increasing (a) and decreasing (b) part of the loadeffect process.

The only values considered to be of interest to the loadeffect process are the maxima and minima, that is between which the derivatives of the process have the same sign. In the example, FIG. 5.2.1-2, there are four such points 1-4, which are defining alternatingly maxima and minima. The path of the process through points 2-3 can be seen as a deviation from the dashed line of a respectively increasing and decreasing part of a loadeffect process. Such an elimination of a loadeffect range is called a four point count, subroutine FPCOUNT, and leads to storage of the eliminated range-level, Z and W, through subroutine STOREZW and the removal of points 2 and 3 from the process.

The routine continuously reads values from the loadeffect process until a maximum or minimum is reached. They are stored as they come up with the help of subroutine STOQ and the first FPCOUNT attempt is made when there are four values stored. If it is then impossible to eliminate a range the next maximum (or minimum) is read and stored and the FPCOUNT is repeated. If a range is counted the second and third points are removed from the stored suite of maxima and minima and a new FPCOUNT is attempted. The four point count subroutine FPCOUNT is left when only 3 stored values remain or when the count is unsuccesful.

The FPCOUNT is unsuccesful when the conditions according to FIG. 5.2.1-2 are impossible to fulfill. This is the case, as can be seen in FIG. 5.2.1-3, when the third point is a minimum and less than the last minimum (a) or it is a maximum and greater than the last maximum (b). It can also happen if the fourth point is a maximum and less than the last maximum (c) or it is a minimum and greater than the last minimum (d).

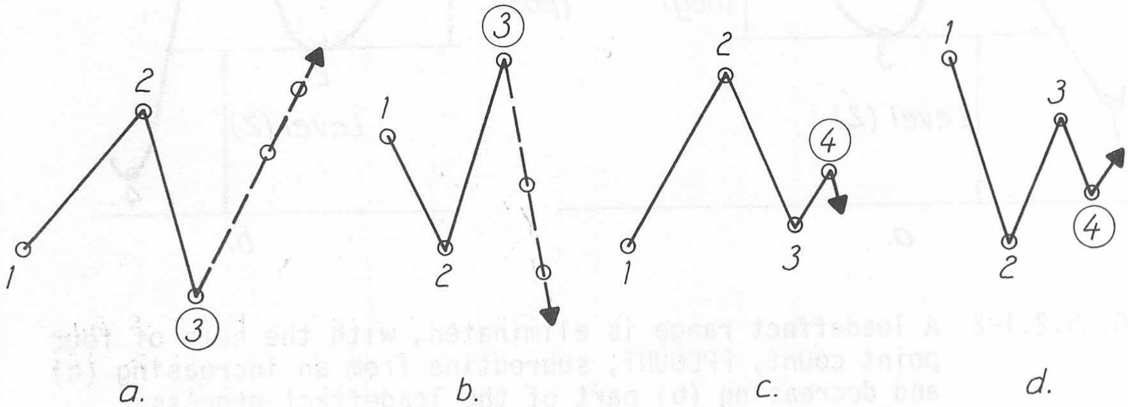


FIG. 5.2.1-3. Four cases when the four point count, FPCOUNT, is unsuccessful.

The readings of values from the loadeffect process is continued until the LECOUNT routine reaches an end condition, which occurs if a total of Q9 readings has been done or if I8 unchanged values has been read.

The end condition - limited number of readings - is used in the loadeffect calculation model NULESP, which is described later, when it is definitely known at the entrance of the counting routine, how many readings that part of the loadeffect process includes. The other end condition also indicates that the current loadeffect activities have ceased and therefore a final count on the remaining stored values can be made. When determining the end condition one must have in mind what the lowest permissible frequency, longest duration, of the counted loadeffect ranges are.

As the end condition is reached and LECOUNT has stopped reading, the concluding count is performed, by the subroutine ENDCOUNT, on the remaining stored maxima and minima that could not be eliminated by the four point count subroutine. The principle shapes of the remaining process are shown in FIG. 5.2.1-4.

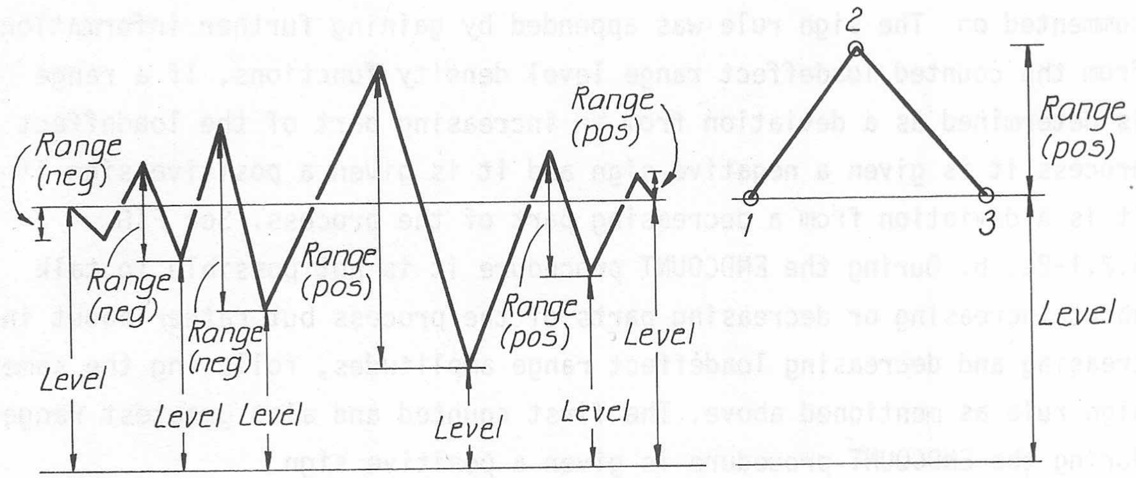


FIG. 5.2.1-4. Results of ENDCOUNTs on the remaining parts of two loadeffect processes at end condition.

The ENDCOUNT analysis is performed in the following manner. The greatest maximum and the smallest minimum are found, FPCOUNT and STOQ provide pointers for that. Those two values, which will be located adjacent to each other, form the greatest loadeffect range of the remaining process. Loadeffect ranges are then formed in the same way by pairing off maxima and minima on both sides of the starting range. The procedure can be studied in FIG. 5.2.1-4. As can be seen, it might happen that the last counted ranges at both ends only include one maximum or one minimum except for the starting and closing points.

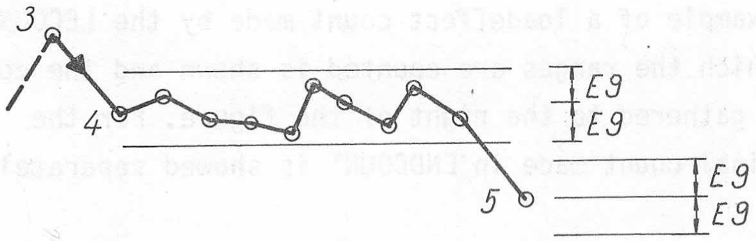


FIG. 5.2.1-5. The reading is dropped if it differs less than ±E9 from the last valid reading.

If it is undesirable to count ranges with amplitudes below a certain magnitude this is accomplished by setting the variable E9 to half the amplitude of the greatest tolerable "noise", see FIG. 5.2.1-5.

Finally the negative and positive sign of the loadeffect range shall be commented on. The sign rule was appended by gaining further information from the counted loadeffect range level density functions. If a range is determined as a deviation from an increasing part of the loadeffect process it is given a negative sign and it is given a positive sign if it is a deviation from a decreasing part of the process. See FIG. 5.2.1-2a, b. During the ENDCOUNT procedure it is not possible to talk about increasing or decreasing parts of the process but rather about increasing and decreasing loadeffect range amplitudes, following the same sign rule as mentioned above. The first counted and also greatest range during the ENDCOUNT procedure is given a positive sign.

In this report the sign facility is only used to count the total number of positive and negative ranges. (In procedure RLSTORE, variable RNB(.), in the NULESP program.) No information about the time scales is stored, but as pointed out before it is easy to expand the LECOUNT routine to cover analyses where the time is also incorporated. Of course it is also possible during the counting to sort out certain loadeffect range-levels which pocess special characteristics.

5.2.2 Summary chart and example.

Below is a summary chart over the LECOUNT routine shown. A more detailed description and program listing for both the Basic and Algol version is found in Appendix C.

FIG. 5.2.2-1 shows an example of a loadeffect count made by the LECOUNT routine. The order in which the ranges are counted is shown and the corresponding range-levels gathered to the right of the figure. For the sake of clearness the final count made in ENDCOUNT is showed separately.

In the figure are also shown the number of maxima and minima that have to be stored during the procedure.

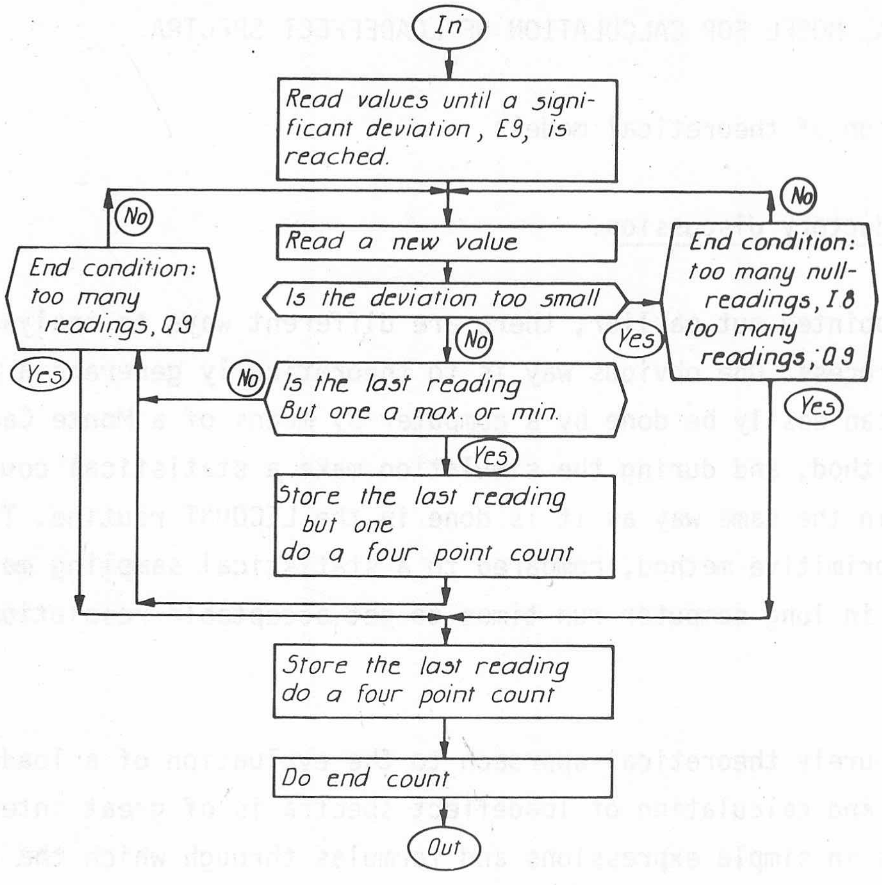


FIG. 5.2.2-1. Summary chart over LECOUNT.

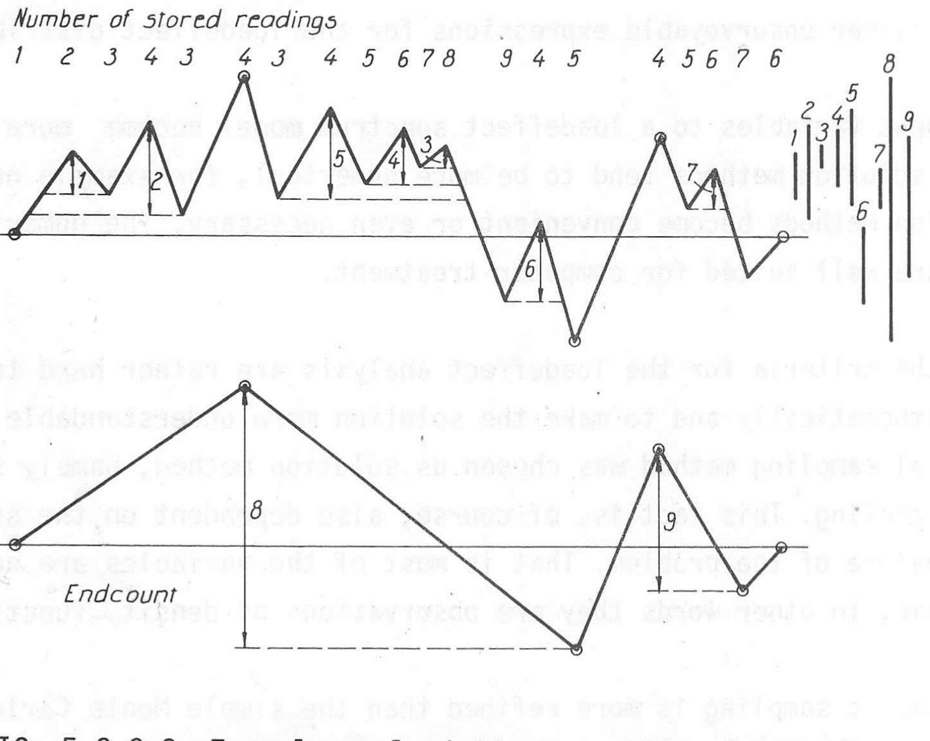


FIG. 5.2.2-2. Example on loadeffect range-level counting with the LECOUNT routine.

6 THEORETICAL MODEL FOR CALCULATION OF LOADEFFECT SPECTRA.

6.1 Derivation of theoretical models.

6.1.1 Introductory discussion.

As has been pointed out earlier, there are different ways to analyse a loadeffect process. One obvious way is to theoretically generate a process, which can easily be done by a computer by means of a Monte Carlo simulation method, and during the simulation make a statistical counting, for example in the same way as it is done in the LECOUNT routine. This is a rather primitive method, compared to a statistical sampling method, as it brings in long computer run times to get acceptable resolution in the result.

Of course a purely theoretical approach to the evaluation of a loadeffect process and calculation of loadeffect spectra is of great interest if it results in simple expressions and formulas through which the different variables influence on the result can be studied and also the loadeffect spectra directly calculable. Such a solution is shown for triangular influence lines and evenly distributed loads in Capter 6.3. Though rather large simplifications regarding the input (loads, axle configuration, influence line appearance) are made, the calculations leads to rather unsurveyable expressions for the loadeffect distribution.

As the input variables to a loadeffect spectrum model become more complex, the solution methods tend to be more numerical, for example numeric integration methods become convenient or even necessary. The numerical methods are well suited for computer treatment.

Because the criteria for the loadeffect analysis are rather hard to describe mathematically and to make the solution more understandable a statistical sampling method was chosen as solution method, namely systematic sampling. This fact is, of course, also dependent on the stochastic nature of the problem. That is most of the variables are non-deterministic, in other words they are observations of density functions.

The systematic sampling is more refined than the simple Monte Carlo simulation, because it is possible to increase the calculation efforts for certain interesting variable values. In Monte Carlo simulation random values are drawn from the different density functions, and if one is unlucky, results that have a small probability of comming up will not be calculated and poor results will be obtained. Unfortunately, these rare combinations are important in this case because they are often associated with high loadeffects.

The systematic sampling method used, which is further described in Chapter 6.4.1, is systematic in the respect that all possible combinations of variable values are made, the arising parts of the loadeffect process are analysed and the result for each combination is added to the final solution with a weight that is proportional to its probability of coming up. The stochastic variables are supposed to be independent of each other. The density functions have to be made discrete, else the variables can take an infinite number of values. The discrete density functions are for some calculations further reduced. The new variable values are though mean values of those values they could take within their former (wider) variation widths (class widths).

The results of the calculations will be unbiased and will also contain information about rare loadeffect values at the cost of a somewhat lesser resolution for lower loadeffects. Furthermore, the method is easy to understand and follow and is not too complicated to translate into a computer program.

6.1.2 Chosen input variables.

The input variables to the model are of more or less stochastic nature. If a variable is judged to remain nearly constant or if a small change of its value will not affect the solution significantly, it is treated as deterministic. A good reason to hold the number of non-deterministic variables low is that the amount of calculations increases rapidly with the number of these variables (too many possibilities to combine variable values). All variables both deterministic and non-deterministic are supposed to have the same properties in the calculations during the regarded time period, for example 50 years - a bridge life time.

The applying forces are the vehicle gross weights, acting through the vehicle axles. The load (gross weight) density function, expressed as occurences per lane and time period, is two-dimensional with the variables vehicle type and load (gross weight). It can also be represented as a one-dimensional total gross weight density function (the vehicle represented as one load) or an axle gross weight density function (all vehicle axles gathered in one density function). The vehicle type appearance is fixed as well as the distribution of weight on axles, (an axle distance density function though is used in some calculations). Each "geographical" region is defined by a specific load density function and an equivalent time, a factor that expresses the relation between the time the vehicles are in motion/real time. It is further supposed that the vehicles run freely from each other withing the region. The load input is achieved as an output from the load spectrum model (computer program LOSP).

The regarded bridge structure carries the load spectrum. The bridge properties are supposed to be deterministic but the bridge-vehicle system causes dynamic effects that are of stochastic nature. These effects though are not considered until a static loadeffect density function has been calculated. The bridge properties are expressed through influence volumes for each lane. The influence volume is defined by a length shape (influence line) and a lateral shape (lateral influence function), which are determined by, in which point of the structure, structural point, the loadeffect process are studied.

The last group of input parameters is the traffic data, which indirectly describes how the load will act on the bridge. What track will the vehicles follow? Will they cause overlapping loadeffects? The vehicle speed will determine the time scale of the loadeffect process. This scale is not considered in the calculated loadeffect spectra. The vehicle speed is important though because it affects the probability of two vehicles meeting on the bridge. The faster they go the shorter time they will spend on the bridge. As the vehicle drives over the bridge the vehicle speed is supposed to be constant for all vehicles in both lanes. It is possible to show theoretically that the assumption about undisturbed traffic flow is satisfactory also for partial flows of lorries. However, when the time distances are too short the rules are not guilty and queues are formed. When the vehicles drive over the bridge to close to each other loadeffect overlapping can again occur. In the model for calculation of loadeffect spectra the input considering queues consists of a critical queue distance, in seconds, that determines if two vehicles will queue and if a queue is formed, the distance between the vehicles is picked from a queue distance density function. Finally it is assumed that the vehicles, independent of each other, follow different tracks when they drive over the bridge, according to a lateral track density function.

In all calculations made in this report the bridge can carry either a single lane, two meeting lanes or two parallel lanes. Also if there are two meeting lanes the number of vehicles per time unit in each lane are equal.

6.1.3 Representation of results.

The final result of the loadeffect analysis is a two-dimensional discrete range level density function, where the function gives the number of, relative or absolute, loadeffect ranges that have occured on different loadeffect levels.

In the derived counting procedure, LECOUNT, it is also possible to split the density function into two functions where one is valid for ranges that have occured during increasing loadeffect process and the other during decreasing process. This quality is not made use of in the loadeffect spectra calculation model presented in this report, except for determining the share of negative ranges.

In order to make the total picture of the density function more comprehensible it is advantageous to integrate it and represent it as a distribution function or a spectrum. These functions are still two-dimensional but monotonously growing in every point.

FIG. 6.1.3-1 shows the differences between two possible two-dimensional representations of the range-level density function. It is obvious that the spectrum representation is more convenient to handle, for example when a comparison to a prescribed spectrum shall be done but it is harder to see the underlying density function in detail.

The spectrum can be described as one minus the distribution function with the axle directions changed. The X-axis denotes the "number of ranges greater than or equal" the "range" values of the Y-axis. If the spectrum contains many curves each curve is valid for loadeffect ranges that has occured on or over a specific loadeffect level.

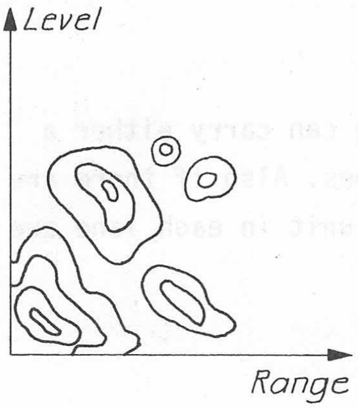


FIG. 6.1.3-1a. Isolevel representation of a range-level density function.

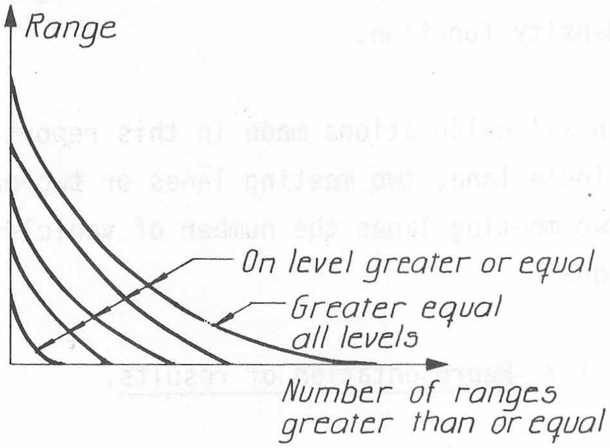


FIG. 6.1.3-1b. Spectrum representation of a range-level density function.

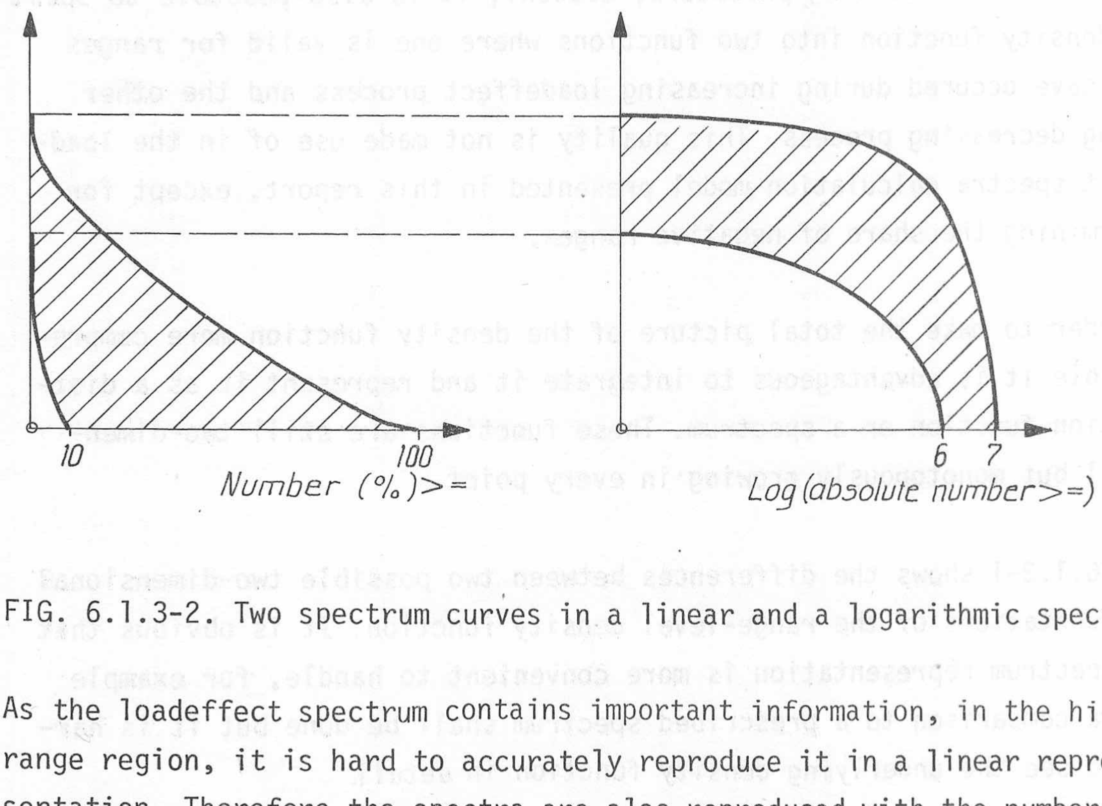


FIG. 6.1.3-2. Two spectrum curves in a linear and a logarithmic spectrum.

As the loadeffect spectrum contains important information, in the high range region, it is hard to accurately reproduce it in a linear representation. Therefore the spectra are also reproduced with the number of ranges in a logarithmic scale. In a logarithmic representation the shapes (curve placements) are depending on the regarded time period. Thus these spectra are only valid for a specific time period, the bridge life. The linear spectra are reproduced in a linear relative scale, 0-1. FIG. 6.1.3-2 shows how the two representations complement each other.

6.1.4 Computer program INFLU.

The following chapter serves as an introduction to the loadeffect spectrum model described later, NULESP. The calculations and print-outs are performed in a computer program, INFLU, written in Basic language and run at the minicomputer at the Departement. The program is further descibed in Appendix D.

In the input section, two vehicle types are described regarding number of axles, axle distances and weight distribution on axles.

There are three main types of influence lines and their shapes are determined from input values. Their principle appearances are shown below, FIG. 6.1.4-1. The same influence lines are found in NULESP.

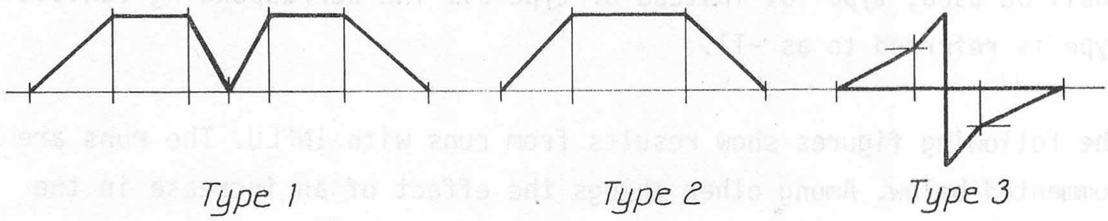


FIG. 6.1.4-1. Principle shapes of influence lines.

The vehicle type influence lines are then calculated and plotted. The calculations are done in the following way. Each vehicle axle determines an influence line, where the influence values are multiplied with the relative axle weight, the total vehicle weight is unity, and the X-coordinates are related to the first axle through a displacement of the influence line. The axle influence lines are added successively in the procedure INFLADD. The same procedure written in Algol is found in NULESP.

The vehicle type influence lines are analysed in procedure LECOUNT, also found in NULESP, and the result is plotted, showing closed loop of loadeffect variations, their ranges and levels. These ranges are stored in a two-dimensional density function and later converted to linear loadeffect spectra and plotted. These spectra are found in the upper right of the plotting area. No distinctions due to levels are made.

To show what happens when the vehicle type influence lines overlap, overlap calculations are performed in the following way. The two vehicle types are given weights through multiplications with loadeffect factors. The vehicle type influence lines are overlapped, added a certain number of times (input) equal to the number of evenly distributed meeting sections (see Chapter LIST OF TERMS). As there are two vehicles involved in all the overlap calculations, the obtained number of ranges must be reduced according to number of meeting sections, before a comparison to the corresponding non-overlap spectra can be made. The overlap spectra are two-dimensional in the respect that each curve is valid for loadeffect ranges with levels greater or equal to a certain value. This value is plotted in the figures.

If the influence line is non-symmetric (type 3) it is important if it is created by a vehicle running in the same or the opposite direction to the other vehicle. The program asks if a turned influence line type shall be used, type -J1 instead of type J1. The corresponding vehicle type is referred to as -T1.

The following figures show results from runs with INFLU. The runs are commented below. Among other things the effect of an increase in the number of meeting sections on the resolution of the result is shown.

FIG. 6.1.4-2. Influence line type 2 with a total length of 5 metres. The largest axle distance is 5 metres that is no overlapping occurs due to axles belonging to the same vehicle. The results of LECOUNT are seen to the right of the vehicle type influence lines. The principle changes in spectra shapes when going from the upper right to the upper left, non-overlap to overlap spectra, are that the total number of ranges decreases and the range amplitudes increase.

FIG. 6.1.4-3a-b. Influence line type 1, length 24 metres. FIG. a is calculated with 5 and FIG. b with 25 meeting sections. As can be seen there is a difference in the resolution of overlap spectra but it is not unexpectedly great especially for higher range values.

FIG. 6.1.4-4a-b. Influence line type 3, length 10 metres. FIG. b shows the result with vehicle type 2 meeting influence line used in the calculations.

As expected the range values tend to decrease.

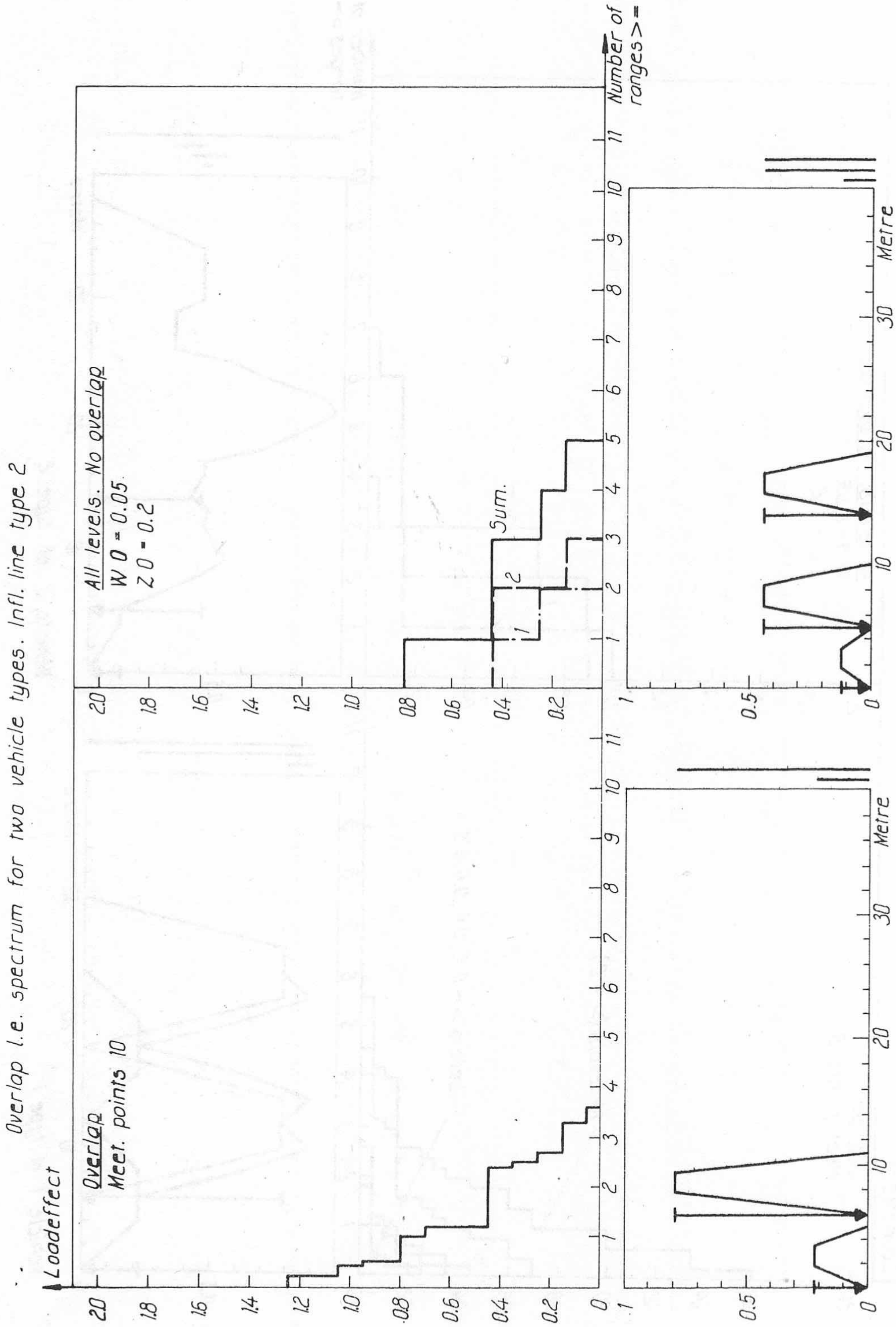


FIG. 6.1.4-2

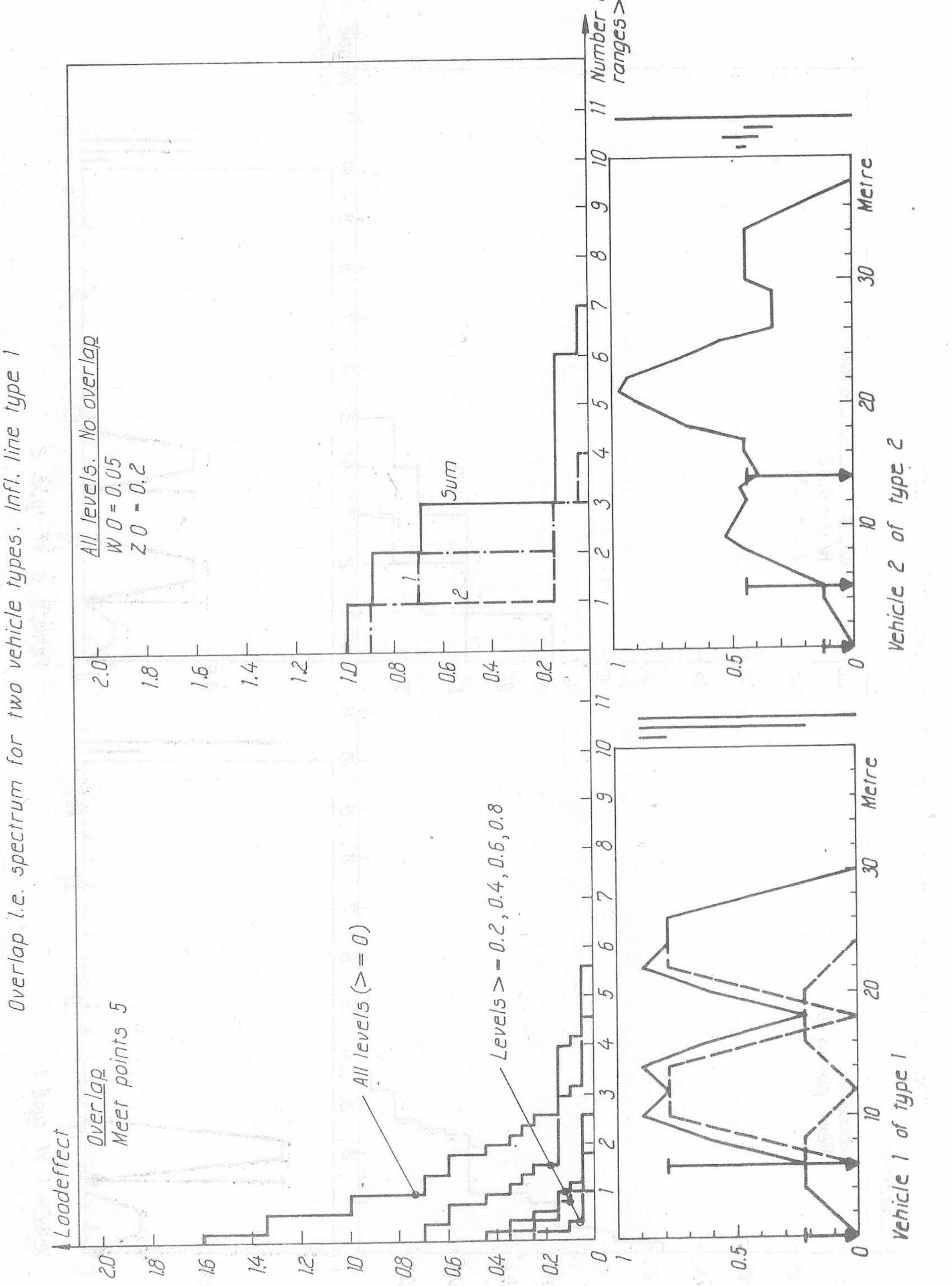

Overlap i.e. spectrum for two vehicle types. Infl. line type 1
Loadeffect
Overlap
Meet points 5
All levels (>= 0)
Levels >= 0.2, 0.4, 0.6, 0.8
All levels. No overlap
W 0 = 0.05
Z 0 = 0.2
Sum
Number of ranges >=
Metre
Vehicle 1 of type 1
Vehicle 2 of type 2

FIG. 6.1.4-3a

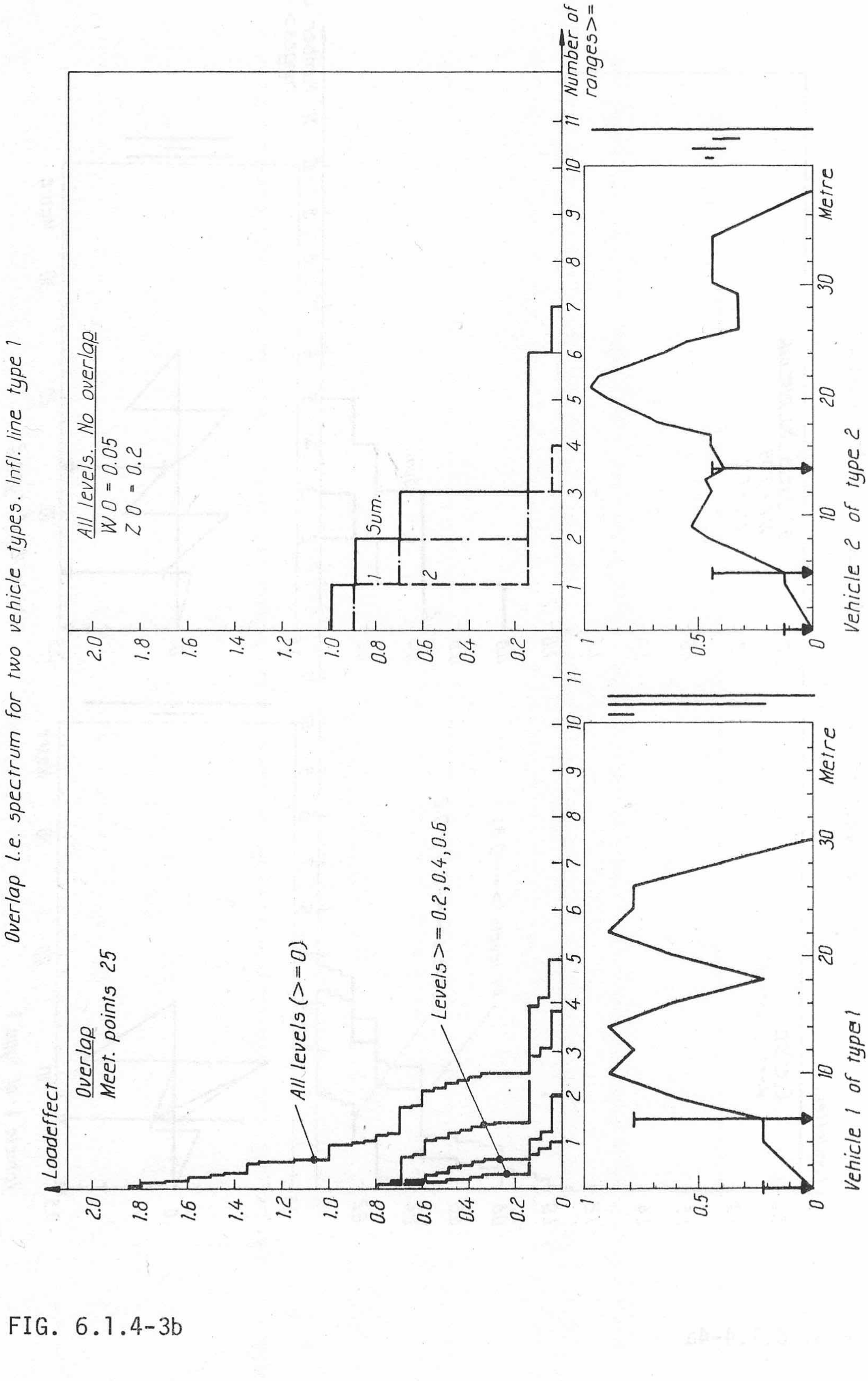

Overlap l.e. spectrum for two vehicle types. Infl. line type 1
Loadeffect
Overlap
Meet. points 25
All levels (>=0)
Levels >= 0.2, 0.4, 0.6
All levels. No overlap
W 0 = 0.05
Z 0 = 0.2
Sum.
Number of ranges >=
Metre
Vehicle 1 of type1
Vehicle 2 of type 2

FIG. 6.1.4-3b

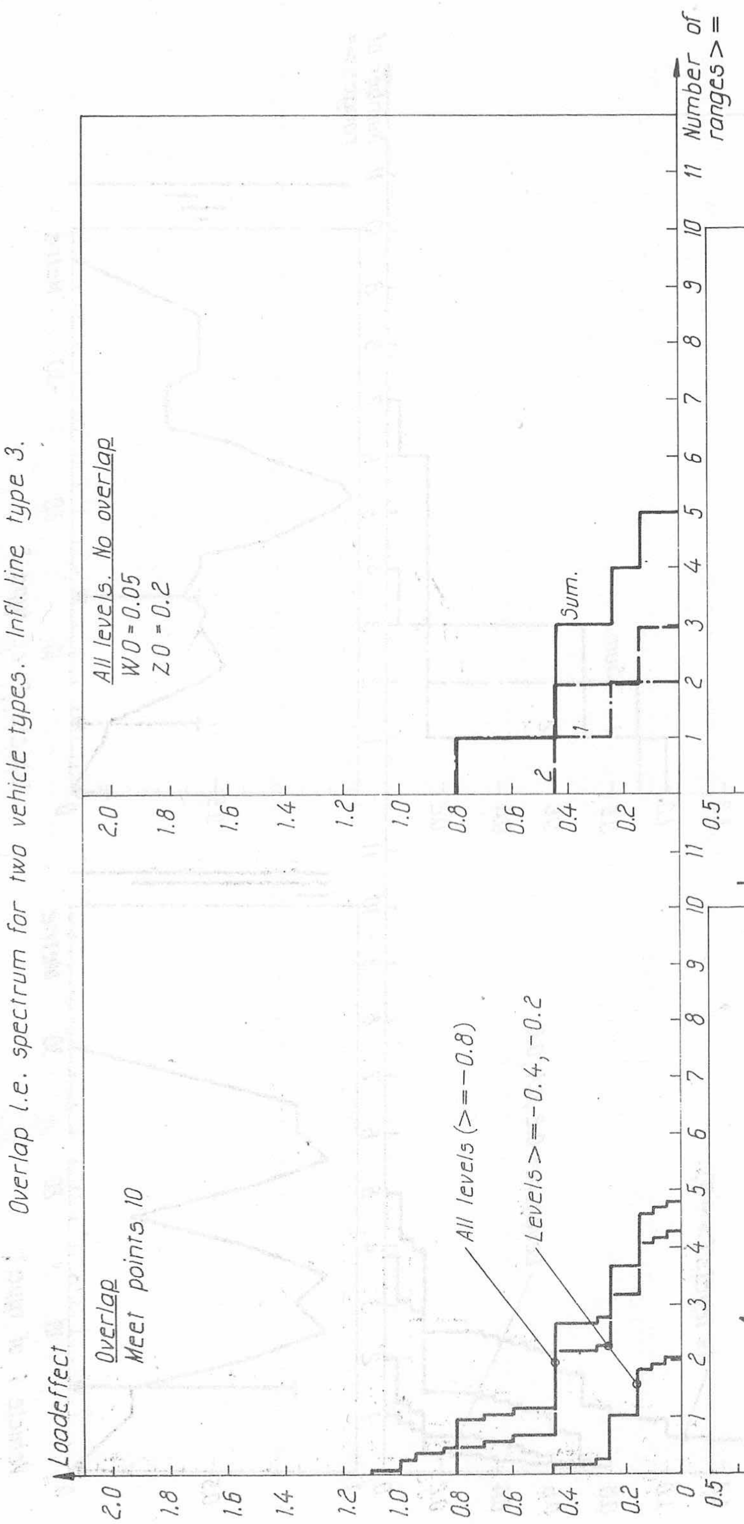

Overlap i.e. spectrum for two vehicle types. Infl. line type 3.
Loadeffect
Overlap
Meet points 10
All levels (>=-0.8)
Levels>=-0.4,-0.2
All levels. No overlap
W0=0.05
Z0=0.2
Sum.
Number of ranges >=
Metre
Vehicle 1 of type 1
Vehicle 2 of type 2

FIG. 6.1.4-4a

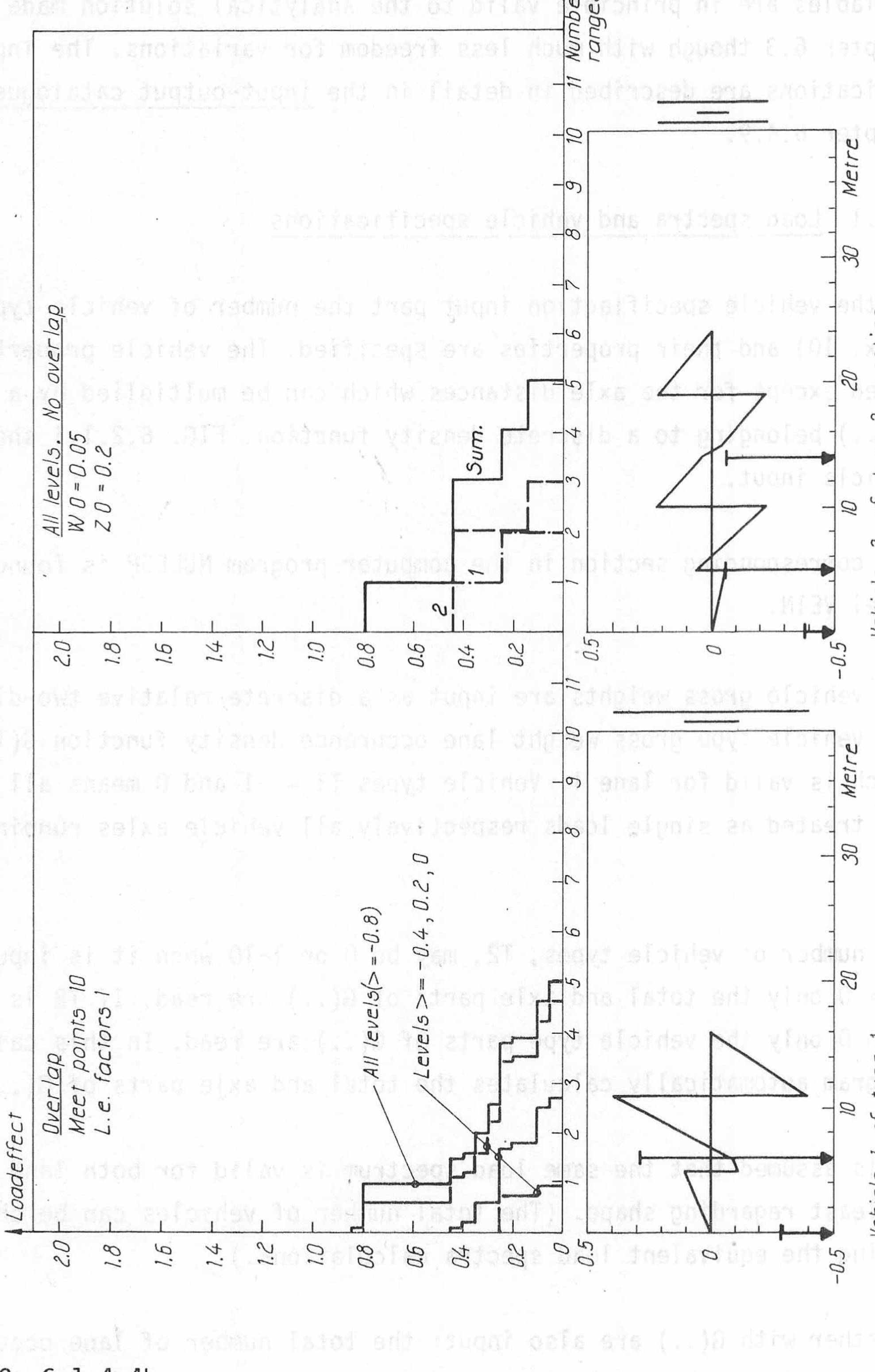

Overlap l.e. spectrum for two vehicle types. Infl. line type 3
Loadeffect
Overlap
Meet points 10
L.e. factors 1
All levels(>=-0.8)
Levels >= -0.4, 0.2, 0
All levels. No overlap
W 0 = 0.05
Z 0 = 0.2
Sum.
Number of ranges >=
Metre
Vehicle 1 of type 1
Vehicle 2 of type 2 meeting

FIG. 6.1.4-4b

6.2 Description of input variables.

The following chapters describe the input variables to the "numerical model for calculation of loadeffect spectra", NULESP. The same input variables are in principle valid to the analytical solution made in Chapter 6.3 though with much less freedom for variations. The input specifications are described in detail in the input-output catalogue in Chapter 6.4.9.

6.2.1 Load spectra and vehicle specifications.

In the vehicle specifiaction input part the number of vehicle types (max. 10) and their properties are specified. The vehicle properties are fixed except for the axle distances which can be multiplied by a factor H(...) belonging to a discrete density function. FIG. 6.2.1-1 shows the vehicle input.

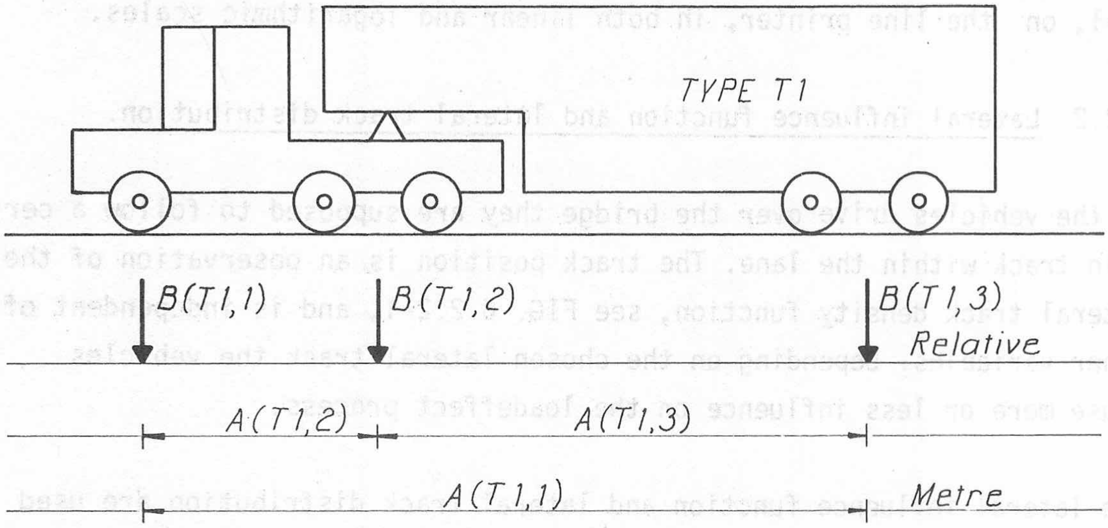
The corresponding section in the computer program NULESP is found at label VEIN.

The vehicle gross weights are input as a discrete relative two-dimensional vehicle type gross weight lane occurence density function G(T1,.), which is valid for lane 1. Vehicle types T1 = -1 and 0 means all vehicles treated as single loads respectively all vehicle axles running freely.

The number of vehicle types, T2, may be 0 or 1-10 when it is input. If T2 = 0 only the total and axle parts of G(..) are read. If T2 is greater than 0 only the vehicle type parts of G(..) are read. In this case the program automatically calculates the total and axle parts of G(..).

It is assumed that the same load spectrum is valid for both lane 1 and 2 at least regarding shape. (The total number of vehicles can be changed during the equivalent load spectra calculations.)

Together with G(..) are also input: the total number of lane occurences per year for each vehicle type, the regarded time period YØ (years) and the class width P1.



Number of vehicle types = T2.

V(T1,1) number of axles
M(3,T1) number of axle distance factors
H(T1,2,I1) axle distance factor density function
H(T1,1,I1) axle distance factor

FIG. 6.2.1-1. Vehicle input specifications, label VEIN.

FIG. 6.2.1-2 explains the load spectrum input. The input part is found at label LOIN in NULESP.

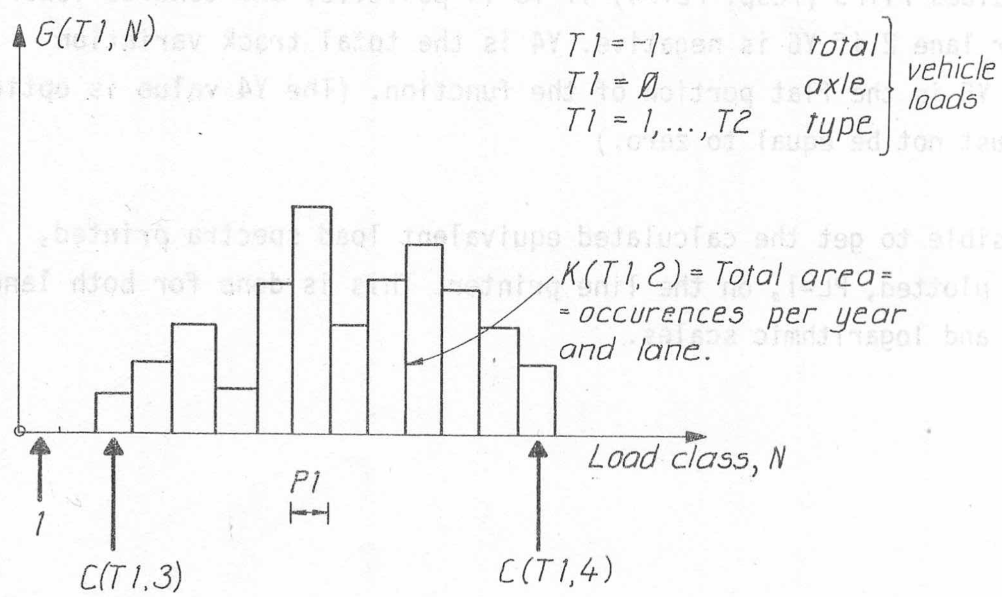


FIG. 6.2.1-2. Load spectrum input, label LOIN.

It is possible to get the input load spectra printed, PR=1, and plotted PL=1, on the line printer, in both linear and logarithmic scales.

6.2.2 Lateral influence function and lateral track distribution.

As the vehicles drive over the bridge they are supposed to follow a certain track within the lane. The track position is an observation of the lateral track density function, see FIG. 6.2.2-1, and is independent of other variables. Depending on the chosen lateral track the vehicles cause more or less influence on the loadeffect process.

The lateral influence function and lateral track distribution are used when the equivalent load spectra are calculated. The corresponding input section is found at label LINF in NULESP.

The lateral influence functions are supposed to be straight lines specified through F1, F3 and F2, F4. The F1 and F2 values are valid for the middle tracks of lane 1 and lane 2, which do not necessarily equal the mean tracks. The lateral influence specifications for the second lane (F2, F4) are always input though this lane is not used in some loadeffect calculation cases.

The lateral track density functions are specified through the variables Y4, Y5 and Y6. Y6 denotes the slanting portion towards the higher influence values F1+F3 (resp. F2+F4) if Y6 is positive, and towards lower F2-F4, for lane 2 if Y6 is negative. Y4 is the total track variation width and Y5 is the flat portion of the function. (The Y4 value is optional but must not be equal to zero.)

It is possible to get the calculated equivalent load spectra printed, PR=1, and plotted, PL=1, on the line printer. This is done for both lanes in linear and logarithmic scales.

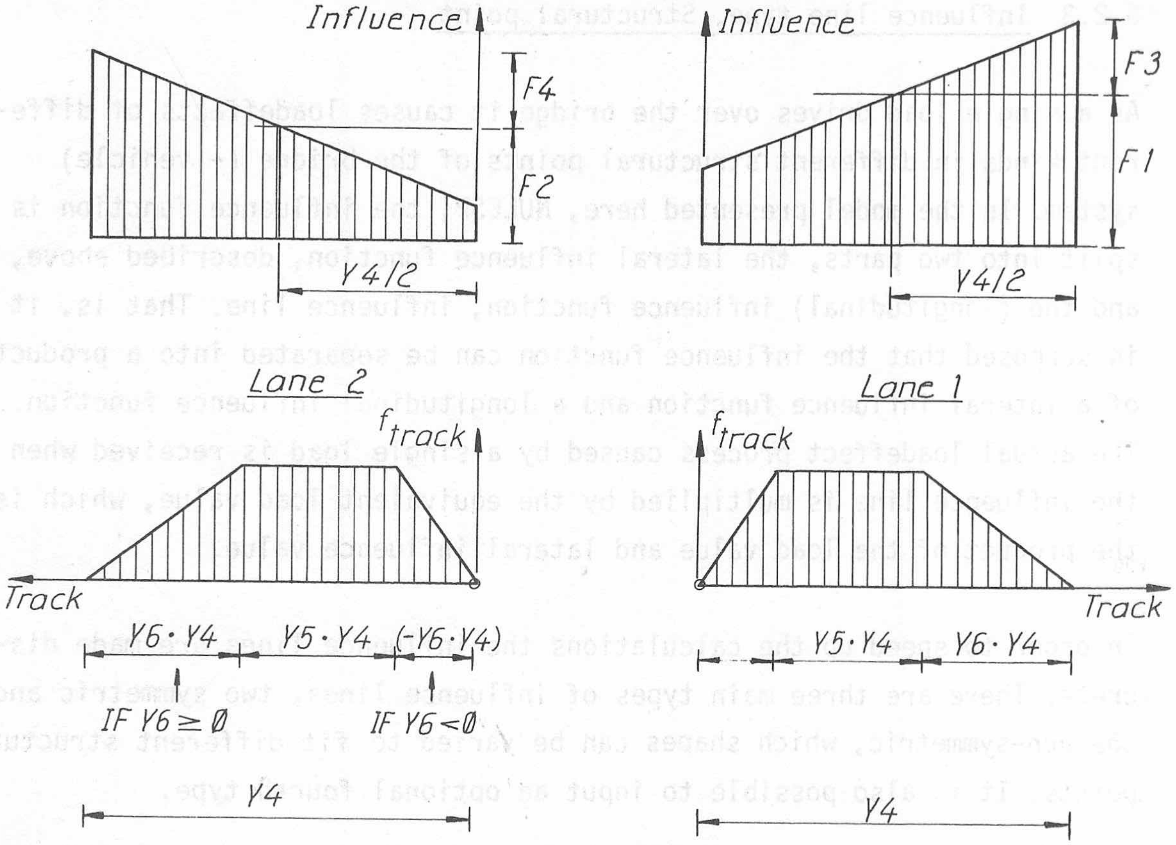


FIG. 6.2.2-1. Lateral influence functions and lateral track distribution specifications, label LINF.

6.2.3 Influence line type. Structural point.

As a single load drives over the bridge it causes loadeffects of different kinds in different structural points of the bridge (- vehicle) system. In the model presented here, NULESP, the influence function is split into two parts, the lateral influence function, described above, and the (longitudinal) influence function, influence line. That is, it is supposed that the influence function can be separated into a product of a lateral influence function and a longitudinal influence function. The actual loadeffect process caused by a single load is received when the influence line is multiplied by the equivalent load value, which is the product of the load value and lateral influence value.

In order to speed up the calculations the influence lines are made discrete. There are three main types of influence lines, two symmetric and one non-symmetric, which shapes can be varied to fit different structural points. It is also possible to input an optional fourth type.

The influence lines are used in NULESP when the vehicle type influence lines are calculated. They are described in FIG. 6.2.3-1 and the corresponding input section is found at label SINF in NULESP. Influence line type = J1, total number of types = J2.

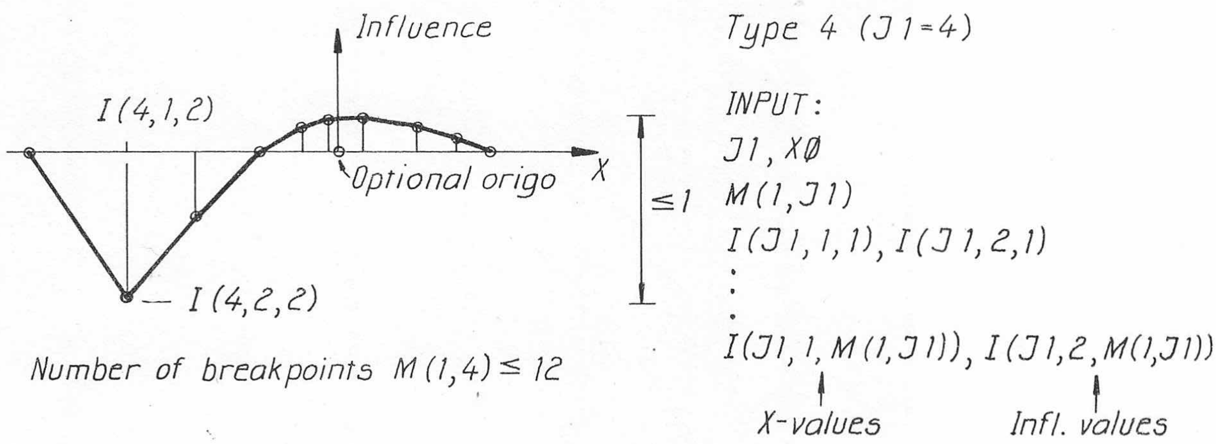


FIG. 6.2.3-1a. Optional influence line specification, J1=4, label SINF.

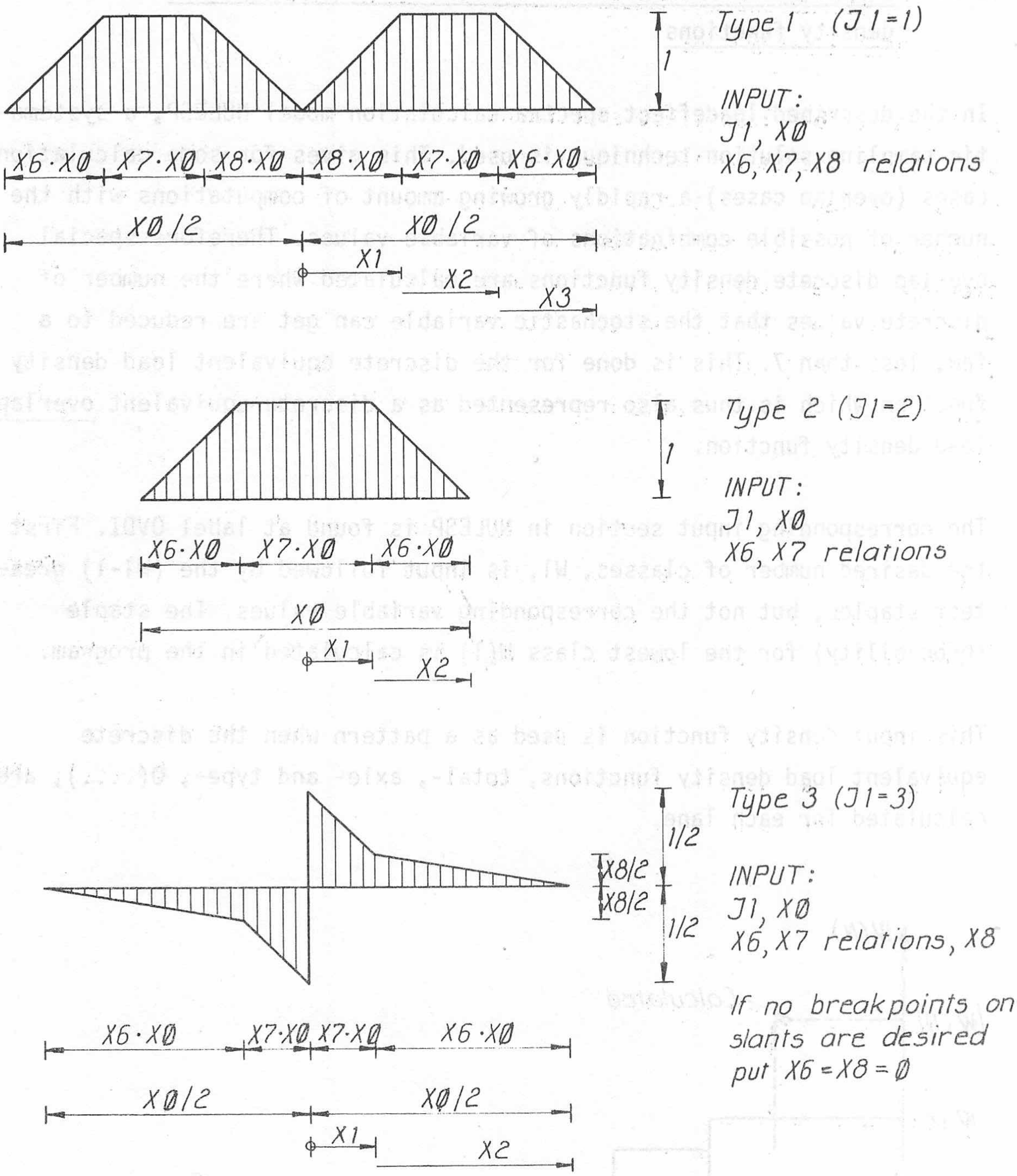


FIG. 6.2.3-1b. Standard influence line specifications, J1=1 to 3, label SINF.

6.2.4 Directives for calculation of equivalent overlap load density functions.

In the described loadeffect spectra calculation model NULESP, a systematic sampling solution technique is used. This gives for some calculation cases (overlap cases) a rapidly growing amount of computations with the number of possible combinations of variable values. Therefore special overlap discrete density functions are calculated where the number of discrete values that the stochastic variable can get are reduced to a few, less than 7. This is done for the discrete equivalent load density function which is thus also represented as a discrete equivalent overlap load density function.

The corresponding input section in NULESP is found at label OVDI. First the desired number of classes, W1, is input followed by the (W1-1) greatest staples, but not the corresponding variable values. The staple (probability) for the lowest class W(1) is calculated in the program.

This input density function is used as a pattern when the discrete equivalent load density functions, total-, axle- and type-, O(....), are calculated for each lane.

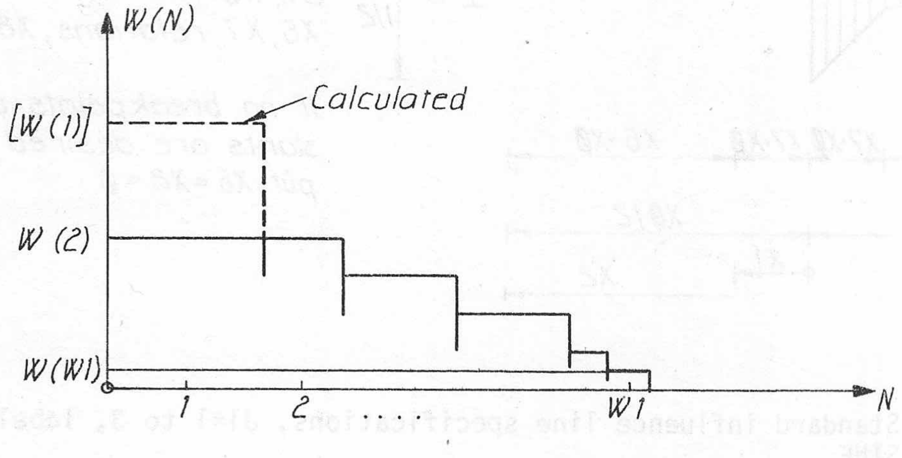


FIG. 6.2.4-1. Input of desired discrete equivalent overlap load density function, label OVDI.

6.2.5 Traffic data.

Beside the lateral track distribution some further data is necessary to describe the traffic.

It is supposed that all traffic with the vehicles concerned takes place during a fraction, equivalent time TE, of the day. It is also supposed that all vehicles have the same speed, VE, when they drive over the bridge.

In the model the probabilities for meetings and overtakings within the influence area are calculated under the assumption of Poisson distributed flows. The expression for the number of meetings during a time period contains the mean flows during the time period (adjusted for equivalent time TE) and the vehicle speed VE. It is also possible through input of a multiplicator, F8, to adjust the meeting probabilities. Corresponding factor on overtaking probabilities is F7.

In the same manner the number of different queuing events are calculated. These calculations require knowledge about the critical queue time, T9, which denotes the longest time between two vehicle passages in the lane, that (with probability = 0.5) will cause queue conditions. The calculated number of queuing events can also be adjusted by a multiplicator, F9.

If a queue has arisen, the queue distance is picked from a queue distance density function with shortest and longest queue distances SØ and S1.

The input section is found at label TRIN in NULESP. The input parameters are shortly described below.

VE	vehicle speed, m/s
TE	equivalent time (fraction of day)
F8	factor on meeting probabilities
F7	factor on overtaking probabilities
T9	critical queue time, s
SØ	shortest queue distance, m
S1	longest queue distance, m
F9	factor on queuing probabilities

6.2.6 Loadeffect calculation directives.

There are some variables and constants in the loadeffect calculation model, NULESP, which are used to direct the calculations. The two main variables are L1 and TØ. If L1=1 only a single lane is assumed. If L1=2 parallel lanes are assumed and if L1=-2 meeting lanes. TØ can be given three values -1, Ø and 1 which causes total , axle and vehicle type equivalent load spectra respectively to be used in the calculations. As shall be seen in Chapter 6.4 (description of NULESP), different calculation cases are performed depending on the values of L1 and TØ.

WØ and ZØ denotes the desired increment for loadeffect ranges and loadeffect levels in the calculated spectra. A9 is an upper level for the dynamic amplification factor. This value is input before the dynamic factor distribution, because dynamic arrays (matrices) are declared with the help of an algorithm at this stage of the program (NULESP, line 948).

The great, "infinite" number of meeting sections and queue distances are reduced to N3 and S4 which are equally distributed along the overlap lengths.

To get prints of intermediate (partial) loadeffect spectra, that is results from the overlap and single passage calculations, PR is put to 1. To get the corresponding plots on the line printer PL is put to a value between 1 and 25. PL=Ø means no plot. The intermediate loadeffect spectra are then plotted in linear and logarithmic scales with PL curves, for different "levels greater or equal", evenly spread over the plotting area.

In the same manner but through the input variables PRT and PLT it is settled how or if the final loadeffect spectra, before dynamic amplification, are to be printed and plotted.

The loadeffect calculation directives input section is found at label LEDI. The input variables are shortly described below.

WØ	loadeffect range increment
ZØ	loadeffect level increment
A9	maximum dynamic amplification factor
L1	single, parallel or meeting lanes (1, 2, -2)

TØ	total, axle or type equivalent load spectra (-1, Ø, 1)
N3	number of meeting sections
S4	number of queue distances
PR	= 1 print of intermediate (partial) spectra
PL	= Ø no plot of intermediate (partial) loadeffect spectra
	= 1-25 plot intermediate (partial) loadeffect spectra for PL different loadeffect levels "greater than or equal"
PRT	= 1 print of total (final) loadeffect spectra
PLT	= Ø no plot of total (final) loadeffect spectra
	= 1-25 plot total (final) loadeffect spectra.

6.2.7 Dynamic amplification factor distribution.

In the NULESP model it is supposed that the only dynamic effect that has to be considered in the calculations is the dynamic amplification factor. This factor is of stochastic nature, therefore it is specified as a density function, discrete, in the input, according to FIG. 6.2.7-1.

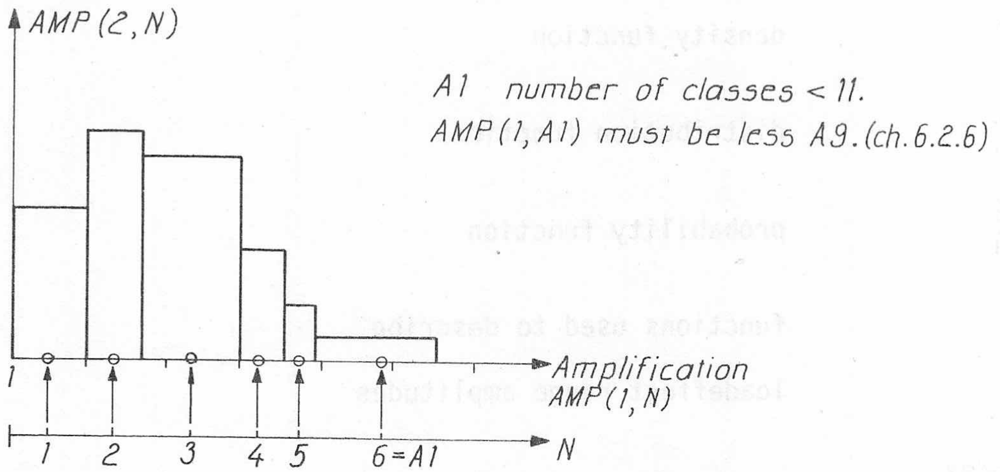


FIG. 6.2.7-1. Dynamic amplification factor distribution input, label DYDI.

After the calculations are performed, the loadeffect spectra are printed, both linear and logarithmic, if PRT=1. The corresponding plots are output on the line printer if PL does not equal Ø. The plotting area will then be evenly covered with PL, 1-25, curves, each guilty for a specific "level greater than or equal".

The dynamic factor distribution input is found at label DYDI in NULESP.

6.3 Introductory study for triangular influence line. Analytical solution.

This chapter deals with a purely analytical determination of loadeffects of a bridge structure. The solution is made for a very simplified variable input. As the solution is rather apart from the numerical model, NULESP, and due to simplifications in the writings of the deductions, some computer variables are abandoned and new, simple and indexed variables and constants are introduced. They are found in the list below.

It should be mentioned that the very simplified input leads to solutions which are only comparable to the numerical solutions for some special cases. Though an analytical approach is described one should keep in mind that a more complex model rapidly leads to expressions which have to be solved numerically and therefore no final analytical solution can be put up.

Variable explanation:

$f_{\text{index 1}}^{\text{index 2}}$	density function
$F_{\text{index 1}}^{\text{index 2}}$	distribution function
$P_{\text{index 1}}^{\text{index 2}}$	probability function
$\mu(X)$	functions used to describe
$\alpha(X)$	loadeffect range amplitudes
$G_{\text{index}}^{\text{lane index}}$	vehicle gross weight
$U_{\text{index}}^{\text{lane index}}$	maximum loadeffect
$K_{\text{index}}^{\text{lane index}}$	number of vehicles per year
Z1, Z2, Z3	zones 1, 2, 3
p	probability of meeting
$L = \frac{X\emptyset}{2}$	half the bridge length

Variables explained in the NOTATIONS:

TE, T	equivalent time
VE, V	vehicle speed
X	bridge length coordinate
XØ	length of influence line
W	loadeffect range

6.3.1 Description of input variables.

The load spectra, which for example are picked from the load spectrum model, LOSP, do not have a regular form. In the analytical solution it is assumed that there is just one type of vehicle, having one axle with a gross weight either rectangularly distributed between a lower value, $G_Ø$, and an upper value, G_1, or with a fixed mean gross weight, G_2. The flow of vehicles per lane and year is K.

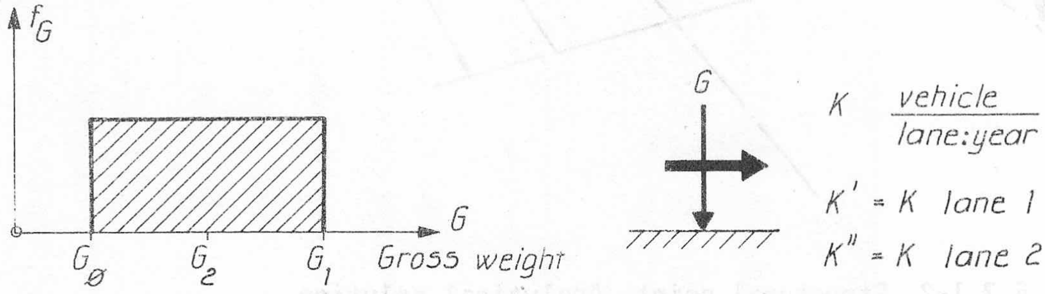


FIG. 6.3.1-1. Load density function and vehicle type input for both lanes. Analytical solution.

All vehicles in the lane are supposed to follow the same track, causing a lateral influence of 1.

The structural point considered might be a point in the flange in the middle of a transverse member, carrying both lanes. The stress variation in that point is the loadeffect considered, see FIG. 6.3.1-2. The corresponding influence line is shown in FIG. 6.3.1-3 (see also FIG. 6.2.3-1b, type 2).

The vehicle speed is VE m/s for all vehicles as they drive over the bridge. All traffic is concentrated to the fraction TE, equivalent time, of the day. It is assumed that the shortest queue distance is longer than the influence line, which implies no overlap effects from queuing vehicles. Furthermore no account is taken to dynamic effects.

Regarding the lane configuration it is of no importance it the second lane is a meeting or parallel lane because of the symmetric influence line.

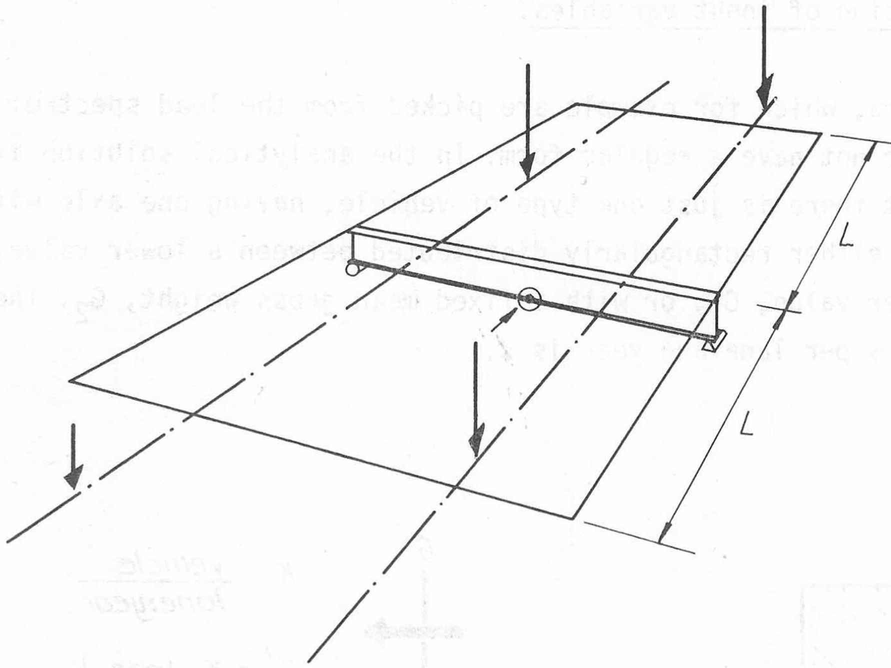


FIG. 6.3.1-2. Structural point. Analytical solution.

(Type 2, FIG 6.2.3-1b)

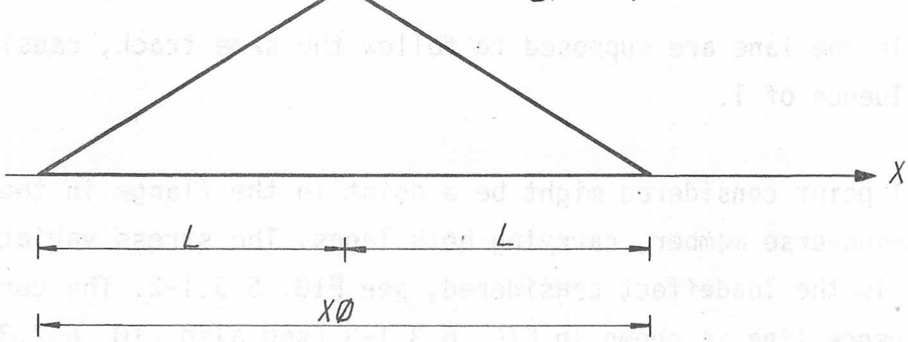


FIG. 6.3.1-3. Influence line. Analytical solution.

6.3.2 Method of analysis.

With the assumption made about the lateral influence function and the influence line, the maximum value of the loadeffect, U, produced by a vehicle will be numerically equal to the vehicle gross weight, that is

$$U(G) = G$$

The density function for U is shown in FIG. 6.3.2-1.

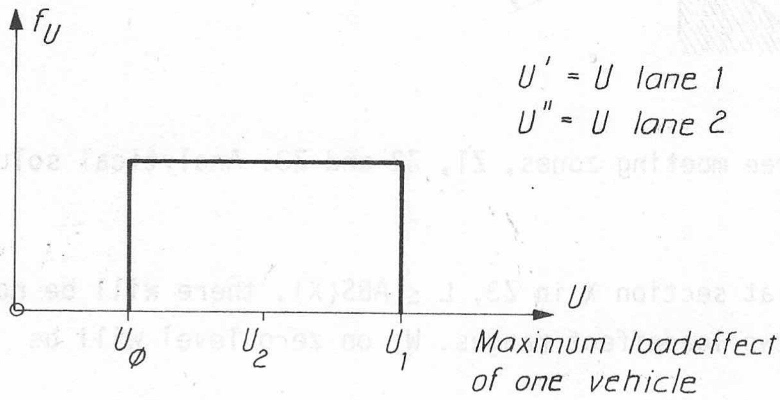


FIG. 6.3.2-1. Density function for maximum loadeffect during single vehicle passages. Analytical solution.

If the dynamic effects are not considered a loadeffect process for example like the one in FIG. 6.3.2-2 will arise.

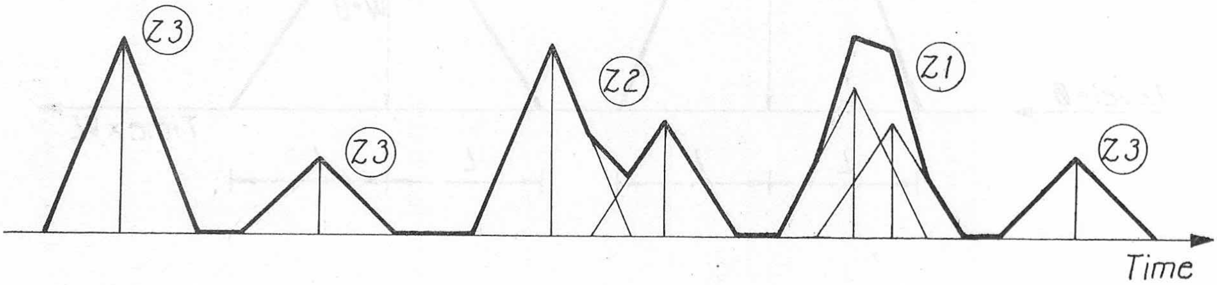


FIG. 6.3.2-2. Part of loadeffect process. Analytical solution.

As can be seen there are three main types of loadeffect variations marked Z1, Z2 and Z3. Z1 and Z2 each consists of two overlapping vehicle influence lines arising from different lanes. As has been pointed out earlier overlap effects of queuing vehicles can not occur. Dependent on meeting zone, the analyses of the loadeffects produced by two meeting vehicles will give different results.

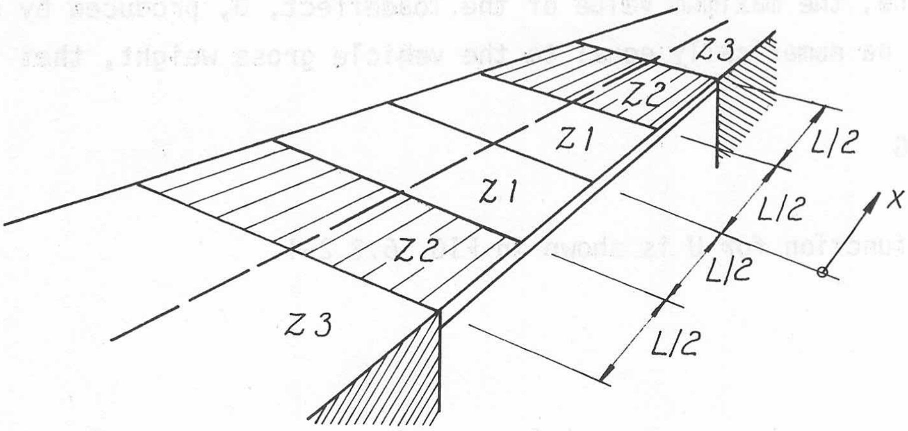


FIG. 6.3.2-3. The three meeting zones, Z1, Z2 and Z3. Analytical solution.

If the vehicles meet at section X in Z3, L ≤ ABS(X), there will be no overlap effects and two loadeffect ranges, W, on zero level will be counted.

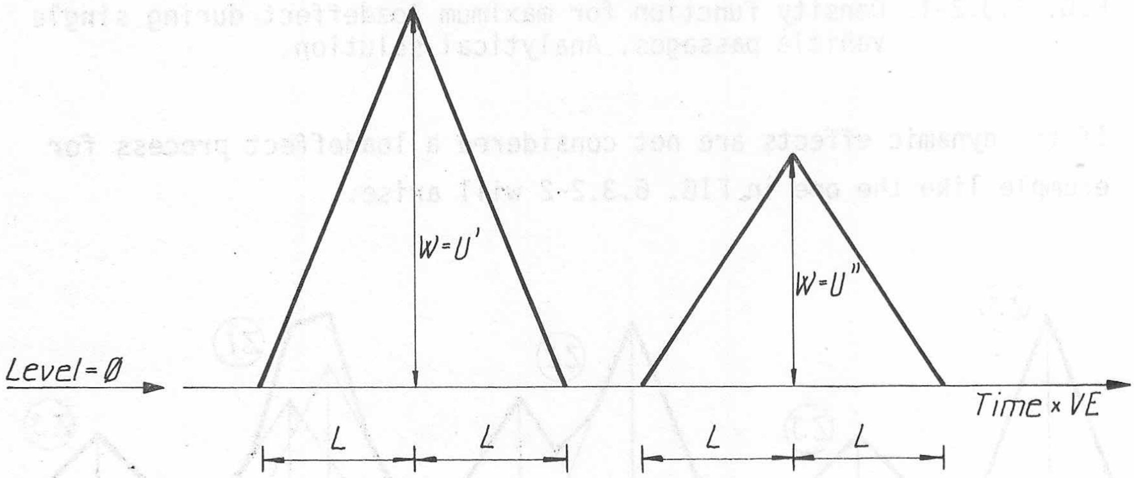


FIG. 6.3.2-4. Vehicles meeting in zone 3, Z3. Two loadeffect ranges, W, counted. Analytical solution.

If the vehicles meet at X in Z2, L/2 ≤ ABS(X) < L, that is the outer quarters of the bridge, the loadeffects will overlap and give rise to loadeffect variations corresponding to FIG. 6.3.2-5.

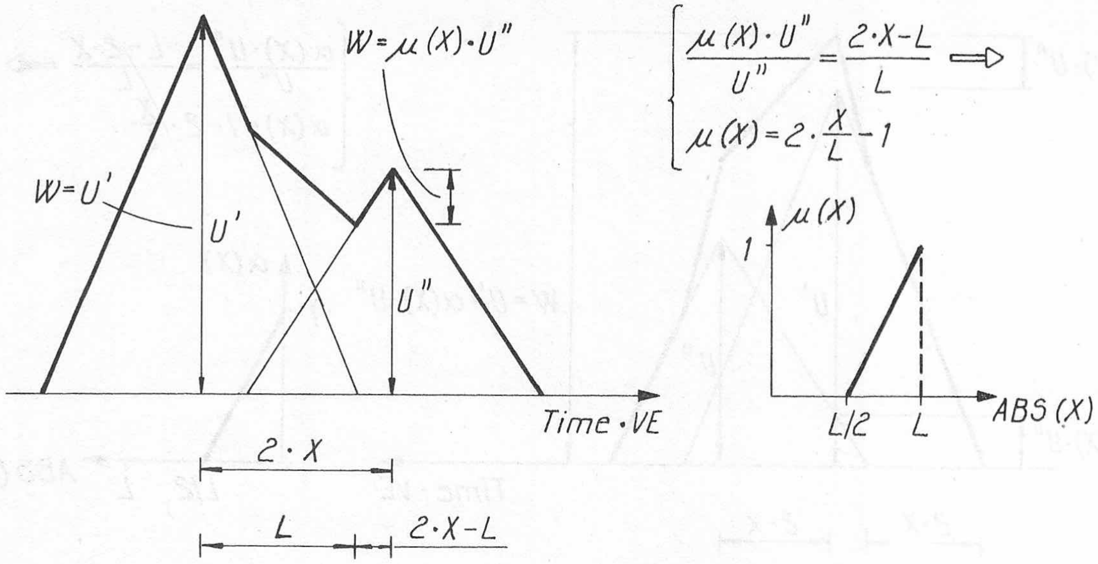


FIG. 6.3.2-5. Vehicles meeting in zone 2, Z2. Two loadeffect ranges, W, counted. Analytical solution.

The analysis of this part of the process is done in the same way as described in counting routine LECOUNT, see Chapter 5.2, and two loadeffect ranges will be added to the final result. Namely range U' on level Ø and range μ(X)·U" on level (1-μ(X))·U", where X is the meeting section. FIG. 6.3.2-5 also shows the expression for μ(X). If U' had been smaller than U", the same result should be valid with U' substituted for U".

Finally a meeting at section X in Z1, Ø ≤ ABS(X) < L/2, will cause a process part according to FIG. 6.3.2-6, which after analysis can be described as one loadeffect range U'+α(X)·U" on level Ø. If U" is greater than U', U" and U' shall change places. The expression for α(X) is also shown.

In the analysis no regard is given to the level on which the loadeffect ranges occur.

The number of meetings on the bridge per year is calculated in the same way as described later in Chapter 6.4.5, under the assumption of traffic flow following a Poisson process, which leads to the expression

$$\frac{4 \cdot L \cdot K' \cdot K''}{VE \cdot YSEC} = K \cdot p = \text{meetings on the bridge per year}$$

where YSEC = number of seconds in one year

p = probability for meetings

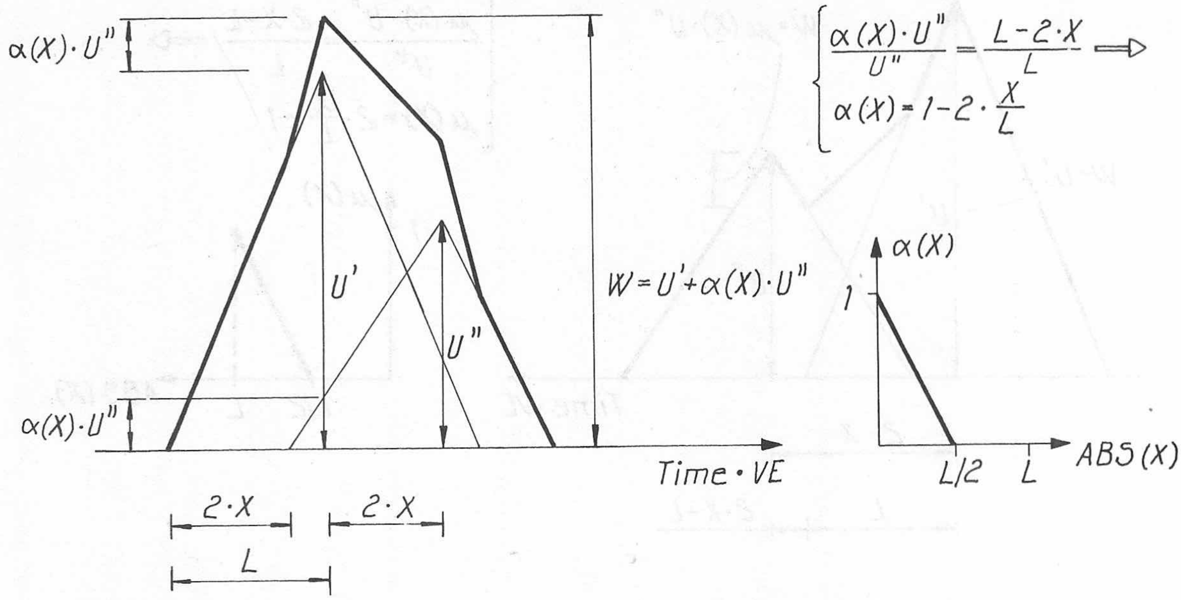


FIG. 6.3.2-6. Vehicles meeting in zone 1, Z1. One loadeffect range W, counted. Analytical solution.

The deductions made are split into two parts, one for deterministic loads, that is they are all constant, and one for non-deterministic loads with density function f_G. In the latter case the final result is presented separate in Chapter 6.3.5. The solutions are presented as density functions.

Finally, examples are calculated and commented in Chapter 6.3.6.

6.3.3 Description of analysis for deterministic loads.

Suppose that the vehicle gross weights are deterministic and all equal to G_2 for both lanes. The vehicle passages will then cause a maximum loadeffect U_2 in the studied structural point. The analysis for each meeting zone will yield loadeffect ranges according to FIG. 6.3.3-1.

In one year there will be K·p vehicles per lane involved in meetings on the bridge thus causing overlap effects. The meeting sections, X, are evenly spread along the meeting zones and as Z1 and Z2 both cover L length units of the bridge, there will be 1/2·K·p meetings in Z1 and 1/2·K·p in Z2. The number of meeting sections outside the bridge is K·(1-p), that is 2·K·(1-p) vehicles drive over the bridge without being involved in overlapping.

Zone / X	W: Amplitude	W: number	W: number / year
Z3: $L \le ABS(X)$	U_2	2	$2 \cdot K(1 \cdot p)$
Z2: $\frac{L}{2} \le ABS(X) < L$	U_2	1	$\frac{1}{2} \cdot K \cdot p$
	$\mu(X) \cdot U_2$	1	$\frac{1}{2} \cdot K \cdot p$
Z1: $0 \le ABS(X) < \frac{L}{2}$	$(1+\alpha(X)) \cdot U_2$	1	$\frac{1}{2} \cdot K \cdot p$

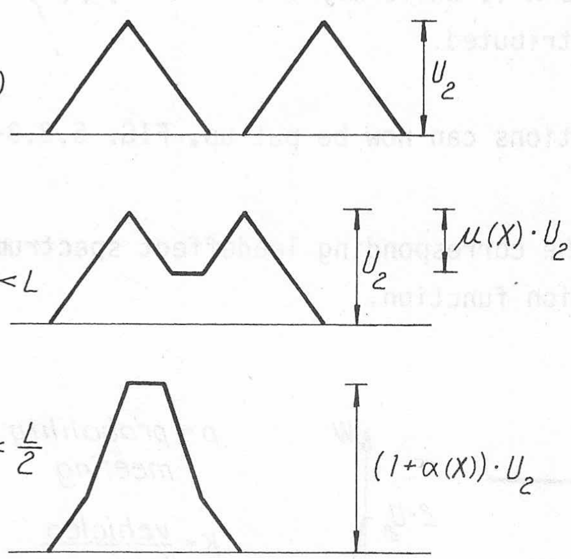


FIG. 6.3.3-1. Loadeffect count for different meeting zones. Deterministic loads. Analytical solution.

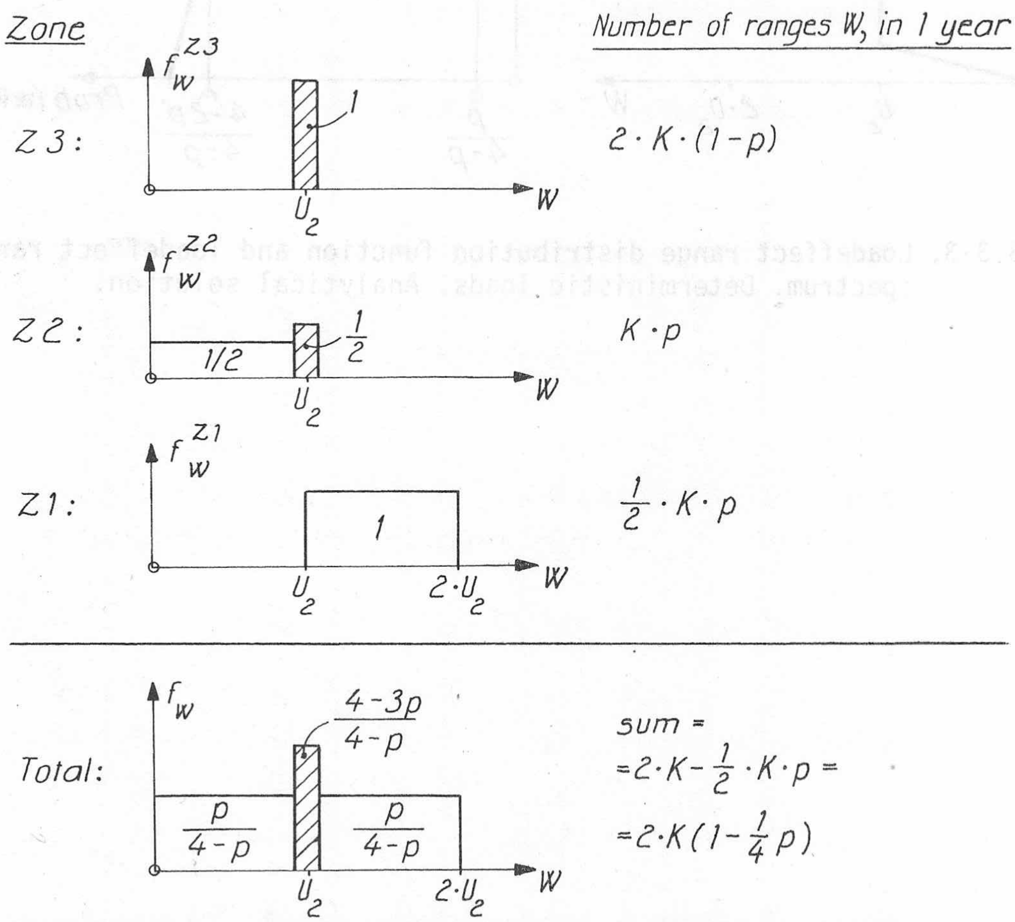


FIG. 6.3.3-2. Loadeffect range density functions. Deterministic loads. Analytical solution.

It has been shown that $\mu(X)$ has a linear variation between Ø-1 for $L/2 \leq ABS(X) < L$ and that $\alpha(X)$ also has a linear variation between 1-Ø for $Ø \leq ABS(X) < L/2$ and as X is uniformly distributed, $\mu(X)$ and $\alpha(X)$ will also be uniformly distributed.

The following density functions can now be put up, FIG. 6.3.3-2.

In FIG. 6.3.3-3 is shown the corresponding loadeffect spectrum and for clarity also the distribution function.

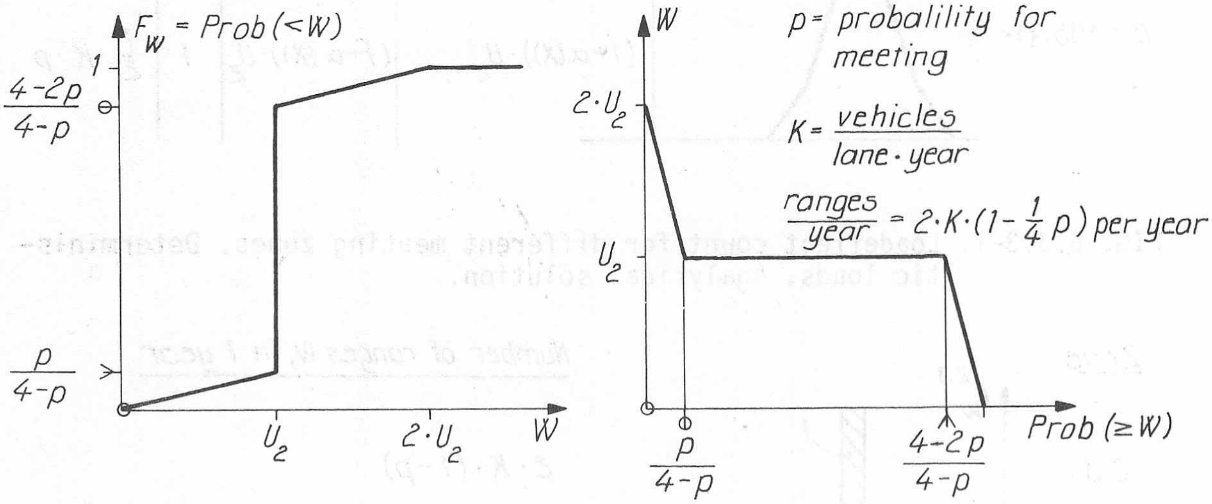


FIG. 6.3.3-3. Loadeffect range distribution function and loadeffect range spectrum. Deterministic loads. Analytical solution.

6.3.4 Description of analysis for non-deterministic loads.

To make the text more survayeble this chapter is divided into subchapters:

- Analysis zone 3, Z3
- Analysis zone 2, Z2. Fixed X
- Loadeffect range density function zone 2, Z2
- Analysis zone 1, Z1. Fixed X
- Loadeffect range density function zone 1, Z1

The combined loadeffect range density function for all zones, non-deterministic loads, is summarized in the next Chapter, 6.3.5.

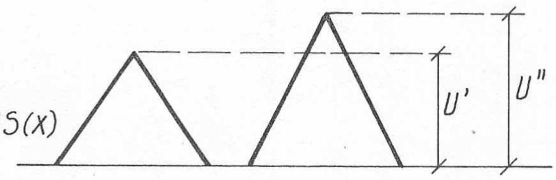
Analysis zone 3, Z3

The meeting section X is situated outside the bridge, ABS(X) ≥ L, and a meeting between two vehicles will give rise to the loadeffect count according to FIG. 6.3.4-1.

Zone / X

Z3

L ≤ ABS(X)



Amplitude	W Number	Number year
U'	1	K·(1-p)
U"	1	K·(1-p)

FIG. 6.3.4-1. Loadeffect count zone 3, Z3. Non-deterministic loads. Analytical solution.

The loadeffect range density function for zone 3, f_W^{Z3}, becomes, (see FIG. 6.3.2-1)

$$f_W^{Z3}(W) = \frac{1}{U_1 - U_\emptyset} \qquad (1)$$

where $U_\emptyset \le W \le U_1$

The number of meetings in Z3, is K·(1-p), that is each lane causes K·(1-p) loadeffect ranges in one year.

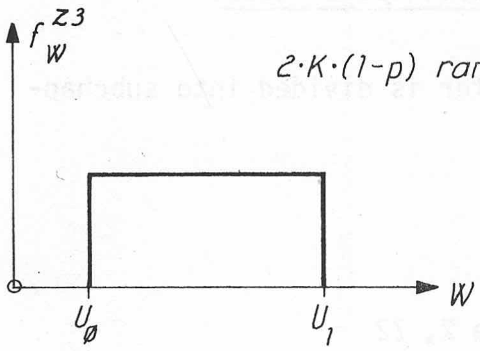


FIG. 6.3.4-2. Loadeffect range density function for zone 3, Z3. Non-deterministic loads. Analytical solution.

Analysis zone 2, Z2. Fixed X.

The meeting section is determined by $L/2 \le ABS(X) < L$. The analysis is made for $L/2 \le X < L$ as the analysis for negative X will yield the same result.

Study FIG. 6.3.4-3. It shows the principle appearances of the loadeffect variations for different X (three sections). U_h is the greatest of the maximum loadeffects U' and U" and U_ℓ is the lowest.

$$U_h = MAX\{U', U''\}$$
$$U_\ell = MIN\{U', U''\} \qquad (2)$$

As can be seen each meeting section X causes

1 loadeffect range U_h and
1 loadeffect range $\mu(X)\cdot U_\ell$

Remember the following density and distribution functions.

Variabel	distribution function	density function
U_h	$F_{U_h}(U,X)$	$f_{U_h}(U,X)$
$\mu(X)\cdot U_\ell$	$F_{\mu\cdot U_\ell}(U,X)$	$f_{\mu\cdot U_\ell}(U,X)$
U_ℓ	$F_{U_\ell}(U)$	$f_{U_\ell}(U)$
U'	$F_{U'}(U) = F_U(U)$	$f_{U'}(U) = f_U(U)$
U"	$F_{U''}(U) = F_U(U)$	$f_{U''}(U) = f_U(U)$

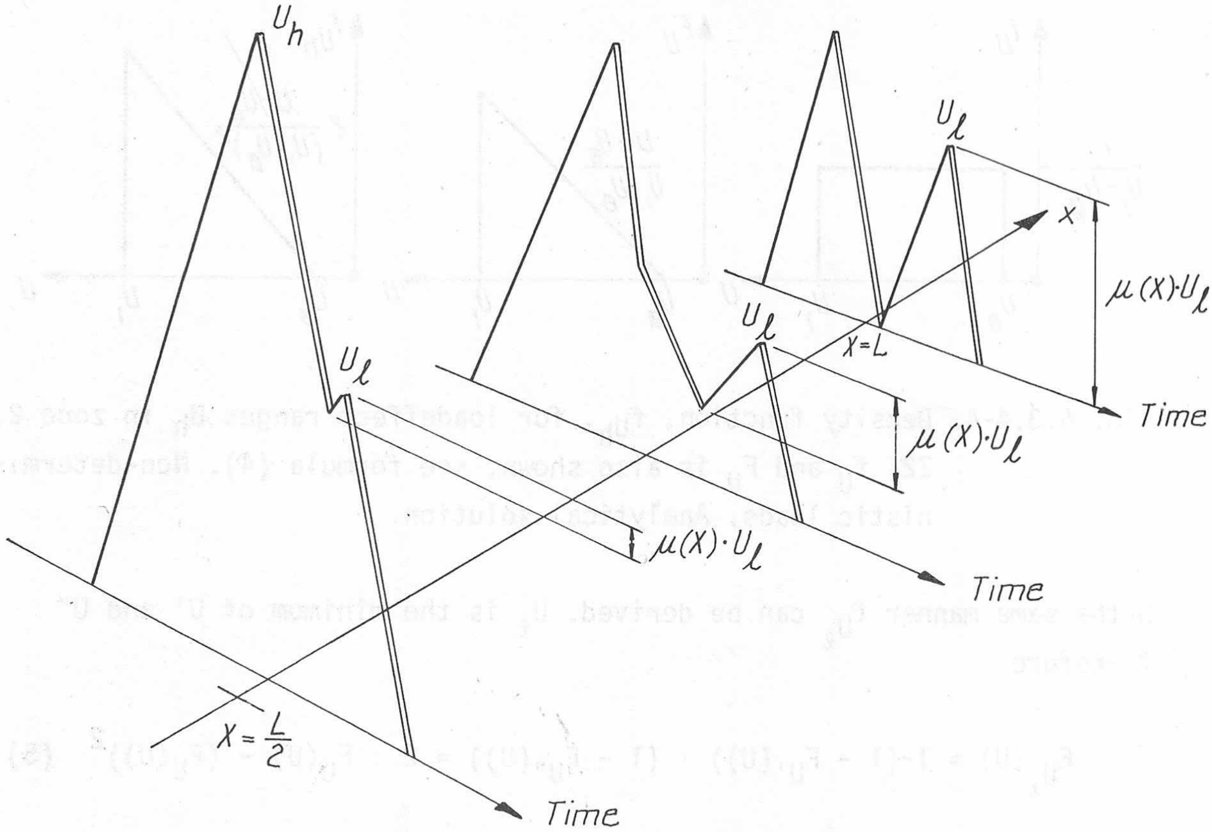


FIG. 6.3.4-3. The principle loadeffect variations for three meeting sections, X, in zone 2, Z2. Non-deterministic loads. Analytical solution.

The aim is to put up expressions for $f_{U_h}(U,X)$ and $f_{\mu \cdot U_\ell}(U,X)$ and integrate over the zone X = L/2 to X = L, to form the final density function for Z2, f_W^{Z2}. The integration is made in the next subchapter.

U_h is the maximum of U' and U" and F_{U_h} can therefore be written

$$F_{U_h}(U,X) = F_{U'}(U) \cdot F_{U''}(U) = (F_U(U))^2 \tag{3}$$

The density function is achieved by a derivation

$$f_{U_h} = \frac{d}{dU}(F_{U_h}(U,X)) = 2 \cdot F_U(U) \cdot f_U(U) = 2 \cdot \frac{U - U_\emptyset}{(U_1 - U_\emptyset)^2} \tag{4}$$

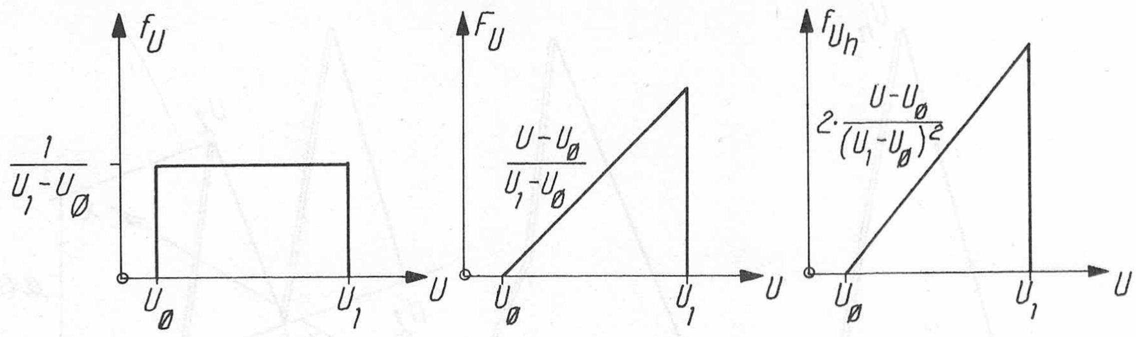


FIG. 6.3.4-4. Density function, f_{U_h}, for loadeffect ranges U_h in zone 2, Z2. f_U and F_U is also shown, see formula (4). Non-deterministic loads. Analytical solution.

In the same manner f_{U_ℓ} can be derived. U_ℓ is the minimum of U' and U" therefore

$$F_{U_\ell}(U) = 1-(1 - F_{U'}(U)) \cdot (1 - F_{U''}(U)) = 2 \cdot F_U(U) - (F_U(U))^2 \quad (5)$$

$$f_{U_\ell}(U) = \frac{d}{dU}(F_{U_\ell}(U)) = 2 \cdot f_U(U) - 2 \cdot F_U(U) \cdot f_U(U) =$$

$$= 2 \cdot f_U(U) - f_{U_h}(U) = 2 \cdot \frac{U_1 - U}{(U_1 - U_\emptyset)^2} \quad (6)$$

The density function for the loadeffect range $W = \mu(X)\cdot U_\ell$ can now be put up

$$f_{\mu\cdot U_\ell}(U,X) = 2 \cdot \frac{\mu(X) \cdot (U_1 - \frac{U}{\mu(X)})}{\mu(X)^2 \cdot (U_1 - U_\emptyset)^2} =$$

$$= 2 \cdot \frac{1}{(U_1 - U_\emptyset)^2} \cdot \left(\frac{U_1}{\mu(X)} - \frac{U}{\mu(X)^2}\right) \quad (7)$$

where $\mu(X) \cdot U_\emptyset \le U \le \mu(X) \cdot U_h$

FIG. 6.3.4-5 shows the function for two values of the meeting section X.

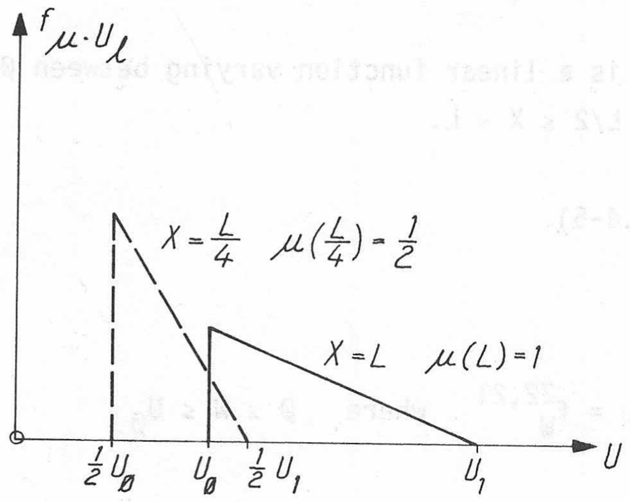


FIG. 6.3.4-5. Density function, $f_{\mu \cdot U_\ell}$, for loadeffect range $\mu(X) \cdot U_\ell$ in zone 2, Z2. Non-deterministic loads. Analytical solution.

Loadeffect range density function zone 2, Z2.

Above is the density functions shown for the loadeffect ranges U_h and $\mu(X) \cdot U_\ell$, which are caused by meetings at section X in zone 2, Z2. The final density function for zone 2, f_W^{Z2}, is achieved by integration over the entire zone remembering that the meeting sections are uniformly distributed over the zone.

$$2 \cdot f_W^{Z2} = f_W^{Z2,1} + f_W^{Z2,2} \tag{8}$$

where $$f_W^{Z2,1} = \int_{\text{zone 2}} f_{U_h} \cdot dx$$

$$f_W^{Z2,2} = \int_{\text{zone 2}} f_{\mu \cdot U_\ell} \cdot dx$$

As $f_{U_h}(W)$ is not dependent on X, $f_W^{Z2,1}$ can be written direct

$$f_W^{Z2,1}(W) = f_{U_h}(W) = 2 \cdot \frac{W - U_Ø}{(U_1 - U_Ø)^2} \tag{9}$$

where $U_Ø \leq W \leq U_1$

At the calculation of $f_W^{Z2,2}$ the integration has to be divided into two parts to prevent W from falling outside the definition area of $f_{\mu \cdot U_\ell}$.

This area varies with X.

It shall be remembered that $\mu(X)$ is a linear function varying between Ø and 1 over the zone, that is for $L/2 \leq X < L$.

Thus $f_W^{Z2,2}$ becomes (see FIG. 6.3.4-5).

$$f_W^{Z2,2} = \begin{cases} \displaystyle\int_{W/U_1}^{W/U_\emptyset} f_{\mu \cdot U_\ell}(W,\mu) \cdot d\mu = f_W^{Z2,21} & \text{where} \quad \emptyset \leq W \leq U_\emptyset \\ \displaystyle\int_{W/U_1}^{1} f_{\mu \cdot U_\ell}(W,\mu) \cdot d\mu = f_W^{Z2,22} & \text{where} \quad U_\emptyset < W \leq U_1 \end{cases} \qquad (10)$$

and after integration

$$f_W^{Z2,2} = \begin{cases} \dfrac{2}{(U_1 - U_\emptyset)^2} \cdot (U_\emptyset - U_1 + U_1 \cdot \ell n(\dfrac{U_1}{U_\emptyset})) & \text{where} \quad \emptyset \leq W \leq U_\emptyset \\ \dfrac{2}{(U_1 - U_\emptyset)^2} \cdot (W - U_1 - U_1 \cdot \ell n(\dfrac{W}{U_1})) & \text{where} \quad U_\emptyset < W \leq U_1 \end{cases} \qquad (11)$$

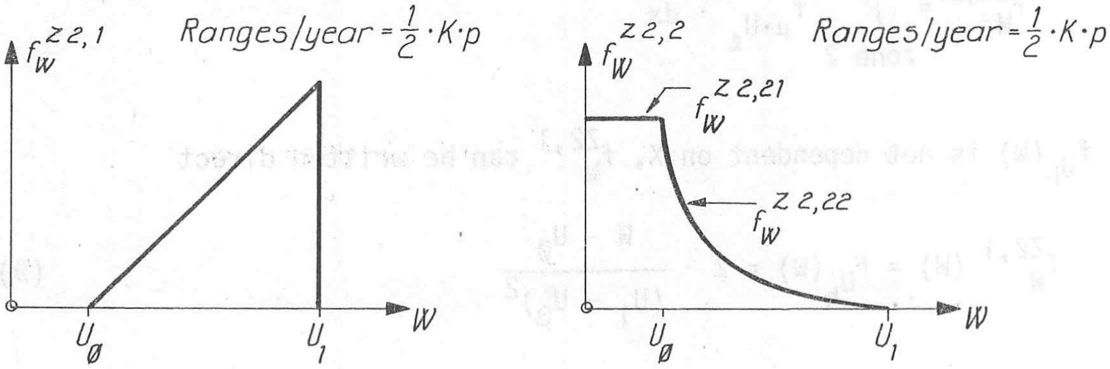


FIG. 6.3.4-6. Principle appearance of loadeffect range density functions $f_W^{Z2,1}$ and $f_W^{Z2,2}$ of zone 2, Z2. Non-deterministic loads. Analytical solution.

The total number of ranges in the zone is as before K·p equally distributed on the two types of ranges.

Analysis zone 1, Z1. Fixed X.

The meeting sections are uniformly distributed over $\emptyset \leq \mathrm{ABS}(X) < \frac{L}{2}$. As before, analysis is only performed for positive X.

It has been shown before, FIG. 6.3.2-6, that in this zone, Z1, there will be one loadeffect range, with amplitude U_m, for every meeting. That is

1 loadeffect range U_m

where

$$U_m = \{U' + \alpha(X) \cdot U'' \quad \text{if} \quad U' \geq U'' ;$$

$$U'' + \alpha(X) \cdot U' \quad \text{if} \quad U'' > U'\} \tag{12}$$

The distribution function for U_m, F_{U_m}, becomes

$$F_{U_m}(U,X) = P^1_{U_m}(U,X) + P^2_{U_m}(U,X) \tag{13}$$

where

$$\begin{cases} P^1_{U_m}(U,X) = \text{Prob. } (U' + \alpha(X) \cdot U'' \leq U \quad \text{and} \quad U' \geq U'') \\ P^2_{U_m}(U,X) = \text{Prob. } (U'' + \alpha(X) \cdot U' \leq U \quad \text{and} \quad U'' > U') \end{cases}$$

The maximum loadeffects U' and U" are observations of $f_{U'}$ and $f_{U''}$. The joint probability density function $f_{U'U''}$ is shown in FIG. 6.3.4-7. This figure also indicates lines $U = U' + \alpha(X) \cdot U''$ and $U' = U''$, which including the boundaries of the definition area of $f_{U'U''}$ forms the integration areas explained below.

The aim is to calculate $P^1_{U_m}$ for a fixed X, that is a fixed $\alpha(X)$. This is done by an integration over the hatched area of FIG. 6.3.4-7. To simplify the calculations $P^1_{U_m}$ is split into two functions $P^{11}_{U_m}$ and $P^{12}_{U_m}$.

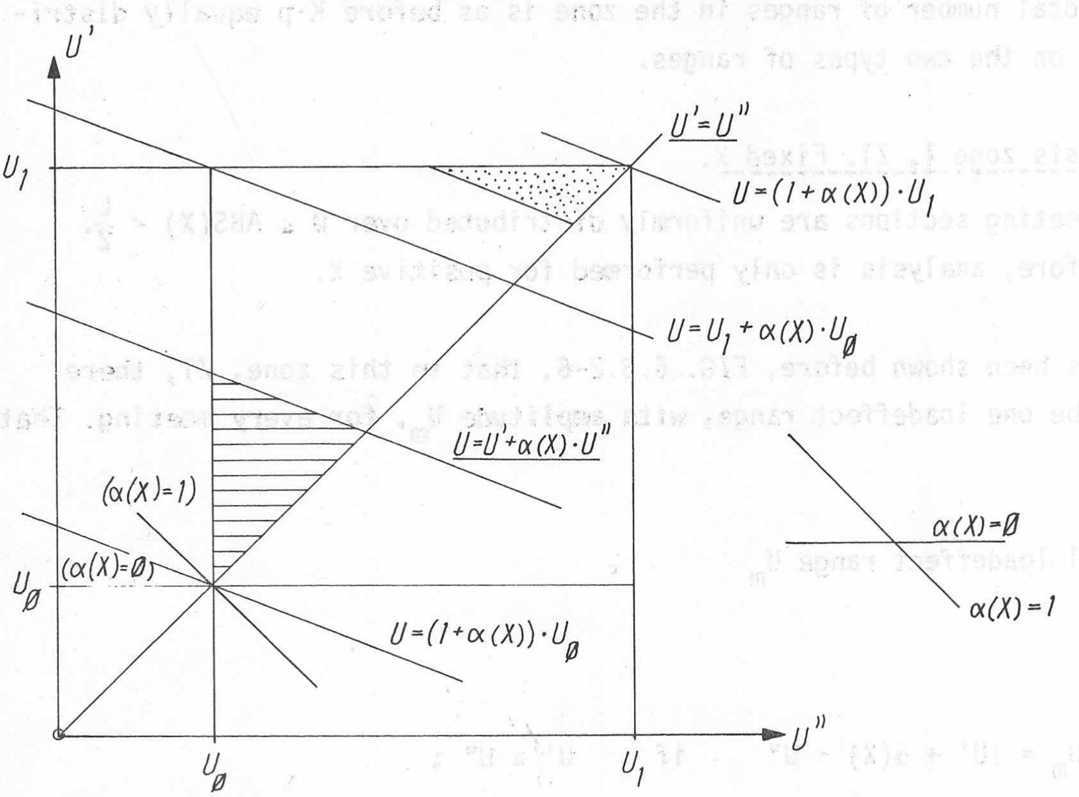
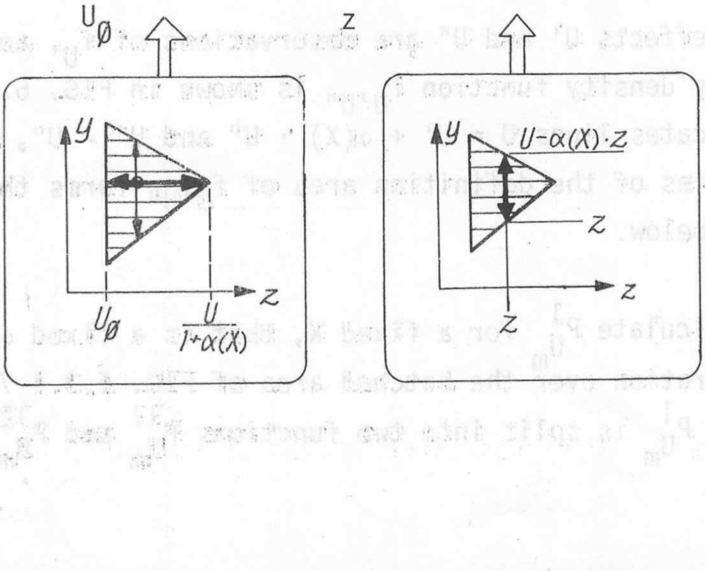


FIG. 6.3.4-7. Integration areas in the joint probability density function $f_{U'U''}$, zone 1, Z1. Non-deterministic loads. Analytical solution.

$$P^{1}_{U_m}(U,X) = P^{11}_{U_m}(U,X) + P^{12}_{U_m}(U,X) \qquad (14)$$

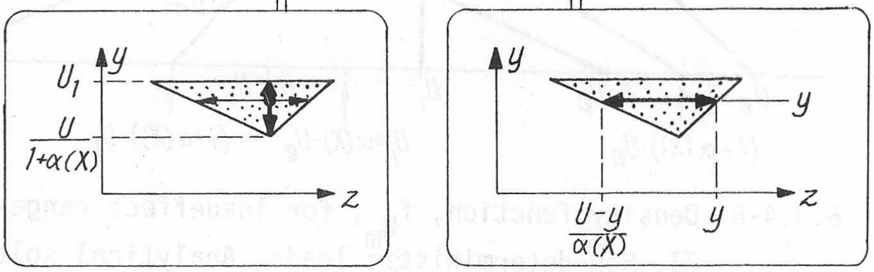
$P^{11}_{U_m}$ is calculated as the integral over the hatched area and $P^{12}_{U_m}$ as $\frac{1}{2}$ minus the integral over the dotted area.

$$P^{11}_{U_m}(U,X) = \int_{U_\emptyset}^{\frac{U}{1+\alpha(X)}} f_{U''}(z) \left[\int_{z}^{U-\alpha(X)\cdot z} f_{U'}(y) \cdot dy \right] dz \qquad (15)$$



where $(1 + \alpha(X)) \cdot U_\emptyset \le U \le U_1 + \alpha(X) \cdot U_\emptyset$

$$P^{12}_{U_m}(U,X) = \frac{1}{2} - \int_{U_1}^{\frac{U}{1+\alpha(X)}} f_{U'}(y) \cdot \left[\int_{y}^{\frac{U-y}{\alpha(X)}} f_{U''}(z) \cdot dz \right] dy \qquad (16)$$



where

$U_1 + \alpha(X) \cdot U_\emptyset < U \le (1 + \alpha(X)) \cdot U_1$

The corresponding function $P^1_{U_m}$ for U" > U' is not calculated, because $f_{U'}$ is equal to $f_{U''}$, which causes $P^2_{U_m}$ to be equal to $P^1_{U_m}$. Thus, after calculation of $P^{11}_{U_m}$ and $P^{12}_{U_m}$, the density function for U_m, f_{U_m}, becomes

$$f_{U_m}(U,X) = \frac{d}{dU}(F_{U_m}(U,X)) = \frac{d}{dU}(2 \cdot P^1_{U_m}(U,X)) = f^1_{U_m}(U,X) + f^2_{U_m}(U,X) \qquad (17)$$

where

$$f^1_{U_m}(U,X) = 2 \cdot \frac{d}{dU}(P^{11}_{U_m}(U,X)) = \frac{2}{(U_1 - U_\emptyset)^2} \cdot \left(\frac{U}{1 + \alpha(X)} - U_\emptyset\right) \qquad (18)$$

where $(1 + \alpha(X)) \cdot U_\emptyset \le U \le U_1 + \alpha(X) \cdot U_\emptyset$

$$f^2_{U_m}(U,X) = 2 \cdot \frac{d}{dU}(P^{12}_{U_m}(U,X)) = \frac{2}{(U_1 - U_\emptyset)^2 \cdot \alpha(X)} \cdot \left(U_1 - \frac{U}{1 + \alpha(X)}\right) \qquad (19)$$

where $U_1 + \alpha(X) \cdot U_\emptyset < U \le (1 + \alpha(X)) \cdot U_1$

FIG. 6.3.4-8 shows $f_{U_m}(U,X)$ for three values of the meeting section X.

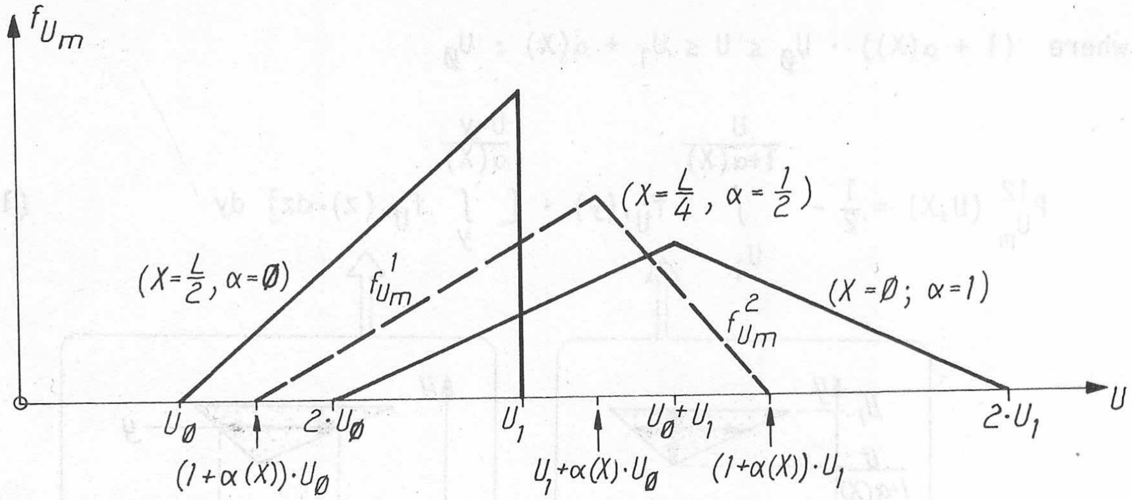


FIG. 6.3.4-8. Density function, f_{U_m}, for loadeffect ranges U_m in zone 1, Z1. Non-deterministic loads. Analytical solution.

Loadeffect range density function zone 1, Z1.

To get the final density function, f_W^{Z1}, for zone 1, Z1, f_{U_m} is integrated over the zone, that is from X = ∅ to X = L/2, (only positive X). It shall be remembered that α(X) is a linear function between ∅ and 1 over the zone.

$$f_W^{Z1}(W) = \int_{\text{zone } 1} f_{U_m}(W,X)\cdot dx \tag{20}$$

As for zone 2, the integration has to be divided into subintegrals, otherwise W could fall outside the definition area of f_{U_m}. This area varies with X, see also FIG. 6.3.4-8. The integration limits for α(X) are thus defined from the condition that $f_{U_m}(W,\alpha)$ may not be moved outside current W during the integration.

Below are the 5 subintegrals defined, together with integration limits for α and the proper definition areas. The expressions are valid for $2\cdot U_\emptyset \le U_1$.

$$f_W^{Z1} = f_W^{Z1,1} + f_W^{Z1,2} + f_W^{Z1,3} + f_W^{Z1,4} + f_W^{Z1,5} \tag{21}$$

Density function	Integration limits	Definition areas	
$f_W^{Z1,1}(W) = \int f_{U_m}^1(W,\alpha)\cdot d\alpha$	$\emptyset \le \alpha < \frac{W-U_\emptyset}{U_\emptyset}$	$U_\emptyset \le W < 2\cdot U_\emptyset$	(22)
$f_W^{Z1,2}(W) = \int f_{U_m}^1(W,\alpha)\cdot d\alpha$	$\emptyset \le \alpha \le 1$	$2\cdot U_\emptyset \le W \le U_1$	(23)
$f_W^{Z1,3}(W) = \int f_{U_m}^1(W,\alpha)\cdot d\alpha$	$\frac{W-U_1}{U_\emptyset} < \alpha \le 1$	$U_1 < W \le U_1+U_\emptyset$	(24)
$f_W^{Z1,4}(W) = \int f_{U_m}^2(W,\alpha)\cdot d\alpha$	$\frac{W-U_1}{U_1} < \alpha < \frac{W-U_1}{U_\emptyset}$	$U_1 < W \le U_1+U_\emptyset$	(25)
$f_W^{Z1,5}(W) = \int f_{U_m}^2(W,\alpha)\cdot d\alpha$	$\frac{W-U_1}{U_1} < \alpha \le 1$	$U_1+U_\emptyset < W \le 2\cdot U_1$	(26)

After fulfilled integrations $f_W^{Z1,1}$ to $f_W^{Z1,5}$ becomes

$$f_W^{Z1,1}(W) = \frac{2}{(U_1-U_\emptyset)^2}\cdot\left(W\cdot \ell n\left(\frac{W}{U_\emptyset}\right)-W+U_\emptyset\right) \qquad U_\emptyset \le W < 2\cdot U_\emptyset \qquad (27)$$

$$f_W^{Z1,2}(W) = \frac{2}{(U_1-U_\emptyset)^2}\cdot\left(W\cdot \ell n(2)-U_\emptyset\right) \qquad 2\cdot U_\emptyset \le W \le U_1 \qquad (28)$$

$$f_W^{Z1,3}(W) = \frac{2}{(U_1-U_\emptyset)^2}\cdot\left(W\cdot \ell n(2)-U_\emptyset-W\cdot \ell n\left(\frac{W+U_\emptyset-U_1}{U_\emptyset}\right)+W-U_1\right)$$

$$U_1 < W \le U_1+U_\emptyset \qquad (29)$$

$$f_W^{Z1,4}(W) = \frac{2}{(U_1-U_\emptyset)^2}\cdot\left(U_1\cdot \ell n\left(\frac{U_1}{U_\emptyset}\right)+W\cdot \ell n\left(\frac{W+U_\emptyset-U_1}{W}\right)\right)$$

$$U_1 < W \le U_1+U_\emptyset \qquad (30)$$

$$f_W^{Z1,5}(W) = \frac{2}{(U_1-U_\emptyset)^2}\cdot\left(W\cdot \ell n(2)-U_1\cdot \ell n\left(\frac{W-U_1}{U_1}\right)+W\cdot \ell n\left(\frac{W-U_1}{W}\right)\right)$$

$$U_1+U_\emptyset < W \le 2\cdot U_1 \qquad (31)$$

As before the total number of ranges is $\frac{1}{2}\cdot K\cdot p$ per year in zone 1. FIG. 6.3.4-9 shows the principle shapes and subfunctions of f_W^{Z1}, with $U_\emptyset=4$ and $U_1=14$.

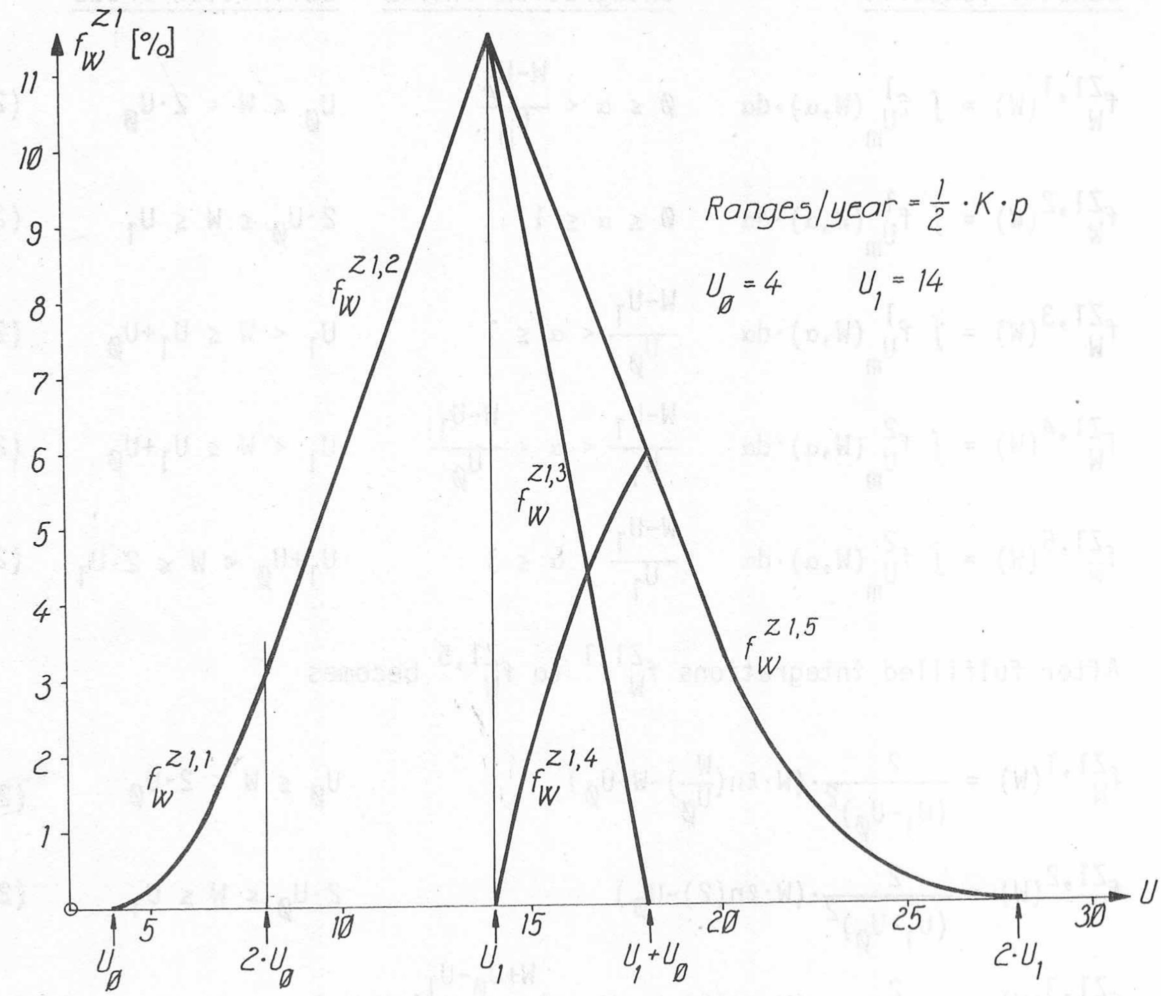


FIG. 6.3.4-9. Principle appearance of loadeffect range density function f_W^{Z1}, with subfunctions, zone 1, Z1. Non-deterministic loads. Analytical solution.

6.3.5 Analytical solution for non-deterministic loads. Computer program EF2.

In the preceding chapter derivations have been made of the loadeffect range density function for non-deterministic loads. FIG. 6.3.5-1 below contains the subdensity functions together with the number of ranges per year they stand for.

A computer program EF2 has been made which draws linear and logarithmic spectra for both deterministic and non-deterministic loads. The program is found in Appendix E.

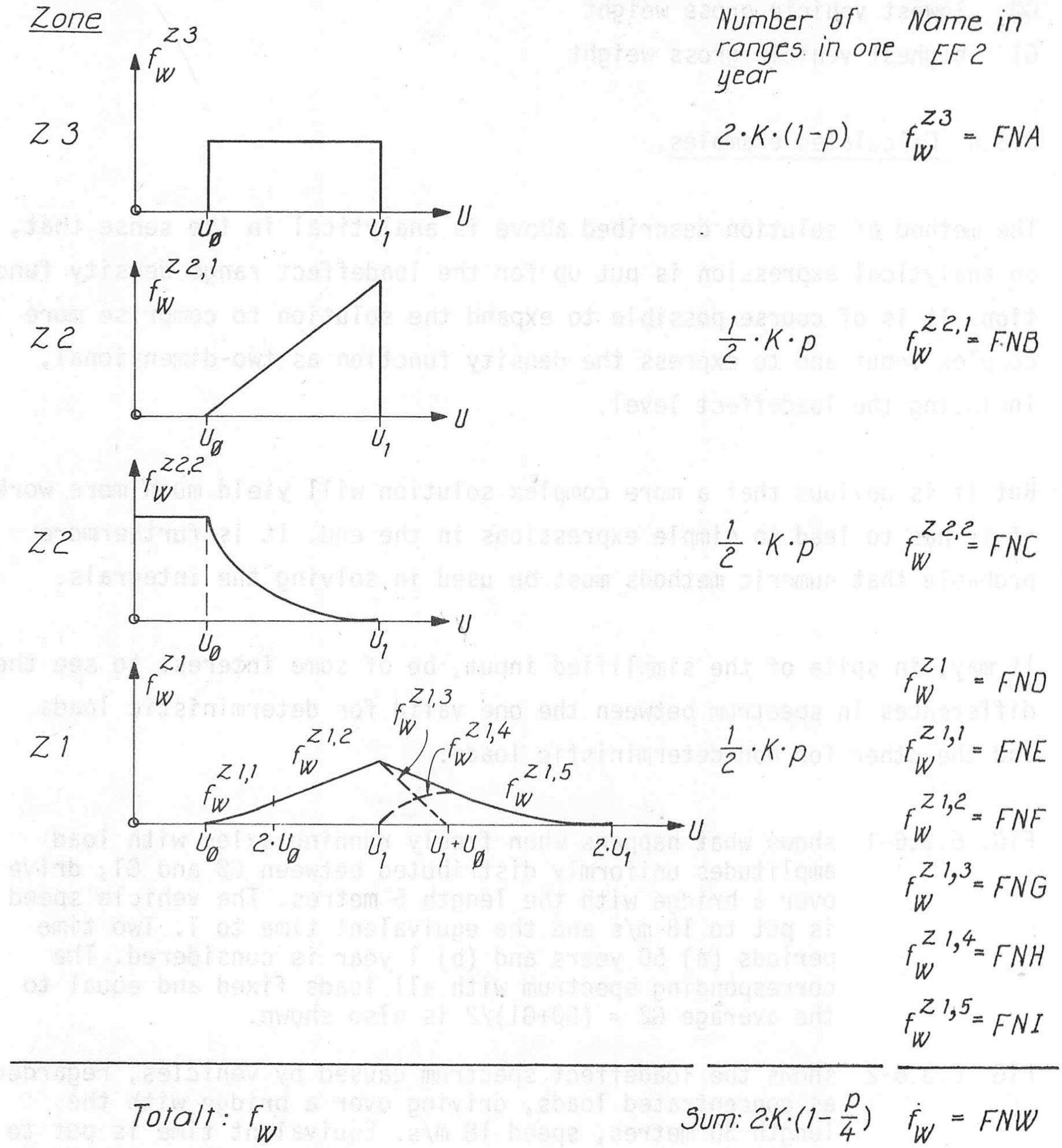


FIG. 6.3.5-1. Loadeffect range subdensity functions. Non-deterministic loads. Analytical solution.

It is assumed that $2 \cdot U_\emptyset \le U_1$ that is $2 \cdot G_\emptyset \le G_1$.

The input to the EF2 program consists of

K number of vehicles per lane and year

YØ regarded time period (years)

L length of bridge (m)

V vehicle speed (m/s)

T equivalent time

GØ lowest vehicle gross weight

G1 highest vehicle gross weight

6.3.6 Calculated examples.

The method of solution described above is analytical in the sense that, an analytical expression is put up for the loadeffect range density function. It is of course possible to expand the solution to comprise more complex input and to express the density function as two-dimensional, including the loadeffect level.

But it is obvious that a more complex solution will yield much more work if it has to lead to simple expressions in the end. It is furthermore probable that numeric methods must be used in solving the integrals.

It may, in spite of the simplified input, be of some interest to see the differences in spectrum between the one valid for deterministic loads and the other for non-deterministic loads.

FIG. 6.3.6-1 shows what happens when freely running axles with load amplitudes uniformly distributed between GØ and G1, drive over a bridge with the length 5 metres. The vehicle speed is put to 18 m/s and the equivalent time to 1. Two time periods (a) 50 years and (b) 1 year is considered. The corresponding spectrum with all loads fixed and equal to the average G2 = (GØ+G1)/2 is also shown.

FIG. 6.3.6-2 shows the loadeffect spectrum caused by vehicles, regarded as concentrated loads, driving over a bridge with the length 30 metres, speed 18 m/s. Equivalent time is put to 1. The vehicle gross weights are uniformly distributed between GØ and G1. The corresponding spectrum for deterministic loads, equal to G2, is also shown. For comparison the corresponding spectra with meeting probabilities equal to Ø are also shown.

The main limitations of the model are

the vehicle loads must be uniformly distributed

the loads are concentrated

the influence line must have triangular shape

no account is given to lateral influence function and lateral track distribution (gives equivalent loads).

only meeting overlap considered

no dynamic effects.

The next chapter describes a numerical model for calculation of loadeffect spectra, NULESP, which takes into consideration those circumstances not incorporated in the analytical solution.

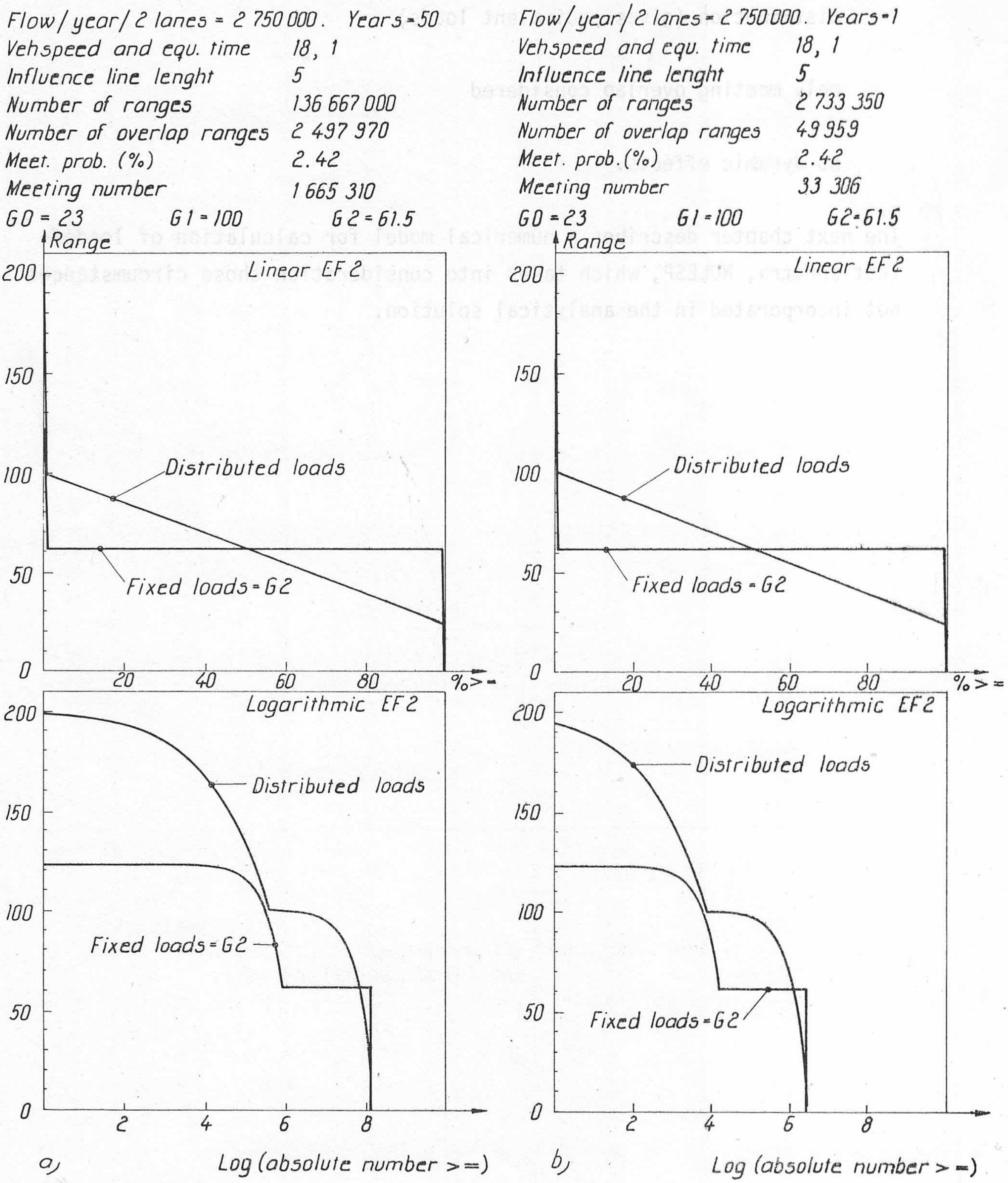

Flow/year/2 lanes = 2 750 000. Years = 50
Vehspeed and equ. time 18, 1
Influence line lenght 5
Number of ranges 136 667 000
Number of overlap ranges 2 497 970
Meet. prob. (%) 2.42
Meeting number 1 665 310
G0 = 23 G1 = 100 G2 = 61.5
Flow/year/2 lanes = 2 750 000. Years = 1
Vehspeed and equ. time 18, 1
Influence line lenght 5
Number of ranges 2 733 350
Number of overlap ranges 49 959
Meet. prob. (%) 2.42
Meeting number 33 306
G0 = 23 G1 = 100 G2 = 61.5
Range
Linear EF 2
Distributed loads
Fixed loads = G2
%>=
Logarithmic EF 2
Distributed loads
Fixed loads = G2
a)
b)
Log (absolute number >=)

FIG. 6.3.6-1

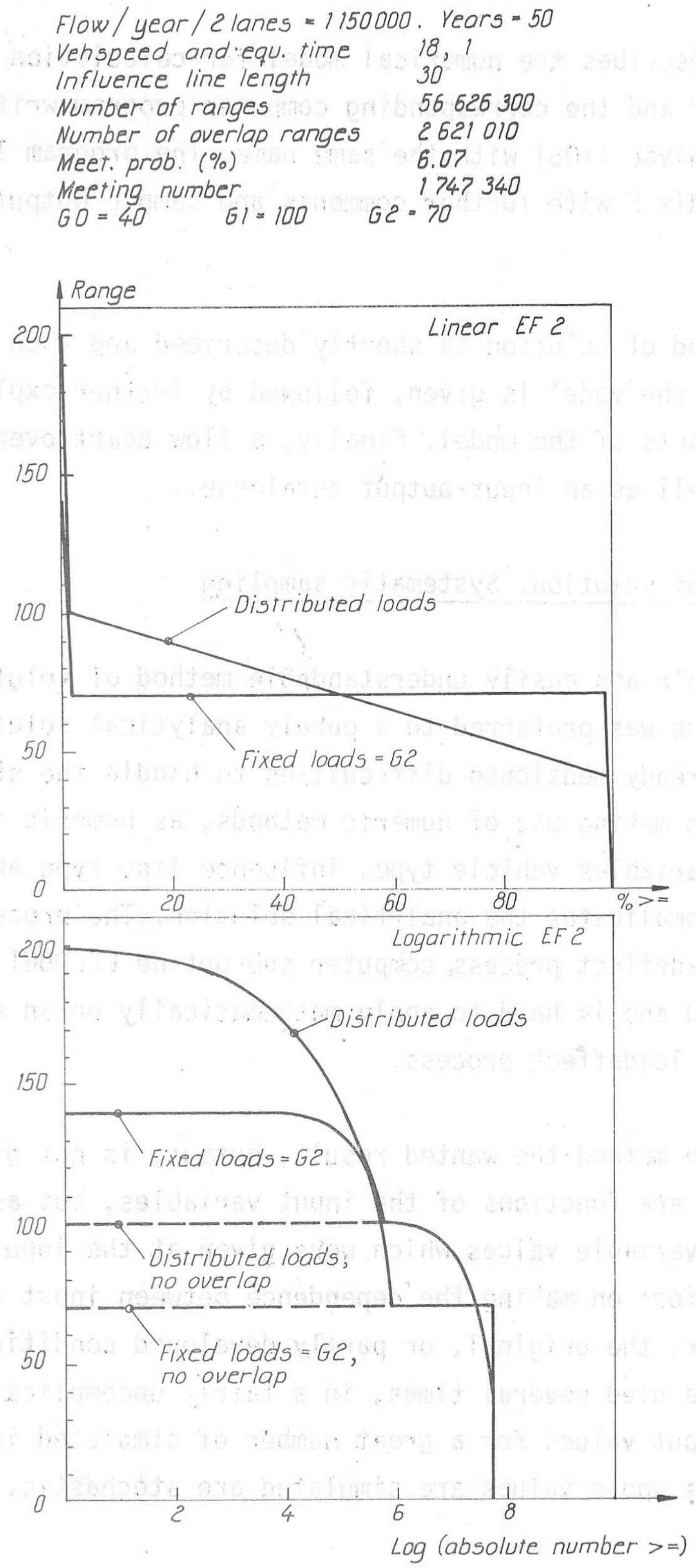

Flow / year / 2 lanes = 1150000. Years = 50
Vehspeed and equ. time 18, 1
Influence line length 30
Number of ranges 56 626 300
Number of overlap ranges 2 621 010
Meet. prob. (%) 6.07
Meeting number 1 747 340
G0 = 40 G1 = 100 G2 = 70
Range
Linear EF 2
200
150
100
50
0
Distributed loads
Fixed loads = G2
20
40
60
80
% >=
Logarithmic EF 2
200
150
100
50
0
Distributed loads
Fixed loads = G2
Distributed loads, no overlap
Fixed loads = G2, no overlap
2
4
6
8
Log (absolute number >=)

FIG. 6.3.6-2

6.4 Description of numerical model for calculation of loadeffect spectra, NULESP.

This chapter describes the numerical model for calculation of loadeffect spectra, NULESP and the corresponding computer program written in Algol (Nualgol for Univac 1108) with the same name. The program listing is found in Appendix F with further comments and sample output from a RUN.

First the method of solution is shortly described and then a schematic description of the model is given, followed by further explanations of some central parts of the model. Finally, a flow chart over NULESP is presented as well as an input-output catalogue.

6.4.1 Method of solution. Systematic sampling.

To get a flexible and easily understandable method of solution, a simulation technique was preferred to a purely analytical solution. In addition to the already mentioned difficulties to handle the stochastic variables without making use of numeric methods, as numeric integration, the discrete variables vehicle type, influence line type and overlap case further complicates the analytical solution. The procedure used to analyse the loadeffect process, computer subroutine LECOUNT, is called a counting method and is hard to apply mathematically on an analytical breakdown of a loadeffect process.

In a simulation method the wanted result, output, is not given in final formulas which are functions of the input variables, but as a specific result of the variable values which were given at the input. So instead of spending effort on making the dependence between input and output variables clear, the original, or partly developed conditions describing the problem are used several times, in a fairly uncomplicated algorithm, to produce output values for a great number of simulated input values. Those variables whose values are simulated are stochastic.

The progress of the simulation technique is of course a consequence of the growing accessibility to computers. The computer performs in the simulation model a rather simple algorithm but does it many times and does it fast.

The main advantages of the simulation methods are that the simulation model is rather simply formulated, the model is uncomplicated and easy to understand (it can often be a copy of a real chain of occurences) and it is easy to make changes in the model. The main disadvantage is that it requires many "runs" to get a complete picture of the input variables influence on the output.

It has been mentioned before that it is important to choose a simulation technique that gives an optional result in shortest computer time. The most simple form of Monte Carlo simulation is not satisfactory in this case because the most interesting part of the result will get relatively too low resolution, because the probability of coming up for dangerous variable combinations is too low.

There are different methods to direct the simulation. The one used in this work is called systematic sampling. In contrast to the simple Monte Carlo method, where all drawings from the input stochastic variables are randomly distributed according to their density functions, the systematic sampling includes "all" possible combinations of variable values. The calculated output for each combination is added to the final result with a weight equal to the probability for the combination of coming up. It is clear that the input variable density functions have to be made discrete and through a proper choice of division emphasis on certain interesting input circumstances can be made, see FIG. 6.4.1-1.

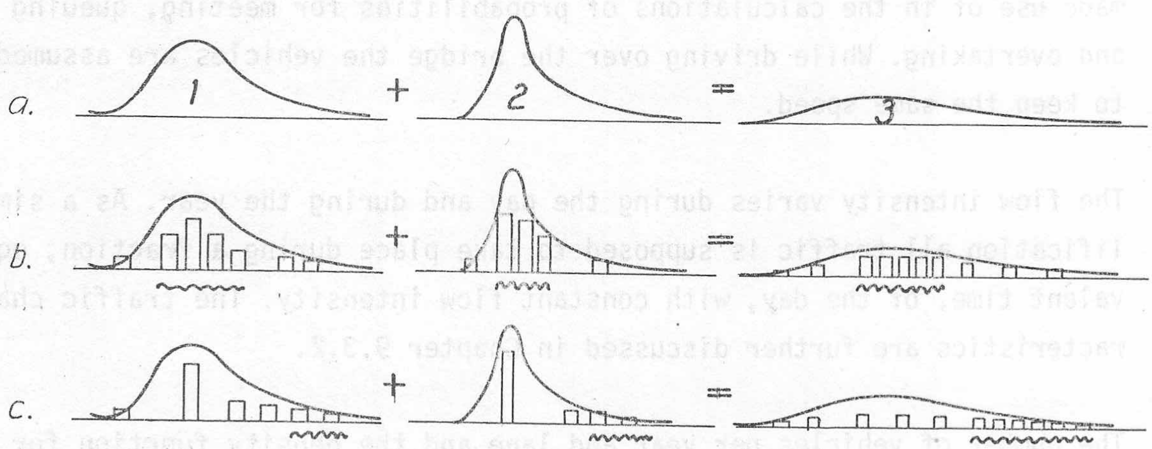


FIG. 6.4.1-1. Aspects on making density functions discrete before input in a systematic sampling. The underlined parts are considered to be of special interest. In this example it is supposed that the density functions (1) and (2) are added resulting in a density function (3).

The number of possible combinations of variable values increases rapidly with a finer division, therefore the number of discrete values a variable can take should be held at a minimum.

6.4.2 Schematic description of NULESP.

It is supposed that the bridge can carry one lane, two parallel lanes or two meeting lanes. The number of vehicles that pass on a lane section during a time period is equal for all lanes but can easily be altered in the model. In the case of parallel lanes it is supposed that no vehicles drive in the second lane, except when overtaking.

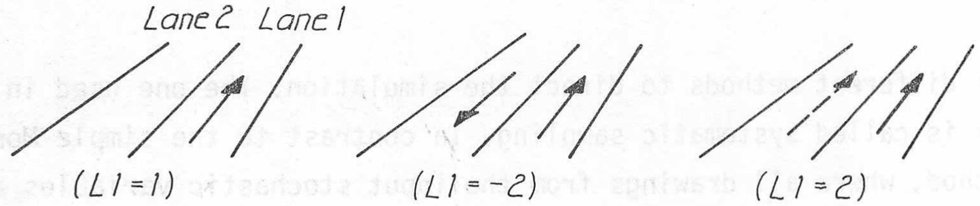


FIG. 6.4.2-1. Three types of lane configuration in NULESP.

The vehicle flow is described through a Poisson process, that is the vehicles travel independent of each other, with time distances between passages of a lane section exponentially distributed. Also partial flows of vehicles are assumed to be described by a Poisson process, a fact made use of in the calculations of probabilities for meeting, queuing and overtaking. While driving over the bridge the vehicles are assumed to keep the same speed.

The flow intensity varies during the day and during the year. As a simplification all traffic is supposed to take place during a fraction, equivalent time, of the day, with constant flow intensity. The traffic characteristics are further discussed in Chapter 9.3.2.

The number of vehicles per year and lane and the density function for the vehicle gross weights form the load 'spectrum' input together with the vehicle type specifications. The load density function input is split up into a total (all vehicle), axle and vehicle type part, and may be picked from the output of the load spectrum model LOSP.

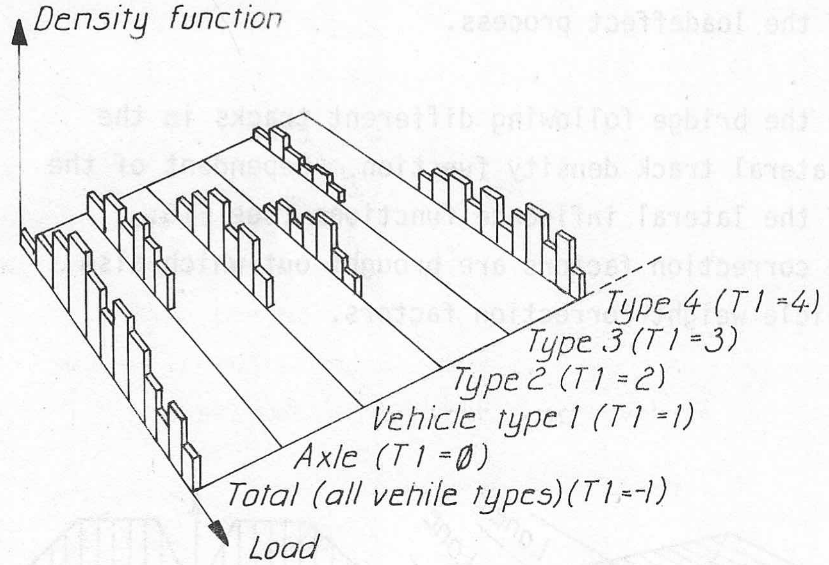


FIG. 6.4.2-2. Principle appearance of the discrete load density function input, NULESP.

As the vehicles drive over the bridge they give rise to varying kinds of loadeffects, for example stresses and deformations, in different points of the structure. These variations form the loadeffect processes which are to be analysed. The shape and magnitude of a process is determined by the appropriate influence volume and the load (vehicle weight) magnitudes. The influence values are defined by a function which is separated into two functions namely the longitudinal influence line and the lateral influence function. After the structural point is determined these functions are defined. The separation of the influence function was judged to be acceptable by the fact that it extensively simplifies the model (elimination of the lateral track variable from the systematic sampling procedure). It is, however, possible to define separate longitudinal influence lines for the two lanes through small changes in the program.

The influence lines and lateral influence functions are build up of straight lines in order to simplify the analyses. This simplification is further discussed in Chapter 6.5.1.

It should be pointed out that at this stage it is assumed that no dynamic effects, except those already incorporated in the influence function, occur during the passage. This assumption is also made to speed up the calculations, obtained by eliminating a stochastic variable namely the dynamic amplification factor, from the systematic sampling procedure used in the analysis of the loadeffect process.

The vehicles drive over the bridge following different tracks in the lane according to the lateral track density function. Dependent of the corresponding values of the lateral influence functions (see FIG. 6.4.2-3, influence line correction factors are brought out which also may be described as vehicle weight correction factors.

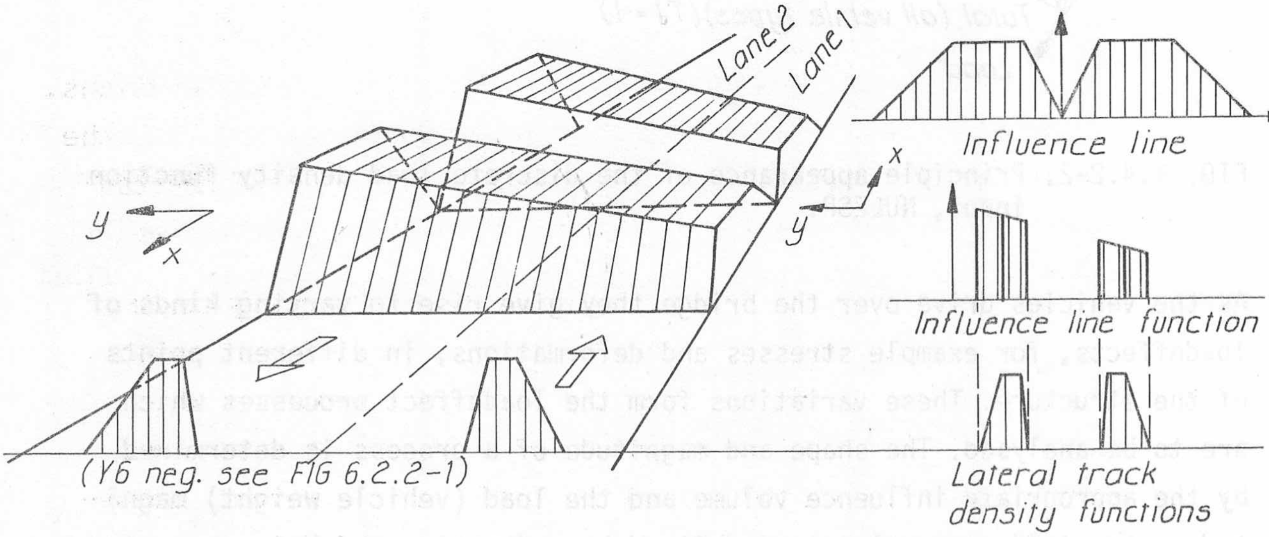


FIG. 6.4.2-3. Example on influence volume for a structural point (stresses in the flange of a two span longitudinal girder in lane 2). The lateral track density functions are also shown.

The vehicle (and axle) weights can now be translated into equivalent vehicle loads where the equivalent load is not properly a load but a loadeffect as it is multiplied by a loadeffect factor expressed through the lateral influence function. The <u>equivalent load spectrum</u> is to the structural point a load spectrum created by vehicles following the same track but with adjusted weights. This is true because the vehicle axles are treated as concentrated loads acting through the center of the axles, which will yield the same result as, on the wheels equally distributed weight making influence through the linear lateral influence function.

The lateral influence functions are separately defined for each lane.

The lateral track density functions have the same shape for the two lanes but may be turned (mirrored) for lane 2. (See Chapter 6.2.2.)

It shall also be mentioned here that when vehicles cause overlap loadeffects through overtaking the equivalent loads for the lane in which they overtake are used as if it was a meeting lane. Therefore the same original load density function must be used (same shape) when the equivalent load density functions are calculated, however, the total lane flow intensities do not have to be equal.

The calculations of equivalent load spectra are described in Chapter 6.4.3.

The vehicle type influence lines are then calculated. The distribution of vehicle weight on axles is defined in the vehicle type specifications. As there are M(3,Tl) axle distance factors for each vehicle type Tl, the same number of specific vehicle type influence lines can be calculated for each vehicle type and lane. This section of the program is commented on in Chapter 6.4.4.

It is now possible to make loadeffect process analyses by means of the loadeffect counting routine, LECOUNT, for single vehicles passing the bridge. First, however, to keep the analyses assembled some preparations for the overlap calculation cases must be made, namely creation of equivalent overlap load density functions, probabilities for meeting, overtaking, queuing, queuemeeting and queue meeting queue and the vehicle behaviour at these events and finally directives about the overlap cases that are valid and the type of loads, total, axle or vehicle type, that shall be used at the calculations.

The equivalent overlap load density function expresses actually the same thing as the equivalent load density function but with less resolution. In order to shorten the calculation time, and not spending time on calculations that will contribute little to the final solution, the number of possible equivalent load values are reduced according to principles shown in FIG. 6.4.1-1c. This part of the program is further described in Chapter 6.4.3.

The road sections where the meeting takes place, referring to the front axles of the vehicles, are uniformly distributed along the road and bridge, as the same density function for arrival times is valid for every section. With the assumption about Poisson distributed flows as a basis, the number of meetings (and overtakings) between the different vehicle types can now be calculated. These numbers can be altered through input factors.

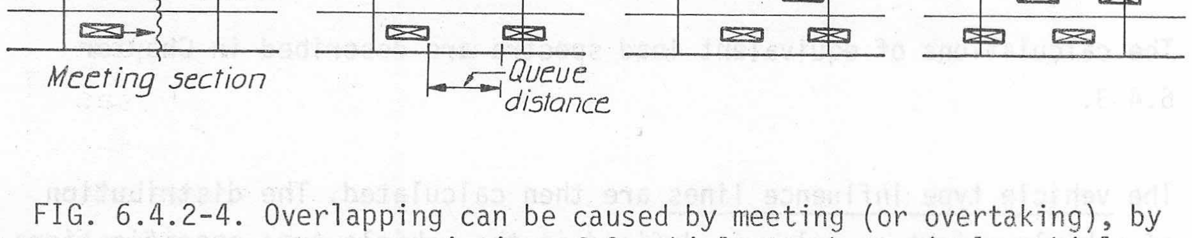


FIG. 6.4.2-4. Overlapping can be caused by meeting (or overtaking), by queues consisting of 2 vehicles or by a single vehicle meeting a queue or by queue meeting queue in the NULESP model.

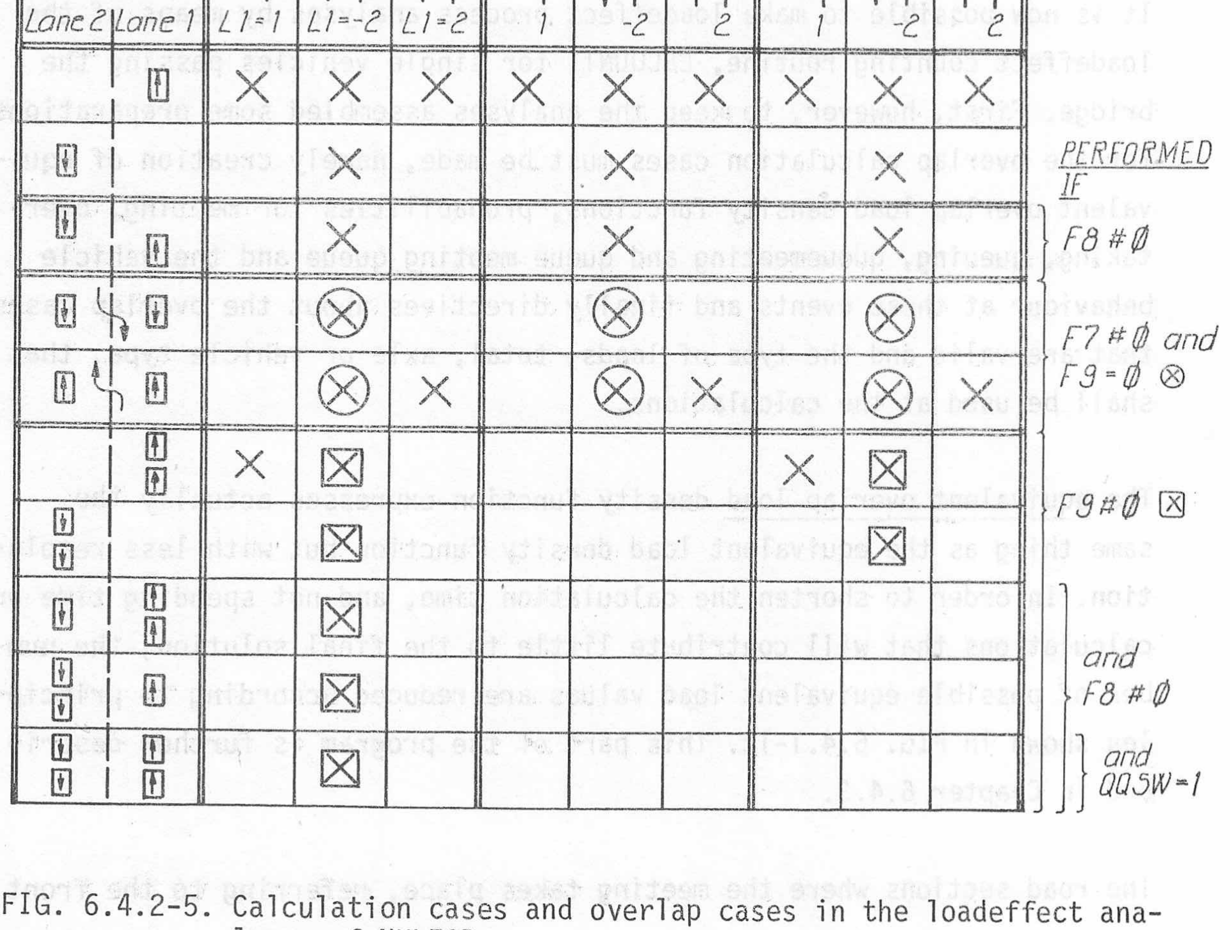


FIG. 6.4.2-5. Calculation cases and overlap cases in the loadeffect analyses of NULESP.

In a similar manner the number of queues are calculated. This number can also be altered through an input factor. A queue is assumed to come up (by a probability equal to 0.5) if the arrival time for the following vehicle is less than the critical queue time T9, and once a queue has been formed the queue distance is determined by a queue distance density function. Those overlap cases which are treated in the model are shown in FIG. 6.4.2-4. The number of vehicles in the queue is put equal to two vehicles because it is estimated that longer queues will be so long that all the vehicles can not influence at the same time. The calculations of corresponding probabilities are described in Chapter 6.4.5.

The <u>loadeffect calculations</u> are divided into different calculation cases depending on the type of used loads (axle, total or vehicle type, variable TØ), and on the assumed lane configuration (single lane, meeting lanes or parallel lanes, variable L1). A diagram over these cases is shown in FIG. 6.4.2-5.

It can be seen in the table that the axle load case, TØ = Ø, is not calculated for queuing vehicles. This is because all axles are supposed to run independently of each other in these calculations, even when belonging to the same vehicle, which excludes influence lines longer than the shortest axle distance. Thus no overlapping of axles belonging to the same vehicle and particularly not of queuing vehicles can occur.

The type load case, TØ = 1, excludes the queue meeting and queue meeting queue cases because they are of rather rare occurance compared to the queue case, and it is possible through this elimination to considerably reduce the computing time. The effect of the reduced calculations can be studied if the total load, TØ = -1, is used instead, as the queuemeeting and queue meeting queue cases are incorporated for this load, (further discussed in Chapter 6.5.5).

When two parallel lanes are assumed there is no flow in lane 2 except when an overtaking is to be made. It is further supposed that no queues arise on the 2 parallel lane roads, instead the vehicle overtake one another as they get too close.

In the case of meeting lanes no overtaking is assumed if queues are allowed to arise. The behaviour of queues of heavy vehicles and their overtaking behaviour is not very well known. It is here supposed that the duration of a queue is long in comparison to the time it takes to dissolve it by overtaking. The queue does not have to be dissolved through a regular overtaking but for example the front vehicle can make room for passage by moving to a side lane. This case will though probably be better treated as a two parallel lane case.

If queues are not allowed to arise, that is for low vehicle flow intensities, which is accomplished by setting F9 = Ø, the vehicles in each meeting lane behave like in the parallel lane case, that is they are allowed to overtake each other. Of course overlap effects of meetings will arise and be added to the final result.

Because of the poor knowledge about the queuing and overtaking behaviour of heavy vehicles, it was considered that the assumption made that queuing and overtaking can not both arise during a specified time period is satisfactory until further knowledge about these circumstances is gained (see also discussion in Chapter 9.3.2).

The calculations of loadeffect ranges and corresponding levels are now performed with the help of routine LECOUNT for all overlap cases and variable combinations. These calculations are described in Chapter 6.4.6, single vehicle passages and in Chapter 6.4.7 for the overlap cases.

The results of the calculations are loadeffect range level density functions which are printed and plotted as loadeffect spectra in linear and logarithmic (base 10) scales. It is also possible to get output partial spectra for the different overlap cases.

There is now one thing left to do and that is to correct the loadeffect spectra for dynamic effects. One dynamic effect may be expressed as a time varying wheel force which superposes the static force, also some of the vibration modes of the bridge will be started up causing larger loadeffects and extra oscillations which continue even after the vehicles have left the bridge.

In FIG. 6.4.2-6 the appearance of a static, that is slow vehicle passage, and corresponding dynamic part of a loadeffect process are sketched out. In the current version of NULESP only the amplification effect is taken into consideration. It is judged that the extra oscillations can be treated separately when the dynamic behaviour of the various vehicle bridge system is further studied and surveyed from a dynamic point of view.

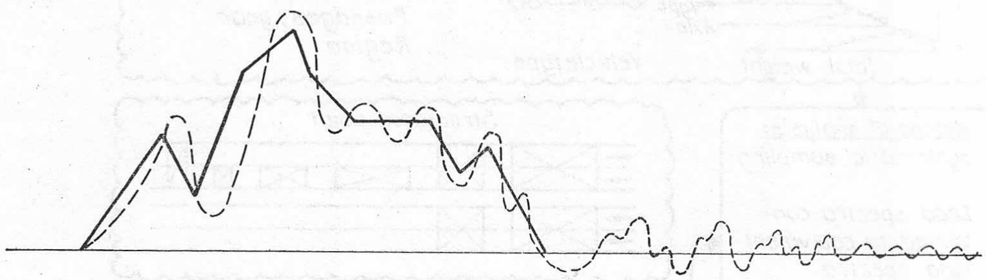


FIG. 6.4.2-6. Part of loadeffect process modified for dynamic effects.

The dynamic amplification factor is assumed to belong to a density function described through input data. The loadeffect range level density function is converted to a final dynamic loadeffect density function by means of a redistribution of each range according to the amplification factor distribution. The modification of the loadeffect spectra for dynamic effects is further described in Chapter 6.4.8 and discussed in Chapter 9.3.3.

The loadeffect spectra calculation model, NULESP, with its essential parts is summarized in FIG. 6.4.2-7.

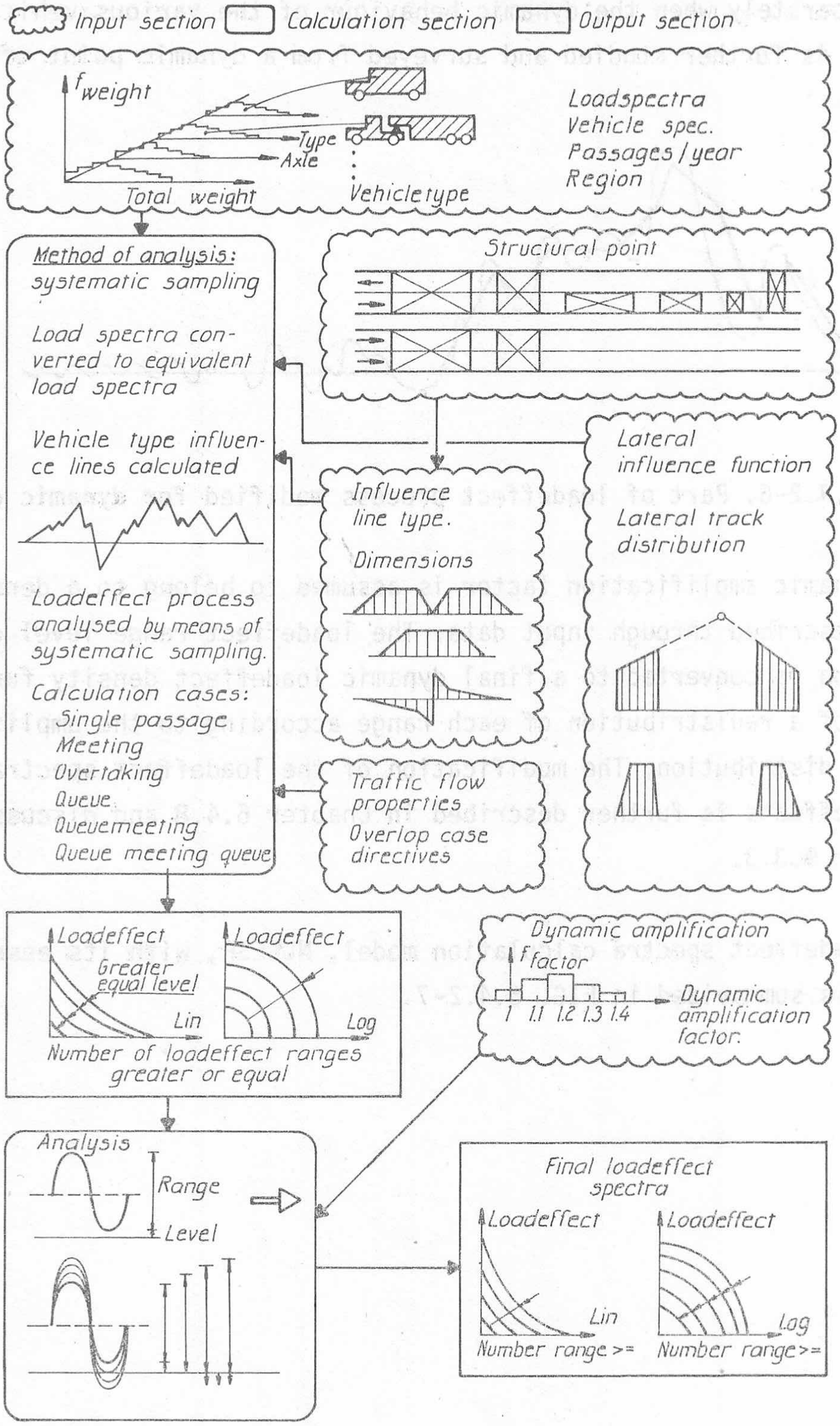


FIG. 6.4.2-7. Numerical model for calculation of loadeffect spectra, NULESP.

6.4.3 Calculation of equivalent load distributions and equivalent overlap load distributions.

Each vehicle driving over the bridge chooses a track and through the lateral influence function (see also FIG. 6.4.2-3 and FIG. 6.2.2-1) the weight of the vehicle can be translated to a corresponding equivalent load, which multiplied with the vehicle type influence line gives a part of the loadeffect process. This part can be superposed by process parts caused by other vehicles.

The input load density function for vehicle weights is transformed to an equivalent load density function in a manner described below. The corresponding section in the program is found at label EQCA, and the corresponding input section at label LINF.

FIG. 6.4.3-1 shows how each discrete load value, by multiplication of lateral influence function values between two limits, is transformed to equivalent load values varying within the variation width of a specific discrete equivalent load value, class I1. That is the loads of class N with values K3 are moved to class I1 of the equivalent load density function, with a weight explained below. The greatest lateral influence function value, K2/K3, by which the load value, K3, shall be multiplied to fall below the upper class border, K2, of I1 is calculated as well as the corresponding lateral track value YH. The smallest lateral influence function value, with corresponding lateral track YL, is picked from the upper limit of the preceding class, I1-1. The probability for the lateral influence function values to fall within the above mentioned limits is calculated as the integral of the lateral track density function between the corresponding tracks YL and YH. This is done in the procedure LATINT (Y4, Y5, Y6, Y1, YH, LØ), and G(T1,N) will be added to the final equivalent load density function X(...) with that weight.

This procedure is then repeated, until Y becomes equal to Y4, (that is the greatest lateral track value), for each discrete load value, each type of load and each lane.

The procedure for calculating equivalent load density functions is the same for each lane. The only difference is that the middle lateral influence function value, FØ, gets another value (see also FIG. 6.2.2-1) and that the track distributions are anti-symmetric if Y6 is negative, (see also FIG. 6.4.2-3).

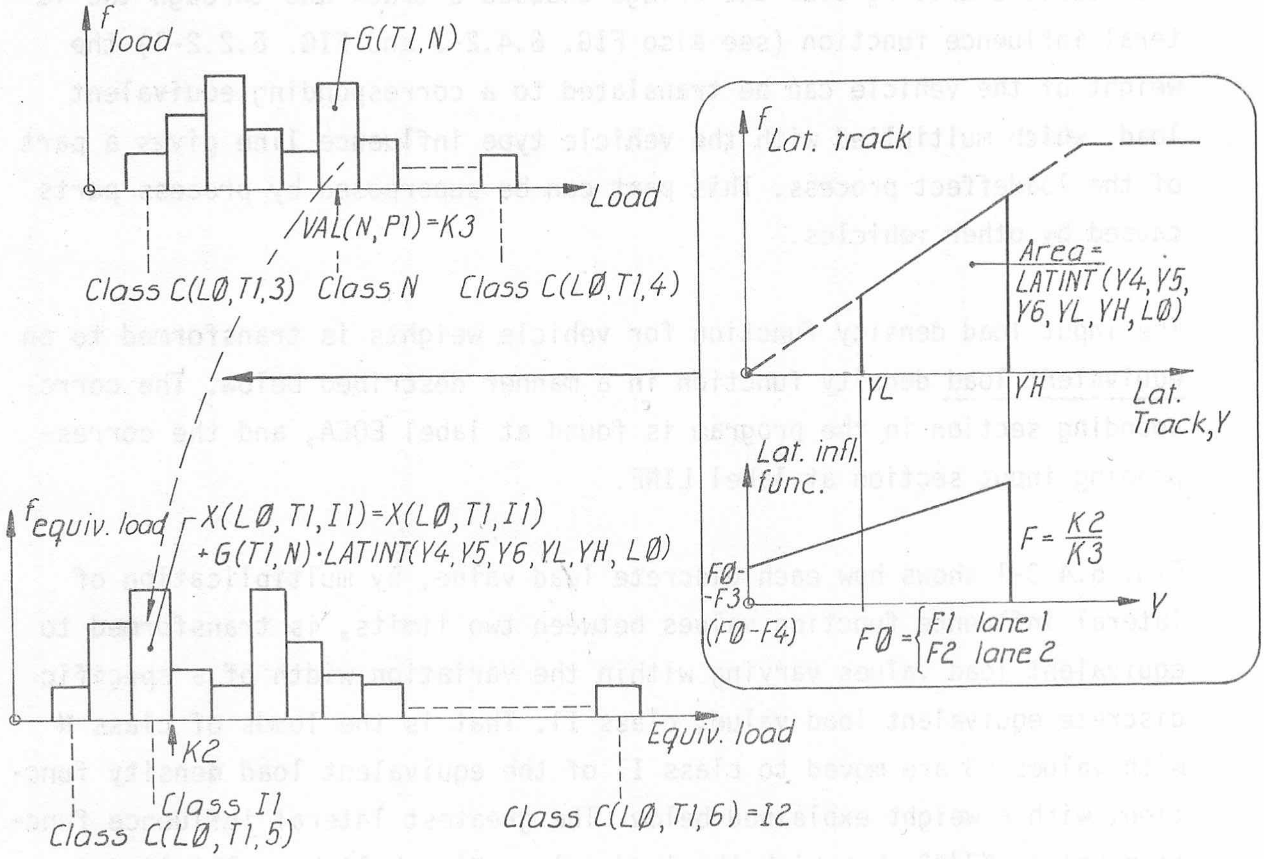


FIG. 6.4.3-1. Calculation of equivalent load density functions. Labels EQCA and LINF (input) in NULESP. (VAL function see NOTATIONS.)

The equivalent overlap load density function is used in the analyses of loadeffect process parts caused by more than one vehicle. Chapter 6.2.4 describes the input section where the desired discrete density function is specified by menas of histogram staple areas.

At label OVCA in NULESP the equivalent overlap load density functions are calculated, in a manner described below, see FIG. 6.4.3-2.For each lane, LØ, and load type, T1, the load density function is gone through from the greatest load value to the lowest. As soon as enough staples are collected to form an area (probability) greater or equal to the desired, a new class is formed with an equivalent overlap load value equal to the mean of the collected load classes. This is repeated until one class is left to be formed, the lowest, which automatically will consist of the remaining classes of the load density function. The equivalent overlap load density function is stored in O(LØ,T1,..).

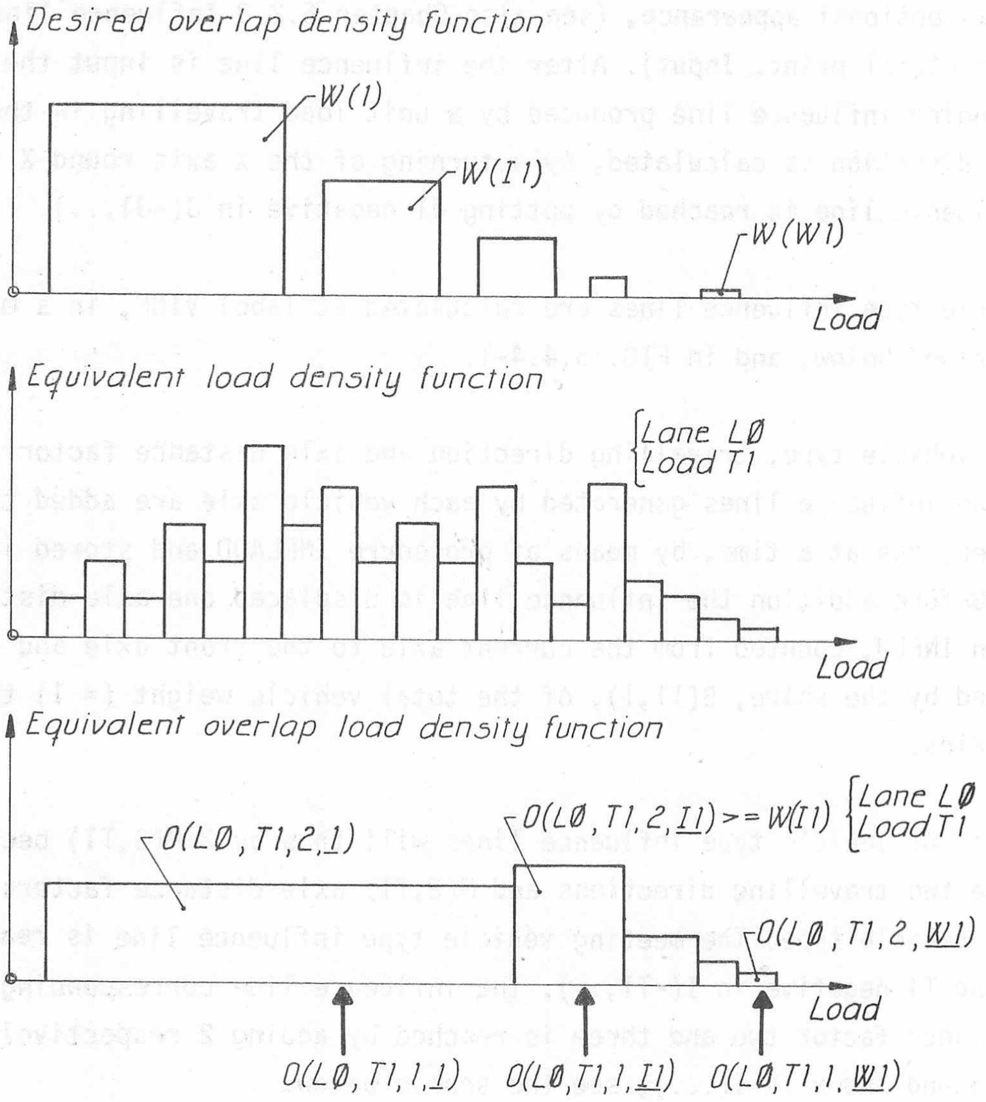


FIG. 6.4.3-2. Calculation of equivalent overlap load density functions. Labels OVCA and OVDI (input) in NULESP.

6.4.4 Calculation of vehicle type influence lines.

The influence line is input at label SINF in NULESP and stored in J(J1,..). There are four main types, J1, of influence lines of which the fourth has optional appearance, (see also Chapter 6.2.3 Influence line type. Structural point. Input). After the influence line is input the corresponding influence line produced by a unit load travelling in the opposite direction is calculated, by a turning of the X axis round X = Ø. This influence line is reached by putting J1 negative in J(-J1,..).

The vehicle type influence lines are calculated at label VINF, in a manner described below, and in FIG. 6.4.4-1.

For each vehicle type, travelling direction and axle distance factor H(...) the influence lines generated by each vehicle axle are added to each other, one at a time, by means of procedure INFLADD and stored in I(...). Before addition the influence line is displaced one axle distance, D3 in INFLU, counted from the current axle to the front axle and multiplied by the share, B(T1,1), of the total vehicle weight (= 1) that axle carries.

The number of vehicle type influence lines will thus be 2·M(3,T1) because there are two travelling directions and M(3,T1) axle distance factors for each vehicle type. The meeting vehicle type influence line is reached by putting T1 negative in I(-T1,..). The influence line corresponding to axle distance factor two and three is reached by adding 2 respectively 4 to the second index in I(...), see the scheme below.

Vehicle type influence line	meeting direction	axle distance factor number
I(T1,1,I1) = X value	I(-T1,1,I1)	1
I(T1,2,I1) = influence value	I(-T1,2,I1)	
I(T1,3,I1) = X value	I(-T1,3,I1)	2
I(T1,4,I1) = influence value	I(-T1,4,I1)	
I(T1,5,I1) = X value	I(-T1,5,I1)	3
I(T1,6,I1) = influence value	I(-T1,6,I1)	

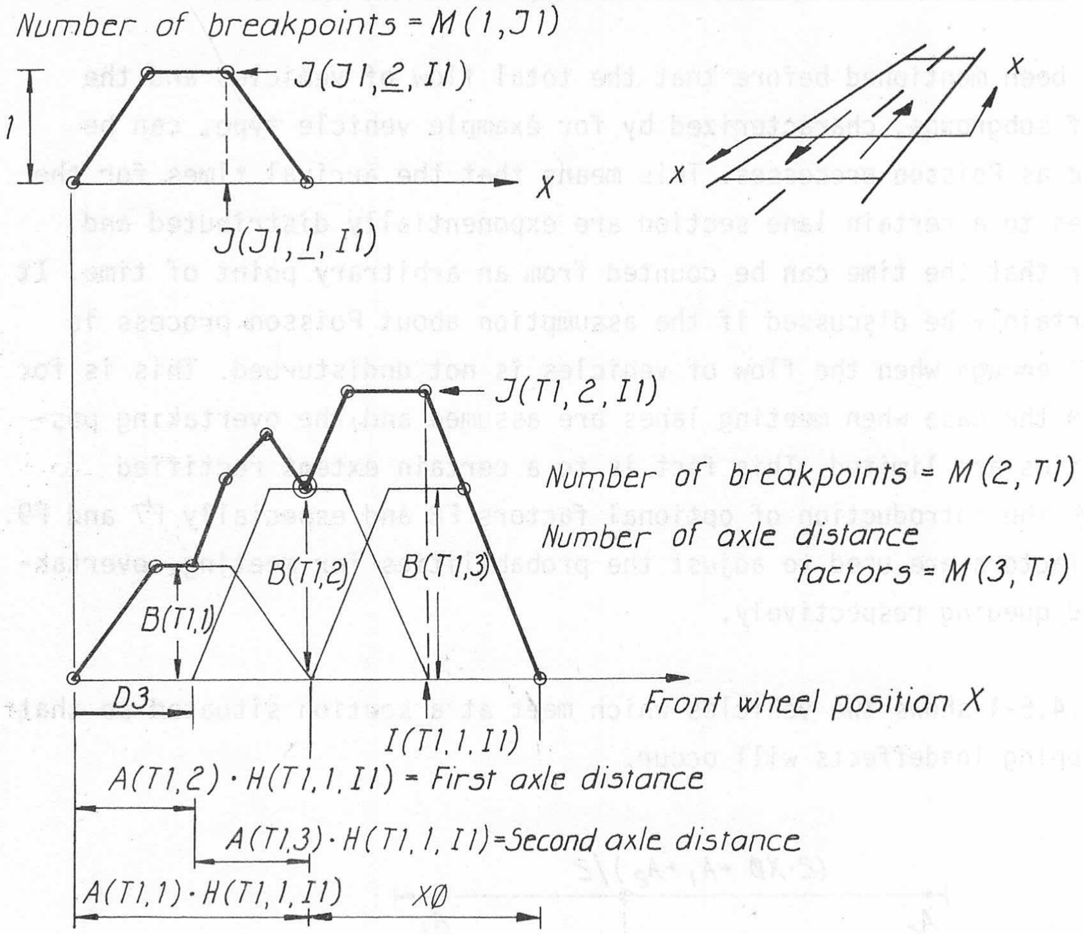


FIG. 6.4.4-1. Calculation of vehicle type influence lines.

It shall be pointed out that it is only in connection with J(...) and I(...) that negative J1 and T1 can be used thus meaning meeting direction. A negativ T1 (-1) used in connection with load descriptions means that the vehicle weights are treated as concentrated loads (total loads) in the calculations.

6.4.5 Calculations of probabilities for meeting and queuing.

It has been mentioned before that the total flow of vehicles and the flow of subgroups, characterized by for example vehicle type, can be treated as Poisson processes. This means that the arrival times for the vehicles to a certain lane section are exponentially distributed and further that the time can be counted from an arbitrary point of time. It may certainly be discussed if the assumption about Poisson process is correct enough when the flow of vehicles is not undisturbed. This is for example the case when meeting lanes are assumed and the overtaking possibilities are limited. This fact is to a certain extent rectified through the introduction of optional factors F8 and especially F7 and F9. These factors are used to adjust the probabilities for meeting, overtaking and queuing respectively.

FIG. 6.4.5-1 shows two vehicles which meet at a section situated so that overlapping loadeffects will occur.

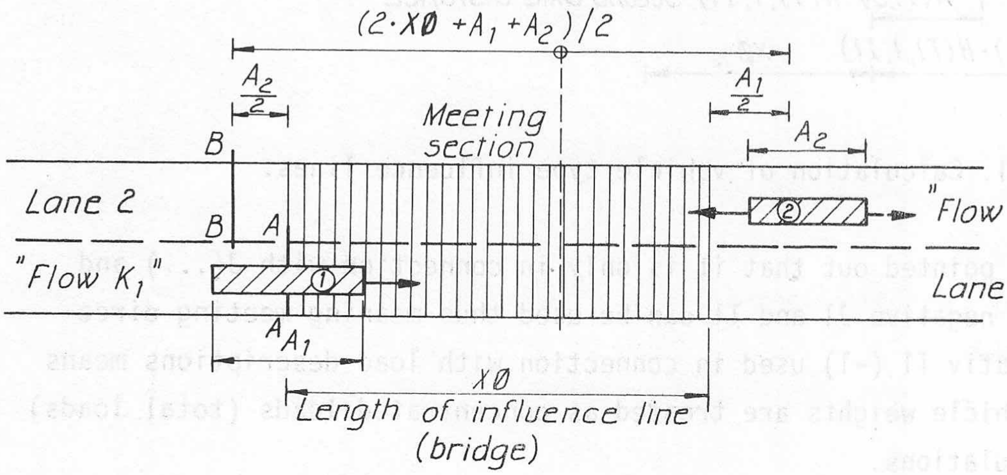


FIG. 6.4.5-1. Two vehicles meet causing overlapping loadeffects.

Vehicle 1, which is A_1 long, belongs to a flow of vehicles with K_1 vehicles passing the lane section during the time period YSEC, that is with mean intensity K_1/YSEC. Vehicle 2, in lane 2 with a length A_2, belongs to a flow with the mean intensity K_2/YSEC.

All vehicles are assumed to drive over the bridge with constant speed equal to VE. The value of the regarded time period YSEC is optional (for example the estimated bridge life time) multiplied by the equivalent time TE, which is a factor that can be used to reduce the available time if the traffic flow is very small or non-existent during a fraction of the day. Also weekly, monthly and yearly fluctuations can be compensated in this way.

The density functions for arrival times t at a lane section, of vehicles in flow K_i, where the time is referred to the front axle passages of the vehicles, becomes

$$f_i(t) = \frac{K_i}{YSEC} \cdot e^{-\frac{K_i}{YSEC} \cdot t} \qquad (1)$$

The number of meetings between vehicles in flow K_1 and K_2 that will cause overlapping loadeffects can now be calculated.

A vehicle from flow K_1 arrives at section A, see FIG. 6.4.5-1, at time pont t=Ø. If a vehicle from K_2 arrives at the same section within the time period - A_2/VE to (XØ+A_1+XØ)/VE overlapping loadeffects will arise. The corresponding meeting section variation range is marked in FIG. 6.4.5-1. Thus a vehicle from K_2 has to arrive to section B not later than t_m after the vehicle from K_1 passed it. The probability for this event becomes

$$P_{arrival} = \int_{\emptyset}^{t_m} \frac{K_2}{YSEC} \cdot e^{-\frac{K_2}{YSEC} \cdot t} \cdot dt = 1 - e^{-\frac{K_2 \cdot t_m}{YSEC}} \simeq$$

$$\simeq \frac{K_2 \cdot t_m}{YSEC} \qquad (2)$$

where

$$t_m = \frac{2 \cdot X\emptyset + A_1 + A_2}{VE}$$

$P_{arrival}$ is simplified to the first two terms of the Taylor Serie of $e^{-x} = 1-x+x^2/2-x^3/6+ \ldots$. This is justified by the fact that the exponent x is small and that it is an approximation on the safe side.

The probability that a certain vehicle from K_1 meets a vehicle from K_2 is $P_{arrival}$. The total number of meetings during YSEC, K_1^2, now becomes

$$K_1^2 = K_1 \cdot P_{arrival} = \frac{K_1 \cdot K_2 \cdot (2 \cdot XØ + A_1 + A_2)}{VE \cdot YSEC} \cdot F8 \qquad (3)$$

$$(\cdot F7/2)$$

As mentioned before a factor F8 for meeting and F7 for overtaking is introduced, which normally is put to 1, in order to make adjustment possible.

The same discussion as above can be made for a vehicle 2 overtaking a vehicle 1. It is assumed that vehicle 2 is in lane 2 during the overlap period. If vehicle 1 passes section A at time t=Ø, then vehicle 2 must pass the same section within $-(XØ+A_2)/VE$ to $(XØ+A_1)/VE$, that is the same time difference as above, t_m. The occurence intensities, however, have to be divided by two because each event is counted twice (K_2 followed by K_1 and K_2 ahead of K_1). The reason for expressing the probability for overtaking in this way is that the same computer routine can now be used to calculate overlap effects of meeting and overtaking.

Approximate expressions for the number of queues consisting of one vehicle from flow K_1 followed by one from K_2 is discussed below.

As mentioned before there are great uncertainties about the vehicle queue behaviour. The problem is dealt with in the following way. First the probability for a queue driving over the bridge is estimated then the distance between the vehicles at bridge passage is picked from a queue distance density function, which is found in Chapter 6.4.7 Analyses of different overlap cases. It is assumed that overlapping of more than two vehicles in one lane can not occur, because it requires a too long influence line. All the vehicles have the same speed during passage of the bridge.

In section A, which is situated a distance apart from the bridge, FIG. 6.4.5-2, the time gap between two vehicles in the Poisson flow is observed. If this time is less than the critical queue time, T9, it is assumed that conditions for a queue to arise exist with a probability equal to 0.5. The figure 0.5 is an estimation based upon an idealized

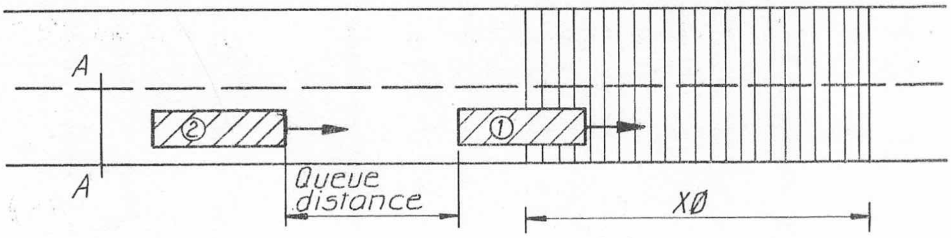


FIG. 6.4.5-2. Two vehicle forming a queue causing overlap loadeffects.

assumption that in half the cases the second vehicle is running faster than the first vehicle after the passage of section A. The queue is still treated as two separate vehicles in the flow which involves that subsequent vehicles within T9 seconds to the queue may be parts of other two-vehicle-queues together with the vehicles ahead. In this way a queue of n vehicles will be treated as (n-1) two-vehicle-queues and loadeffects of (n-2) extra singel vehicles are introduced. The advantage is that vehicles situated inside the queue are allowed to cause overlapping effects with neighbouring vehicles, see FIG. 6.4.5-3.

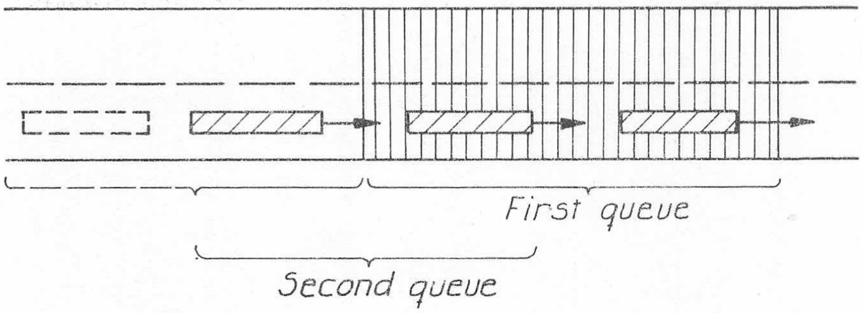


FIG. 6.4.5-3. Treatment of queues longer than two vehicles.

The probability that a vehicle 2 belonging to flow K_2 will arrive at section A, see FIG. 6.4.5-2, T9 seconds after vehicle 1 belonging to K_1 has passed that section, is calculated in a similar manner as $P_{arrival}$ above.

$$2 \cdot P_{follow} = \int_{\emptyset}^{T9} \frac{K_2}{YSEC} \cdot e^{-\frac{K_2 \cdot t}{YSEC}} \cdot dt \simeq \frac{K_2 \cdot T9}{YSEC} \qquad (4)$$

The probability that a specific vehicle from K_1 is followed by a vehicle from K_2 is P_{follow}, thus the total numbers of queues, $K_{1,2}$, during YSEC becomes

$$K_{1,2} = K_1 \cdot P_{follow} = \frac{K_1 \cdot K_2 \cdot T9}{YSEC \cdot 2} \cdot F9 \qquad (5)$$

The number of queues can be adjusted through the factor F9, which normally is put to 1.

An example of how the queue can arise is shown. The time gap between two vehicles at section A is 10 seconds, which in this case is judged to be a critical queue time. Suppose that vehicle 2 travels with the average speed 22 m/s during the bridge approach and vehicle 1 with 20 m/s. 10 seconds time gap corresponds to ≈ 200 m length gap. If the vehicle length is neglected it takes 200/(22-20) = 100 seconds to reduce the length gap to a queue gap, which is done on 22·100=2200 m road length.

The flows K_1^2 and $K_{1,2}$ are now used to derive the number of occurences for the other overlap cases that are used in the model. See the table, FIG. 6.4.5-4 below.

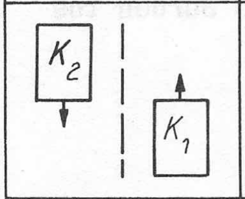
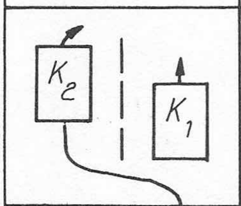
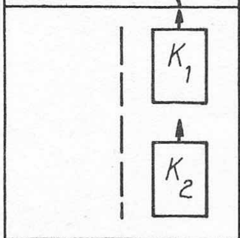
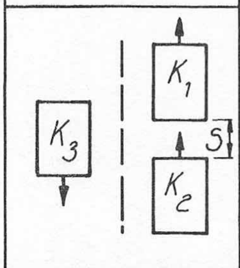
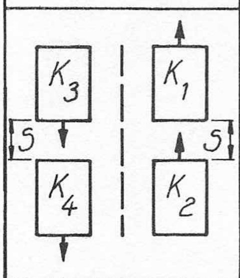
OVERLAP CASE	$\boxed{K_i}$ = vehicle belonging to flow K_i Vehicle length = A_i Bridge length = $X\emptyset$ Queue distance = S
	MEETING: $$K_1^2 = \frac{K_1 \cdot K_2 \cdot (2 \cdot X\emptyset + A_1 + A_2)}{VE \cdot YSEC} \cdot F8 \text{ ----- } (3A)$$
	OVERTAKING: $$K_1^2 = \frac{K_1 \cdot K_2 \cdot (2 \cdot X\emptyset + A_1 + A_2)}{VE \cdot YSEC \cdot 2} \cdot F7 \text{ ------ } (3B)$$
	QUEUE: $$K_{1,2} = \frac{K_1 \cdot K_2 \cdot T9}{YSEC \cdot 2} \cdot F9 \text{ -------------- } (5)$$
	QUEUE MEETING: $$K_{1,2(3)}^{3} = \frac{K_{1,2} \cdot K_3 \cdot (2 \cdot X\emptyset + A_1 + A_2 + S + A_3)}{VE \cdot YSEC} \cdot F8 =$$ $$= \frac{K_1 \cdot K_2 \cdot K_3 \cdot (2 \cdot X\emptyset + A_1 + A_2 + A_3 + S) \cdot T9}{VE \cdot YSEC \cdot YSEC \cdot 2} \cdot F8 \cdot F9 \text{ ------ } (6)$$
	QUEUE MEETING QUEUE: $$K_{1,2(3)}^{3,4} = \frac{K_{1,2} \cdot K_{3,4} \cdot (2 \cdot X\emptyset + A_1 + A_2 + A_3 + A_4 + 2 \cdot S)}{VE \cdot YSEC} \cdot F8 =$$ $$= \frac{K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot (2 \cdot X\emptyset + A_1 + A_2 + A_3 + A_4 + 2 \cdot S) \cdot T9 \cdot T9}{VE \cdot YSEC \cdot YSEC \cdot YSEC \cdot 4} F8 \cdot F9 \cdot F9 \text{ -----} (7)$$

FIG. 6.4.5-4. Number of overlap occurences involving partial vehicle flows.

6.4.6 Analyses of loadeffect process caused by single vehicles.

At label LEDI directives are given for the loadeffect calculations made in NULESP. The calculations are performed at label LECA. The analyses of those parts of the loadeffects which are caused by single vehicles or axles are described separately in this chapter so as not to burden the overlap analyses description in Chapter 6.4.7.

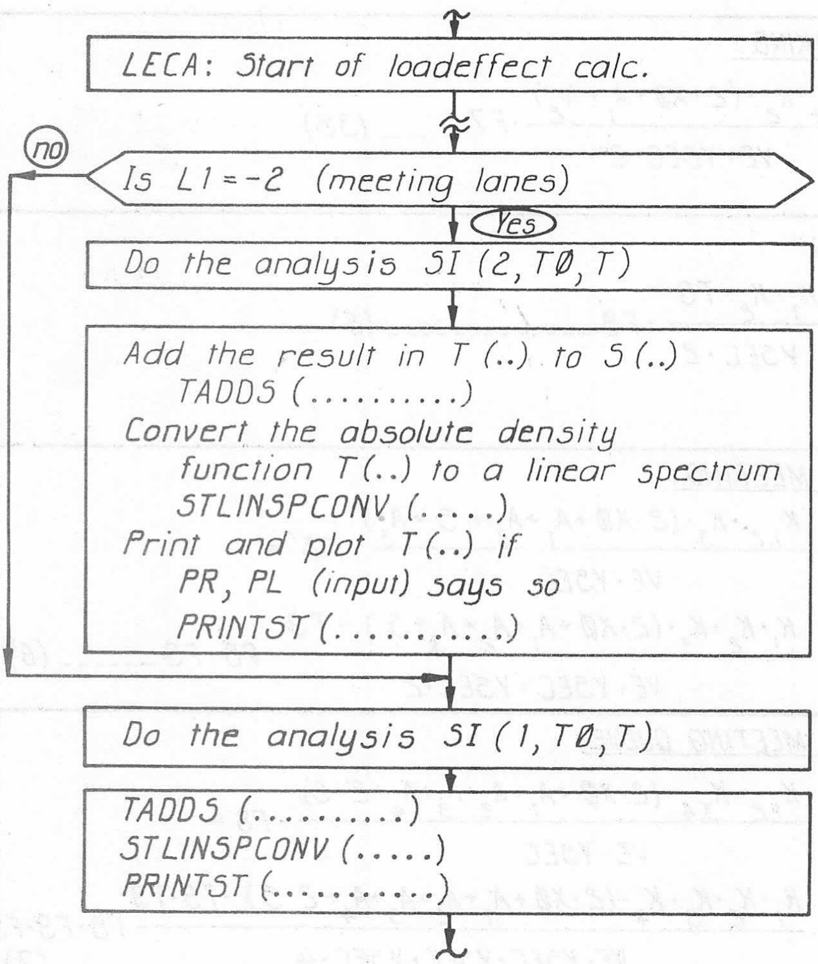


FIG. 6.4.6-1. Analyses of loadeffect process of single vehicles.

The actual analyses of the loadeffect process are performed in procedure SI(...) ("single")

SI(LS,TØ,T)

where LS = lane 1 or 2 carrying single vehicles

TØ = type of used load

T(..) = array in which the result is stored

FIG. 6.4.6-1 shows, through a flow chart, the main elements of the single vehicle analyses, which have to be executed after the overlap analyses, because those vehicles already involved in overlapping must be extracted from the total number of vehicles, K(LS,T1,2), passing a lane section during the studied time period, bridge life.

Procedure SI(LS,TØ,T) does the following:

If TØ = -1 or Ø, that is concentrated (total) loads or axle loads are used, the proper influence line is picked from J(...) and transfered to Q(..), by procedure INFLTOYQ(J,J1,1,.,1,.,.,.,Q,.). The LECOUNT(Q,.,R,...) procedure does the loadeffect process analysis storing the counted ranges and corresponding levels in R(..).

For each load class, N, of the equivalent load density function, the corresponding value of the load

VAL(N,P1)

and number of vehicle passages (TØ=-1 or TØ=Ø)

FACT = X(LS,TØ,N) · (K(LS,TØ,2) - SONB(LS,TØ))

are calculated. As can be seen the total number of vehicles are reduced with SONB(..), which is the sum of vehicles of type T1 and lane LS, already used in the overlap calculations.

Each counted loadeffect range-level is now multiplied with the load value, VAL(N,P1), of the class and added to matrix T(..) with a weight equal to FACT.

If TØ = 1, that is vehicle type loads are used, the analyses are carried out principally in the same manner. Two more pointers are introduced, namely vehicle type T6 and axle distance factor AX and instead of transferring J(...) the proper vehicle type influence line I(...) is transferred by INFLTOYQ(I,T6,AX,.,1,.....). The weight, FACT, will be altered to

FACT = X(LS,T6,N) · H(T6,2,AX) · (K(LS,T6,2) - SONB(LS,T6))

For further study of procedure SI(...) reference is made to the NULESP program.

6.4.7 Analyses of different overlap cases.

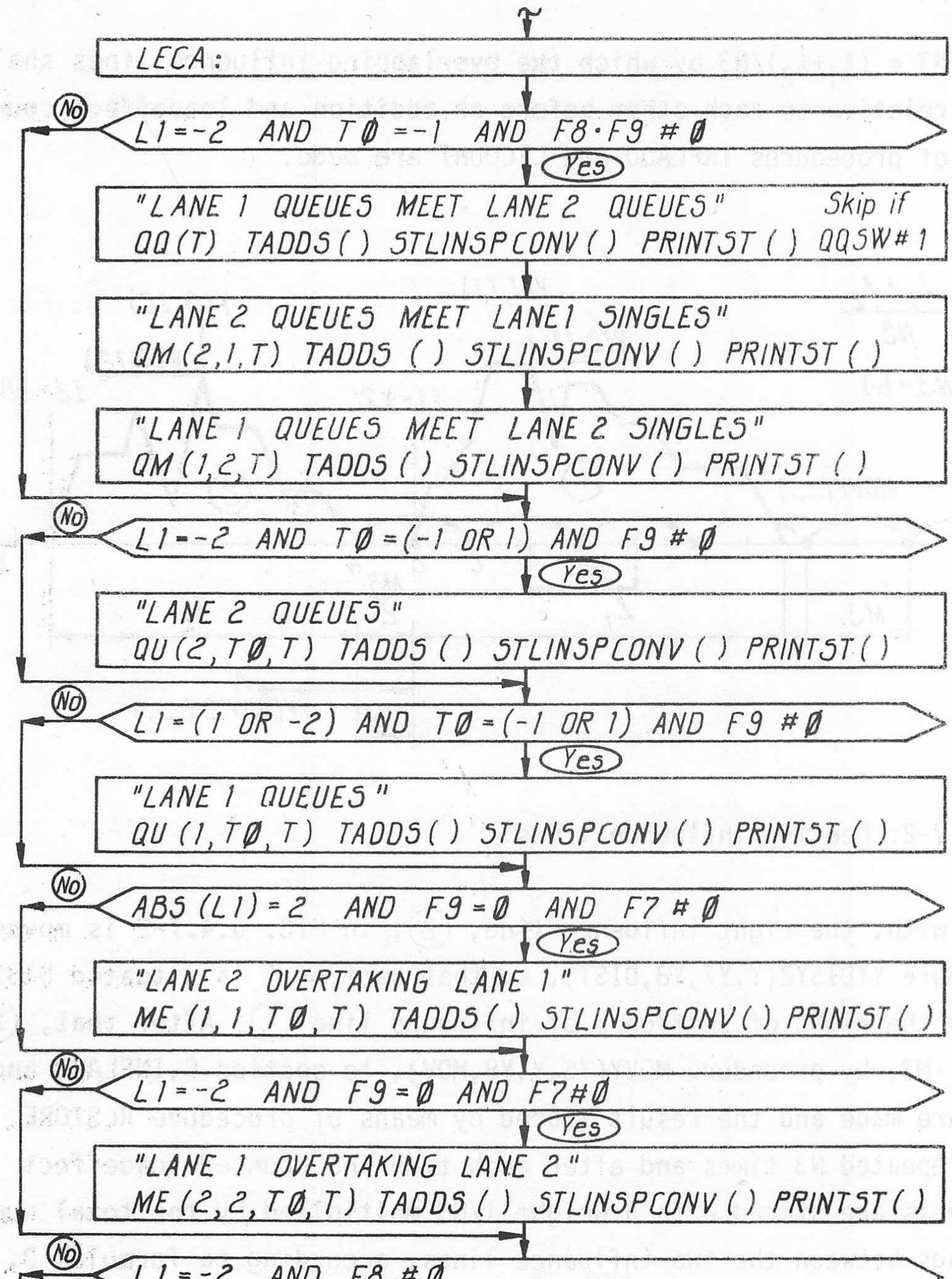
At label TRIN, traffic data input, and LEDI, loadeffect calculation directives, the necessary information is given for guiding the overlap calculations. FIG. 6.4.7-1 shows the main elements of the analyses and furthermore describes how the analyses are guided through the different calculation cases (see also the table in FIG. 6.4.2-5). The main procedures used are (except those later described which do the actual loadeffect process analyses) TADDS(.........) which adds result matrix T(..) to cumulative matrix S(..), STLINSPCONV(.....) which converts the absolute loadeffect density function T(..) to a linear spectrum and finally PRINTST(..........) which prints and plots the spectrum if desired.

The approximation is made, on the safe side, that the vehicles involved in an overlap case still participate in the total undisturbed Poisson flow. If TØ = -1 or Ø, that is concentrated (total) vehicle loads or axle loads are assumed, the influence line J(...) is used and if TØ = 1, type loads, the vehicle type influence lines I(...) are used. In all the calculations the equivalent overlap load spectrum O(LØ,T1,.,N) is used instead of X(LØ,T1,N) (LØ = lane number, T1 = vehicle type (-1 to T2) and N = class number).

Before som comments on the different parts of the analysis are made, the technique used to calculate the overlap loadeffect range-levels of meeting and queuing influence lines will be described.

Meeting influence lines:

The influence lines which are meeting in a way that overlapping occurs are placed in matrix Y(..). Each meeting section along the meeting zone has equal probability to be subjected to a meeting. Therefore it is assumed that the meetings take place in N3, along the total meeting zone, uniformly distributed meeting sections, where each section gets 1/N3 of the total number of meetings. This gives a meeting increment



L1=1 one lane
-2 meeting lanes
2 parallell lanes

TØ=-1 total load
Ø axle load
1 type load

F7 factor on overtaking prob.

F8 factor on meeting prob.

F9 factor on queue prob.

FIG. 6.4.7-1. Analyses of overlap loadeffect process with procedure calls.

distance M3 = $(\ell_1+\ell_2)/N3$ by which the overlapping influence lines shall be moved relative to each other before an addition and loadeffect count by means of procedures INFLADD and LECOUNT are made.

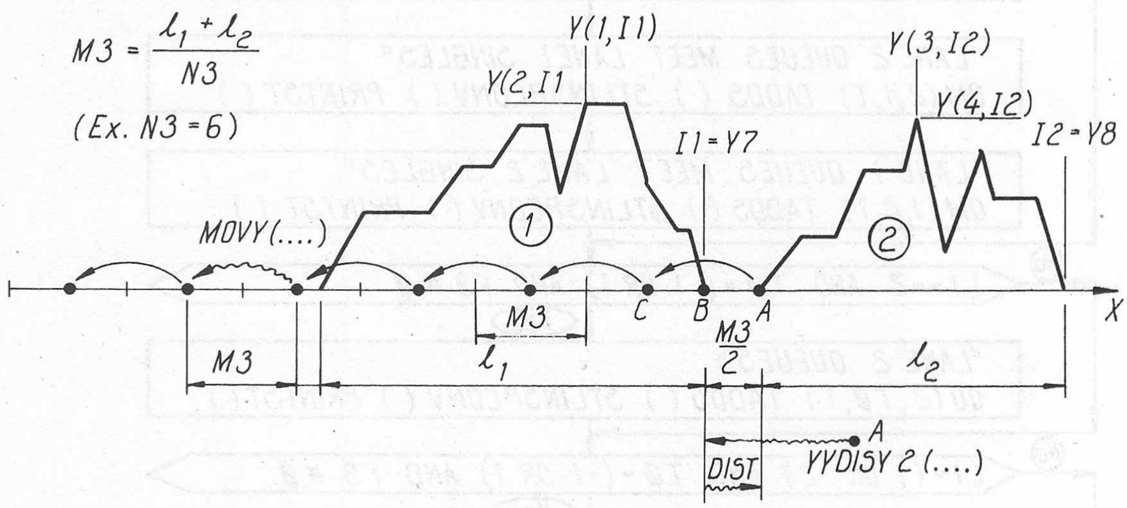


FIG. 6.4.7-2. Meeting influence lines.

To start with, the right influence line, (2), in FIG. 6.4.7-2 is moved, by procedure YYDISY2(Y,Y7,Y8,DIST), so that section A is situated DIST = = M3/2 to the right of section B of influence line (1). After that, (2) is moved -M3, by procedure MOVY(YS,Y,Y8,MOV), to section C,INFLADD and LECOUNT are made and the result stored by means of procedure RLSTORE. This is repeated N3 times and after each time the counted loadeffect range-levels are stored with a weight 1/N3 multiplied by the total number of meetings between the two influence lines, according to formulas 3, 6 or 7 of Chapter 6.4.5.

Queuing influence lines

The queue distances are assumed to be distributed according to FIG. 6.4.7-3.

As before the influence lines are placed in Y(..). The queue case is calculated for S4 discrete queue distances between SØ and S1.

If the largest queue distance S1 is greater than the bridge length XØ, S1 is put equal to XØ and F9, the factor by which the number of queue occassions can be adjusted is automatically reduced. If the shortest queue distance SØ is greater than XØ, F9 is put to Ø.

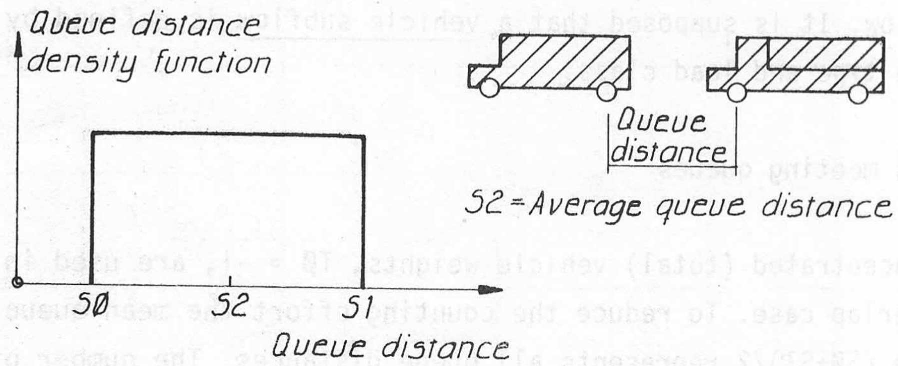


FIG. 6.4.7-3. Queue distance density function.

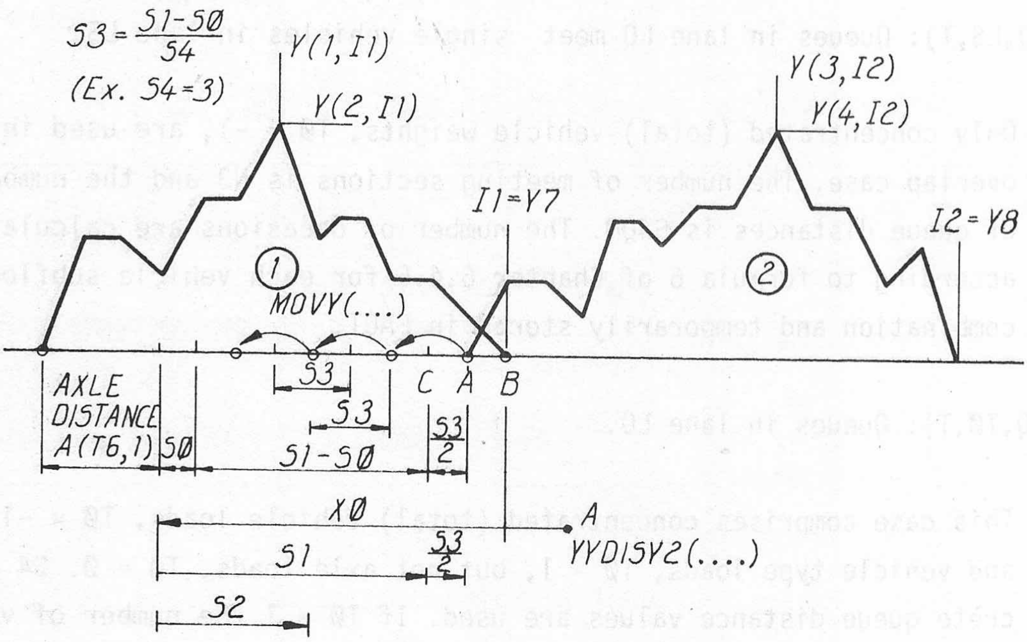


FIG. 6.4.7-4. Queuing influence lines.

Influence line (2) is now placed S1+S3/2 behind the last axle of influence line (1), by procedure YYDISY2(Y,Y7,Y8,S1+S3/2-XØ). S3 = (S1-SØ)/S4 is the queue distance increment. After that (2) is moded -S4 by procedure MOVY to section C, INFLADD and LECOUNT are made and the result stored by means of procedure RLSTORE. This is repeated S4 times and each time the counted range-levels are stored with a weight 1/S4 (because the queue distances are supposed to be uniformly distributed) multiplied by the total number of queues involving the two influence lines, which are calculated according to formula 5 of Chapter 6.4.5.

The actual analyses of the loadeffect process is done by the procedures described below. It is supposed that a vehicle subflow is defined by lane, vehicle type and load class.

QQ(T): Queues meeting queues

Only concentrated (total) vehicle weights, TØ = -1, are used in this overlap case. To reduce the counting effort the mean queue distance (SØ+S1)/2 represents all queue distances. The number of meeting sections are N3 and the number of occasions is calculated according to formula 7 of Chapter 6.4.5 for each vehicle subflow combination and temporarily stored in FACT.

QM(LQ,LS,T): Queues in lane LQ meet single vehicles in lane LS.

Only concentrated (total) vehicle weights, TØ = -1, are used in this overlap case. The number of meeting sections is N3 and the number of queue distances is S4QM. The number of occasions are calculated according to formula 6 of Chapter 6.4.5 for each vehicle subflow combination and temporarily stored in FACT.

QU(LQ,TØ,T): Queues in lane LQ.

This case comprises concentrated (total) vehicle loads, TØ = -1, and vehicle type loads, TØ = 1, but not axle loads, TØ = Ø. S4 discrete queue distance values are used. If TØ = 1 the number of vehicle subflows is increased, pointers T6 and T7 to vehicle types, leading to two more calculation loops and greater counting effort. The number of meeting occasions for each subflow combination is calculated according to formula 5 of Chapter 6.4.5 and temporarily stored in FACT.

ME(LA1,LA2,TØ,T): Single vehicles of lane LA1 meeting single vehicles of lane LA2 (LA1≠LA2).
Single vehicles of lane LA2 overtaking single vehicles of lane LA1 (LA1=LA2).

All types of loads can be treated in this overlap case. The number of meeting sections (overtaking sections) is N3. The number of meeting (overtaking) occasions for each vehicle subflow combination is calculated according to formula 3 of Chapter 6.4.5 and temporarily stored in FACT.

In all of the above mentioned procedures the proper influence lines and vehicle type influence lines are transferred to a temporary matrix by procedure INFLTOYQ(....,0,JØ,.,...). The influence values are multiplied by 0 and if JØ = -1 the "meeting" influence line is transferred.

The number of vehicles involved of different types and lane belongings are counted in ONB(LØ,T1) for each overlap case and accumulated in SONB(LØ,T1) when the overlap case calculations is left. In the same way the number of occurences for each overlap case are counted in OCC and accumulated in SOCC.

In order to give an idea about the number of loadeffect process parts which have to be analysed by LECOUNT, some guiding figures are presented below in FIG. 6.4.7-5.

Suppose: T2 = 5 vehicle types N3 = 10 meeting sections
W1 = 6 overlap cases S4 = 10 queue distances
L1 = -2 meeting lanes S4QM = 3 queue distances

PROCEDURE	TØ = -1 Total	TØ = Ø Axle	TØ = 1 Type
QQ	$W1^4 \cdot N3 = 12960$	———	———
QM·2	$W1^3 \cdot N3 \cdot 2 \cdot S4QM = 12960$	———	———
QU·2	$W1^2 \cdot S4 \cdot 2 = 720$		$(T2 \cdot W1)^2 \cdot S4 \cdot 2 = 18000$
ME·2 (overtake)	$W1^2 \cdot N3 \cdot 2 = (720)$	$W1^2 \cdot N3 \cdot 2 = (720)$	$(T2 \cdot W1)^2 \cdot N3 \cdot 2 = (18000)$
ME	$W1^2 \cdot N3 = 360$	$W1^2 \cdot N3 = 360$	$(T2 \cdot W1)^2 \cdot N3 = 9000$
Suppose that the number of vehicle resp. axle weight classes in X(...) = 60 resp. 20. Put the number of axle distance factors to 3. An approximation of the number of process parts caused by single vehicles can now be made.			
SJ·2	$60 \cdot 2 = 120$	$60 \cdot 2 = 120$	$60 \cdot T2 \cdot 3 \cdot 2 = 1800$

FIG. 6.4.7-5. Estimation of the number of loadeffect process parts to be analysed.

6.4.8 Modification of loadeffect spectra for dynamic effects.

The modification of the loadeffect range-level density function for a dynamic amplification factor is found at label DYCA in the NULESP program. The stochastic dynamic amplification factor is input at label DYDI and further described in Chapter 6.2.7 Dynamic amplification factor distribution.

The modification calculations are executed in procedure DYNCONV(S,...., AI,AM,T,....), where S(..) is converted and stored in T(..). The dynamic amplification factor density function is stored in AM(..) and consists of AI classes.

FIG. 6.4.8-1 shows how the conversion is made for one range-level value. The loadeffect range amplitude is enlarged according to the amplification factor values. The number of new range amplitudes is equal to the original number multiplied by the corresponding probabilities for the amplification factors of coming up. The new levels are calculated outgoing from a symmetric range amplitude amplification. The dynamic effects are further discussed in Chapter 9.3.3.

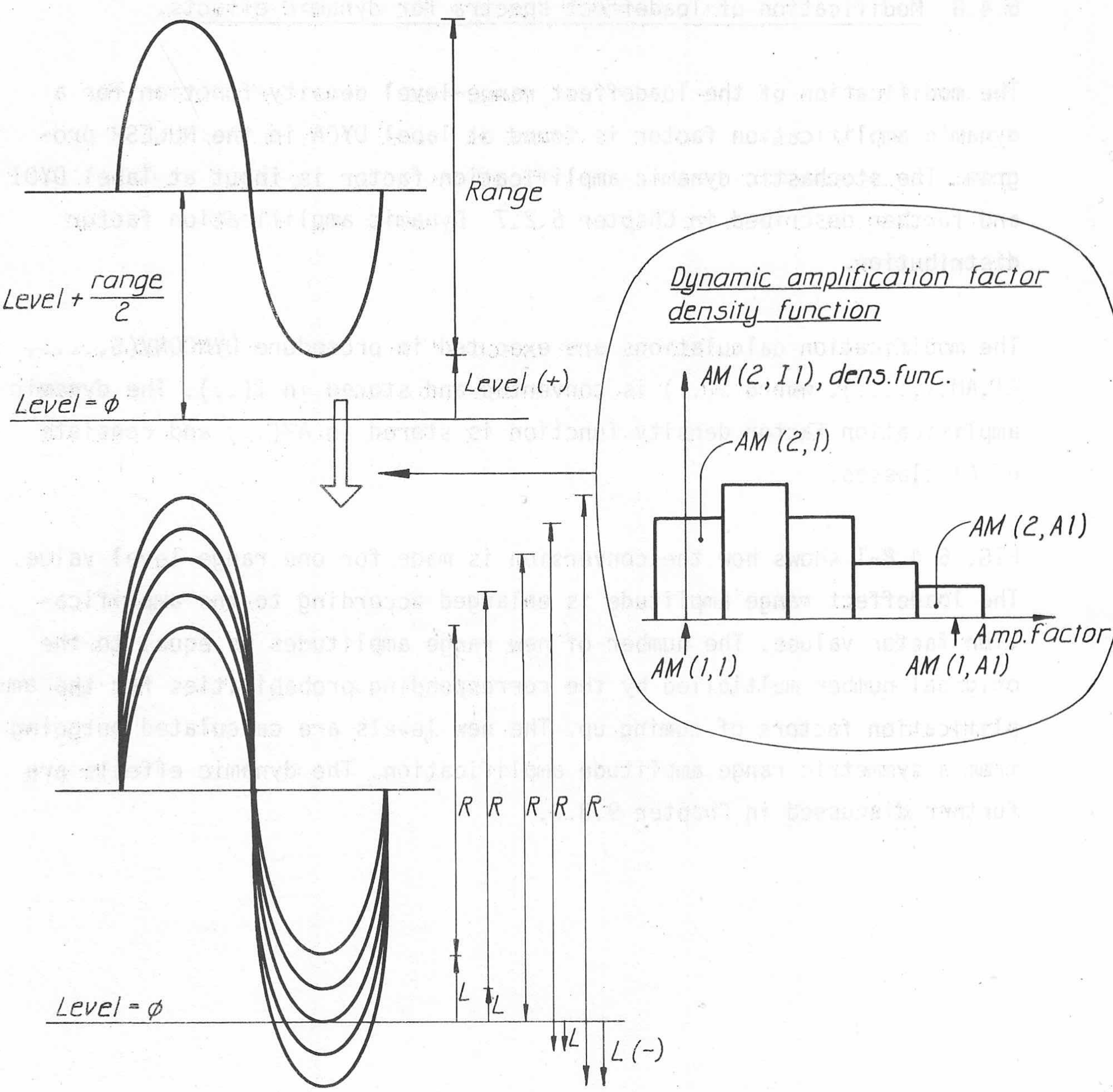
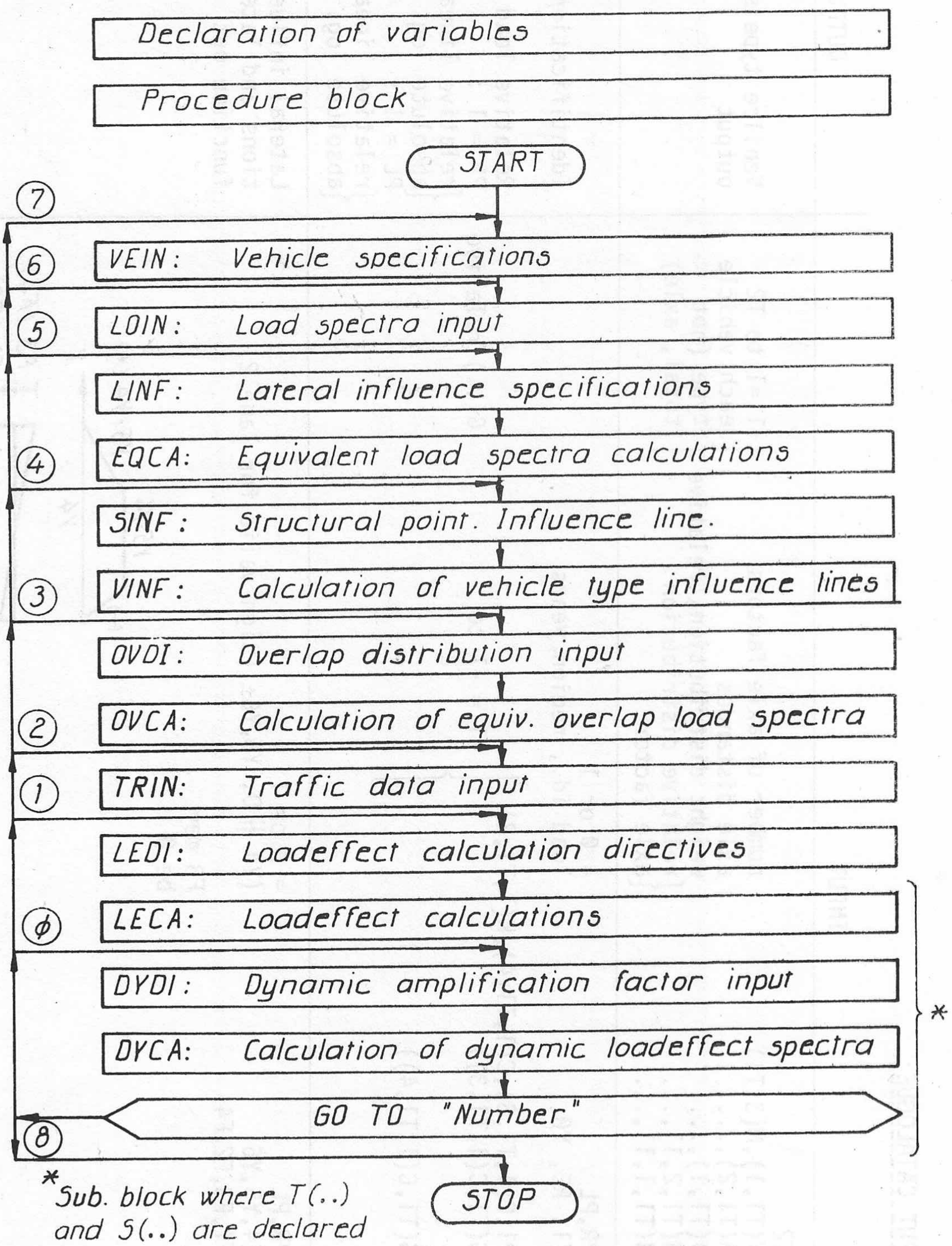


FIG. 6.4.8-1. Dynamic amplification of a loadeffect range.

6.4.9 Flow chart and input-output catalogue.

This chapter contains a flow chart including the main elements of the algol computer program NULESP. The input-output catalogue is aimed to be a support for the memory when arranging the input values and determining the output.

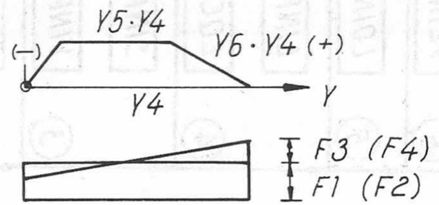
FLOWCHART NULESP:

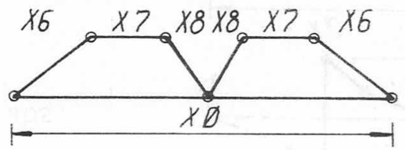
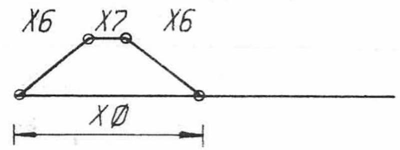


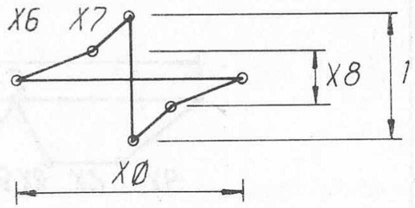
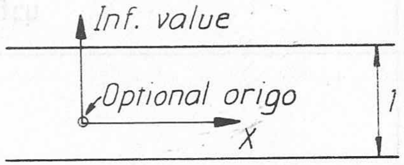
*Sub. block where T(..) and S(..) are declared

INPUT-OUTPUT CATALOGUE:

LABEL:	INPUT		OUTPUT
VEIN:	T2 V(T1,1),M(3,T1) A(T1,2),... B(T1,1),... H(T1,2,1),... H(T1,1,1),...	number of axle factors axle distances weight distribution, relative {relative distribution {axle factor } T1=1 to T2 each vehicle type (not total, axle)	Vehilce type specification output
LOIN:	PR,PL Y1, RE, YØ P1,C(1,T1,3),C(1,T1,4),K(1,T1,2) G(T1,C(1,T1,3)) : G(T1,C(1,T1,4))	= Ø or 1 load id., region, years } T1 = -1 to T2 G(..) relative	Identifications out Relative load density function TABLE PR = 1 : {relative linear load spectrum TABLE {absolute log. load spectrum TABLE PL = 1 : {relative linear load spectrum PLOT {absolute log. load spectrum PLOT
LINF:	PR,PL Y4,Y5,Y6 F1,F3,F2,F4	= Ø or 1 (Y4 ≠ 0, Y5,Y6± (Sign valid for lane 2) F3 may be Ø	Lateral influence track specifications and lateral influence function out



LABEL:		INPUT	OUTPUT	
EQCA:			Relative equivalent load density function. Lane 1	TABLE
			Same Lane 2	TABLE
			PR = 1: (PR,PL from LINF)	
			Relative linear equivalent load spectrum Lane 1	TABLE
			Absolute log. equivalent load spectrum Lane 1	TABLE
			PL = 1 :	
			Same. Linear Lane 1	PLOT
			Same. Logarithmic Lane 1	PLOT
			PR = 1	
			Same. Linear Lane 2	TABLE
			Same. Logarithmic Lane 2	TABLE
			PL = 1	
			Same. Linear Lane 2	PLOT
			Same. Logarithmic Lane 2	PLOT
SINF:	J1, Ø	influence line type length	Influence line specifications	
	J1 = 1 : X6,X7,X8	relative 	Loadeffect count on influence line and meeting influence line	
	J1 = 2: X6,X7	relative 		

LABEL:	INPUT		OUTPUT
	J1 = 3 : X6,X7,X8	rel., rel., abs. 	
	J1 = 4 : M(1,J1) J(4,1,1),J(4,2,T) : J(4,1,M(1,J1)),J(4,2,M(1,J1))	number of points ≤ 12, (X, infl. value) (Infl. variation ≤ 1) 	
VINF:			Vehicle type influence lines for all vehicle types, axle factors and two driving directions are printed + prints of LECOUNTS
OVDI:	W1 W(2),...W(W1)	number of classes ≤ 6 absolute	desired overlap distribution out
OVCA:			Print of equivalent overlap load density functions T1 = -1 to T2, two lanes
TRIN:	VE, TE, F8, F7 T9,SØ,S1,F9	speed, equivalent time, meeting overtaking factor critical queue time, low-high queue distance queuing factor	Traffic data is output. F9 may have been changed.

LABEL:	INPUT		OUTPUT
LEDI:	L1,TØ	L1=1,-2,2 Single, meeting and parallel lanes TØ=-1,Ø,1 total, axle and type load	Computed T(..) and S(..) dimensions WØ,ZØ N3,S4,S4QM
	WØ,ZØ,A9,QQSW	range-level increment, max. dynamic amplication factor, QQSW=Ø no QQ calculations	
	N3,S4,S4QM	N3,S4,S4QM number of meet. and queue sections (in proc. ME (QQ), QU and QM)	
	PR,PL,PRT,PLT	partial spectra {PR=1 print, PL=number of curves to be plotted total spectra {PRT=1 print, PLT=number of curves to be plotted	
LECA:			(PR,PL,PRT,PLT from LEDI) PR=1: {Relative linear loadeffect spectrum. Partial = overlap case. — TABLE {Absolute logarithmic loadeffect spectrum. Partial. — TABLE PL # 0: {Same. Linear — PLOT {Same. Logarithmic — PLOT : : { For each overlap case — TABLES PLOTS PRT=1: {Relative linear loadeffect spectrum. Total (no dynamic effects). — TABLE {Absolute logarithmic. Same. — TABLE

LABEL:	INPUT		OUTPUT	
			PLT ‡ Ø: {Same. Linear {Same. Loagarithmic	 PLOT PLOT
DYDI:	A1 AM(2,1),...AM(2,A1) AM(1,1),...AM(1,A1) PRT,PLT	number of classes ≤ 1Ø relative distribution dynamic amp. factor (≤ A9) PR = 1 print, PLT curves to be plotted	Dynamic amplification factor density function out	
DYCA:			PRT = 1: {Relative linear loadeffect {spectrum. Total {Absolute logarithmic. Same. PLT ‡ Ø: {Same. Linear. {Same. Logarithmic	 PRINT PRINT PLOT PLOT
	Switch = 0 go to DYDI 1 LEDI 2 TRIN 3 OVDI 4 SINF 5 LINF 6 LOIN 7 VEIN 8 END			

6.5 Discussion of certain variables influence on the result.

This chapter contains information about the response of the loadeffect spectrum model to changes in certain input values. Information is also given about the absolute influence were it is judged to be meaningful. The studies are only made on the logarithmic spectra representations which will emphasize the high loadeffect ranges. No regard is given to the levels on which the loadeffect ranges occur.

Of course it is not possible to make the studies complete because of the great number of possible input values and the rather limited computer time resources available. Neither is it the authors aim to make a too comprehensive study because, as pointed out earlier, there are great uncertainties in the underlying data and NULESP, therefore, has to be regarded as a rather coarse tool or aid for calculation of loadeffect spectra.

Three types of influence lines were used in the study. In practical calculations the best estimations of input values are used at a first stage and then the obtained result may be studied and adjusted by means of the conclusions drawn in this chapter and if necessary new runs will be performed.

The shapes of the used influence lines, see FIG. 6.5-1, are the same as the standard shapes of the NULESP model and may be representative of the moment at support of a two-span beam, the deflection or dynamically smoothed moment at midspan of a simply supported beam and finally, shear forces at midspan of a simply supported beam. The used base load spectrum is picked from Chapter 4.3, Predicted load spectra, and valid for the rural long distance region. The lateral influence function was supposed to vary between 0.4 and 0.6 for the two lanes with a corresponding uniformly distributed lateral track. The dynamic amplification factor influence is studied separately.

Much of the obtained results from the runs are not reproduced here. Samples from a run are found in Appendix F.

In the first chapter below, 6.5.1, influences of variables which are entirely tied to the chosen model and solution technique are discussed. In the last Chapter, 6.5.8 Summing up results, a short summing up of the most important input variables is made and suggestions are given to values of variables, which could be held fixed.

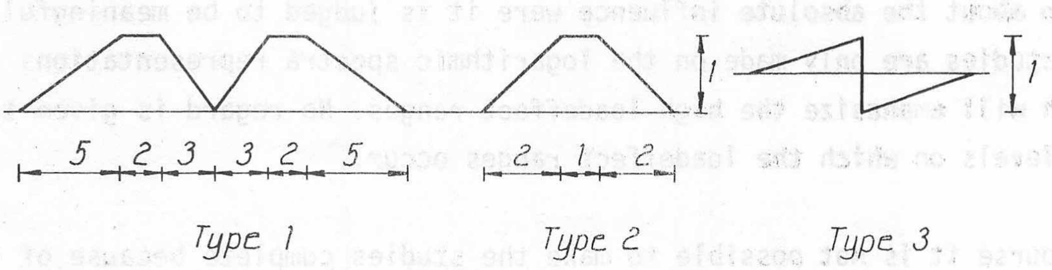


FIG. 6.5-1. Used influence lines.

6.5.1 Number of meeting sections. Appearance of overlap load distribution. Influence line detail appearance.

The number of meeting sections N3 and queuing distances S4 (S4QM) must be great enough in the overlap calculations so that great and dangerous loadeffect ranges are not lost, that is loadeffect process parts for certain meeting sections do not arise. The number of meeting sections ought to be odd, thus allowing two vehicle influence lines of the same type to coincide exactly (the vehicles will meet in mid section of the bridge) causing maximum loadeffects if the influence line is symmetric.

There are algorithms placed at label LEDI in the NULESP program which automatically calculates N3, S4 and S4QM if the input values are negative (positive values are not changed). The value of the negative figure which may be even, is equal to the desired number of increments in the calculations per counted range of the original influence line. The total number of increments, meeting sections N3 and queuing distances S4, is then calculated one for all, for the worst case, namely meeting (queuing) between the longest vehicle types (see the program listing, Appendix F, at label LEDI).

One analytically calculated loadeffect spectrum, picked from Chapter 6.3.6, valid for uniformly distributed axle loads, triangular influence lines and meeting lanes, was compared to NULESP calculated. This comparison confirmed that N3 ought to be odd. This is of course more true for symmetric influence lines as one is then assured of getting the maximum possible ranges counted. The maximum loadeffect ranges became about 5 % smaller than those of the analytical solution. For N3 = 19 (in this case corresponding to -9 in input) the differences between the analytical and the numerical solutions were within the line printer plot resolution. For N3 = 9(N3 = -4 in input) the maximum ranges were counted but a deviation of less than 5 %, on the safe side, arose in the upper 20 % spectrum region.

Similar tests with influence line type 1 (20 metres and meeting vehicle type loads) showed a deviation of less than 2 %, on the safe side, in the upper 20 % region for N3 = -1 compared to N3 = -3 or -5. For the later two values the spectra did not differ. No deviations for N3 = -1, -3, -5 were found when influence line of type 3 was used instead, under all the same conditions. If parallel lanes were supposed though deviations occured, on the safe side, for this non-symmetric influence line, in the upper 50 % region of the spectra which amounted to less than 6 % for a change of N3 from -5 to -1 and less than 2 % for a change of N3 from -3 to -1.

The number of queue distances, S4QM, in the queue meeting single (QM) case is recommended to be manually given (positive sign) a small figure, that is if this rather costly calculation case is judged to be relevant, according to the result of a comparison between the shortest queue distance and the length of the vehicle type influence lines.

The conclusion drawn is that with N3 and S4 equal to -3 enough accuracy is obtained in the calculations.

The desired equivalent overlap load distribution is input at label OVDI and used in the calculations at label OVCA (see FIG. 6.4.3-2). As well as it is of interest to keep N3 and S4 small, the number of classes W1 in the equivalent overlap load distribution should also be kept low in order to reduce the computer run time, (see also Appendix F for estimation of computer run times). Tests were performed with influence line type 1 (20 m and meeting vehicle type loads) with different desired equivalent overlap load distributions.

The conclusions drawn are that three classes are not enough to keep the spectrum free from "steps" below the correct spectrum. Five classes seem to be enough provided they are given proper values. It is important that the highest class is given a small probability of coming up (0.1 o/oo or less) leading to incorporation of only the highest class of the different equivalent load distributions into the overlap distributions. The following distribution is suggested (-), 0.15, 0.03, 0.005 and 0.001.

The used influence lines are built up of straight lines, which of course is a simplification. In the NULESP program there is also an optional fourth influence line type which may be used to build up influence lines with a greater number of break points than the standard shapes provide, thus approaching the real influence line. Calculations were performed with two additional influence lines, beside type 1 of FIG. 6.5-1, all 20 metres long (meeting vehicle type loads). The influence lines and the essential results of the calculations are shown in FIG. 6.5.1-1.

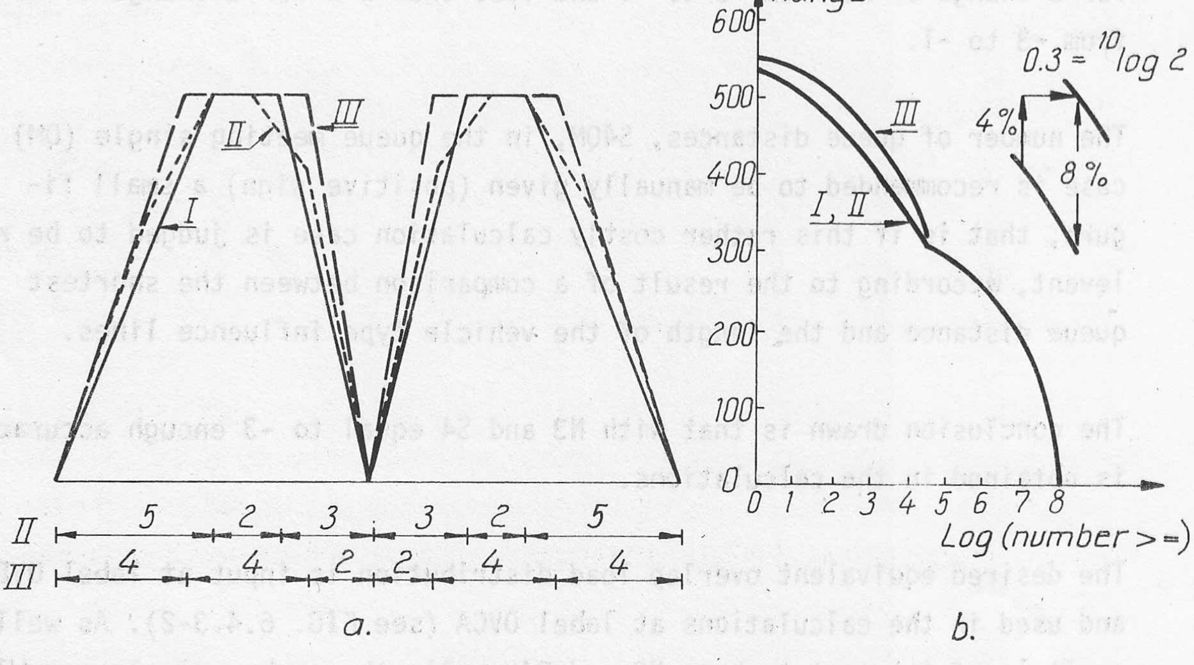


FIG. 6.5.1-1. Influence of the detail appearance of the influence line.

The differences between the spectra based on influence line I, and the more exact with eleven breakpoints, II, were negligible (less than 2 %). The maximum stress ranges of the spectrum based on influence line III were increased by 4 % compared to the I- and II-spectrum, which could be predicted from the increase in the relevant ranges obtained from counts on the vehicle type influence lines. Furthermore an increase of about

8 % was received in the upper 50 % of the III-spectrum which may be a consequence of the greater probabilities for high loadeffect values in this case. As can be seen from FIG. 6.5.1-1a the probability for the influence lines to be equal to their maximum is 100 % greater for shape III than for shape I, for an arbitrary moment during the vehicle passage. This fact may be roughly expressed as a doubling of the number of overlap ranges of the III-spectrum compared to the I-spectrum.

6.5.2 Lateral track distribution and lateral influence function.

The lateral influence function is used together with the lateral track distribution in the calculations of equivalent load spectra, which is performed at label EQCA in the NULESP program (see also Chapter 6.4.3).

A change in a deterministic lateral influence value causes a corresponding vertical displacement of the equivalent load spectrum and loadeffect spectrum. In a test run, four different symmetric shapes of the lateral track density functions were used to represent a linear variation of the lateral influence function between 0.4 and 0.6, that is with mean value equal to 0.5. The result of the runs and the used density functions are sketched in FIG. 6.5.2-1. The four calculated equivalent load spectra did not differ more than 4 % in the upper 50 % of the spectrum and were placed between the spectra valid for deterministic lateral influence values 0.5 and 0.6.

Suppose that the same lateral influence functions are valid for two lanes and that an estimation are to be made of the effect of an decrease of one of the factors. It is then suggested that the reduction should be made on the different partial loadeffect spectra (which will be added later), to the same degree as the maximum lateral influence values indicates. For example, suppose that F is distributed between 0.4 and 0.6 (mean 0.5) for two lanes and the effect of a decrease in these values to 0.15 and 0.35 (mean 0.25) for one lane is to be estimated. The reduction factors will then become (0.35+0.6)/(0.6+0.6) ≈ 0.8 for the partial meeting loadeffect spectrum and 0.35/0.6 ≈ 0.6 for the reduced partial single lane spectrum (the other is unchanged). It is suggested that the lateral track density function may be held constant and equal to the rectangular density function at least for estimated moderate maximum variations of the lateral influence function. This is justified by the relatively small influence a change in the shape was shown to give rise to and by the fact that very little is known about the real lateral track distributions.

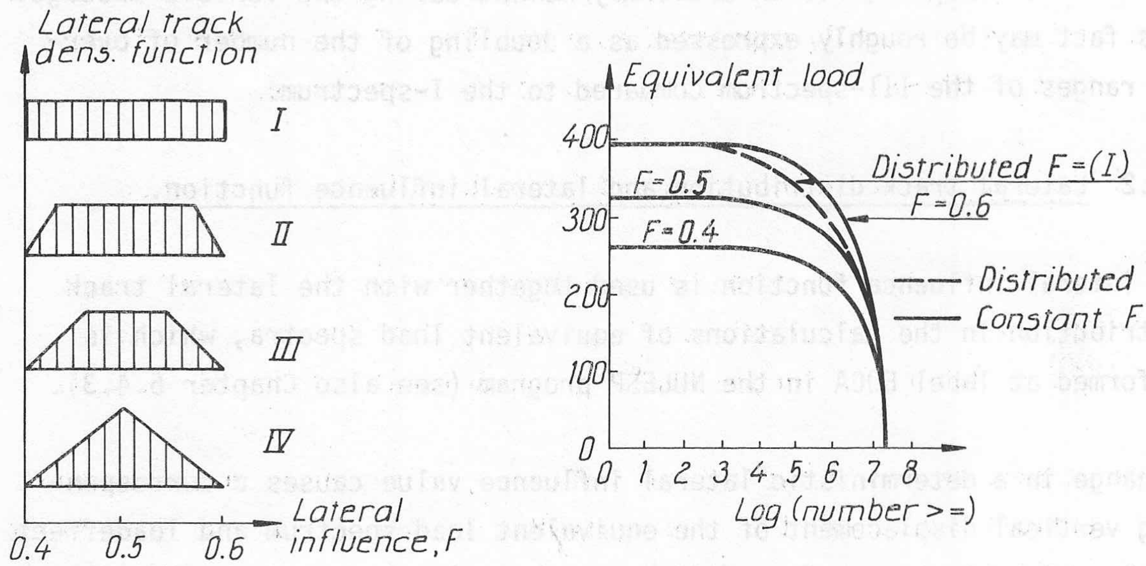


FIG. 6.5.2-1. Principal influence of lateral track distribution and lateral influence function.

6.5.3 <u>Axle distance factor distribution. Distribution of vehicle weights on axles.</u>

In the NULESP model it is supposed that the total axle distances are stochastic through multiplication by vehicle type axle distance factors. The relations between the different axle distances of the vehicle type is thus kept constant. To reduce the calculation efforts the axle distribution facility was used only in the single vehicle passage calculations. The distribution of vehicle weight on axles is assumed to be deterministic for each vehicle type, this of course is a simplification.

The reason for keeping the number of stochastic variables low is that the number of possible variable value combinations in the systematic sampling procedure will rapidly increase for each additional stochastic variable that is introduced. This circumstance shall be put in relation to other uncertainties and assumptions made which will also reduce the resolution of the received results. For example it is assumed that all vehicles have the same speed during bridge passage. This will cause all time lengths for each vehicle type to be equal. Furthermore the assumptions made about fixed vehicle properties must be shown in relation to the approximate handling of the dynamic effects.

To give an idea about the influences of changes in the axle distance factors and the distribution of vehicle weight on axles, a few test runs were made.

It is clear that when short influence lines (shorter than the axle distances) are used a variation of the axle distances will have no effect on the appearance of the loadeffect spectrum (in these cases the axles may be assumed to run freely on the road according to the discussion in Chapter 6.5.5). An increase in the amount of carried vehicle weight of an axle will though be recognized as a proportional lift of the spectrum if the axle which already carries the greatest weight is used. This was confirmed in test runs.

The very long influence lines, in comparison to the total axle distances, will yield low sensitivity in the results for variations in both axle distance factors and weight distribution on axles because the vehicle weights may be treated as concentrated loads in this case.

Calculations involving influence lines of medium lengths will be more sensitive to the variations under discussion. Test runs for influence line of type 2 (20 metres, meeting vehicle type loads) were performed resulting in a lift in the loadeffect spectrum equal to 8 % in the overlap region and 19 % in the middle region. The 8 % was caused by a 20 % axle overweight and could be predicted from the relation between those ranges, of counts performed on the vehicle types, causing maximum effects. The 19 % percent lift was caused by a change from a deterministic axle distance factor (equal to 1) to a distributed factor with the same mean value. An additional lift to a concealed 28 % (instead of 19 %) in the upper regions of the partial single vehicle passage spectra (consealed by the overlap part) indicates that in this case an additional lift of the total spectrum in the upper regions would be expected if the dangerous axle distance factor or factors were also used in the overlap calculations. The lift was caused by the 0.8 value of the discrete axle factor distribution, which in the calculations was set to 1, 0.8 and 1.2 all values having the same probability of coming up.

It is hard to give simple rules to predict the influence of changes in the deterministic distribution of vehicle weight on axles and of variations in the axle distance factors (either these factors are treated as deterministic or stochastic variables). A preliminary study of the range counts, made on the vehicle type influence lines, and maximum vehicle weights will though give guidance to a proper choice of the most dangerous input combinations. For example one ought to place the most dangerous (causing high loadeffects) axle distance factor as the first in the vehicle specification input entailing that it will be used in the overlap calculations. (In the example above the input distributions 0.8, 1, 1.2 or 0.8, 1.2, 1, will yield the same results.)

6.5.4 Influence line appearance. Traffic properties and lane configuration.

The NULESP model offers the user the opportunity to choose between three types of lane configurations namely single lane, two meeting lanes or two parallel lanes. The single lane and two parallel lane cases are both supposed to involve the same number of vehicles per time unit (the lane 1 flow). Queues are not allowed to be formed in the two parallel lane case, the vehicles will instead overtake one another. In the case of meeting lanes it is possible to choose between overlapping of queuing vehicles or overtaking vehicles, but not of both cases in the same run. The thought behind this is that in case of low vehicle flow intensities the possibilities for the heavy vehicles to overtake one another are much greater than in the case of dense traffic.

The derived formulas by which the number of occurences for different overlap cases are calculated is found in FIG. 6.4.5-4. The intensities of occurences are received if the expressions are divided by the total regarded time period (YSEC). As can be seen the occurence intensities are not dependent on the regarded time period. This entails that calculated, or measured, loadeffect spectra valid for a time period t, simply through multiplication by a factor f will represent the new time period f·t. This is accomplished by a horizontal displacement equal to log(f), see FIG. 6.5.4-1.

If f is greater than 1 it can be seen from the figure that formerly concealed parts of the spectrum ought to appear (only possible for calculated spectra). In the same figure b) the effect on the appearance of the loadeffect spectrum of a doubling of the probability for meeting is also principally shown (for example through a change of equivalent time value, TE, from 1 to 0.5).

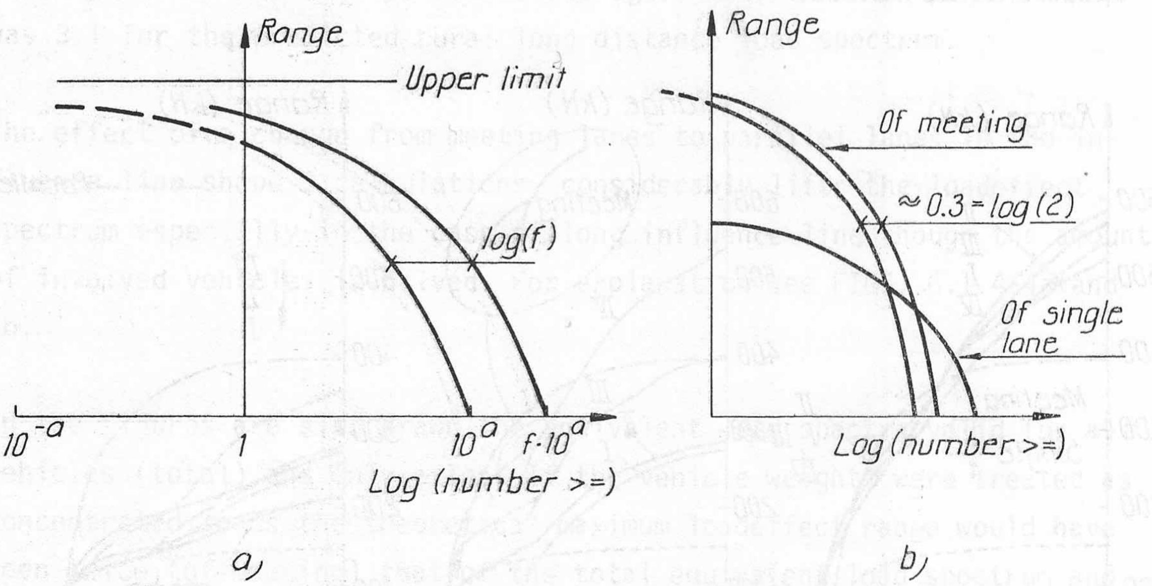


FIG. 6.5.4-1. a) Change in regarded time period length by a factor f.
b) The probability for meeting is doubled (for example equivalent time, TE, changed from 1 to 0.5).

FIG. 6.5.4-2 shows collections of calculated loadeffect spectra. The influence line shapes and influence line lengths were varied in the calculations. The main lane configuration was put to two meeting lanes. In the case of non-symmetric influence lines, especially of the oscillating shear force type (shape 3), it is also interesting to study the influence of meeting lanes replaced by parallel lanes, which accordingly was done.

Queues were allowed to arise in the shape 1 calculations with queue distances equally distributed between 20-30 metres. As expected the queue distances were too long to give rise to noticable effects on the appearance of the load spectrum. The used critical queue time was equal to 6 sec.. In the next Chapter, 6.5.5, the effect of shorter queue distances is further discussed in connection with effects of vehicle weights represented as concentrated loads, in which case the NULESP model can also handle the queuemeeting and queue meeting queue overlap cases.

Below some comments are made on FIG. 6.5.4-2. As can be seen from the figures the upper parts of the loadeffect spectra (≈ 1 o/oo of the counted ranges) originate from overlapping effects of meeting vehicles and the lower parts from single vehicle passages. The knee between these two contributions tended to be straightened out when distributed axle distances were used, which caused the partial single vehicle loadeffect spectra to be raised.

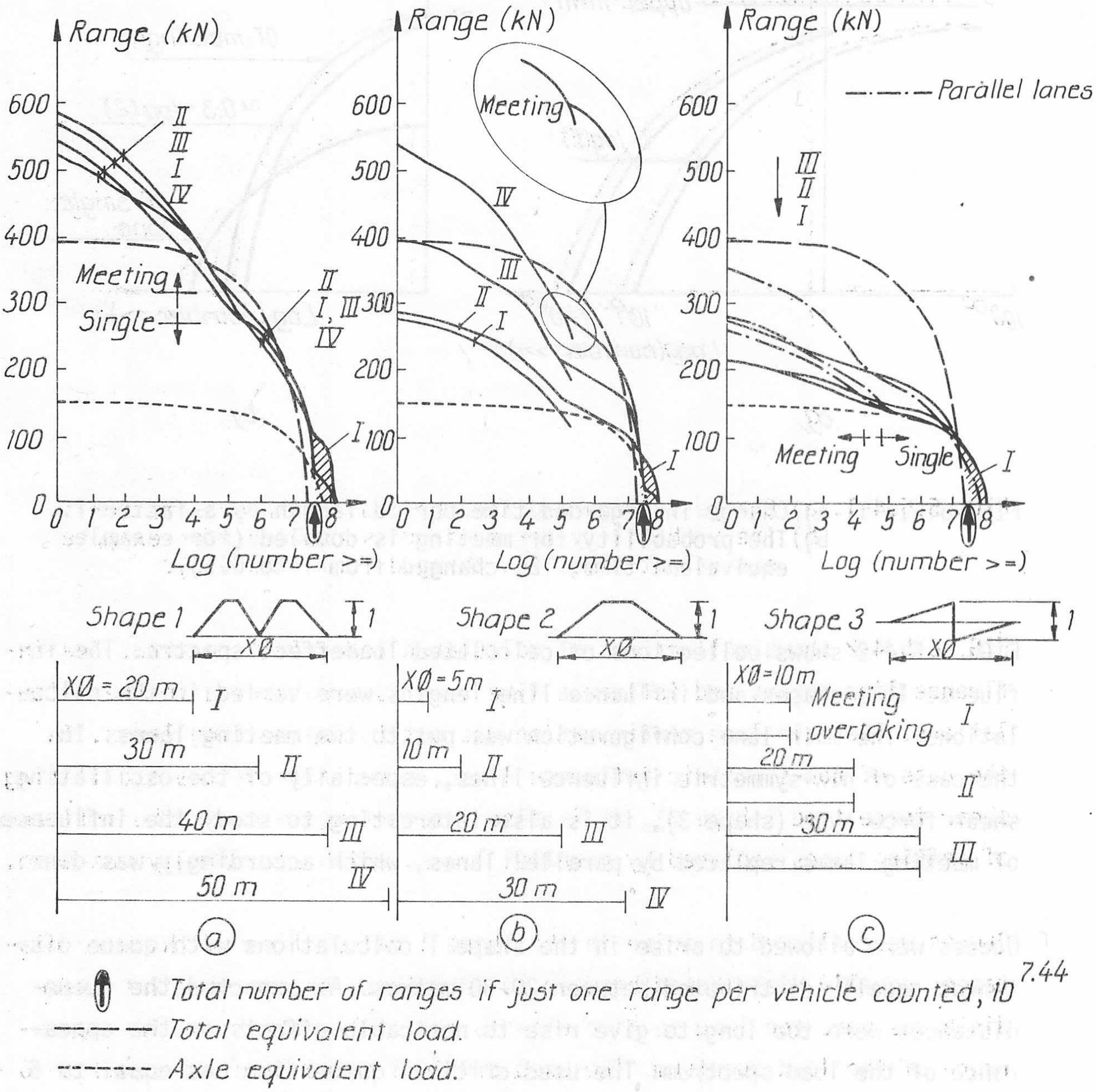


FIG. 6.5.4-2. Collection of loadeffect spectra, calculated for different influence line shapes and lengths, meeting lanes and no dynamic effects.

The shaded areas to the right of the arrows (at logarithmic number of exceedings = 7.44) reflect the effect of the complete range countings made by means of the LECOUNT routine in comparison to a registration of just one maximum range for each single vehicle passage or meeting occurence. The relations between the total number of ranges counted in these two ways were 3 to 4 for influence line shape 1, 1.3 to 2.4 for shape 2 (the smaller relation valid for 10 metres influence line) and finally, about 3 for shape 3. The average number of axles per vehicle was 3.1 for the predicted rural long distance load spectrum.

The effect of a change from meeting lanes to parallel lanes in the influence line shape 3 calculations, considerably lifts the loadeffect spectrum especially in the case of long influence line though the amount of involved vehicles is halved. For explanation see FIGS. 6.1.4-4a and 4b.

In the figures are also drawn the equivalent load spectra valid for all vehicles (total) and only axles. If the vehicle weights were treated as concentrated loads the theoretical maximum loadeffect range would have been twice (of meeting) that of the total equivalent load spectrum and twice that of the equivalent axle load spectrum if the vehicle axles were assumed to run freely on the roads.

The shown spectra are drawn to give hints of expected results of loadeffect spectra calculations, and farreaching conclusions shall, therefore, not be drawn from studies of such a limited selection of spectra.

6.5.5 Total, axle and type load.

It is possible to choose between three vehicle weight representations in the NULESP model, namely the vehicle weight represented as one concentrated load, total load, as a set of axle load, type loads, or as axle loads with no connection to each other, axle loads.

The most correct form for representing the vehicle loads is the type load form. It is though adventageous if it is possible to use the total or axle load representation instead as the computing time then gets considerably reduced.

If the influence line is shorter than the shortest vehicle axle distance it seems as if the deterministic grouping of axles to vehicles have no noticable effect on the appearance of the loadeffect spectrum compared to spectra which are calculated under the assumption of freely running axles. Of course those events when free axles are nearer each other than the shortest axle distance are disregarded in the calculations.

From the derived expressions for the number of occurences of different overlap cases during the regarded time period, FIG. 6.4.5-4, it can be seen that these expressions are reduced for each additional vehicle involved, roughly by a factor equal to the total vehicle flow per lane and second. From the predicted rural long distance spectrum this factor is estimated to 0.01. Therefore the overlap cases involving three and four vehicles, the queuemeeting, QM, and queue meeting queue, QQ, cases which were expected to be rare, are only considered in the total load and not in the type load calculations. In this way the type load calculation times could be greatly decreased, (see also FIG. 6.4.7-5).

The test runs presented below are intended to give an idea about the effects the queuemeeting (queue meeting single) and queue meeting queue overlap cases have on the appearance of the loadeffect spectrum. To get noticable effects of queuing the queue distances must be held short in comparison to the influence line length (the queue distance is counted from rear to front axle). The result of the run and the main input data are shown in FIG. 6.5.5-1, which is commented below.

The loadeffect spectrum valid for type loads may be compared to spectrum IV of FIG. 6.5.4-2a which is calculated under the same assumptions but for longer queue distances and deterministic axle distance factors. The differences are found in the middle parts of the spectrum where the before mentioned knee has been straightened out due to effects of queuing and non-deterministic axle distances. If the QQ and QM overlap effects are excluded from the total load loadeffect spectrum the two spectra approximately differ by a factor equal to the range relation, counted on the vehicle type influence lines, causing the highest loadeffects (≃ 0.73). As the partial loadeffect spectra of the QQ and in particular the QM overlap cases are added the spectrum according to the figure is received. The effects of the QQ case are only noticable at the very top (8 ranges) of the spectrum.

The hatched area represents the adjustment made by simply using the 0.73

factor on the upper part of the total load loadeffect spectrum. The upper dotted line is calculated by means of a factor 0.81 corresponding to a range relation involving axle factor number two instead of number one. Factor number one is used in the type load overlap calculations.

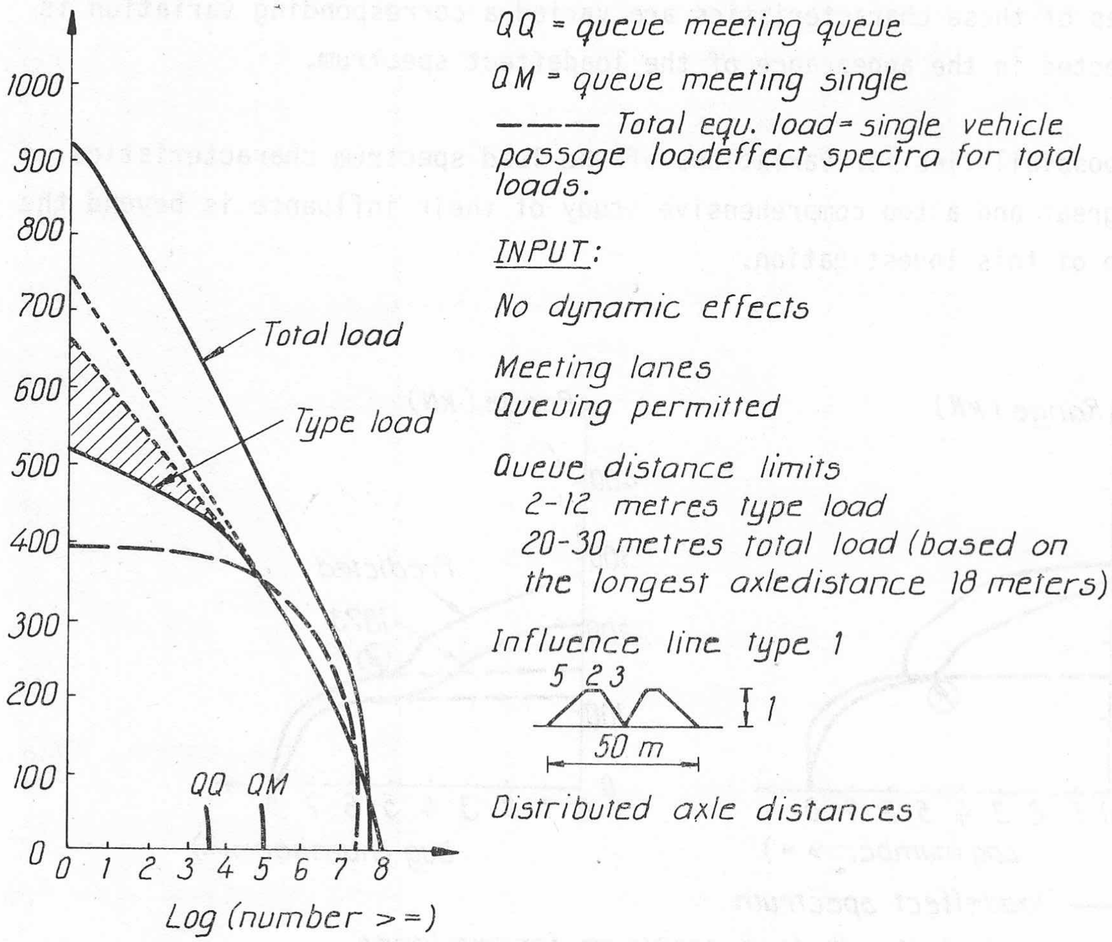


FIG. 6.5.5-1. Vehicle type load loadeffect spectrum adjusted for queue-meeting and queue meeting queue influences.

The described approximate relation between loadeffect spectra calculated by means of total loads and type loads seems to be usable to estimate the queue meeting single, QM, and queue meeting queue, QQ, influences on the appearance of the type load loadeffect spectra. Similar comparisons made on calculations comprising overlap effects of meeting or overtaking and influence lines longer than 25 metres showed that the upper regions of the type load loadeffect spectra could be well estimated, always slightly (< 8 %) on the safe side. However, in the case of non-symmetric influence line and meeting lanes this approximation do not seem to be usable.

6.5.6 Load spectrum.

Together with the bridge specifications, the load spectrum and vehicle specifications form very important input parts. The load spectrum may be characterized by the total number of lane occurences, the maximum possible load amplitude and the principal shape of the spectrum. If the values of these characteristics are varied a corresponding variation is reflected in the appearance of the loadeffect spectrum.

The possibilities for variations of the load spectrum characteristics are great and a too comprehensive study of their influence is beyond the scope of this investigation.

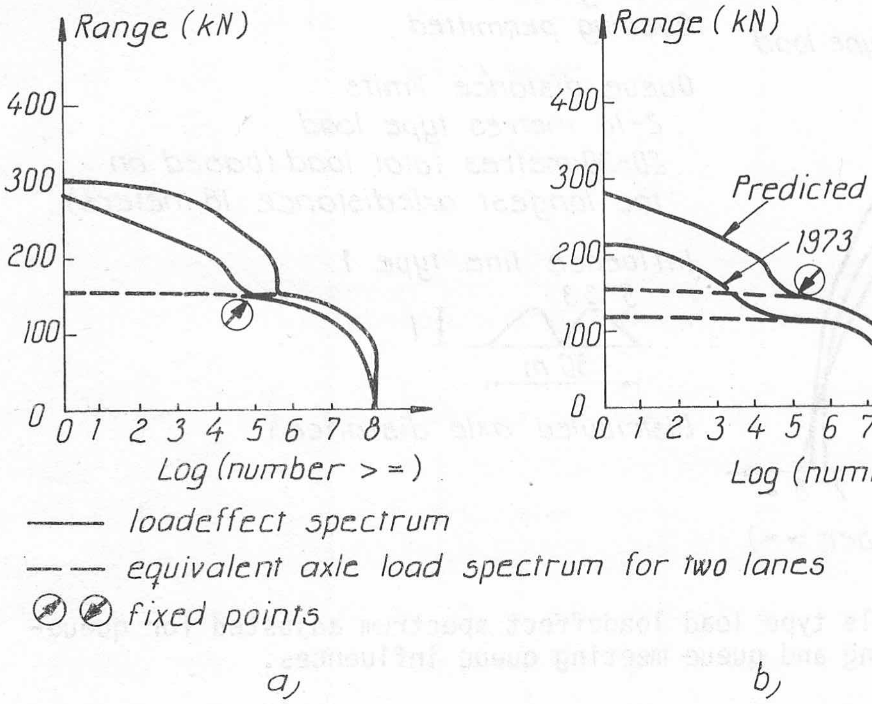


FIG. 6.5.6-1. a) Effect of a radical change of axle load spectrum shape (all axles assumes the former max. weight = 240 kN).
b) Predicted and 1973 rural long distance spectra used. Influence line type 2 (5 metres), meeting lanes.

Two examples are presented above. The first example, FIG. 6.5.6-1a shows the result of a radical change in the load spectrum shape and the second example, FIG. 6.5.6-1b, shows two loadeffect spectra valid for a predicted load spectrum and a 1973 load spectrum. Only free axle loads and meeting lanes were treated. The lateral influence function was as before supposed to be uniformly distributed between 0.4 and 0.6 with mean 0.5.

The influence line was of type 2 and 5 metres long. In Chapter 8.1 where measured and calculated spectra are compared, the corresponding predicted loadeffect spectra are also drawn.

6.5.7 Dynamic amplification factor distribution.

The dynamic amplification effects are handled by means of a stochastic amplification factor which is input as a discrete density function (see also Chapter 6.4.8). The nature of the influence of this density functions appearance is very much like that of the lateral track distribution together with the lateral influence function. However, one has complete freedom to shape the distribution in this case.

FIG. 6.5.7-1 shows the result of a test run performed with three deterministic amplification factor values equal to 1, 1.15 and 1.3 and for distributed factors all with mean equal to 1.15. As can be seen from the figure the value of the upper factor limit is of great importance.

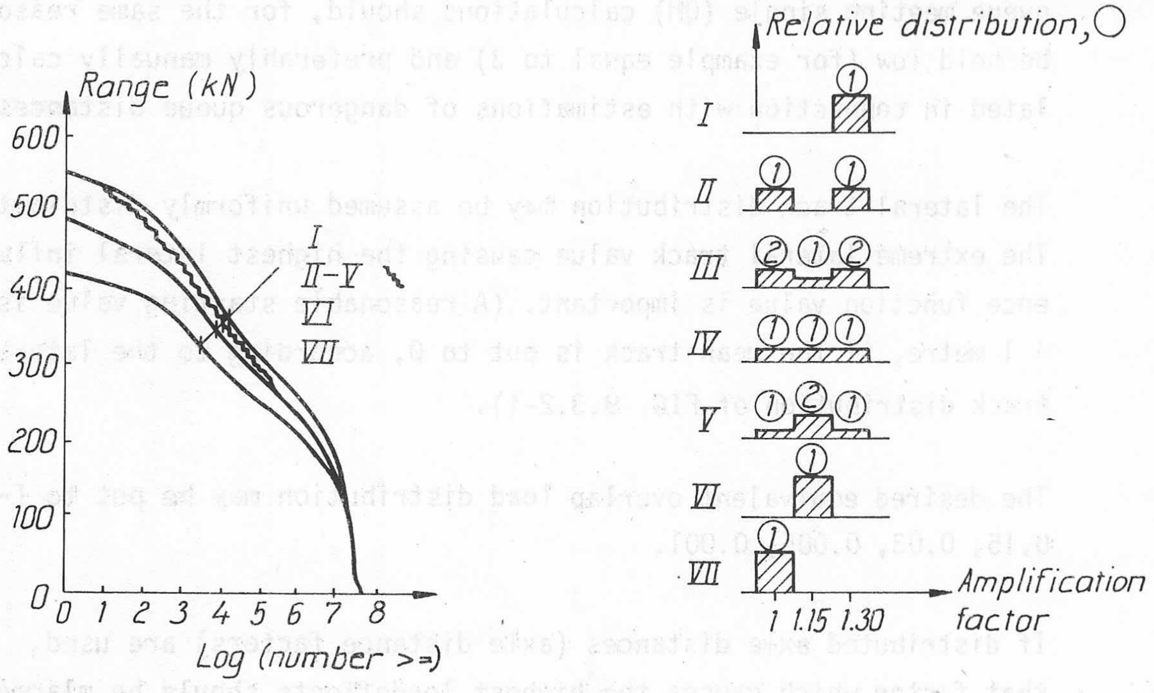


FIG. 6.5.7-1. Influence of dynamic amplification factor distribution.

6.5.8 Summing up results.

The discussions carried out in the preceding chapters are only intended to give an over-all picture of the NULESP model response to variations in different variable values. Only influence lines of standard shapes (type 1, 2 and 3 in the model) were used. Furthermore the model response was only studied through the logarithmic loadeffect spectrum representation and no regard was given to wether the ranges had positive or negative sign (counted during decreasing or increasing process) or to the levels they occurred on. Below though some general lines are sketched which are intended to simplify the administration of input data.

The number of discrete meeting sections (per mean influence line range length) and queuing distances (N3, S4) may be put to -3 in the case of symmetric or anti-symmetric influence lines. However, if dynamic effects in the form of an oscillating loadeffect is superposed it may be necessary to use smaller values to ensure reasonable computing times. (N3 = -1 or a manually estimated positive odd value.) The number of discrete queue distances in the queue meeting single (QM) calculations should, for the same reason, be held low (for example equal to 3) and preferably manually calculated in connection with estimations of dangerous queue distances.

The lateral track distribution may be assumed uniformly distributed. The extreme lateral track value causing the highest lateral influence function value is important. (A reasonable starting value is ≃ 1 metre, if the mean track is put to Ø, according to the lateral track distribution of FIG. 9.3.2-1).

The desired equivalent overlap load distribution may be put to (-), 0.15, 0.03, 0.005, 0.001.

If distributed axle distances (axle distance factors) are used, that factor which causes the highest loadeffects should be placed as the first one at input. (The input order of factor values is optional. The first factor is used in the overlap calculations.)

Axle loads may be used instead of vehicle type loads in connection with calculations comprising influence lines shorter than the shortest axle distance.

The effect of queue meeting single vehicle, QM, and queue meeting queue, QQ, may be approximately translated from loadeffect spectrum valid for total loads to spectrum valid for type loads unless non-symmetric influence lines plus meeting lanes are assumed.

The more vehicles involved in overlapping cases the greater relative importance these cases get. This is accomplished by an increase of the vehicle flows and a decrease of vehicle speed and equivalent time.

Uniformly distributed dynamic amplification factors may be used if basic data are lacking.

Finally, it shall be pointed out that the favourable quality of using relatively few meeting sections can not be safely used in the case of non-symmetric influence lines. Roughly if a resolution of 5 % in the calculated spectra is desired an "increase" on N3 to -9 should be done. It is though hard to give any definite rules, for example single influence line ranges with high amplitude and short duration may cause bad resolution. In those cases it is advised that a proper N3 value be manually estimated.

7 COMPUTER CONTROLLED LOAD SPECTRA AND LOADEFFECT SPECTRA RECORDINGS.

It is of course of great interest to receive connected data on loads, traffic properties and loadeffects in order to make a further validation and calibration of the load spectrum, LOSP, and loadeffect spectrum, NULESP, models possible.

The National Road Administration are for the time being planning future field measurments of load spectra and loadeffect spectra. In cooperation with the author of this report a computer controlled data acquisition system was proposed which will make possible simultaneous counting on several loadeffect processes arising in different parts of a bridge structure. In order to get information about the load spectrum causing the loadeffects the author of this report, during 1974-1975, developed a mobile weighing transducer which can be used without interfering with the vehicle flow. The weighing transducer with its electronic equipment, which may be computer controlled or used by itself, is shortly described below as well as the proposed computer controlled acquisition system.

In connection with the description of the proposed acquisition system comments are also made on the lay out of the governing software, computer programs.

7.1 Mobile weighing transducer.

The weighing transducer, for which patent has been pended, is built up of, in vertical direction elastic strips, which act as capacitors in parallel connection. The total height of the transducer, including a covering plate, is 12 mm (1/2 inch). It may be placed directly on the road surface and fastened by means of nailing or screwing without difficulty.

The transducer is enclosed by two ramps of which the off-ramp has metal-sheets embedded which act as lateral position switches.

During a vehicle passage over the transducer a vertical deflection, which is linear to the applied load, occurs underneath the wheel, causing the capacitance of the strips to be increased. The change in capacitance is detected by means of a specially developed discharge to time converter, which is placed a few metres from the transducer, and converted to an analogue voltage which is transmitted to the signal conditioning and control unit, SCU.

The SCU contains signal conditioning circuits as amplifier and analogue memory and further it contains control electronics, analogue-to-digital converter, data buffers and a real time clock.

An optional recording unit, for example a paper tape punch, may be connected to the SCU. The weighing station will then work as a stand alone unit, recording binary data for each axle passing over. These data groups consist of axle load, lateral position, real time (resolution 1 ms) and the time for the axle to pass over the transducer (resolution 0.4 ms).

In case the weighing station is to be used together with a computer, it is possible to use a SCU of less complex layout which will only furnish the computer with digital information on axle loads and lateral positions.

Test runs involving a prototype have been made with promising results. The axle loads (wheel loads) were measured with an accuracy of ± 1.2 kN, which for the most part is determined by the noice level of the electronic device. (The change in capacitance per applied kN is about 0.005 % over a total capacitance of 5600 pico farad.) The estimated linearity is within ± 3%.

Further tests are planned in order to get a picture of the dynamic effects at high speeds.

The transducer with electronic devices is presented in Christiansson /35/ (with summary in English).

7.2 Computer controlled acquisition system.

The proposed system, which for the time being is only planned to be built up, is meant to consist of a mini-computer, containing 8 or 16 kilo words of memory, a teletype-console and a multiplexer, with attached analogue-to-digital converter, capable of handling about 10 analogue input signals.

The main advantages of using a computer controlled system is that it is possible through programming efforts to make very flexible system solutions which are easy to adapt to different test objects. It is also possible to do a great deal of data processing immediately on the recorded data.

The studied loadeffect (strain) processes will be subjected to continuous counting by means of the LECOUNT routine and the received range-level data will be stored in matrices in the computer memory. The counting will be performed simultaneously on the processes by means of using the computer interrupt technique.

The vehicle axle loads recordings, which will be received from the above described mobile weighing station, may be grouped into vehicle types through processing of the axle load time distances. If the weighing transducer is passed over by a queue of vehicles, entailing small time gaps between rear axles to following front axles, difficulties arise in the classifying of axles into vehicle type groups, unless it is assumed that a single wheel may only belong to a truck front axle. A single wheel is distinguished from a twin-wheel through the lateral position information. The twin-wheel will namely activate a greater number of lateral switches than the single wheel.

The recorded time distances between the axles of a vehicle may be translated to metric lengths by using the recorded information on the time durations of vehicle axle passages over the weighing transducer. This translation requires knowledge about the transducer width.

It is possible to make thorough studies of certain vehicle characteristics. For example the following distributions may be collected for each vehicle type: weight distribution on axles distributions as function of vehicle gross weight, axle distance distributions as function of vehicle gross weight, vehicle speed distributions as function of vehicle gross weight. The vehicle type gross weight spectra and axle gross weight spectra will be stored as matrices in the memory.

The traffic characteristics may be expressed in terms of: distribution of time gaps between vehicles, distribution of the number of vehicles formning a queue, distribution of time gaps between queues and within queues and lateral track distributions as function of vehicle gross weight and vehicle type. It is also possible to make certian studies of the vehicle gross weight ratios of the vehicles participating in queue formations.

To be able to get information on the overtaking behaviour of the trucks two weighing transducers have to be used in order to make a separation of vehicle axle loads possible.

Intermediate results may be written out on the console either automatically at certain time points or at special request.

It is understood from the sketch of a computer controlled acquisition system above that a complex software is required if all the different data processings are to be implemented. In the first stage the different routines must be worked out and tested before they are collected to a complete software package.

8 CALCULATED AND MEASURED LOADEFFECT SPECTRA.

Very few measurements of loadeffect spectra have been done in Sweden. This chapter contains comparisons between two spectra and the corresponding calculated spectra by means of the NULESP model. The measurments were performed by the National Road Administration and comprise stress range registrations at midspan of an endspan of a continuous steel girder, which was in composite action with a concrete deck resting on 7 supports and stress range registrations in a steel cross member which carried a two parallel lane orthotropic steel deck.

Further field investigations are planned by the National Road Administration partly in cooperation with the author of this report. These investigations are intended to involve a computer controlled load and loadeffect spectra collecting system (see further Chapter 7).

Measurments of loadeffect spectra have been performed abroad for some years, especially in the United States (see further Chapter 2, LITERATURE REVIEW). In most cases the measurments involve structural members of type medium to long main girders of highway bridges. The stress range amplitudes are mostly calculated as the difference between the maximum and minimum stress amplitude during vehicle passage.

The important but seldom occuring overlap occurences are difficult to catch and consequently to get a picture of during a field investigation of limited time length.

8.1 Calculated and measured spectra for the year 1973.

The stress histories were collected and automatically evaluated at the bridge sites by means of a level crossing counter. Each time the signal passed a predetermined level a counter was incremented on condition that the signal was growing and that it had been below a predetermined return level, associated with that counter, since the last increment was done. This method of breaking down the loadeffect process does not, except under special conditions, yield the same loadeffect spectra at the end as the earlier described counting routine LECOUNT would have done. Depending on the interpretation of the level crossing distribution, different loadeffect spectra will be obtained. In the measurements presented below the acting loads have a comparatively short extension in comparison to the influence lines. This condition makes the appearance of the loadeffect spectrum less sensitive to the chosen method of evaluating the level crossing distribution.

In Chapter 9.3.4 the level crossing and positive peak distributions in connection with analysis of loadeffect processes will be further discussed as these distributions may be analytically derived under certain circumstances (see also Chapter 2, LITERATURE REVIEW).

8.1.1 Longitudinal girder at Köpmannebro.

FIG. 8.1.1-1 principally shows the bridge and the structural point under consideration. The bending stresses were measured in a flange of the longitudinal girder at midspan of an endspan. The spectrum was collected over a 45 day period in April and May 1974.

Köpmannebro is situated in the rural region, at a national main road in the middle of southern Sweden. The 1973 rural short distance load spectrum was used (12.1973) as load input (see Chapter 4.2) together with the vehicle specifications also found in the same chapter. The original weight distribution on axles was used, that is no additional axle overweights were assumed, besides the already accounted overload loading level. Further the axle distances were assumed distributed through axle distance factors with equal probabilities for values 1, 0.8 and 1.2 (base data were lacking). The longitudinal influence line was described by five break points according to FIG. 8.1.1-1. Test runs gave rise to influence lines of similar shapes.

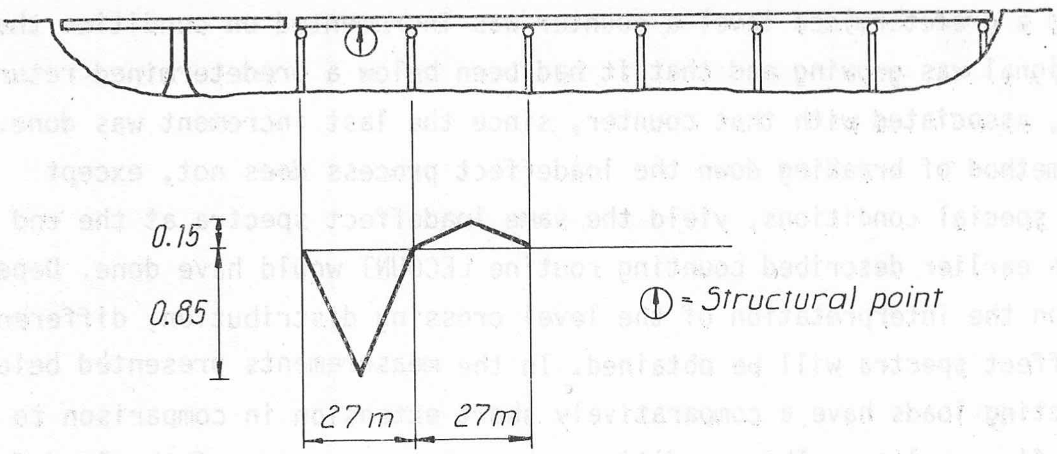


FIG. 8.1.1-1. View of highway bridge at Köpmannebro with assumed longitudinal influence line. Two meeting lanes.

FIG. 8.1.1-2 shows a cross section of the bridge and an approximate lateral influence function, calculated under the assumption that the torsion of the bridge is carried only by the girders. The lateral track distribution was assumed to be uniformly distributed between -1 and +1 metre (base data lacking).

The test runs were performed with a 4.5 metres (axle distance) 217 kN lorry. From this test runs a loadeffect factor equal to 0.077 $(MN/m^2)/kN$ was achieved. The dynamic amplification factor was assumed to be uniformly distributed between 1 and 1.3. The test results, which were recorded on an oscillograph, gave maximum amplification factors equal to 1.3.

Two different lane configurations were assumed in the NULESP runs. In the first, I in FIG. 8.1.1-3, the influence of the meeting lane was disregarded and in the second, II, the effects of the meeting lane was incorporated, however, with the variation width of the lateral track distribution decreased, because the model can not handle negative equivalent loads. The vehicle speed was put to 18 m/s (65 km/h). No regard was taken to effects of queuing. The regarded time period was 50 years.

The effect of including the meeting lane in the calculations was limited to effects of single passages, because the high amplitude overlap effects

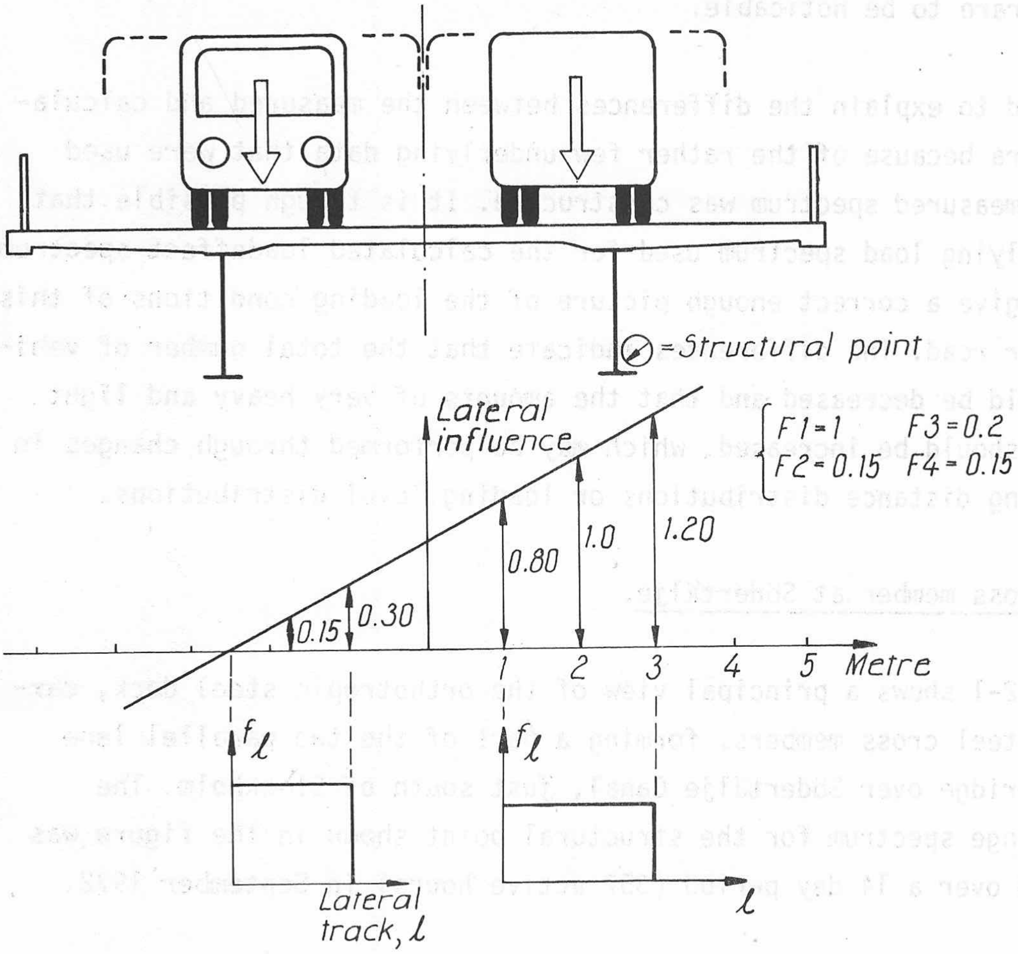


FIG. 8.1.1-2. Cross section of the Köpmannebro bridge and assumed lateral influence specifications.

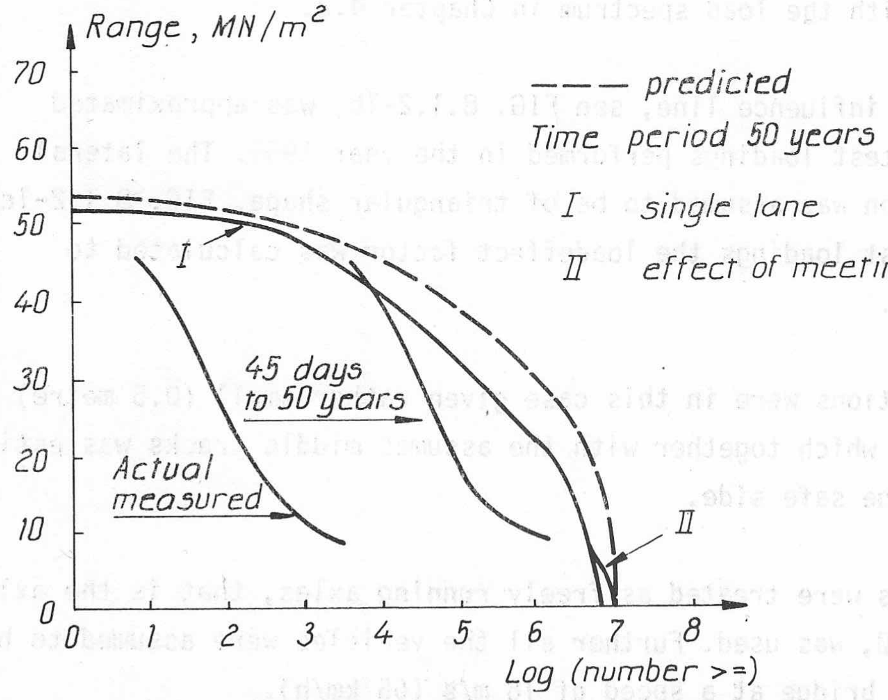


FIG. 8.1.1-3. Calculated and measured loadeffect spectra for the highway bridge at Köpmannebro.

were too rare to be noticable.

It is hard to explain the differences between the measured and calculated spectra because of the rather few underlying data that were used when the measured spectrum was constructed. It is though possible that the underlying load spectrum used for the calculated loadeffect spectrum does not give a correct enough picture of the loading conditions of this particular road. The differences indicate that the total number of vehicles should be decreased and that the amounts of very heavy and light vehicles should be increased, which may be performed through changes in the driving distance distributions or loading level distributions.

8.1.2 Cross member at Södertälje.

FIG. 8.1.2-1 shows a principal view of the orthotropic steel deck, carried by steel cross members, forming a part of the two parallel lane highway bridge over Södertälje Canal, just south of Stockholm. The stress range spectrum for the structural point shown in the figure was collected over a 14 day period (357 active hours) in September 1972.

The bridge is situated on the European Highway No. 4 and therefore the rural long distance (11.1973) load spectrum was used in the input. The original distributions of vehicle weight on axles were retained and are found together with the load spectrum in Chapter 4.2.

The longitudinal influence line, see FIG. 8.1.2-1b, was approximated from results of test loadings performed in the year 1965. The lateral influence function was assumed to be of triangular shape, FIG. 8.1.2-1c. From the same test loadings the loadeffect factor was calculated to 0.242 $(MN/m^2)/kN$.

Lateral distributions were in this case given rather small (0.5 metre) variation widths which together with the assumed middle tracks was estimated to be on the safe side.

The vehicle loads were treated as freely running axles, that is the axle load case, TØ = Ø, was used. Further all the vehicles were assumed to be driving over the bridge at a speed of 18 m/s (65 km/h).

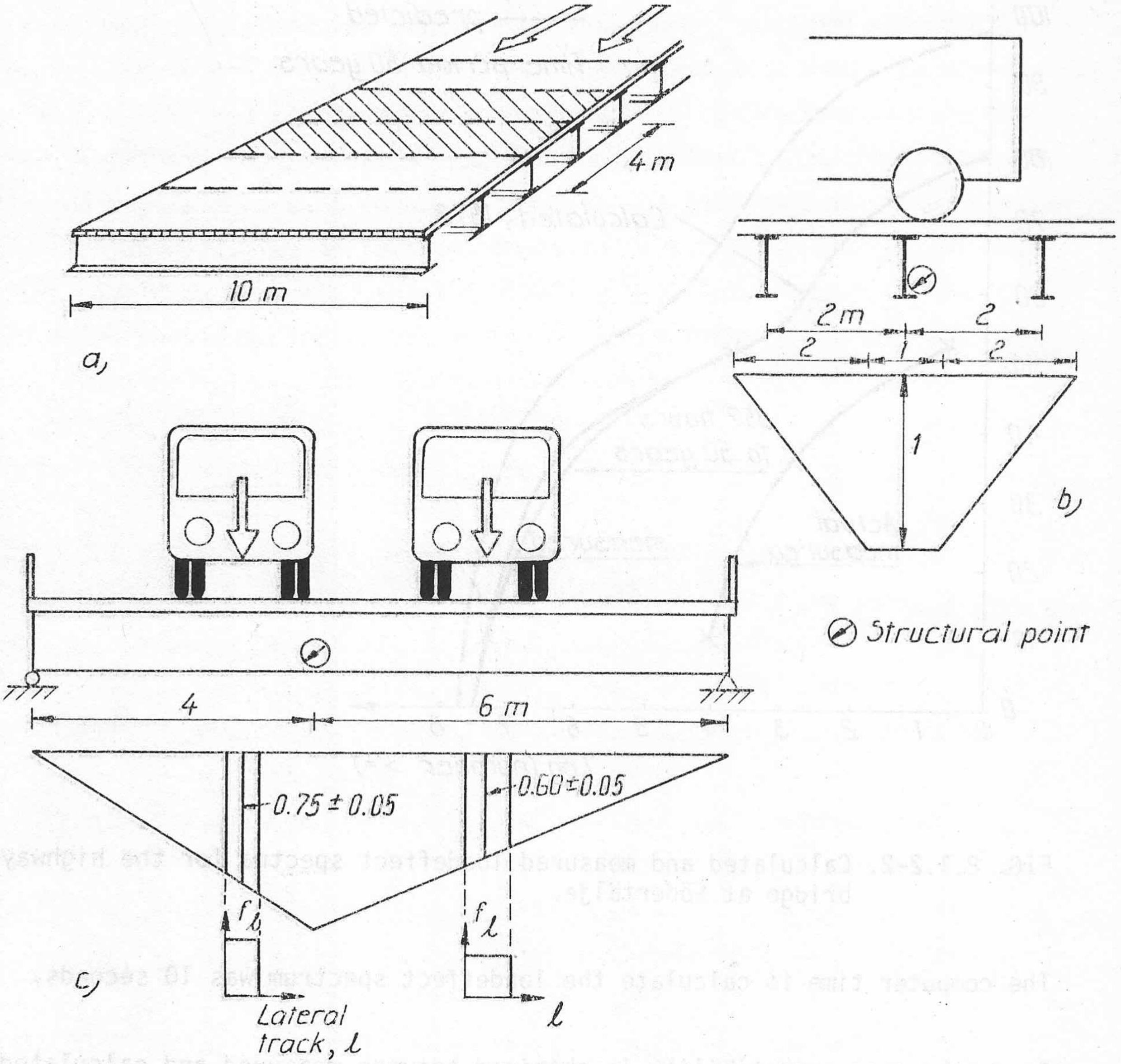


FIG. 8.1.2-1. Cross member at Södertälje. a) Principal view. b) Longitudinal influence line. c) Lateral influence specifications.

Due to lack of basic data the dynamic amplification factor in these calculations was also supposed to be uniformly distributed between 1 and 1.3.

FIG. 8.1.2-2 shows the results of the calculations and the corresponding measured spectrum. For comparison the predicted loadeffect spectrum is also shown in the figure. The regarded time period was 50 years.

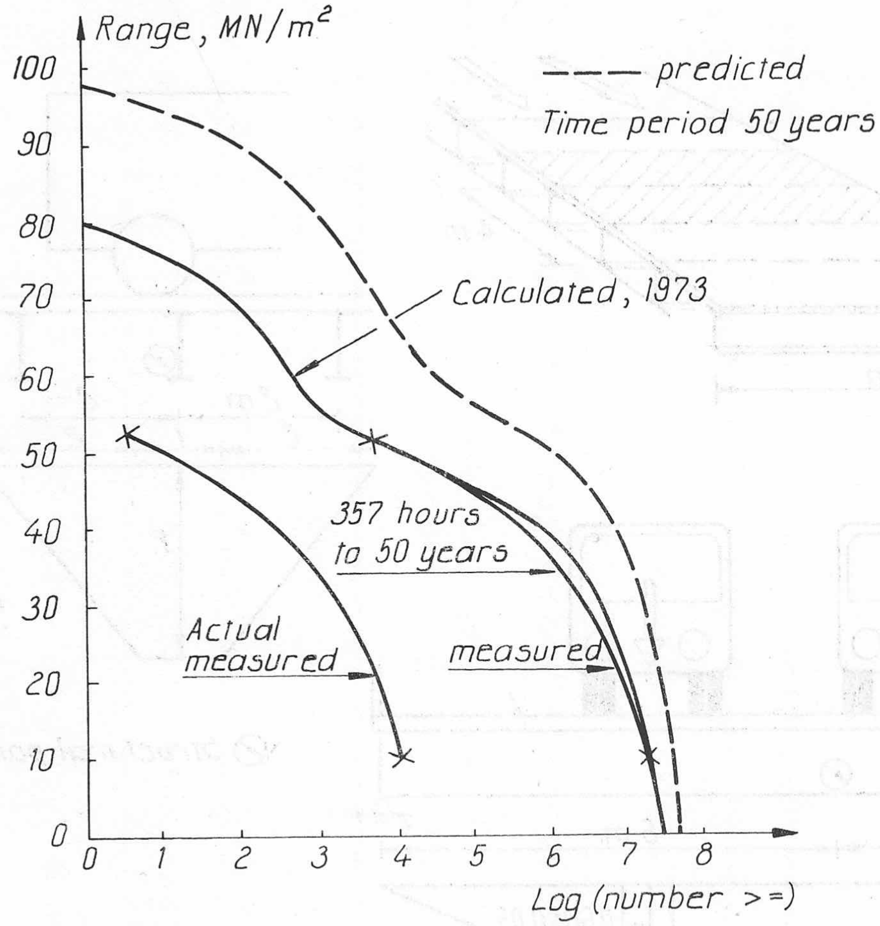


FIG. 8.1.2-2. Calculated and measured loadeffect spectra for the highway bridge at Södertälje.

The computer time to calculate the loadeffect spectrum was 10 seconds.

As can be seen compatibility is obtained between measured and calculated spectra.

9 DISCUSSION.

In this report two probabilistic numerical models are presented, one is used to calculate load spectra, LOSP, and the other to calculate load-effect spectra, NULESP. As mentioned before the research objectives were: (a) to develop a method which could be easily used to make estimations of the distributions of loads which would act on a bridge during a specified time period, (b) to estimate the corresponding loadeffect ranges including the very rare that would arise in different points of the bridge structure due to the load spectrum. Furthermore the method should provide abilities for estimations of the influence of different variables on the appearance of the spectra. This chapter contains a discussion of the two models, which can be used independently of each other, and a discussion of some of the made assumptions.

9.1 Introduction.

Many of the factors which contribute to the appearance of the load spectra and loadeffect spectra are of a non-deterministic nature to a greater extent than others, that is they ought to be treated as stochastic variables whose values are observations of different estimated density functions. As a result of the chosen solution technique, simulation performed as systematic sampling, it has been possible to handle these stochastic variables under rather realistic design conditions and complex criteria for the analyses of the created loadeffect process. The main groups of participating variables may be described as vehicle characteristics (load), bridge characteristics (load to loadeffect) and traffic characteristics (overlapping loadeffects). An important step was taken in the model design when the differences in model response between a static and dynamic bridge-vehicles system was treated in a separate stage, which introduced great simplifications in the model design work. This separate treatment of the dynamic effects was judged to be justified in comparison to the other uncertainties introduced into the model due to the other assumptions made.

A correct treatment of the dynamic influences, expressed as amplifications and extra oscillations, is not an easy task. Much work concerning this subject has been performed both in theory and practice. With the exception of vehicle and bridge weights conditions and natural frequencies of the vehicles and bridge, factors such as vehicle speeds, surface irregularities, initial condition of bridge-vehicles system, vehicle horizontal acceleration and the lateral positions of the vehicles have influence on the resulting bridge response.

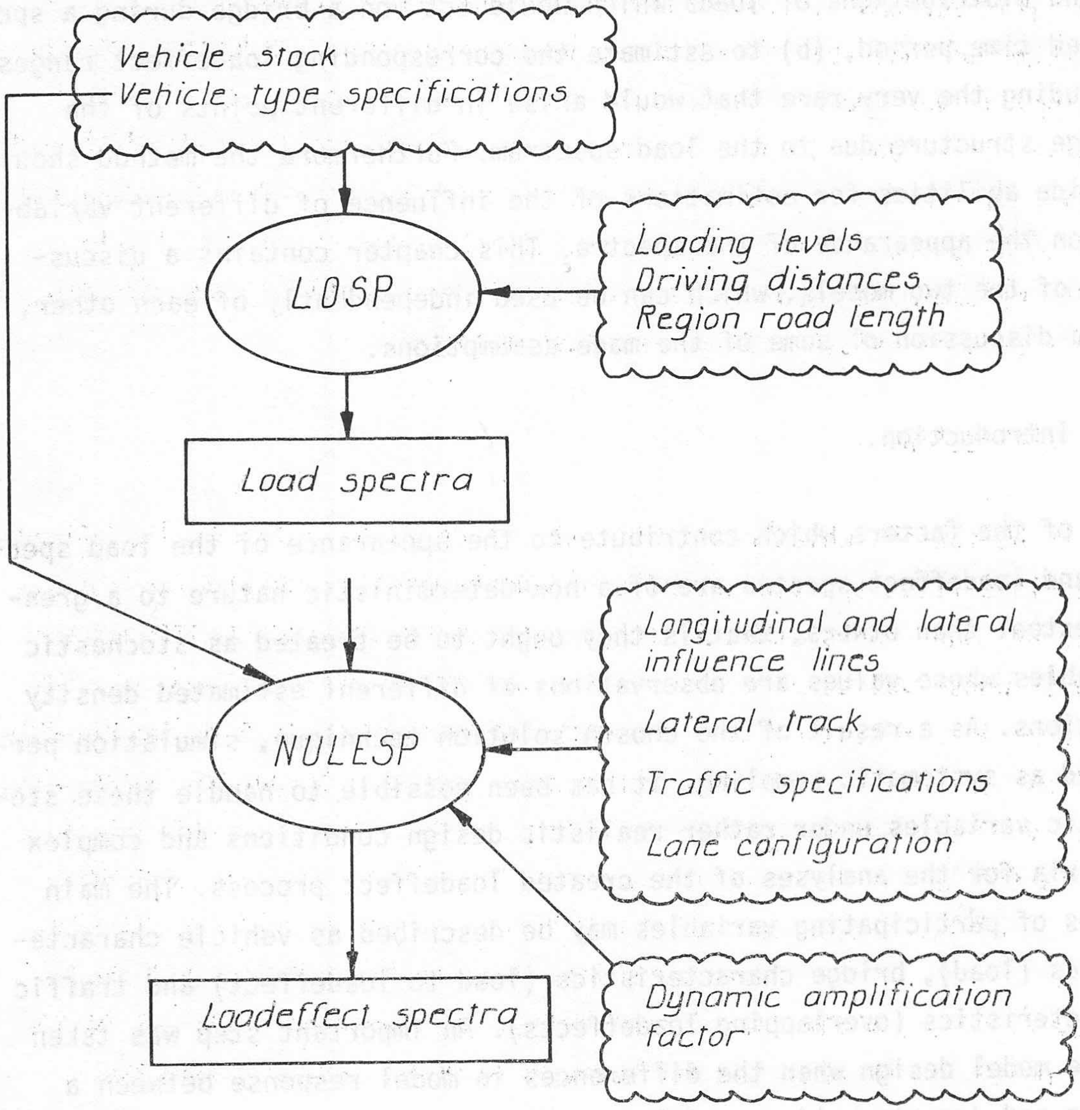


FIG. 9.1-1. Schematic description of the numerical load spectrum model, LOSP, and loadeffect spectrum model, NULESP.

FIG. 9.1-1 shows a schematic scheme of the two models. The following variables are assumed to be non-deterministic: vehicle type total weight, vehicle type axle distances, vehicle type loading level, vehicle lateral track, distances between vehicles in undisturbed flow, queue distances and dynamic amplification factor. The following variables are treated as deterministic: vehicle type weight distribution on axles, vehicle driving distances (mean values for each vehicle type total weight class within the region), vehicle speed during passage, structural point influence surface and vehicle flow intensities during the equivalent time of day.

If the assumed variable properties are estimated to vary considerably during the regarded time period the calculations have to be divided into sub-time periods and the achieved results added up to final spectra valid for the whole time period.

Chapters 9.2 and 9.3 contain a discussion of some of the assumptions made in the LOSP and NULESP models. Some possible model extensions, which are quite simple to do without prolonging the computer times too much, are also presented below. In connection with future field investigations a further validation of the models have to be done.

9.2 Numerical model for calculation of load spectra, LOSP. Discussion.

By means of the load spectrum model, LOSP, distributions are calculated which are valid for vehicle gross weights passing over an optional lane section of the regarded region during a specified time period. The vehicle type specifications are not needed unless axle gross weight distributions are also wanted at this stage. The axle gross weight distributions are recalculated, if desired, in the NULESP model.

9.2.1 Loading level. Driving distance. Discussion.

The vehicle type loading levels are treated as stochastic variables, which are defined for each vehicle type. They are assumed to be independent of variations, as vehicle weight, within the vehicle type. If for example it is judged that the very heavy vehicles have other loading specifications which are noticable such as much higher probability to be overloaded, this circumstance may be taken into consideration by simply defining new vehicle types. Moderate shape differences between the loading level distributions though, do not have to lead to such actions, according to the discussion made in Chapter 3.4.1.

The typical two maxima of the gross weight lane occurence distributions (see for example FIG. 4.3.2-2) which occur because of empty and fully loaded vehicles, were also reported, from field tests, in Ruhl et al. /12/.

A further mapping of the vehicle driving distances in different geographical regions has to be made in order to increase the knowledge about the load spectra of the different regions.

9.3 Numerical model for calculation of loadeffect spectra, NULESP. Discussion.

By means of the loadeffect spectrum model, NULESP, two-dimensional loadeffect range-level distributions are calculated for different structural points of a bridge structure. Below some comments are made on the model.

9.3.1 Weight distribution on axles. Axle spacings. Discussion.

The vehicle type specifications are supposed to be fixed in the overlap calculation parts of the NULESP model. In the single vehicle passage calculations distributed axle distances are though allowed through distributed axle distance factors. These factors are supposed to act with the same value on all the axle distances of a vehicle type. Because of the axle distance factor facility, it is also easy to introduce distributed axle distances in the overlap calculations. From the discussion in Chapter 6.5 it seems to be acceptable if the most dangerous axle distance factor is put in the first place at input, which brings out that it will be used in the overlap calculations.

From Moses et al. /20/ and especially Ruhl et al. /12/ measured axle distance distributions are reported. These distributions are in most cases valid for the 3S-2 semitrailer combinations (with tandem drive and rear axles) which are very common in the USA. (The axle distance factor distributions used in this present report, 0.8, 1, 1.2 having equal probabilities of coming up, are fairly similar to those reported from the USA. However, in some cases should a higher probability for the mean value 1 as well as a greater variation width be used.)

The vehicle type weight distributions on axles are assumed to be fixed and thus independent of the actual vehicle weight and other internal vehicle type variables. This distribution may have a considerable influence on the loadeffect spectrum appearance especially for the short influence lines if there exists divergences for the high axle weights. According to Moses et al. /20/ who reported axle weight distributions, as well as Ruhl et al. /12/, the weight distribution on axles seems to be stable for the high vehicle weights. Furthermore it is reported that in connection with semitrailer combinations (3S-2) the front axle weight always lies around 40 kN (engine and chassi weights) which indicates that these axles get too low a weight portion for the lower gross weights, which therefore ought to be an approximation on the safe side.

In those parts of the LOSP and NULESP models where the axle gross weight distributions are calculated, it is quite possible to introduce special rules for the distribution of the vehicle gross weight on axles, when further knowledge about these circumstances is available from field measurements.

9.3.2 Traffic characteristics. Discussion.

In the derivations of probabilities for meeting it was assumed that the vehicle flows were described by means of Poisson processes, see for example Kapacitetsutredning /26/. This assumption seems to be true for low vehicle flow intensities and distances beyond some truck lengths where the interaction between the vehicles is negligable. This entails that the meeting behaviour ought to be well described as is done in Chapter 6.4.5. In case of dense flows and rather short vehicle distances, the traffic pattern becomes more complex.

Not very much is known about truck behaviour at short time distances. It seems though that in the case of parallel lanes the Poisson assumption will underestimate the real number of such occurences at low time distances between 3-4 seconds and 1 second. These time distances comprise the queue or platoon events, see Moses et al. /20/, Kapacitetsutredning /26/ (all vehicles included). According to Moses et al. /20/ there are also indications that at distances below ≈ 1 second, including overtakings, the number of occurences may be overestimated if Poisson flow is assumed. Desrosier et al. /27/ manually counted the frequencies of multiple truck loadings, on two and three parallel lanes within 100-400 feet sections. They found that the truck volume was the best predictor of multiple truck loading.

In case of meeting lanes nothing has been found in the literature about the truck behaviour. However, there are stored data, waiting for evaluation received from field measurements performed in 1973-1974 at the National Swedish Road and Traffic Research Institute, in connection with validation of a traffic simulation model. It is probable that the evaluation of these data will cast some light on the queue and overtaking behaviour of heavy trucks travelling on meeting lanes.

Due to lack of knowledge, only approximate expressions are put up in the model for the calculations of overtaking and queuing probabilities. As further information is achieved these expressions may be changed by means of the introduced correction factors F7 and F9. The queue distances are assumed to be uniformly distributed but may be changed, if necessary, to an arbitrary distribution.

The vehicle speeds are assumed to be constant and equal during the bridge passage. Besides the fact that the dynamic effects are dependent on speed, the vehicle speed also affects the meeting and overtaking probabilities, which can be interpreted as a change in the time durations of the vehicle type influence lines. The vehicle speed should be given a low rather than a high value, which may be picked from an estimated or measured speed distribution, in order not to cause under estimations of the probabilities for meetings and overtakings. The effect of difference in speeds between vehicles involved in overlapping was not studied as it was estimated that these effects would be concealed by the dynamic effects.

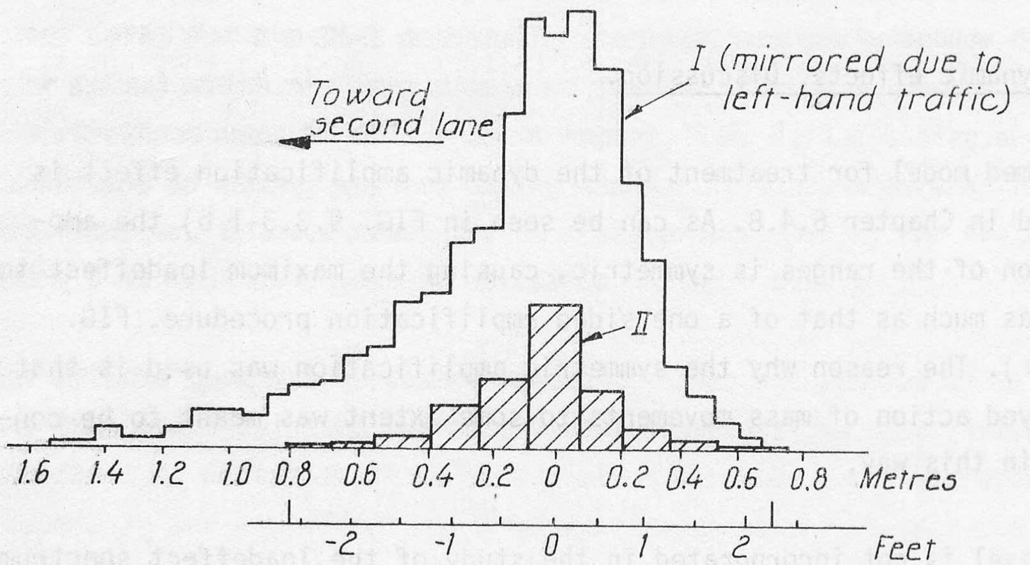


FIG. 9.3.2-1. I) Lateral track, Nunn et al. /11/. (The lane surface was part of a test site. May have disturbed the drivers.)
II) Lateral track, Ruhl et al. /12/. (289 observations.)

The truck traffic follows daily, weekly, monthly and long term yearly variations. It is supposed in the model that mean traffic flows are used and only exist during a fraction, the equivalent time TE, of the day. In this way it is possible to adjust the vehicle flows to intensities that will give conservative estimations of the overlap probabilities.

The lateral track distributions are assumed to be equal for all vehicles though it may be mirrored for the second lane. Very little information was found in the literature about the lateral track distributions for trucks. In FIG. 9.3.2-1 two distributions are sketched, registered on two parallel lane configurations, picked from Ruhl et al. /12/ (II) and Nunn et al. /11/ (I). It was reported in the latter report that no relation between vehicle load and lateral track was found. The lateral track is supposed to be fixed during vehicle passage. This fact is made use of in the equivalent load calculations together with the assumption about separable influence functions. The effect of these assumptions, which greatly simplifies the loadeffect spectrum model and help to keep to computing times low, shall be compared to the other uncertainties introduced into the model which have an effect on the appearance of the vehicle type influence lines. Until further knowledge is gained it is preferable to specify the lateral influence properties on the safe side.

9.3.3 Dynamic effects. Discussion.

The assumed model for treatment of the dynamic amplification effect is described in Chapter 6.4.8. As can be seen in FIG. 9.3.3-1 b) the amplification of the ranges is symmetric, causing the maximum loadeffect to be half as much as that of a one sided amplification procedure, FIG. 9.3.3-1 a). The reason why the symmetric amplification was used is that the delayed action of mass movements to some extent was meant to be considered in this way.

If the level is not incorporated in the study of the loadeffect spectrum there will be no differences between the spectra calculated by means of one sided or symmetric amplification. It should though be strongly emphasized that the assumed model, characterized as a multiplication of the loadeffect distribution by a dynamic amplification factor distribution, involves too many simplifications to admit any deeper conclusions to be drawn about the levels that the ranges are supposed to occur on, after the transformation of the spectrum is performed.

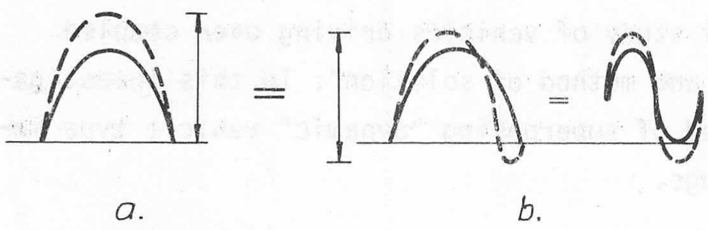


FIG. 9.3.3-1. One sided (a) and symmetric (b) dynamic amplification of a loadeffect range.

The static influence line may at input be superposed an oscillating component as well as any desired deterministic shape adjustment, see FIG. 9.3.3-2. However, if the loads are represented as vehicle type loads (that is not as concentrated gross weights or freely running axles) it is probably better if this correction is directly applied on the vehicle type influence line. (Such a complementary addition may be placed at label VINF in NULESP.) It is further suggested that the extra oscillations which arise after the vehicles have left the bridge, FIG. 9.3.3-2 (I), should be estimated separately with regard to the dynamic properties of the bridge.

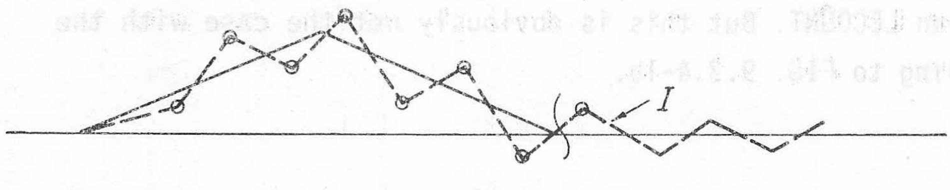


FIG. 9.3.3-2. On the static influence line superposed dynamic oscillation. (I = separately treated free vibrations of the bridge.)

To put up the most proper dynamic specification input requires knowledge about the dynamic properties of the bridge and the structural members involved in the bridge vehicles dynamic system. It was judged that studies aiming at a mapping of such knowledge would lead too far to fall within the scope of this investigation and would not even be necessary as the proposed model already contains many approximate elements. For further references and discussions on dynamic effects, see for exemple

Christiansson /1/, Ruhl et al. /12/ and Moses et al. /20/.

Further information about the dynamic influences may later be brought out from another investigation, performed by the author of this report, which is entitled "Theoretical study of vehicles driving over coupled bridge slabs. Dynamic effects and method of solution". In this investigation the effect will be studied of superposing "dynamic" vehicle type influence lines among other things.

9.3.4 Counting of loadeffect ranges. Discussion.

The statistical counting routine LECOUNT described in Chapter 5.2 is meant to be a clearly defined counting method which can be used on any loadeffect process without restrictions. It also provides information about the levels on which the different loadeffect ranges occur, which will result in a two-dimensional loadeffect range-level spectrum at the end.

Below some cursory comments are made on the comparison between spectra received by means of the LECOUNT routine and those achieved by means of peak counting or level crossing counting methods.

If the loadeffect process has a principal appearance according to FIG. 9.3.4-1a the peak density function will yield the same spectrum as that received from an LECOUNT. But this is obviously not the case with the process according to FIG. 9.3.4-1b.

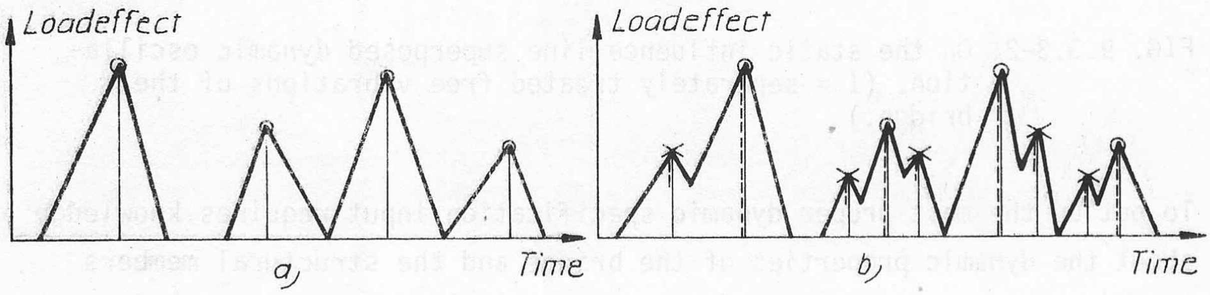


FIG. 9.3.4-1 a) Peak count and LECOUNT yield equivalent results.
b) Peak count gives the same number of ranges but with greater amplitudes (the result of LECOUNT is shown as dashed lines).

The result of a level crossing counting is shown in FIG. 9.3.4-2c.

By cutting out ranges from the level crossing density function according to FIGS. 9.3.4-2c and d it is possible to get a set of ranges that may be compared to those shown in FIG. 9.3.4-2e, which are achieved by means of the LECOUNT routine. The principal difference between the two sets of ranges is that those deduced from the level crossing count do not have to be built up in a close form, that is the individual ranges may be composed of parts which are impossible to fit together without disregarding the actual occurence sequences.

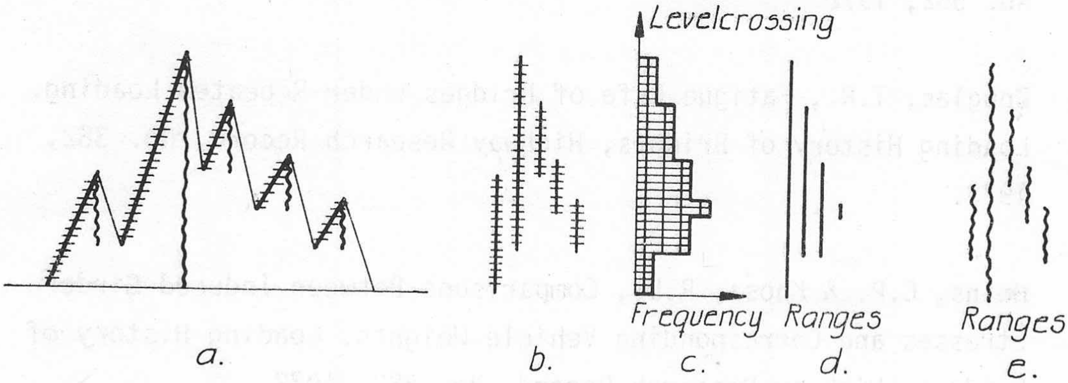


FIG. 9.3.4-2 a) Part of loadeffect process.
b) Counted level crossings during increasing process.
c) Level crossing density function.
d) From "c" cut out ranges.
e) Counted ranges by means of LECOUNT.

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Appendix A Loading level distribution.

FIG. 3.4.1-1 shows a loading level distribution with parameters (I1) referring to L(T1,I1) (see also LIST OF TERMS). In the figure new identifiers are also introduced which are used in the deductions below and in Chapter 3.4.1, Loading level distribution influence.

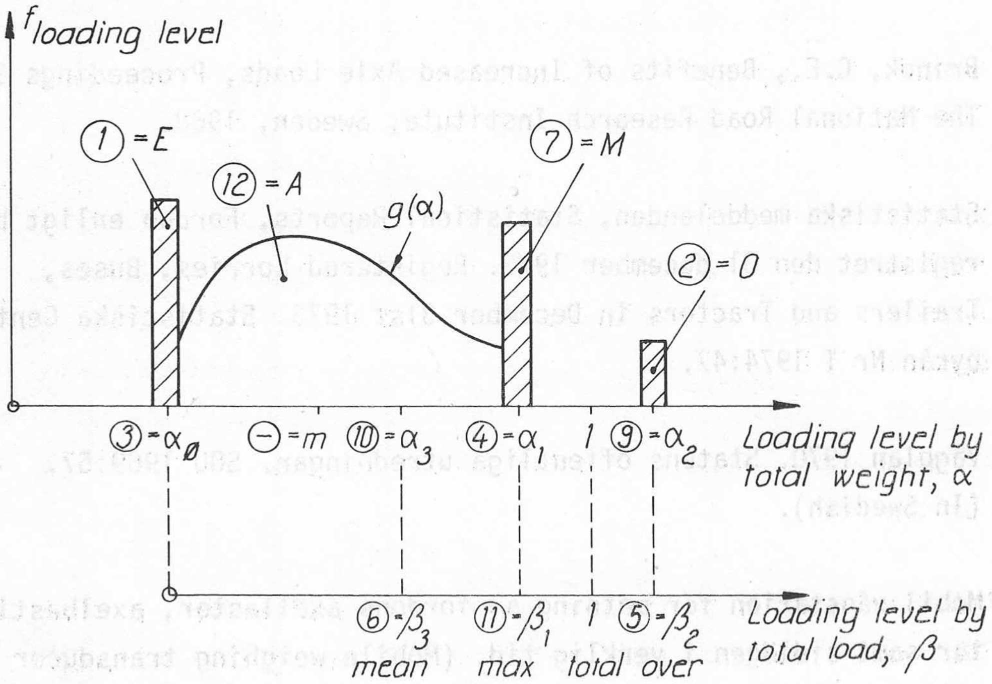


FIG. A-1. Loading level distribution.

Parameters:

α		loading level by total weight
β		loading level by total load
$\alpha_\emptyset$	(3)	tare weight/total weight
E	(1)	tare weight/total weight portion
A	(12)	$\int_{\alpha_\emptyset}^{\alpha_1} g(\alpha)\cdot d\alpha$ = area under $g(\alpha)$
M	(7)	max.weight/total weight portion
O	(2)	overweight/total weight portion
α_1	(4)	max.weight/total weight
α_2	(9)	overweight/total weight
α_3	(10)	mean weight/total weight

β_1	(11)	max load/total load
β_2	(5)	overload/total load
β_3	(6)	mean load/total load
m	(-)	mean of $g(\alpha)$. m(r) see below
$g(\alpha)$		distributed loading level part
h	(8)	parameter describing $g(\alpha)$
s	(13)	parameter describing $g(\alpha)$
r	(14)	$= (m-\alpha_\emptyset)/(\alpha_1-\alpha_\emptyset)$ (A-1) Non-dimensional mean of $g(\alpha)$. $\emptyset \leq r \leq 1$
m(r)		$= \alpha_1 \cdot r + \alpha_\emptyset \cdot (1-r)$ (A-2)

T1 in L(T1, (I1)) points to type of vehicle, (however, used to point to $g(\alpha)$ type in the not listed routine LLTEST used in Chapter 3.4.1). In LOSP are only parameters L(.,I1) with index I1 less equal 9 used.

The loading level is assumed to be described by input parameters

$\alpha_\emptyset$, E, α_1, β_2, O and mean β_3

(if $g(\alpha) = \emptyset$ E is not given input value)

The loading level distribution is then completely described when M and $g(\alpha)$ have been determined. This is done only under the imposed statistical conditions namely the total area to be 1, formula (A-3), and the total mean to be α_3, (A-4). This will give an infinite number of solutions M and $g(\alpha)$, if no restrictions are laid upon $g(\alpha)$, (shape and mean)

$$A + M = 1 - E - O \qquad \text{(A-3)}$$

$$m \cdot A + \alpha_1 \cdot M = \alpha_3 - \alpha_\emptyset \cdot E - \alpha_2 \cdot O \qquad \text{(A-4)}$$

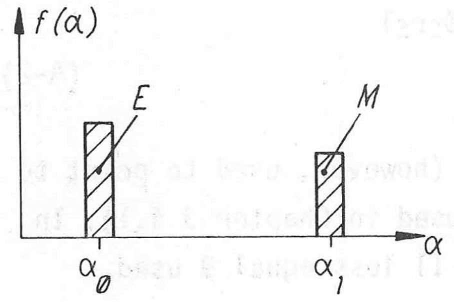
The relations between α and β becomes

$$\alpha = \alpha_\emptyset + \beta \cdot (1 - \alpha_\emptyset) \qquad \text{(A-5)}$$

$$\beta = \frac{\alpha - \alpha_\emptyset}{1 - \alpha_\emptyset} \qquad \text{(A-6)}$$

Below five different $g(\alpha)$ functions are described. Type 3 which is used in the LOSP model is the only one with 0 not equal to $\emptyset$. Though 0 is included in the universal relation deduced for type 2, formula (A-9).

TYPE 1: $g(\alpha) = \emptyset$



INPUT:	CALCULATED:
$\alpha_\emptyset$	E
α_1	M
β_3	

E is introduced as a variable which shall be calculated.

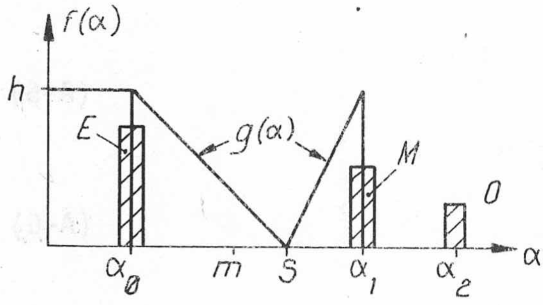
$$\left.\begin{array}{lll} \text{(A-3)} & \rightarrow & M = 1 - E \\ \text{(A-4)} & \rightarrow & \alpha_1 \cdot M = \alpha_3 - \alpha_\emptyset \cdot E \\ \text{(A-5)} & \rightarrow & \alpha_3 = \alpha_\emptyset + \beta_3 (1 - \alpha_\emptyset) \end{array}\right\} \rightarrow$$

$$E = \frac{\alpha_1 - \alpha_\emptyset - \beta_3 (1 - \alpha_\emptyset)}{\alpha_1 - \alpha_\emptyset} \qquad \emptyset \leq E \leq 1 \qquad \text{(A-7)}$$

$$M = 1 - E \qquad \text{(A-8)}$$

Test: $\emptyset \leq E \leq 1$

TYPE 2:



INPUT:	CALCULATED:
$\alpha_\emptyset$	M
E	S
α_1	h
β_3	
r	

(A - 2) (A - 3) (A - 4) (A - 5) →

$$M = \frac{(\beta_3 - \beta_2 \cdot O)\cdot(1 - \alpha_\emptyset)}{(1 - r)\cdot(\alpha_1 - \alpha_\emptyset)} + \frac{r}{1 - r} \cdot E + \frac{r}{1 - r} \cdot O - \frac{r}{1 - r} \qquad \text{(A-9a)}$$

$$E = - \frac{(\beta_3 - \beta_2 \cdot O)(1 - \alpha_\emptyset)}{r \cdot (\alpha_1 - \alpha_\emptyset)} + \frac{1 - r}{r} \cdot M - O + 1 \qquad \text{(A-9b)}$$

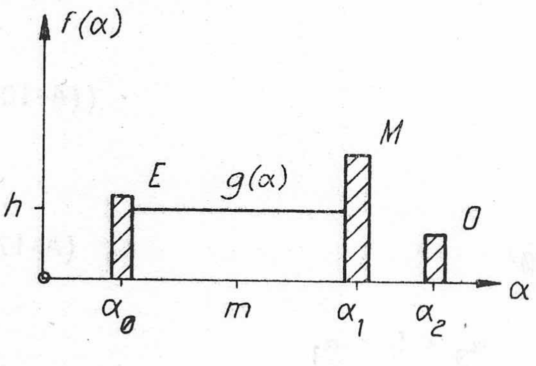
$$h = \frac{2 \cdot (1 - E - M)}{\alpha_1 - \alpha_\emptyset} \qquad \text{(A-10)}$$

$$S = 2 \cdot \alpha_1 - \alpha_\emptyset - 3 \cdot r(\alpha_1 - \alpha_\emptyset) \qquad \text{(A-11)}$$

Test: $\emptyset \leq M \leq 1 \quad \emptyset \leq h \quad \alpha_\emptyset < S < \alpha_1$

$$g(\alpha) = \begin{cases} h \cdot \dfrac{(S - \alpha)}{(S - \alpha_\emptyset)} & \alpha_\emptyset \leq \alpha \leq S \qquad \text{(A-12)} \\ h \cdot \dfrac{(\alpha - S)}{(\alpha_1 - S)} & S < \alpha \leq \alpha_1 \qquad \text{(A-13)} \end{cases}$$

TYPE 3: $g(\alpha) = h$. Used in LOSP



INPUT:	CALCULATED:
$\alpha_\emptyset$	M
E	h
α_1	
β_2	
O	
β_3	

The mean of $g(\alpha)$ is constant with $r = \emptyset.5$

(A-2) (A-3) (A-4) (A-5) →

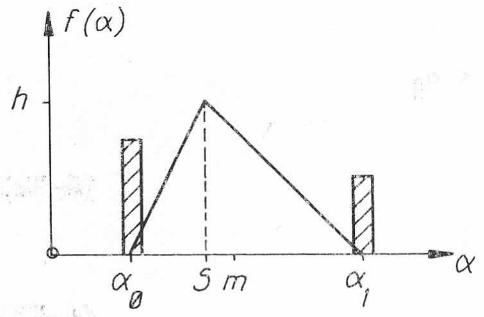
$$M = \frac{2 \cdot (\beta_3 - \beta_2 \cdot 0) \cdot (1 - \alpha_\emptyset)}{\alpha_1 - \alpha_\emptyset} + E + 0 - 1 \qquad \text{(A-14)}$$

$$h = \frac{1 - 0 - M - E}{\alpha_1 - \alpha_\emptyset} \qquad \text{(A-15)}$$

Tests: $\emptyset \leq M \leq 1 \quad \emptyset \leq h$

$$g(\alpha) = h \qquad \text{(A-16)}$$

TYPE 4:



INPUT:	CALCULATED:
$\alpha_\emptyset$	M
E	S
α_1	h
β_3	
r	

(A-2) (A-3) (A-4) (A-5) →

$$M = \frac{\beta_3 (1 - \alpha_\emptyset)}{(1 - r)(\alpha_1 - \alpha_\emptyset)} + \frac{r}{1 - r} \cdot E - \frac{r}{1 - r} \qquad \text{((A-9a))}$$

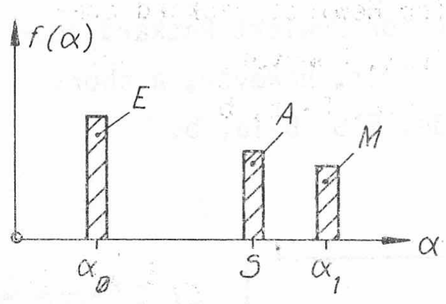
$$h = \frac{2 \cdot (1 - E - M)}{\alpha_1 - \alpha_\emptyset} \qquad \text{((A-10))}$$

$$S = 2 \cdot \alpha_\emptyset - \alpha_1 + 3 \cdot r \cdot (\alpha_1 - \alpha_\emptyset) \qquad \text{(A-17)}$$

Tests: $\emptyset \leq M \leq 1 \quad \emptyset \leq h \quad \alpha_\emptyset < S < \alpha_1$

$$g(\alpha) = \begin{cases} h \cdot \dfrac{(\alpha - \alpha_\emptyset)}{(S - \alpha_\emptyset)} & \alpha_\emptyset \leq \alpha \leq S \qquad \text{(A-18)} \\[2ex] h \cdot \dfrac{(\alpha_1 - \alpha)}{(\alpha_1 - S)} & S < \alpha \leq \alpha_1 \qquad \text{(A-19)} \end{cases}$$

TYPE 5: $g(\alpha)$ = staple



INPUT:	CALCULATED:
$\alpha_\emptyset$	M
E	A
α_1	S
β_3	
r	

(A-2) (A-3) (A-4) (A-5) →

$$M = \frac{\beta_3 \cdot (1 - \alpha_\emptyset)}{(1 - r)(\alpha_1 - \alpha_\emptyset)} + \frac{r}{1 - r} \cdot E - \frac{r}{1 - r} \qquad ((A\text{-}9a))$$

$$A = 1 - E - M \qquad ((A\text{-}3))$$

$$S = \alpha_\emptyset + r \cdot (\alpha_1 - \alpha_\emptyset) \qquad (A\text{-}20)$$

Tests: $\emptyset \leq M \leq 1$ $\quad \emptyset \leq A \leq 1$

Appendix B   Basic-program LOSP. Numerical calculation of load spectra.

Below is listed the computer program LOSP, numerical calculation of load spectra. The program is written in Basic for Hewlett Packard computers (2116C 16K words, 16 bit, or memory). First, however, a short presentation of the BOXPLOT subroutine is made, FIG. B-1a, b.

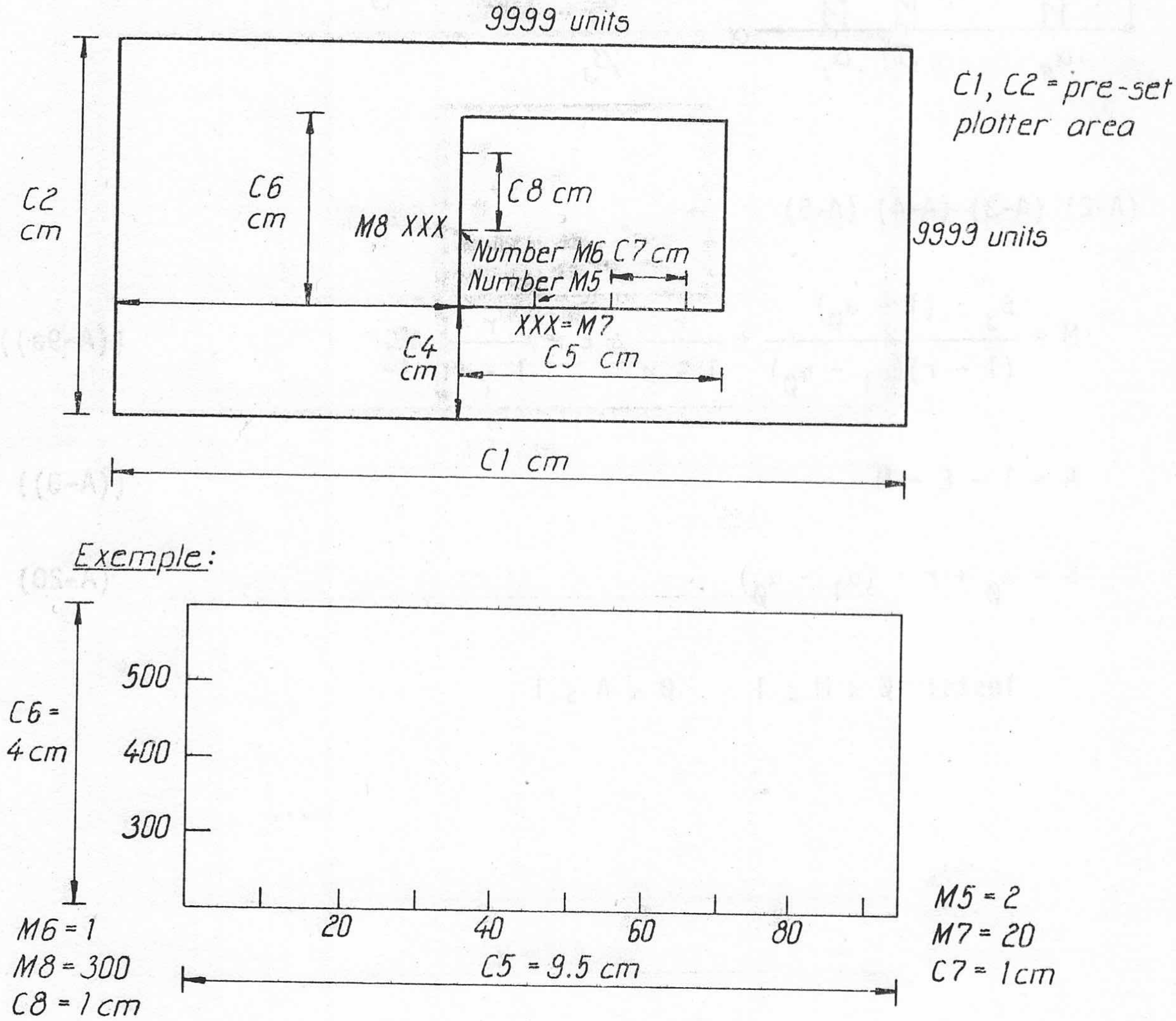


FIG. B-1a. BOXPLOT parameters.
B-1b. Example.

The LOSP program requires ≃ 10 K words (Kilo words) of memory, of which ≃ 4 K are used for array allocations.

```
10  REM *** LOSP ***
15  REM *** CALCULATION OF LOADSPECTRA ***
20  REM *** PER CHRISTIANSSON, LTH 24.1.75 ***
22  REM ** ORG 13576B
100  DIM N[10,70],G[10,70],Y[70],A[10,10],V[10,1],P[2,70]
105  DIM B[10,10],C[10,4],L[10,9],K[10,2],D[10,2]
110  LET Y2=20
115  LET I9=70
117  LET Y3=.27
150  DEF FNC(P)=INT(P/P1)+1
160  DEF FNP(C)=P1*C-P1/2
165  DEF FND(C)=D[T1,1]+(C-C[T1,1])*(D[T1,2]-D[T1,1])/(C[T1,2]-C[T1,1])
200  PRINT "RUN NB.";
205  INPUT Y1
230  GOSUB 1000
240  GOSUB 1500
245  PRINT
250  PRINT "REGION NB.";
255  INPUT R
267  PRINT
270  PRINT "--DRIVING DIST. INPUT--";
275  INPUT S9
280  IF S9#1 THEN 305
300  GOSUB 2000
303  PRINT
305  PRINT "--LOADING LEVEL INPUT--";
310  INPUT S8
315  IF S8#1 THEN 325
320  GOSUB 2500
325  IF S8#1 AND S9#1 THEN 355
327  GOSUB 3000
330  GOSUB 3500
335  GOSUB 4000
355  PRINT
360  PRINT "--DENS PLOT --";
365  INPUT I1
370  IF I1#1 THEN 380
375  GOSUB 6500
377  PRINT
380  PRINT "-- SPECT PLOTT --";
385  INPUT I1
390  IF I1#1 THEN 400
395  GOSUB 7000
400  PRINT "--PUNCH (0=N0, 1=TOT, 2=TOT+TYPE)--";
405  INPUT S9
410  IF S9=0 THEN 420
415  GOSUB 8000
420  GOTO 250
1000  REM --SUB VEH.SPEC--
1001  PRINT "NB. OF VEHICLE TYPES";
1002  INPUT T2
1003  PRINT
1005  PRINT "AXLEDIST=4 WEIGHTDISTR=5 (FROM FRONT) ADD 0:S"
1010  PRINT
1015  FOR T1=1 TO T2
1020  PRINT "--VEH.TYPE";T1
1030  PRINT "NB. OF AXLES";TAB(Y2);
1035  INPUT V[T1,1]
1040  PRINT "AXLEDIST (M)";TAB(Y2);
1042  INPUT A[T1,2],A[T1,3],A[T1,4],A[T1,5]
1044  LET A[T1,1]=0
1045  FOR I2=2 TO V[T1,1]
1047  LET A[T1,1]=A[T1,1]+A[T1,I2]
1050  NEXT I2
1055  PRINT "  TOT AXLEDIST=";A[T1,1]
1060  PRINT "WEIGHT DISTR (REL)";TAB(Y2);
1065  INPUT B[T1,1],B[T1,2],B[T1,3],B[T1,4],B[T1,5]
1070  LET I3=0
1072  FOR I2=1 TO V[T1,1]
1075  LET I3=I3+B[T1,I2]
1080  NEXT I2
1085  PRINT "  WEIGHT DISTR (%/10)";
1090  FOR I2=1 TO V[T1,1]
1095  LET B[T1,I2]=B[T1,I2]/I3
1100  PRINT INT(B[T1,I2]*1000+.5);
1105  NEXT I2
1107  PRINT
1110  NEXT T1
1119  RETURN
1500  REM --TOT WEIGHT INPUT--
1505  PRINT
1510  PRINT "WEIGHT CLASS WIDTH,KN";
1512  INPUT P1
1513  PRINT "TURN ON READER,RUN"
1514  CALL (7)
1515  FOR I1=1 TO 10
1520  FOR I2=1 TO I9
1525  LET N[I1,I2]=0
1530  NEXT I2
1535  NEXT I1
1540  FOR T1=1 TO T2
1550  INPUT K3,K4,I2
1555  LET C[T1,1]=FNC(K3)
1560  LET C[T1,2]=FNC(K4)
1562  LET K[T1,1]=0
1565  IF C[T1,2]=C[T1,1]+I2-1 THEN 1570
1567  PRINT "N[] FAULT TYPE";T1
1568  GOTO 1505
1570  FOR I3=0 TO I2-1
1575  INPUT N[T1,C[T1,1]+I3]
1577  LET K[T1,1]=K[T1,1]+N[T1,C[T1,1]+I3]
1580  NEXT I3
1585  NEXT T1
1590  PRINT "TURN OF READER,RUN"
1595  CALL (7)
1599  RETURN
2000  REM--SUB DRIVING DIST INPUT--
2001  PRINT "*** REGION ROAD LENGTH (KM)=";
2002  INPUT L
2003  PRINT
2005  PRINT "VEH.TYPE","LOWEST WC (KN)","HIGHEST WC (KN)","   KM     KM"
2007  FOR T1=1 TO T2
2010  PRINT T1,FNP(C[T1,1]),FNP(C[T1,2]),
2015  INPUT D[T1,1],D[T1,2]
2020  NEXT T1
2099  RETURN
2500  REM --SUB LOADING LEVEL INPUT--
2502  PRINT
2505  FOR T1=1 TO T2
2507  PRINT
2510  PRINT "-VEH.TYPE";T1;TAB(Y2);
2515  PRINT "TARE/TOT, %, OVERLOAD/MAX LOAD, %, MAX/TOT"
2517  PRINT TAB(Y2);
2520  INPUT L[T1,3],L[T1,1],L[T1,5],L[T1,2],L[T1,4]
2525  LET L[T1,1]=L[T1,1]/100
2530  LET L[T1,2]=L[T1,2]/100
2535  PRINT "MEAN LOAD/TOT LOAD";
2540  INPUT L[T1,6]
2545  LET L[T1,7]=2*(1-L[T1,3])/(L[T1,4]-L[T1,3])
2550  LET L[T1,7]=L[T1,7]*(L[T1,6]-L[T1,5]*L[T1,2])-1+L[T1,1]+L[T1,2]
2555  LET L[T1,8]=(1-L[T1,1]-L[T1,7]-L[T1,2])/(L[T1,4]-L[T1,3])
2560  IF L[T1,7] >= 0 AND L[T1,8] >= 0 THEN 2575
2565  PRINT "!!!!"
2570  GOTO 2515
2575  PRINT "MEAN/TOT  OVER/TOT                    ";
2577  LET L[T1,9]=L[T1,3]+L[T1,5]*(1-L[T1,3])
2580  PRINT L[T1,3]+L[T1,6]*(1-L[T1,3]);L[T1,9]
2582  PRINT "MAX/TOT(%)  H-DISTR                    ";L[T1,7]*100;L[T1,8]
2585  NEXT T1
2599  RETURN
3000  REM --SUB CALC. TOTALW LANEOCC.--
3005  FOR I1=1 TO 10
3010  FOR I2=1 TO I9
3015  LET G[I1,I2]=0
3020  NEXT I2
3025  NEXT I1
3030  FOR T1=1 TO T2
3035  LET K[T1,2]=0
3040  FOR I2=C[T1,1] TO C[T1,2]
3045  LET G[T1,I2]=N[T1,I2]*FND(I2)/2/L
3050  LET K[T1,2]=K[T1,2]+G[T1,I2]
3055  NEXT I2
3060  NEXT T1
3065  RETURN
3500  REM --CALC. GROSSW.LANEOCC--
3505  FOR T1=1 TO T2
3510  FOR I2=1 TO I9
3515  LET Y[I2]=0
3520  NEXT I2
3525  FOR I2=C[T1,1] TO C[T1,2]
3530  LET K4=FNP(I2)
3535  LET I3=FNC(K4*L[T1,3])
3540  LET Y[I3]=Y[I3]+G[T1,I2]*L[T1,1]
3550  LET I4=FNC(K4*L[T1,4])
3555  LET Y[I4]=Y[I4]+G[T1,I2]*L[T1,7]
3565  LET I5=FNC(K4*L[T1,9])
3570  LET Y[I5]=Y[I5]+G[T1,I2]*L[T1,2]
3575  IF I3#I4 THEN 3590
3580  LET Y[I3]=Y[I3]+(L[T1,4]-L[T1,3])*L[T1,8]*G[T1,I2]
3585  GOTO 3640
3590  LET Y[I3]=Y[I3]+((FNP(I3)+P1/2)/K4-L[T1,3])*L[T1,8]*G[T1,I2]
3595  LET Y[I4]=Y[I4]+(L[T1,4]-(FNP(I4)-P1/2)/K4)*L[T1,8]*G[T1,I2]
3600  LET I3=I3+1
3610  IF I3=I4 THEN 3640
3620  LET Y[I3]=Y[I3]+(P1/K4)*L[T1,8]*G[T1,I2]
3630  GOTO 3600
3640  NEXT I2
3641  LET C[T1,3]=FNC(FNP(C[T1,1])*L[T1,3])
3642  LET C[T1,4]=FNC(FNP(C[T1,2])*L[T1,9])
3645  IF L[T1,9] >= L[T1,4] THEN 3650
3647  LET C[T1,4]=FNC(FNP(C[T1,2])*L[T1,4])
3650  FOR I2=1 TO I9
3655  LET G[T1,I2]=Y[I2]
3661  NEXT I2
3670  NEXT T1
3699  RETURN
4000  REM --TOT CALC--
4005  LET N1=N2=0
4010  FOR T1=1 TO T2
4015  LET N1=N1+K[T1,2]
4020  LET N2=N2+V[T1,1]*K[T1,2]
4025  NEXT T1
4030  FOR I1=1 TO I9
4035  LET P[1,I1]=P[2,I1]=0
4040  NEXT I1
4050  FOR I1=1 TO I9
4055  FOR T1=1 TO T2
4060  LET P[1,I1]=P[1,I1]+G[T1,I1]
4070  FOR I2=1 TO V[T1,1]
4075  LET I3=FNC(FNP(I1)*B[T1,I2])
4080  LET P[2,I3]=P[2,I3]+G[T1,I1]
4090  NEXT I2
4095  NEXT T1
4100  NEXT I1
4110  LET Z2=Z3=I9
4115  FOR I1=I9 TO 1 STEP -1
4120  IF P[1,I1]=0 THEN 4130
4125  LET Z2=I1
4127  GOTO 4135
4130  NEXT I1
4135  FOR I1=I9 TO 1 STEP -1
4140  IF P[2,I1]=0 THEN 4155
4145  LET Z4=I1
4150  GOTO 4199
4155  NEXT I1
4199  RETURN
6000  REM -- BOX PLOT --
6002  LET K1=C3/C1*9999
6008  LET K2=C4/C2*9999
6010  CALL (5,-1,0,K1,K2)
6015  IF C7 <= 0 OR C7>C5 THEN 6045
6020  FOR I1=1 TO INT(C5/C7)
6025  CALL (5,1,-1,C7/C1*9999,0)
6030  GOSUB 6300
6040  NEXT I1
6045  CALL (5,1,1,K1+C5/C1*9999,K2)
6050  CALL (5,1,-1,0,C6/C2*9999)
6060  CALL (5,1,-1,-C5/C1*9999,0)
6065  IF C8 <= 0 OR C8>C6 THEN 6105
6070  CALL (5,1,-1,0,(INT(C6/C8)*C8-C6)/C2*9999)
6075  FOR I1=1 TO INT(C6/C8)
6080  GOSUB 6350
6090  CALL (5,1,-1,0,-C8/C2*9999)
6100  NEXT I1
6105  CALL (5,1,1,K1,K2)
6110  LET I1=0
6115  LET I1=I1+M5
6120  IF I1*C7 >= C5 THEN 6145
6125  CALL (5,-1,1,K1+(I1*C7-.4)/C1*9999,K2-1.2*Y3/C2*9999)
6130  GOSUB 6200
```

```
6135  PRINT M7*INT(I1/M5)
6140  GOTO 6115
6145  LET I1=0
6150  LET I1=I1+M6
6155  IF I1*C8 >= C6 THEN 6180
6157  LET I6=M8*INT(I1/M6)
6158  LET I6=(I6>0)+(I6 >= 10)+(I6 >= 100)+1
6160  CALL (5,-1,1,K1-I6*Y3/C1*9999,K2+I1*C8/C2*9999)
6165  GOSUB 6200
6170  PRINT M8*INT(I1/M6)
6175  GOTO 6150
6180  CALL (5,-1,1,K1+Y3/C1*9999,K2+(C6-1.3*Y3)/C2*9999)
6199  RETURN
6200  CALL (6,Y3/C1*9999,0,0,Y3/C2*9999)
6209  RETURN
6300  CALL (5,1,-1,0,.2/C2*9999)
6305  CALL (5,1,-1,0,-.2/C2*9999)
6309  RETURN
6350  CALL (5,1,-1,.2/C1*9999,0)
6355  CALL (5,1,-1,-.2/C1*9999,0)
6359  RETURN
6500  REM -- DENS PLOT --
6505  LET C1=26
6510  LET C2=17.5
6512  LET C5=5
6514  LET C6=7
6515  LET C7=C8=M5=M6=1
6516  LET M7=200
6517  LET M8=2
6518  LET K3=P1/200/C1*9999
6519  CALL (5,-1,1,385,9713)
6520  GOSUB 6200
6525  PRINT "REG-TOTW, LANEOCC-GROSSW, %(OR %/10) VERT &";P1;
6527  PRINT "KN HOR."
6530  CALL (5,1,-1,1/C1*9999,0)
6555  GOSUB 6200
6560  PRINT "=5M (AXLEDIST) =100%(VERT WEIGHTDISTR)";
6565  PRINT ", N-REG/N-LANEOCC (1 YEAR)"
6567  GOSUB 6200
6568  PRINT "RUN";Y1;"  REGION";R
6570  LET C4=16.5
6575  LET T1=1
6580  FOR I2=0 TO 5 STEP 5
6585  LET C4=C4-8
6590  LET C3=-4
6600  FOR T1=T1 TO 5+I2
6605  IF T1=T2+1 THEN 6899
6610  LET C3=C3+5
6645  GOSUB 6000
6650  GOSUB 6200
6655  PRINT "TYPE";T1
6660  GOSUB 6200
6665  PRINT K[T1,1]
6670  GOSUB 6200
6675  PRINT K[T1,2]
6677  CALL (5,-1,1,K1+1/C1*9999,K2+(C6-1.5)/C2*9999)
6680  LET I3=B[T1,1]/C2*9999
6685  CALL (5,1,-1,0,-I3)
6690  CALL (5,1,-1,0,I3)
6700  FOR I4=1 TO V[T1,1]-1
6705  CALL (5,1,-1,A[T1,I4+1]/5/C1*9999,0)
6710  LET I3=B[T1,I4+1]/C2*9999
6720  CALL (5,1,-1,0,-I3)
6725  CALL (5,1,-1,0,I3)
6730  NEXT I4
6750  DEF FNU(I4)=N[T1,I4]/K[T1,1]*(I5=1)+G[T1,I4]/K[T1,2]*(I5=3)
6755  LET I5=1
6760  CALL (5,-1,1,K1+(C[T1,I5]-1)*K3,K2)
6762  GOSUB 6300
6764  LET K4=50/C2*9999
6765  LET I6=0
6766  FOR I4=C[T1,I5] TO C[T1,I5+1]
6767  IF I6>FNU(I4) THEN 6769
6768  LET I6=FNU(I4)
6769  NEXT I4
6770  IF I6<.175 THEN 6773
6771  LET K4=K4/10
6773  FOR I4=C[T1,I5] TO C[T1,I5+1]
6775  CALL (5,1,1,K1+(I4-1)*K3,FNU(I4)*K4+K2)
6780  CALL (5,1,1,K1+(I4)*K3,FNU(I4)*K4+K2)
6785  NEXT I4
6790  CALL (5,1,1,K1+(C[T1,I5+1])*K3,K2)
6795  GOSUB 6300
6800  IF I5=3 THEN 6825
6815  LET I5=3
6816  CALL (5,-1,-1,0,0)
6817  CALL (7)
6820  GOTO 6760
6825  CALL (5,-1,-1,0,0)
6827  CALL (7)
6830  NEXT T1
6835  NEXT I2
6899  CALL (5,-1,1,9999,9999)
6900  RETURN
7000  REM -- SPECT PLOT --
7005  LET C1=26
7015  LET C2=17.5
7020  LET C5=10
7025  LET C6=8
7026  LET C7=C8=M5=M6=1
7027  LET M7=10
7028  LET M8=100
7030  LET K8=N1
7035  LET K9=N2
7105  CALL (5,-1,1,769,9760)
7110  GOSUB 6200
7115  PRINT "GROSSW SPECTRA KN-% KN-LOG(ABS)";
7117  PRINT "    ";
7120  PRINT "AXLEW SPECTRA RUN:REGION";Y1;R
7122  REM  --
7125  LET C3=2
7130  LET C4=9
7150  GOSUB 6000
7153  GOSUB 6200
7156  PRINT "   N1/LANE=";K8
7160  LET K3=1/C1*9999
7165  LET K4=P1/100/C2*9999
7170  FOR T1=0 TO T2
7180  CALL (7)
7185  LET K5=K1+10*K3
7186  IF T1=0 THEN 7190
7187  LET K5=K1+K[T1,2]/K8*10*K3
7190  LET K6=K2
7195  GOSUB 7900
7200  FOR I1=1 TO (T1=0)*Z2+(T1#0)*C[(T1=0)*1+T1,4]
7205  LET K6=K6+K4
7210  GOSUB 7700
7215  IF T1#0 THEN 7230
7220  LET K5=K5-P[1,I1]/K8*10*K3
7225  GOTO 7235
7230  LET K5=K5-G[T1,I1]/K8*10*K3
7235  GOSUB 7700
7250  NEXT I1
7255  CALL (5,-1,-1,0,0)
7260  NEXT T1
7261  CALL (7)
7262  REM --
7265  LET C4=.5
7267  LET M7=1
7268  LET K3=K3/LOG(10)
7270  GOSUB 6000
7275  GOSUB 6200
7280  PRINT "   N50/LANE=";K8*50
7285  FOR T1=0 TO T2
7290  CALL (7)
7300  LET K8=(T1#0)*C[(T1=0)*1+T1,4]+(T1=0)*Z2
7305  LET K6=K2+K8*K4
7310  LET K5=K1
7315  LET I5=0
7320  CALL (5,-1,1,K5,K6)
7325  FOR I6=K8 TO 1 STEP -1
7330  LET I5=I5+((T1#0)*G[(T1=0)*1+T1,I6]+(T1=0)*P[1,I6])*50
7335  LET K5=K1+LOG(I5*(I5>1)+(I5 <= 1))*K3
7340  GOSUB 7700
7345  LET K6=K2+(I6-1)*K4
7350  GOSUB 7700
7355  NEXT I6
7360  GOSUB 7900
7395  CALL (5,-1,-1,0,0)
7400  NEXT T1
7405  CALL (7)
7407  REM --
7410  LET C3=14
7415  LET C4=9
7420  LET C8=2.5
7422  LET M7=10
7425  LET K4=K4*2.5
7427  LET K3=1/C1*9999
7430  GOSUB 6000
7433  GOSUB 6200
7436  PRINT "   N1/LANE=";K9
7440  LET K5=K1+10*K3
7450  LET K6=K2
7455  CALL (5,-1,1,K5,K6)
7460  FOR I1=1 TO Z4
7465  LET K6=K6+K4
7470  GOSUB 7700
7475  LET K5=K5-P[2,I1]/K9*10*K3
7480  GOSUB 7700
7490  NEXT I1
7495  LET C4=.5
7497  LET M7=1
7498  LET K3=K3/LOG(10)
7510  GOSUB 6000
7515  GOSUB 6200
7520  PRINT "   N50/LANE=";K9*50
7530  LET K6=K2+Z4*K4
7535  LET K5=K1
7540  LET I5=0
7545  CALL (5,-1,1,K5,K6)
7550  FOR I6=Z4 TO 1 STEP -1
7555  LET I5=I5+P[2,I6]*50
7560  LET K5=K1+LOG(I5*(I5>1)+(I5 <= 1))*K3
7565  GOSUB 7700
7570  LET K6=K2+(I6-1)*K4
7575  GOSUB 7700
7580  NEXT I6
7590  CALL (5,-1,1,9999,9999)
7599  RETURN
7700  CALL (5,1,1,K5,K6)
7709  RETURN
7900  CALL (5,-1,1,K5,K6)
7905  CALL (5,-1,-1,0,(T1/2+1)/C2*9999)
7910  GOSUB 6200
7912  IF T1=0 THEN 7918
7915  PRINT T1
7917  GOTO 7920
7918  PRINT " T"
7920  CALL (5,-1,1,K5,K6)
7929  RETURN
8000  REM --SUB PUNCH --
8005  CALL (3)
8010  LET Y[1]=Y1
8015  LET Y[2]=R
8020  CALL (4,Y[1],2)
8022  CALL (3)
8025  LET Y[1]=P1
8100  FOR I1=1 TO 2
8105  LET Y[2]=1
8110  LET Y[3]=Z2*(I1=1)+Z4*(I1=2)
8115  LET Y[4]=N1*(I1=1)+N2*(I1=2)
8120  CALL (4,Y[1],4)
8130  FOR I2=Y[2] TO Y[3]
8135  CALL (4,P[I1,I2],1)
8140  NEXT I2
8150  CALL (3)
8160  NEXT I1
8200  IF S9=1 THEN 8255
8205  FOR T1=1 TO T2
8210  LET Y[2]=C[T1,3]
8215  LET Y[3]=C[T1,4]
8220  LET Y[4]=K[T1,2]
8225  CALL (4,Y[1],4)
8230  FOR I1=Y[2] TO Y[3]
8235  CALL (4,G[T1,I1],1)
8240  NEXT I1
8245  CALL (3)
8250  NEXT T1
8255  RETURN
9999  END
```

Appendix C   Loadeffect counting routine LECOUNT

Variables:

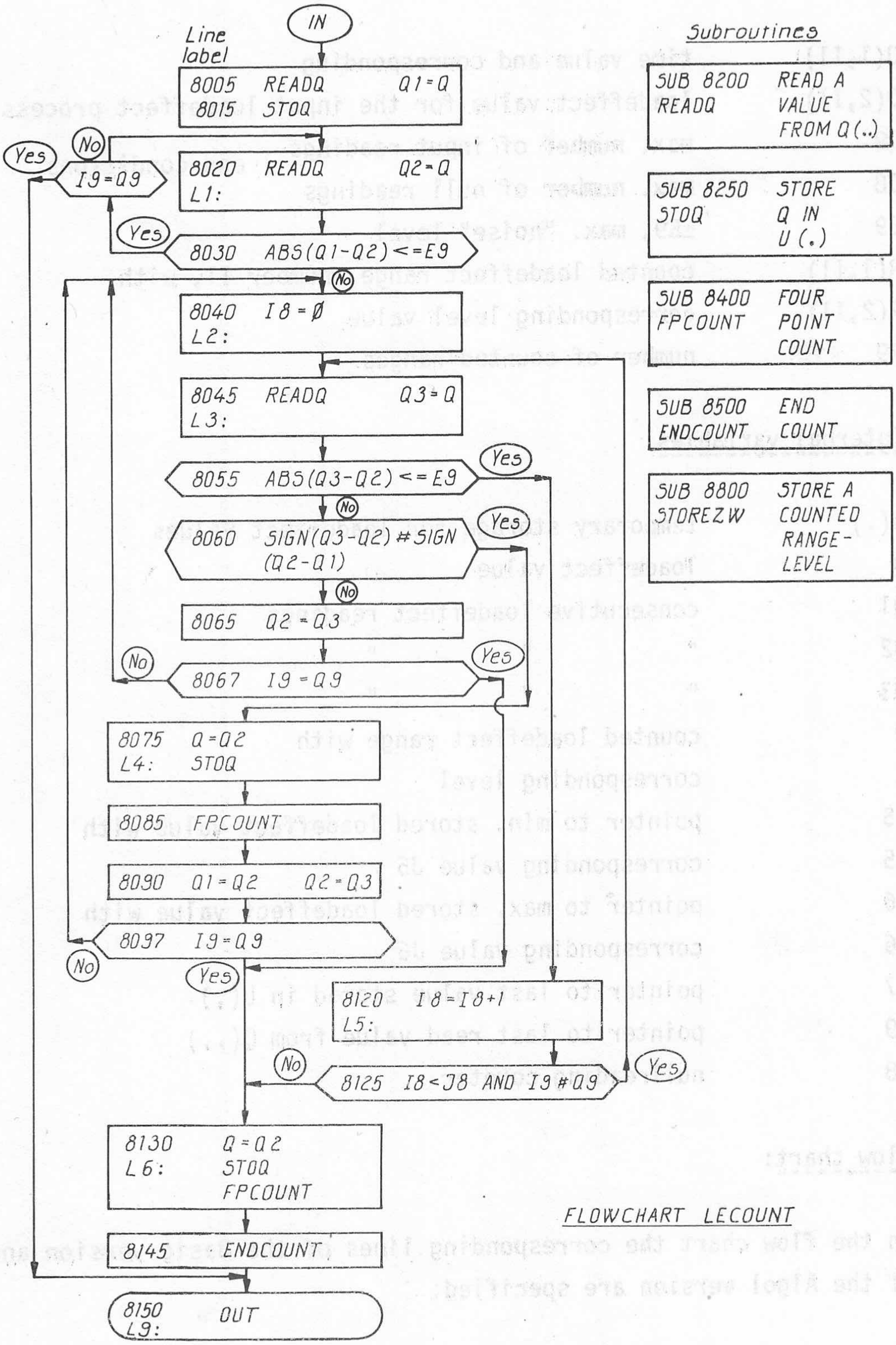
Q(1,I1)	time value and corresponding
Q(2,I1)	loadeffect value for the input loadeffect process
Q9	max. number of input readings } end conditions
J8	max. number of null readings
E9	±E9, max. "noise" level
R(1,I1)	counted loadeffect range, number I1, with
R(2,I1)	corresponding level value
R9	number of counted ranges

Internal variables:

U(.)	temporary storage for loadeffect values
Q	loadeffect value
Q1	consecutive loadeffect readings
Q2	" " "
Q3	" " "
W	counted loadeffect range with
Z	corresponding level
I5	pointer to min. stored loadeffect value with
J5	corresponding value J5
I6	pointer to max. stored loadeffect value with
J6	corresponding value J6
I7	pointer to last value stored in U(.)
I9	pointer to last read value from Q(..)
I8	nullreading counter

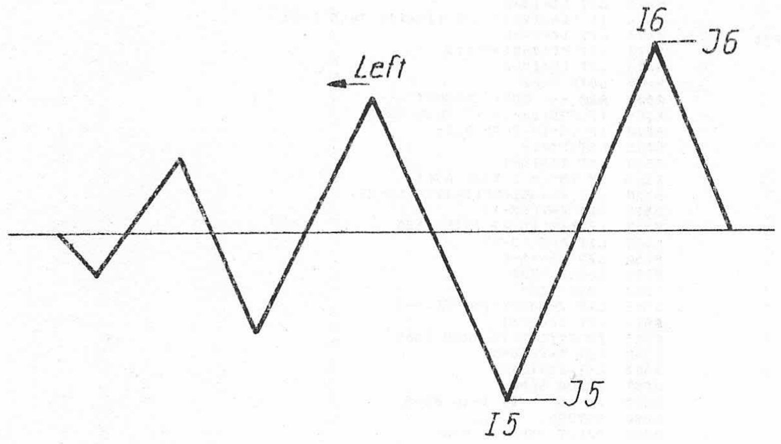
Flow chart:

In the flow chart the corresponding lines of the Basic version and labels of the Algol version are specified.



FLOWCHART LECOUNT

The method of working for the subroutine ENDCOUNT is sketched below.



If I6 is less than I5 they change values, because I5 shall be used as a counter to the left. The maxima and minima are paired off to the left starting with I5-1, I5-2. I5 is then counted down by 2 and the procedure repeated until one or no point is left, that is I5 must be greater than 2 if a pairing off shall be possible. In the same way the pairing off to the right is performed starting with I6-1, I6 (the greatest range). I6 is then counted up by 2 and if I6 is less or equal I7 the pairing off continous.

```
8000  REM --- SUB. LECOUNT ---
8002  DIM Y[30]
8003  LET J5=J6=I7=I9=Ø
8005  GOSUB 8200
8010  LET Q1=Q
8015  GOSUB 8250
8020  GOSUB 8200
8025  LET Q2=Q
8030  IF ABS(Q1-Q2) <= Q9 THEN 8020
8040  LET I8=Ø
8045  GOSUB 8200
8050  LET Q3=Q
8055  IF ABS(Q3-Q2) <= Q9 THEN 8120
8060  IF SGN(Q3-Q2)#SGN(Q2-Q1) THEN 8075
8065  LET Q2=Q3
8070  GOTO 8040
8075  LET Q=Q2
8080  GOSUB 8250
8085  GOSUB 8400
8090  LET Q1=Q2
8095  LET Q2=Q3
8100  GOTO 8040
8120  LET I8=I8+1
8125  IF I8<J8 THEN 8045
8130  LET Q=Q2
8135  GOSUB 8250
8140  GOSUB 8400
8145  GOSUB 8500
8150  RETURN
8200  REM --- SUB. READQ ---
8205  LET I9=I9+1
8210  LET Q=Q[I9]
8215  RETURN
8250  REM --- SUB. STOQ ---
8260  LET I7=I7+1
8265  LET Y[I7]=Q
8270  IF Q<J6 THEN 8285
8275  LET I6=I7
8280  LET J6=Q
8285  IF Q>J5 THEN 8300
8290  LET I5=I7
8295  LET J5=Q
8300  RETURN
8400  REM --- SUB. FPCOUNT ---
8405  IF I7>3 THEN 8415
8410  RETURN
8415  LET K9=(U[I7-1] >= U[I7-3])*(U[I7-2] >= U[I7-1])*(U[I7] >= U[I7-2])
8420  IF K9=1 THEN 8440
8425  LET K9=(U[I7-1] <= U[I7-3])*(U[I7-1] >= U[I7-2])*(U[I7] <= U[I7-2])
8430  IF K9=1 THEN 8440
8435  RETURN
8440  LET Z=Y[I7-2]
8445  IF Z<Y[I7-1] THEN 8455
8450  LET Z=Y[I7-1]
8455  LET W=Y[I7-1]-Y[I7-2]
8460  GOSUB 8800
8470  IF (I5#I7-1) AND (I5#I7) THEN 8474
8472  LET I5=I5-2
8474  IF (I6#I7-1) AND (I6#I7) THEN 8490
8476  LET I6=I6-2
8490  LET Y[I7-2]=Y[I7]
8495  LET I7=I7-2
8499  GOTO 8400
8500  REM --- SUB. ENCOUNT ---
8505  IF ABS(I6-I5)#1 THEN 8605
8510  IF I5<I6 THEN 8525
8515  LET I5=I6
8520  LET I6=I5+1
8525  IF I5 <= 2 THEN 8565
8530  LET W=-ABS(Y[I5-1]-Y[I5-2])
8535  LET Z=Y[I5-1]
8540  IF Z<Y[I5-2] THEN 8550
8545  LET Z=Y[I5-2]
8550  LET I5=I5-2
8555  GOSUB 8800
8560  GOTO 8525
8565  LET W=ABS(Y[I6]-Y[I6-1])
8570  LET Z=Y[I6]
8575  IF Z<Y[I6-1] THEN 8585
8580  LET Z=Y[I6-1]
8585  LET I6=I6+2
8587  GOSUB 8800
8590  IF I6 <= I7 THEN 8565
8600  RETURN
8605  PRINT "ERR.ENCOUNT"
8649  STOP
8800  PRINT "Z,W",Z,W
8810  RETURN
9999  END
```

```
PROCEDURE LECOUNT(QT,Q9,R,R9,J8,E9) ;
 REAL ARRAY QT,R ; INTEGER Q9,R9,J8 ; REAL E9 ;
 BEGIN REAL ARRAY U(1:100) ; REAL Q,Q1,Q2,Q3,Z,W,J5,J6 ;
   INTEGER I5,I6,I7,I8,I9 ;

   PROCEDURE STOQ ;
   BEGIN I7=I7+1 ; U(I7)=Q ;
       IF Q LSS J6 THEN GOTO L1 ELSE BEGIN I6=I7 ; J6=Q END ;
   L1: IF Q GTR J5 THEN GOTO L2 ELSE BEGIN I5=I7 ; J5=Q END ;
   L2: END STOQ ;

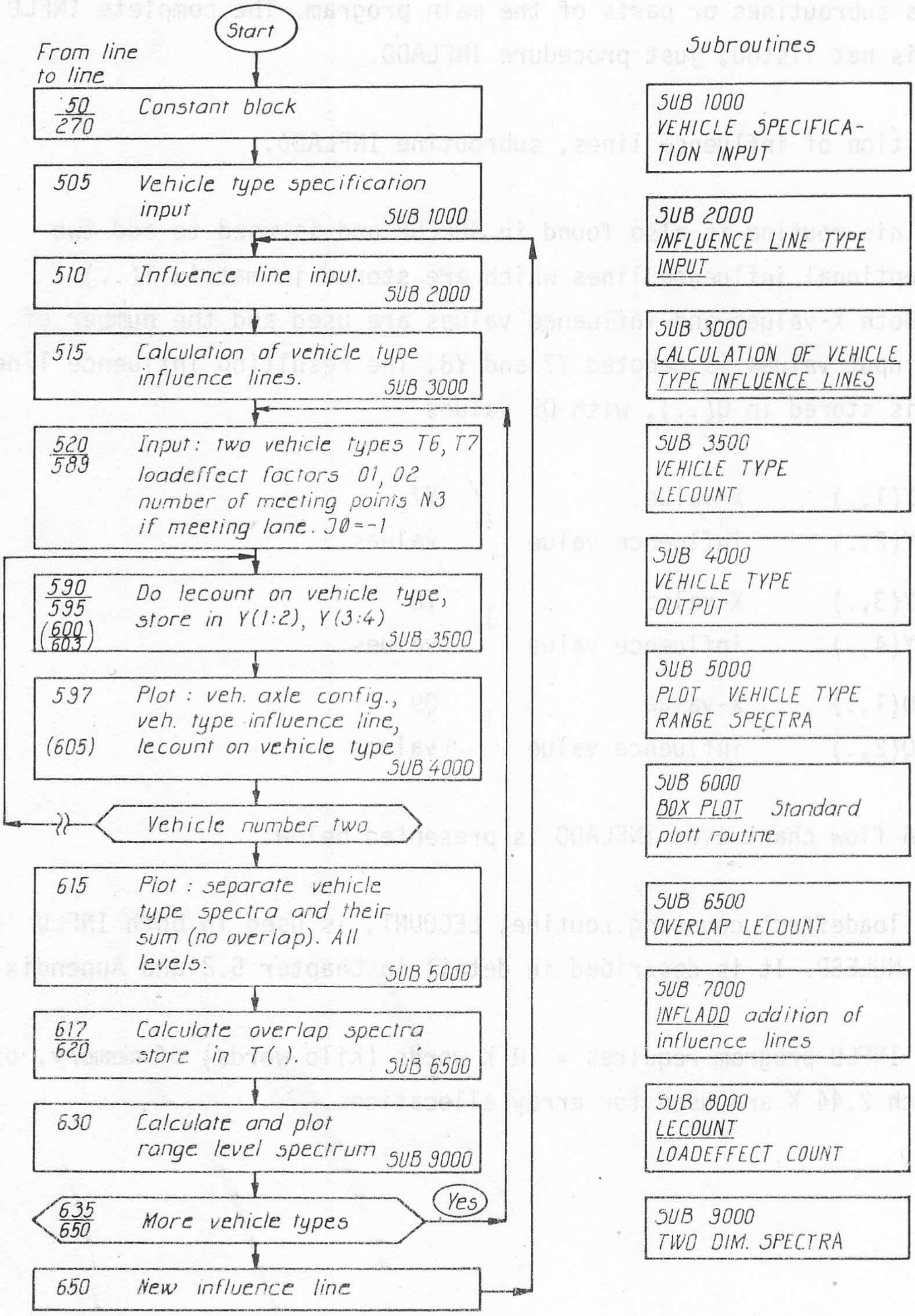
   PROCEDURE FPCOUNT ;
   BEGIN
   L1: IF I7 LEQ 3 THEN GOTO L9 ;
       IF (U(I7-1) GEQ U(I7-3)) AND (U(I7-2) GEQ U(I7-1)) AND
          (U(I7) GEQ U(I7-2)) OR
          (U(I7-1) LEQ U(I7-3)) AND (U(I7-1) GEQ U(I7-2)) AND
          (U(I7) LEQ U(I7-2)) THEN GOTO L2 ELSE GOTO L9 ;
   L2: Z=IF U(I7-2) LSS U(I7-1) THEN U(I7-2) ELSE U(I7-1) ;
       W=U(I7-1)-U(I7-2) ;     STOREZW ;
       IF I5 NEQ (I7-1) AND I5 NEQ I7 THEN GOTO L3 ELSE I5=I5-2 ;
   L3: IF I6 NEQ (I7-1) AND I6 NEQ I7 THEN GOTO L4 ELSE I6=I6-2 ;
   L4: U(I7-2)=U(I7) ; I7=I7-2 ; GOTO L1 ;
   L9: END FPCOUNT ;

   PROCEDURE READQ ;
   BEGIN I9=I9+1 ; Q=QT(2,I9)   END READQ ;

   PROCEDURE STOREZW ;
COMMENT (-) ON W IF PROCESS GROWING ;
BEGIN R9=R9+1 ; R(1,R9)=W ; R(2,R9)=Z ;
END PROCEDURE STOREZW ;

  I7=I9=R9=Ø ; J5=J6=Ø ;
      READQ ; Q1=Q ; STOQ ;
  L1: READQ ; Q2=Q ; IF ABS(Q1-Q2) LEQ E9 THEN
      BEGIN IF I9 EQL Q9 THEN GOTO L9 ELSE GOTO L1 END ;
  L2: I8=Ø ;
  L3: READQ ; Q3=Q ; IF ABS(Q3-Q2) LEQ E9 THEN GOTO L5 ;
      IF SIGN(Q3-Q2) NEQ SIGN(Q2-Q1) THEN GOTO L4 ;
      Q2=Q3 ; IF I9 EQL Q9 THEN GOTO L6 ELSE GOTO L2 ;
  L4: Q=Q2 ; STOQ ; FPCOUNT ; Q1=Q2 ; Q2=Q3 ;
      IF I9 EQL Q9 THEN GOTO L6 ELSE GOTO L2 ;
  L5: I8=I8+1 ; IF I8 LSS J8 AND I9 NEQ Q9 THEN GOTO L3 ;
  L6: Q=Q2 ; STOQ ; FPCOUNT ;
  ENCOUNT:
      IF I5 LSS I6 THEN GOTO L7 ; I5=I6 ; I6=I5+1 ;
  L7: IF I5 LEQ 2 THEN GOTO L8 ;
      W=-ABS(U(I5-1)-U(I5-2)) ;
      Z=IF U(I5-1) LSS U(I5-2) THEN U(I5-1) ELSE U(I5-2) ;
      I5=I5-2 ; STOREZW ; GOTO L7 ;
  L8: W=ABS(U(I6)-U(I6-1)) ;
      Z=IF U(I6) LSS U(I6-1) THEN U(I6) ELSE U(I6-1) ;
      I6=I6+2 ; STOREZW ;
      IF I6 LEQ I7 THEN GOTO L8 ;
  L9: END PROCEDURE LECOUNT ;
END
```

Appendix D Flowchart Basic program INFLU



Comments on INFLU:

Those subroutines underlined in the flowchart, are found in the complete loadeffect calculation model, program NULESP, with small differences, either as subroutines or parts of the main program. The complete INFLU program is not listed, just procedure INFLADD.

Addition of influence lines, subroutine INFLADD.

This routine is also found in NULESP and is used to add two optional influence lines which are stored in matrix Y(..). Both X-values and influence values are used and the number of input values is denoted Y7 and Y8. The resulting influence line is stored in Q(..), with Q9 values

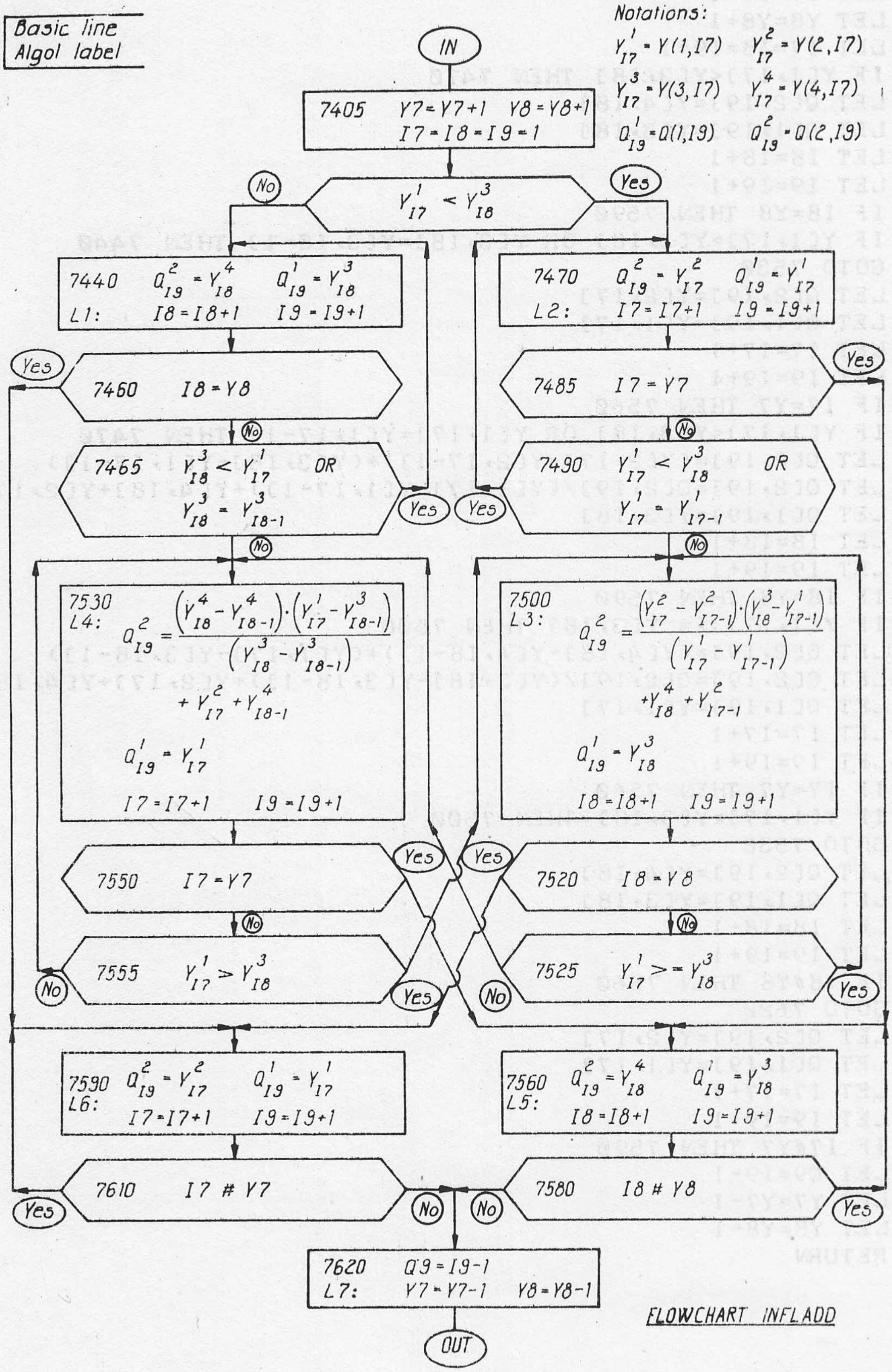
Y(1,.)	X-value	}	Y7
Y(2,.)	influence value		values
Y(3,.)	X-value	}	Y8
Y(4,.)	influence value		values
Q(1,.)	X-value	}	Q9
Q(2,.)	influence value		values

A flow chart over INFLADD is presented below.

The loadeffect counting routine, LECOUNT, is used in both INFLU and NULESP. It is described in detail in Chapter 5.2 and Appendix C.

The INFLU program requires ≃ 10 K words (Kilo words) of memory, of which 2.44 K are used for array allocations.

Subroutine INFLADD, references to both Basic and Algol version.

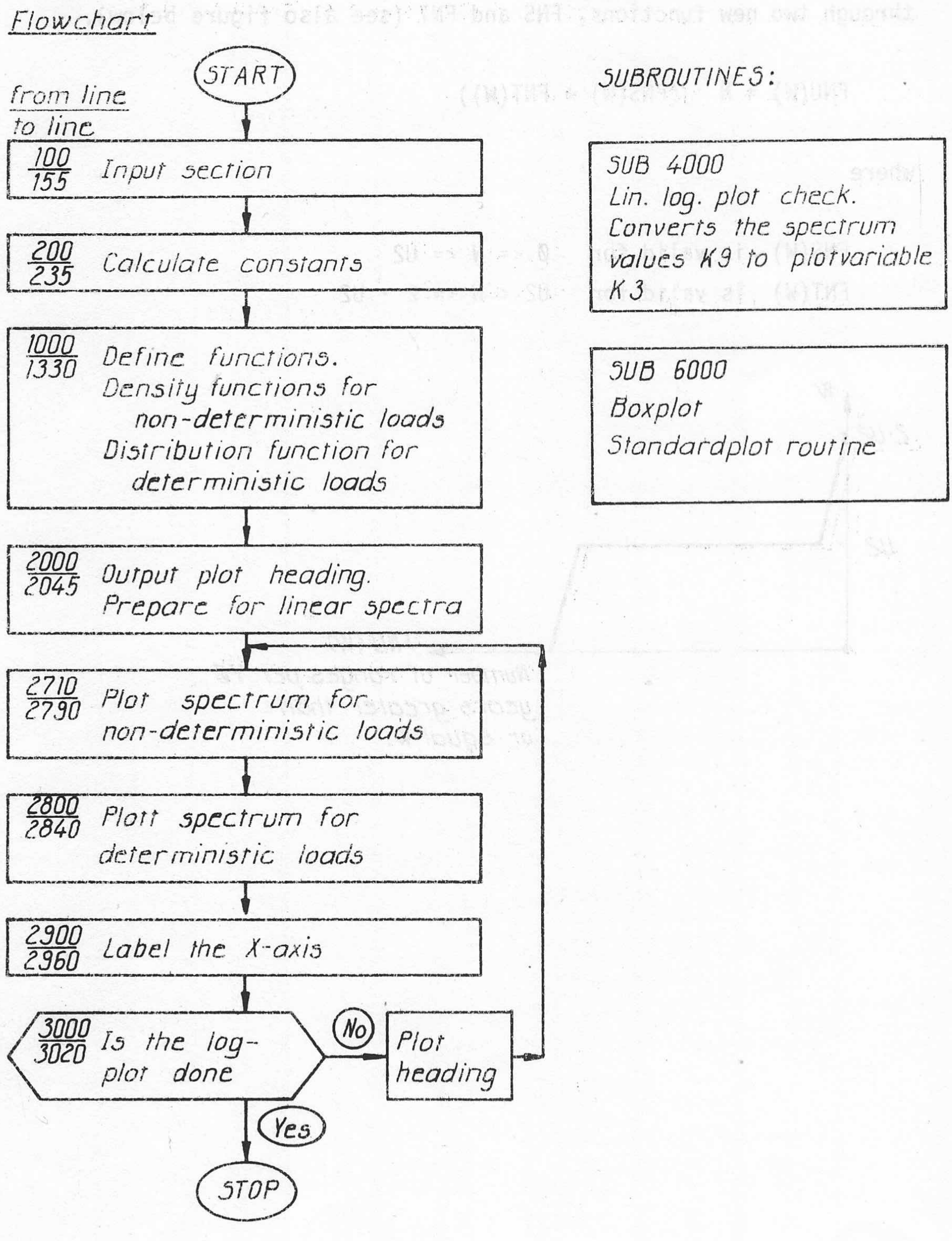


FLOWCHART INFLADD

```
7000   REM --- INFLADD ---
7405   LET Y7=Y7+1
7410   LET Y8=Y8+1
7420   LET I7=I8=I9=1
7430   IF Y[1,I7]<Y[3,I8] THEN 7470
7440   LET Q[2,I9]=Y[4,I8]
7442   LET Q[1,I9]=Y[3,I8]
7445   LET I8=I8+1
7450   LET I9=I9+1
7460   IF I8=Y8 THEN 7590
7465   IF Y[1,I7]>Y[3,I8] OR Y[3,I8]=Y[3,I8-1] THEN 7440
7467   GOTO 7530
7470   LET Q[2,I9]=Y[2,I7]
7472   LET Q[1,I9]=Y[1,I7]
7475   LET I7=I7+1
7477   LET I9=I9+1
7485   IF I7=Y7 THEN 7560
7490   IF Y[1,I7]<Y[3,I8] OR Y[1,I7]=Y[1,I7-1] THEN 7470
7500   LET Q[2,I9]=(Y[2,I7]-Y[2,I7-1])*(Y[3,I8]-Y[1,I7-1])
7505   LET Q[2,I9]=Q[2,I9]/(Y[1,I7]-Y[1,I7-1])+Y[4,I8]+Y[2,I7-1]
7510   LET Q[1,I9]=Y[3,I8]
7515   LET I8=I8+1
7517   LET I9=I9+1
7520   IF I8=Y8 THEN 7590
7525   IF Y[1,I7] >= Y[3,I8] THEN 7500
7530   LET Q[2,I9]=(Y[4,I8]-Y[4,I8-1])*(Y[1,I7]-Y[3,I8-1])
7535   LET Q[2,I9]=Q[2,I9]/(Y[3,I8]-Y[3,I8-1])+Y[2,I7]+Y[4,I8-1]
7540   LET Q[1,I9]=Y[1,I7]
7545   LET I7=I7+1
7547   LET I9=I9+1
7550   IF I7=Y7 THEN 7560
7555   IF Y[1,I7]>Y[3,I8] THEN 7500
7557   GOTO 7530
7560   LET Q[2,I9]=Y[4,I8]
7562   LET Q[1,I9]=Y[3,I8]
7565   LET I8=I8+1
7570   LET I9=I9+1
7580   IF I8#Y8 THEN 7560
7585   GOTO 7620
7590   LET Q[2,I9]=Y[2,I7]
7595   LET Q[1,I9]=Y[1,I7]
7600   LET I7=I7+1
7605   LET I9=I9+1
7610   IF I7#Y7 THEN 7590
7620   LET Q9=I9-1
7625   LET Y7=Y7-1
7630   LET Y8=Y8-1
7699   RETURN
```

Appendix E   Basic-program EF2. Analytical calculation of loadeffect spectra.

The program is written in Basic. It plots load spectra according to the analytically calculated loadeffect range density functions described in Chapter 6.3.



Except for the density functions FNA-FNI, defined in Chapter 6.3.5, there are some aid functions, FNM-FNP, defined in the program, which are used to put the function values to zero outside their definition areas. There are also functions FNK, FNL and FNJ, which are subfunctions used when the original function becomes longer than one line.

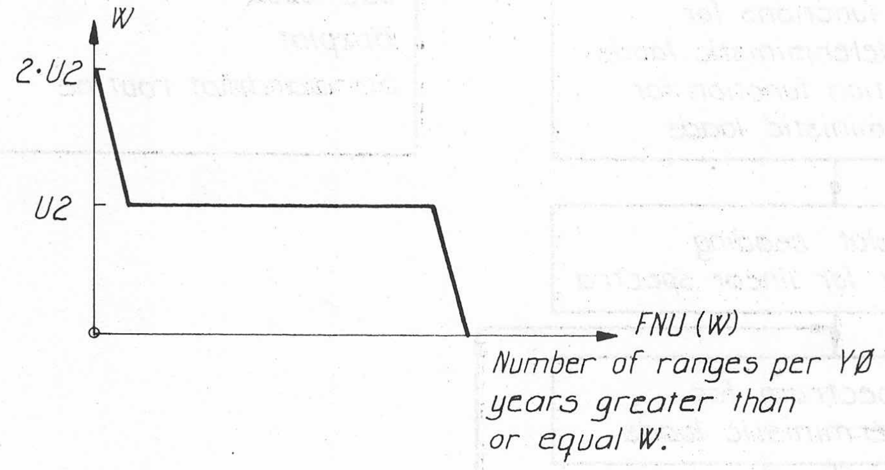
The loadeffect spectrum function, FNU, for deterministic loads is defined through two new functions, FNS and FNT (see also figure below).

FNU(W) = N · (FNS(W) + FNT(W))

where

FNS(W) is valid for Ø <= W <= U2

FNT(W) is valid for U2 < W <= 2 · U2



```
10   REM """"""""""" PROGRAM EF2 """""""""""
20   REM """"" PER CHRISTIANSSON OCT 1975
25   REM """"""""""""""""""""""""""""""""""""""""""""""""
30   REM """"" LOADEFFECT SPECTRUM CACULATIONS
35   REM """"" DETERMINISTIC AND NONDETERMINISTIC LOADS
40   REM """"" TRIANGULAR INFLUENCE LINE
50   REM """"" ANALYTICAL SOLUTION
99   REM """"""""""""""""""""""""""""""""""""""""""""""""
100  REM ---- INPUT SECTION ----
110  PRINT "VEHICLES/LANE/YEAR=";TAB(45);
115  INPUT K
120  PRINT "LENGTH OF INFLUENCE LINE=";TAB(45);
125  INPUT X0
127  LET L=X0/2
130  PRINT "VEHICLE SPEED  EQUIVALENT TIME=";TAB(45);
135  INPUT V,T
140  PRINT "LOWEST (>0)  HIGHEST (<=100)"
141  PRINT "  VEHICLE GROSS WEIGHT=";TAB(45);
145  INPUT G0,G1
150  PRINT "TIME PERIOD=";TAB(45);
155  INPUT Y0
200  REM ----- CALCULATE CONSTANTS -----
205  LET P9=4*L*K/365/24/3600/T/V
207  LET G2=(G0+G1)/2
210  LET U1=G1
215  LET U0=G0
217  LET U2=(U1+U0)/2
220  LET N3=2*K*(1-P9)*Y0
225  LET N2=N1=1/2*K*P9*Y0
227  LET N=2*K*(1-P9/4)*Y0
230  LET I9=700
235  LET Y3=.3
1000 REM ----- DEFINE FUNCTIONS -----
1005 REM --- U0 # 0 ---
1010 REM --- ZONE 3, Z3 ---
1015 DEF FNA(W)=((U0 <= W) AND (W <= U1))*1/(U1-U0)*N3
1020 REM --- ZONE 2, Z2 ---
1030 DEF FNB(W)=((U0 <= W) AND (W <= U1))*2*(W-U0)/(U1-U0)↑2*N2
1035 LET X9=2/(U1-U0)↑2*N2
1040 DEF FNK(W)=((0 <= W) AND (W <= U0))*(U0-U1+U1*LOG(U1/U0))
1045 DEF FNL(W)=((U0<W) AND (W <= U1))*(W-U1-U1*LOG((W+(W <= U0))/U1))
1047 REM -- W<=U0 IN FNL TO PREVENT ARG <=0 IN LOG
1050 DEF FNC(W)=X9*(FNK(W)+FNL(W))
1070 REM --- ZONE 1, Z1 ---
1075 LET X8=2/(U1-U0)↑2*N1
1080 DEF FNM(W)=((U0 <= W) AND (W<2*U0))
1085 DEF FNN(W)=((2*U0 <= W) AND (W <= U1))
1090 DEF FNO(W)=((U1<W) AND (W <= (U1+U0)))
1100 DEF FNP(W)=(((U1+U0)<W) AND (W <= 2*U1))
1110 DEF FNX(W)=W+2*U1*(W <= U1)
1115 REM -- FNX TO PREVENT ARG <=0 IN LOG
1120 REM ---
1130 DEF FNE(W)=X8*(W*LOG(W/U0)-W+U0)
1140 DEF FNF(W)=X8*(W*LOG(2)-U0)
1150 DEF FNG(W)=X8*(W*LOG(2)-U0-W*LOG((FNX(W)+U0-U1)/U0)+W-U1)
1160 DEF FNH(W)=X8*(U1*LOG(U1/U0)+W*LOG((FNX(W)+U0-U1)/W))
1170 DEF FNI(W)=X8*(W*LOG(2)-U1*LOG((FNX(W)-U1)/U1)+W*LOG(1-U1/FNX(W)))
1180 DEF FNJ(W)=FNG(W)+FNH(W)
1190 REM ---
1200 DEF FND(W)=FNM(W)*FNE(W)+FNN(W)*FNF(W)+FNO(W)*FNJ(W)+FNP(W)*FNI(W)
1250 REM --- DEFINE TOTAL DENSITY FUNCTION ---
1270 DEF FNW(W)=FNA(W)+FNB(W)+FNC(W)+FND(W)
1300 REM --- DETERMINISTIC LOADS ---
1305 REM --- (FNU NB. OF RANGES GREATER OR EQUAL IN Y0 YEARS) ---
1310 DEF FNS(W)=((0 <= W) AND (W <= U2))*(1-W*P9/U2/(4-P9))
1320 DEF FNT(W)=((U2<W) AND (W <= 2*U2))*(2*U2-W)/U2*P9/(4-P9)
1330 DEF FNU(W)=N*(FNS(W)+FNT(W))
2000 REM ----- OUTPUT -----
2005 CALL (5,-1,1,1111,9800)
2007 LET C1=18
2008 LET C2=25.5
2010 GOSUB 6200
2015 PRINT "FLOW/YEAR/2LANES=";2*K;TAB(30);"YEARS=";Y0
2017 GOSUB 6200
2018 PRINT "VEHSPEED AND EQU. TIME";TAB(25);V;T
2020 GOSUB 6200
2022 PRINT "INFLUENCE LINE LENGTH=";TAB(25);X0
2024 GOSUB 6200
2025 PRINT "NB. OF RANGES";TAB(25);2*K*(1-P9/4)*Y0
2030 GOSUB 6200
2035 PRINT "NB. OF OVERLAP RANGES";TAB(25);3/2*K*P9*Y0
2037 GOSUB 6200
2038 PRINT "MEET. PROB. (%)=";TAB(25);P9*100
2040 GOSUB 6200
2042 PRINT "MEETING NB.=";TAB(25);K*P9*Y0
2044 GOSUB 6200
2045 PRINT "G0=";G0;" G1=";G1;" G2=";G2
2500 REM -----
2510 LET C3=2
2515 LET C4=11.5
2520 LET C5=10
2525 LET C6=10.5
2530 LET C7=1
2535 LET C8=.5
2540 LET M5=2
2545 LET M6=5
2550 LET M7=20
2555 LET M8=50
2600 GOSUB 6000
2605 GOSUB 6200
2610 PRINT "RANGE  LINEAR  EF2"
2700 REM --- I3=1 LINEAR  =2 LOGARITHMIC  =3 STOP ---
2702 REM --- K3,K4 SPECTRUM COORDINATES ---
2705 LET I3=1
2710 REM --- NONDETERMINISTIC ---
2720 LET K9=0
2725 GOSUB 4000
2730 LET K4=2*U1/20/C2*9999
2740 CALL (5,-1,1,K1+K3,K2+K4)
2745 FOR I1=I9-1 TO 0 STEP -1
2750 LET K9=K9+FNW(I1/I9*2*U1+U1/I9/2)*2*U1/I9
2755 GOSUB 4000
2760 CALL (5,1,1,K1+K3,K2+K4)
2770 LET K4=I1/I9*2*U1/20/C2*9999
2775 CALL (5,1,1,K1+K3,K2+K4)
2780 NEXT I1
2790 REM - EV. HLT
2800 REM --- DETERMINISTIC ---
2802 LET K9=FNU(2*U2)
2803 LET K4=2*U2/20/C2*9999
2804 GOSUB 4000
2806 CALL (5,-1,1,K1+K3,K2+K4)
2810 FOR I1=I9-1 TO 0 STEP -1
2815 LET K4=I1/I9*2*U2/20/C2*9999
2820 LET K9=FNU(I1/I9*2*U2)
2825 GOSUB 4000
2830 CALL (5,1,1,K1+K3,K2+K4)
2835 NEXT I1
2840 REM - EV. HLT
2900 REM --- LABEL X-AXLE ---
2910 CALL (5,-1,1,K1+9.2/C1*9999,K2-.4/C2*9999)
2915 GOSUB 6200
2920 IF I3=2 THEN 2950
2930 PRINT "(% GREATER EQUAL)"
2940 GOTO 3000
2950 PRINT "(10*10LOG GEQ)"
2960 GOTO 3000
3000 REM --- CHECK I3  PREPARE LOGARITHMIC PLOT  ---
3005 LET I3=I3+1
3006 IF I3=3 THEN 9999
3007 LET C4=.5
3008 GOSUB 6000
3010 GOSUB 6200
3013 PRINT "RANGE  LOGARITHMIC  EF2"
3020 GOTO 2710
4000 REM --- LIN LOG PLOT  CHECK ---
4005 IF I3=1 THEN 4025
4010 IF K9>1 THEN 4020
4015 LET K3=0
4017 GOTO 4022
4020 LET K3=LOG(K9)/LOG(10)/C1*9999
4022 RETURN
4025 LET K3=K9/N*C5/C1*9999
4030 RETURN
6000 REM ----- BOX PLOT -----
6002 LET K1=C3/C1*9999
6008 LET K2=C4/C2*9999
6010 CALL (5,-1,0,K1,K2)
6015 IF C7 <= 0 OR C7>C5 THEN 6045
6020 FOR I1=1 TO INT(C5/C7)
6025 CALL (5,1,-1,C7/C1*9999,0)
6030 GOSUB 6300
6040 NEXT I1
6045 CALL (5,1,1,K1+C5/C1*9999,K2)
6050 CALL (5,1,-1,0,C6/C2*9999)
6060 CALL (5,1,-1,-C5/C1*9999,0)
6065 IF C8 <= 0 OR C8>C6 THEN 6105
6070 CALL (5,1,-1,0,(INT(C6/C8)*C8-C6)/C2*9999)
6075 FOR I1=1 TO INT(C6/C8)
6080 GOSUB 6350
6090 CALL (5,1,-1,0,-C8/C2*9999)
6100 NEXT I1
6105 CALL (5,1,1,K1,K2)
6110 LET I1=0
6115 LET I1=I1+M5
6120 IF I1*C7 >= C5 THEN 6145
6125 CALL (5,-1,1,K1+(I1*C7-.4)/C1*9999,K2-1.2*Y3/C2*9999)
6130 GOSUB 6200
6135 PRINT M7*INT(I1/M5)
6140 GOTO 6115
6145 LET I1=0
6150 LET I1=I1+M6
6155 IF I1*C8 >= C6 THEN 6180
6157 LET I6=M8*INT(I1/M6)
6158 LET I6=(I6>0)+(I6 >= 10)+(I6 >= 100)+1
6160 CALL (5,-1,1,K1-I6*Y3/C1*9999,K2+I1*C8/C2*9999)
6165 GOSUB 6200
6170 PRINT M8*INT(I1/M6)
6175 GOTO 6150
6180 CALL (5,-1,1,K1+Y3/C1*9999,K2+(C6-1.3*Y3)/C2*9999)
6199 RETURN
6200 CALL (6,Y3/C1*9999,0,0,Y3/C2*9999)
6209 RETURN
6300 CALL (5,1,-1,0,.2/C2*9999)
6305 CALL (5,1,-1,0,-.2/C2*9999)
6309 RETURN
6350 CALL (5,1,-1,.2/C1*9999,0)
6355 CALL (5,1,-1,-.2/C1*9999,0)
6359 RETURN
9999 END
```

Appendix F   Algol-program NULESP. Numerical calculation of loadeffect spectra.

Below the computer program NULESP, numerical calculation of loadeffect spectra, is listed. The program is written in Nualgol for a Univac 1108 computer. The program requires 23.4 Kilo-words for instruction storage and 6.8 Kilo-words for data storage except for the dynamically allocated fields T(..) and S(..) whose sizes are dependent on the chosen range and level increments. (Each element in T(..) and S(..) requires one additional word of memory.)

The computer run times may, in case vehicle type loads are used, be approximately estimated from FIG. 6.4.7-5 by replacing N3 and S4 (N3 and S4 negative at input) with

$$N3 \leftarrow \boxed{\frac{\text{length of infl. line + longest axledist.}}{\text{length of infl. line}} \cdot n_{\text{infl.range}} \cdot 2 \cdot \text{abs}(N3)} \cdot n_{\text{axle}} \cdot n_{\text{brkpt}} \cdot 0.0017$$

$$S4 \leftarrow \boxed{\frac{\text{queue distance variation width}}{\text{length of influence line}} \cdot n_{\text{infl.range}} \cdot \text{abs}(S4)} \cdot n_{\text{axle}} \cdot n_{\text{brkpt}} \cdot 0.0017$$

where n_{axle} = mean number of axles per vehicle driving over the bridge

n_{brkpt} = number of influence line break points

$n_{\text{infl.range}}$ = number of counted ranges for the influence line

The value obtained in this way will express the computer time in seconds. (If N3 or S4 are positive at input these values replace the above expressions within squares.) The 0.0017 constant are dependent on current algol compiler version, the wanted degree of error checking during execution and the computer characteristics.

Sample output from a run (corresponding to the "calculated 1973" spectrum in FIG. 8.1.2-2) is presented after the program listing.

NULESP

```
BEGIN
COMMENT     PROGRAM NAME IS ** NULESP **
            PER CHRISTIANSSON  JULY 1975
            DIVISION OF STRUCTURAL ENGINEERING
            LUND INSTITUTE OF TECHNOLOGY
     IN THE PROGRAM ARE SOME IMPORTANT COMMENTS MADE
     THE FIRST HALF OF THE PROGRAM CONSISTS OF SUBROUTINES
   --THE PROGRAM DOES THE FOLLOWING (LABELS ALSO MENTIONED):
VEIN:READS VEHICLE SPECIFICATIONS
LOIN:READS LOAD DISTRIBUTION
LINF:READS LATERAL INFLUENCE SPEC. , LATERAL TRACK DISTRIBUTION
EQCA:AND CALCULATES EQUIVALENT LOAD DISTRIBUTIONS
SINF:READS INFLUENCE LINE SPEC.
VINF:AND CALCULATES VEHICLE TYPE INFLUENCE LINES
OVDI:READS DESIRED OVERLAP DISTRIBUTION
OVCA:AND CALCULATES EQUIVALENT OVERLAP LOAD DISTRIBUTION
TRIN:READS TRAFFIC DATA
LEDI:READS LOADEFFECT CALCULATION DIRECTIVES
LECA:AND CALCULATES LOADEFFECT (RANGE-LEVEL) DISTRIBUTIONS
DYDI:READS DYNAMIC AMPLIFICATION FACTOR DISTRIBUTION
DYCA:AND MODIFIES THE TOTAL LOADEFFECT DISTRIBUTION.
 GOTO  0=DYDI  1=LEDI  2=TRIN  3=OVDI  4=SINF  5=LINF  6=LOIN  7=VEIN
      8=L99 (END OF PROGRAM ).
CACULATED DISTRIBUTIONS CAN BE PRINTED,PLOTTED OR BOTH PRINTED/PLOTTED ;
REAL K1,K2,Y1,RE,Y0,P1,Y4,Y5,Y6,F1,F3,F2,K3,YL,YH,X0,X6,X7,X8,D3,
      TE,F8,T9,S0,S1,F9,S2,W0,Z0,SOCC,E9,A2,M3,S3,FACT,OCC,X1,X2,X3,
      YSEC,VE,F0,A9,F7,F4,FD ;
REAL ARRAY A(1:10,1:5),B(1:10,1:5),H(1:10,1:2,1:3),G(-1:10,1:70),
         X(1:2,-1:10,1:90),J(-4:4,1:2,1:12),I(-10:10,1:6,1:60),W(1:7),
          O(1:2,-1:10,1:2,1:7),SONB(1:2,-1:10),AM(1:2,1:10),
          Q(1:2,1:130),Y(1:4,1:130),R(1:2,1:130),ONB(1:2,-1:10) ;
REAL2 ARRAY RNB(-1:1) ;
INTEGER T1,T2,I1,I2,I3,I4,I5,H2,L0,J1,Y7,Q9,Y8,W1,L1,T0,N3,S4,J8,A1,
        R9,TRL,TRH,TLL,TLH,SRL,SPH,SLL,SLH,PR,PL,N,PRT,PLT,
          LTR,HTR,LTL,HTL,LSR,HSR,LSL,HSL,N8,N9,QQSW,S4QM ;
INTEGER ARRAY V(1:10,1:1),M(1:3,1:10),C(1:2,-1:10,3:6),
              K(1:2,-1:10,2:2) ;
STRING TEXT(80) ;
SWITCH JUMP=LEDI,TRIN,OVDI,SINF,LINF,LOIN,VEIN,L99 ;
------------------------------------------------------------------------
EXTERNAL PROCEDURE INFLADD ;
EXTERNAL PROCEDURE LECOUNT ;
INTEGER PROCEDURE NBR(W,W0) ;
 REAL W,W0 ; BEGIN NBR=ENTIER(W/W0)+1 END ;
------------------------------------------------------------------------
REAL PROCEDURE VAL(C,W0) ;
 REAL W0 ; INTEGER C ; BEGIN VAL=W0*C-W0/2 END ;
------------------------------------------------------------------------
PROCEDURE PRINTLSP(SW,L0,PR,PL) ;
COMMENT SW=1 LOASP =2 EQUIV.LOADSP  L0=LANE  PR=1 PRINT PL=1 PLOT
        I1=1 LINSP.  =2 LOGSP.
        I2= HIGH CLASS
        N= CLASS
        I3= X-PLOT  ;
INTEGER SW,L0,PR,PL ;
BEGIN INTEGER I1,I2,I3,I4,I5,T1,N ; REAL ARRAY T(-1:10,0:90) ;
REAL K1 ;
INTEGER ARRAY PLN(-1:10) ;
STRING PLO(12) ;
IF PR EQL 0 AND PL EQL 0 THEN GOTO L9 ;
FOR I1=(-1,1,10) DO FOR I2=(0,1,90) DO T(I1,I2)=0 ;
IF SW EQL 1 THEN
  FOR T1=(-1,1,T2) DO FOR N=(1,1,C(1,T1,4)) DO
   T(T1,N)=G(T1,N)*K(L0,T1,2) ELSE
 FOR T1=(-1,1,T2) DO FOR N=(1,1,C(1,T1,6)) DO
  T(T1,N)=X(L0,T1,N)*K(L0,T1,2) ;
 I2=IF SW EQL 1 THEN MAX(FOR I1=(-1,1,T2) DO C(L0,I1,4)) ELSE
                     MAX(FOR I1=(-1,1,T2) DO C(L0,I1,6)) ;
 FOR T1=(-1,1,T2) DO FOR N=(I2-1,-1,1) DO T(T1,N)=T(T1,N)+T(T1,N+1) ;
 FOR T1=(-1,1,T2) DO FOR N=(1,1,I2) DO T(T1,N-1)=T(T1,N) ;
 FOR T1=(-1,1,T2) DO T(T1,I2)=0 ;
IF PR EQL 0 THEN GOTO L1 ;
 IF SW EQL 1 THEN
 WRITE(<<'***** LIN-LOG LOADSPECTRA '>>) ELSE
 WRITE(<<'***** LIN-LOG EQUIVALENT LOADSPECTRA '>>) ;
 WRITE(<<'LANE',I2,A3>>,L0) ;
 FOR I1=(1,1,2) DO BEGIN IF I1 EQL 1 THEN
     WRITE(<<'--LIN.SPECTRA',A2>>) ELSE WRITE(<<'--LOG.SPECTRA',A2>>) ;
 WRITE(<<'   LOAD',J15,'TOTAL',J24,'AXLE',J30,:T2:(' TYPE',I3),A1>>,
       FOR I3=(1,1,T2) DO I3) ;
 WRITE(<<'   CLASS            -GREATER THAN OR EQUAL-----------',A1>>) ;
 FOR N=(0,1,I2) DO BEGIN
 WRITE(<<D5.1,'-',D5.1>>,VAL(N,P1)+P1/2,VAL(N,P1)+P1*3/2) ;
 IF I1 EQL 1 THEN
 WRITE(<<:T2+2:(I9),A1>>,FOR T1=(-1,1,T2) DO T(T1,N)) ELSE
 WRITE(<<:T2+2:(D9.4),A1>>,FOR T1=(-1,1,T2) DO
       LN(MAX(T(T1,N),0.01))/LN(10)) ;
 END N ;
 END I1 ;
L1:IF PL EQL 0 THEN GOTO L9 ;
MARGIN('M,72,0,0.') ;
PLO(1,12)='TXABCDEFGHIJ' ;
FOR I1=(1,1,2) DO BEGIN I5=0 ;
WRITE(<<:132:('-'),A3>>) ;
 IF SW EQL 1 THEN
 WRITE(<<'***** LIN-LOG LOADSPECTRA '>>) ELSE
 WRITE(<<'***** LIN-LOG EQUIVALENT LOADSPECTRA '>>) ;
 WRITE(<<'LANE',I2>>,L0) ;
 WRITE(<<J58,'TOTAL=',I9,'   AXLE=',I9,A1>>,T(-1,0),T(0,0)) ;
WRITE(<<'  T=TOTAL X=AXLE  TYPES:A=1 B=2 C=3 D=4 E=5 F=6 G=7 H=8 I=9',
      ' J=10',A1>>) ;
WRITE(<<:132:('-'),A1>>) ;
WRITE(<<'I',J8,'LOAD',J18,'I',J65,'GREATER THAN OR EQUAL LOAD'>>) ;
 IF I1 EQL 1 THEN WRITE(<<J95,'LINSPECTRA (%)',J119,'I',A1>>) ELSE
 WRITE(<<J95,'10LOGSPECTRA (*10)',J119,'I',A1>>) ;
FOR N=(I2,-1,0) DO BEGIN I5=I5+1 ;
WRITE(<<'I',D7.2,'-',D7.2,' I'>>,VAL(N,P1)+P1/2,VAL(N,P1)+P1*3/2) ;
WRITE(<<J19,:9:('         .')>>) ;
IF ENTIER(I5/10)*10 EQL I5 THEN
WRITE(<<J19,:9:('..........'),'..........'>>) ;
T1=-1 ;
L2:IF T1 LSS 1 THEN K1=T(T1,0) ELSE BEGIN
   K1=0 ; FOR I4=(1,1,T2) DO K1=K1+T(I4,0) END ;
   I3=IF I1 EQL 1 THEN
   ENTIER(T(T1,N)/K1*100+0.999999) ELSE
   ENTIER(LN(MAX(T(T1,N),0.01))/LN(10)*10+0.999999) ;
   IF I3 GTR 100 THEN I3=100 ; PLN(T1)=I3 ; IF I3 LEQ 0 THEN GOTO L3 ;
   WRITE(<<J(I3+18),S1>>,PLO(T1+2)) ;
   FOR I4=(-1,1,T1-1) DO IF I3 EQL PLN(I4) THEN
    BEGIN WRITE(<<J(I3+18),'*'>>) ; GOTO L3 END ;
```

```
L3:IF T1 NEQ T2 THEN
    BEGIN T1=T1+1 ; GOTO L2 END ;
    WRITE(<<J119,'I',A1>>) ;
 END N ;
WRITE(<<'I',:16:('-'),'+',:20:('---->'),'I',A1>>) ;
WRITE(<<J20,:20:(I5),A1>>,FOR I3=(5,5,100) DO I3) ;
END I1 ;
MARGIN('M,66,6,3.') ;
L9:END PROCEDURE PRINTLSP ;
```

```
REAL PROCEDURE LATINT(Y4,Y5,Y6,YL,YH,LØ) ;
 REAL Y4,Y5,Y6,YL,YH ;
INTEGER LØ ;
 BEGIN REAL Y1,Y2,Y3,H,K1 ;
 Y2=Y4*Y5 ; H=2/Y4/(1+Y5) ;
 IF SIGN(Y6) LSS Ø AND LØ EQL 2
                   THEN BEGIN Y1=ABS(Y6)*Y4 ; Y3=Y4-Y1-Y2 END ELSE
                       BEGIN Y3=Y6*Y4       ; Y1=Y4-Y2-Y3 END ;
 IF YH LSS Y1 THEN BEGIN LATINT=(YH*YH-YL*YL)*H/Y1/2 ; GOTO L9 END ;
 IF YH LEQ (Y1+Y2) THEN BEGIN
  IF YL LSS Y1 THEN LATINT=H/2*(YL/Y1+1)*(Y1-YL)+H*(YH-Y1) ELSE
                    LATINT=H*(YH-YL) ; GOTO L9 END ;
 IF YL GTR (Y1+Y2) THEN
  BEGIN LATINT=H/(Y4-Y1-Y2)*(2*Y4-YL-YH)/2*(YH-YL) ; GOTO L9 END ;
      K1=H/(Y4-Y1-Y2)*(2*Y4-YH-Y1-Y2)/2*(YH-Y1-Y2) ;
  IF YL GEQ Y1 THEN BEGIN LATINT=K1+H*(Y1+Y2-YL) ; GOTO L9 END ;
  LATINT=K1+H*Y2+H/Y1*(YL+Y1)/2*(Y1-YL) ;
L9:END PROCEDURE LATINT ;
```

```
PROCEDURE INIT(T) ;
REAL ARRAY T ;
 BEGIN INTEGER I1,I2 ;
 FOR I1=(LTR,1,HTR) DO FOR I2=(LTL,1,HTL) DO T(I1,I2)=Ø ;
OCC=Ø ; TRL=HTR ; TRH=LTR ; TLL=HTL ; TLH=LTL ;
 FOR I1=(1,1,2) DO FOR I2=(-1,1,1Ø) DO ONB(I1,I2)=Ø ;
COMMENT DELETE THIS ROW TO COMPRESS OUTPUT **;  TRL=1 ;
END PROCEDURE INIT ;
```

```
PROCEDURE QQ(T) ;
REAL ARRAY T ;
BEGIN INTEGER O1,O2,O3,O4,X9 ; REAL ARRAY X(1:2,1:1ØØ) ;
COMMENT LANE1  O1 O2 Y7  LANE2 O3 O4 Y8 ;
INIT(T) ; M3=(2*XØ+2*(SØ+S1)/2)/N3 ;
 FOR O3=(1,1,W1) DO FOR O4=(1,1,W1) DO BEGIN
  INFLTOYQ(J,J1,1,M(1,J1),O(2,-1,1,O3),-1,2,1,Y,Y7) ;
  INFLTOYQ(J,J1,1,M(1,J1),O(2,-1,1,O4),-1,2,3,Y,Y8) ;
  YYDISY2(Y,Y7,Y8,S2-XØ) ;
  INFLADD(Y,Y7,Y8,Q,Q9) ;
  YQTOYQ(1,Q,Q9,1,X,X9) ;
 FOR O1=(1,1,W1) DO FOR O2=(1,1,W1) DO BEGIN
  INFLTOYQ(J,J1,1,M(1,J1),O(1,-1,1,O1),1,1,1,Y,Y7) ;
  INFLTOYQ(J,J1,1,M(1,J1),O(1,-1,1,O2),1,1,3,Y,Y8) ;
  YYDISY2(Y,Y7,Y8,S2-XØ) ;
  INFLADD(Y,Y7,Y8,Q,Q9)  ;
  YQTOYQ(1,Q,Q9,1,Y,Y7) ;
   YQTOYQ(1,X,X9,3,Y,Y8) ;
   YYDISY2(Y,Y7,Y8,M3/2) ;
   FACT=O(2,-1,2,O3)*O(2,-1,2,O4)*(K(2,-1,2)/YSEC*T9)**2*F9*F9*
        O(1,-1,2,O1)*O(1,-1,2,O2)*K(1,-1,2)**2/YSEC/VE/4*F8*M3 ;
 FOR I1=(1,1,N3) DO BEGIN
   MOVY(3,Y,Y8,-M3)    ;            INFLADD(Y,Y7,Y8,Q,Q9) ;
   LECOUNT(Q,Q9,R,R9,J8,E9) ;  RLSTORE(R,R9,FACT,T,TRL,TRH,TLL,TLH) ;
   ONB(2,-1)=ONB(2,-1)+2*FACT ; ONB(1,-1)=ONB(1,-1)+2*FACT ;
 END N3 ;
 END O1,O2 ;
 END O3,O4 ; SONB(2,-1)=SONB(2,-1)+ONB(2,-1) ;
             SONB(1,-1)=SONB(1,-1)+ONB(1,-1) ; OCC=ONB(1,-1)/2 ;
             SOCC=SOCC+OCC ;
END PROCEDURE QQ ;
```

```
PROCEDURE QM(LQ,LS,T) ;
REAL ARRAY T ; INTEGER LQ,LS ;
BEGIN INTEGER I1,O1,O2,O3,JØS,JØQ,S9,S4 ;
 COMMENT LANE LQ:O1 O2 Y7 JØQ  LANE LS: O3 Y8 JØS ;
 JØQ=IF LQ EQL 2 THEN -1 ELSE 1 ;
 JØS=IF LS EQL 2 THEN -1 ELSE 1 ;
 INIT(T) ; S4=S4QM  ;  S3=(S1-SØ)/S4 ;
 FOR S9=(1,1,S4) DO BEGIN M3=(2*XØ+SØ+S3*(S9-Ø.5))/N3 ;
 FOR O1=(1,1,W1) DO FOR O2=(1,1,W1) DO BEGIN
  INFLTOYQ(J,J1,1,M(1,J1),O(LQ,-1,1,O1),JØQ,LQ,1,Y,Y7) ;
  INFLTOYQ(J,J1,1,M(1,J1),O(LQ,-1,1,O2),JØQ,LQ,3,Y,Y8) ;
  YYDISY2(Y,Y7,Y8,S2-XØ) ;
  INFLADD(Y,Y7,Y8,Q,Q9)  ;
  YQTOYQ(1,Q,Q9,1,Y,Y7) ;
 FOR O3=(1,1,W1) DO BEGIN
  FACT=O(LQ,-1,2,O1)*O(LQ,-1,2,O2)*K(LQ,-1,2)/YSEC*K(LQ,-1,2)/YSEC*
       O(LS,-1,2,O3)*K(LS,-1,2)*T9*M3/VE/S4*F8*F9/2 ;
  INFLTOYQ(J,J1,1,M(1,J1),O(LS,-1,1,O3),JØS,LS,3,Y,Y8) ;
  YYDISY2(Y,Y7,Y8,M3/2) ;
 FOR I1=(1,1,N3) DO BEGIN
   MOVY(3,Y,Y8,-M3)    ;           INFLADD(Y,Y7,Y8,Q,Q9) ;
   LECOUNT(Q,Q9,R,R9,J8,E9) ;  RLSTORE(R,R9,FACT,T,TRL,TRH,TLL,TLH) ;
   ONB(LQ,-1)=ONB(LQ,-1)+2*FACT ;
   ONB(LS,-1)=ONB(LS,-1)+FACT    ;
 END N3 ;
 END O3 ;
 END O2,O3 ;
 END S9     ;  SONB(LQ,-1)=SONB(LQ,-1)+ONB(LQ,-1) ;
               SONB(LS,-1)=SONB(LS,-1)+ONB(LS,-1) ; OCC=ONB(LS,-1) ;
               SOCC=SOCC+OCC ;
END PROCEDURE QM ;
```

```
PROCEDURE QU(LQ,TØ,T) ;
REAL ARRAY T ; INTEGER LQ,TØ ;
BEGIN INTEGER I1,O1,O2,T6,T7,JØ ;
COMMENT O1 T6 Y7  O2 T7 Y8 ;
 INIT(T) ; S3=(S1-SØ)/S4 ;
 JØ=IF LQ EQL 2 THEN -1 ELSE 1 ;
IF TØ EQL -1 THEN BEGIN
   FOR O1=(1,1,W1) DO BEGIN
    INFLTOYQ(J,J1,1,M(1,J1),O(LQ,TØ,1,O1),JØ,LQ,1,Y,Y7) ;
   FOR O2=(1,1,W1) DO BEGIN
    INFLTOYQ(J,J1,1,M(1,J1),O(LQ,TØ,1,O2),JØ,LQ,3,Y,Y8) ;
   YYDISY2(Y,Y7,Y8,S1+S3/2-XØ) ;
   FACT=O(LQ,-1,2,O1)*O(LQ,-1,2,O2)*K(LQ,-1,2)/YSEC*K(LQ,-1,2)*
        T9/S4*F9/2 ;
   FOR I1=(1,1,S4) DO BEGIN
    MOVY(3,Y,Y8,-S3)          ; INFLADD(Y,Y7,Y8,Q,Q9) ;
    LECOUNT(Q,Q9,R,R9,J8,E9) ; RLSTORE(R,R9,FACT,T,TRL,TRH,TLL,TLH) ;
    ONB(LQ,-1)=ONB(LQ,-1)+2*FACT ;
```

```
      END S4 ;
      END 02 ;
      END 01 ;
      SONB(LQ,-1)=SONB(LQ,-1)+ONB(LQ,-1) ;  OCC=ONB(LQ,-1)/2  ;
   END T0=-1  ELSE
   BEGIN
    FOR T6=(1,1,T2) DO FOR T7=(1,1,T2) DO BEGIN
      FOR 01=(1,1,W1) DO BEGIN
       INFLTOYQ(I,T6,1,M(2,T6),O(LQ,T6,1,01),J0,LQ,1,Y,Y7) ;
      FOR 02=(1,1,W1) DO BEGIN
       INFLTOYQ(I,T7,1,M(2,T7),O(LQ,T7,1,02),J0,LQ,3,Y,Y8) ;
      YYDISY2(Y,Y7,Y8,S1+S3/2-X0) ;
      FACT=O(LQ,T6,2,01)*O(LQ,T7,2,02)*K(LQ,T6,2)/YSEC*K(LQ,T7,2)*
           T9/S4*F9/2 ;
      FOR I1=(1,1,S4) DO BEGIN
       MOVY(3,Y,Y8,-S3)           ; INFLADD(Y,Y7,Y8,Q,Q9) ;
      LECOUNT(Q,Q9,R,R9,J8,E9) ; RLSTORE(R,R9,FACT,T,TRL,TRH,TLL,TLH) ;
       ONB(LQ,T6)=ONB(LQ,T6)+FACT ; ONB(LQ,T7)=ONB(LQ,T7)+FACT ;
      END S4 ;
      END 02 ;
      END 01 ;
      END T6,T7 ;
      FOR T6=(1,1,T2) DO BEGIN SONB(LQ,T6)=SONB(LQ,T6)+ONB(LQ,T6) ;
                               OCC=OCC+ONB(LQ,T6)/2 END ;
   END T0 NEQ -1 ;
   SOCC=SOCC+OCC ;
   END PROCEDURE QU ;
```

```
   PROCEDURE ME(LA2,LA1,T0,T) ;
   REAL ARRAY T ; INTEGER T0,LA1,LA2 ;
   BEGIN INTEGER I1,01,02,T6,T7,J01,J02,L01,L02 ;
         REAL K1,F78 ;
   COMMENT LANE1 L01-Y8 T7 02 J01  LANE2 L02-Y7 T6 01 J02 ;
   J01=1 ; J02=-1 ; F78=F8 ; L01=LA1 ; L02=LA2 ;
   IF L01 NEQ L02 THEN BEGIN L01=1 ; L02=2 END ;
   IF L01 EQL 1 AND L02 EQL 1 THEN J02=1 ;
   IF L01 EQL 2 AND L02 EQL 2 THEN J01=-1 ;
   IF L01 EQL L02 THEN F78=F7/2 ;
   IF T0 EQL -1 OR T0 EQL 0 THEN BEGIN
    INIT(T) ;  K1=2*X0 ;  M3=K1/N3 ;
      FOR 01=(1,1,W1) DO BEGIN
      INFLTOYQ(J,J1,1,M(1,J1),O(2,T0,1,01),J02,2,1,Y,Y7)  ;
      FOR 02=(1,1,W1) DO BEGIN
      INFLTOYQ(J,J1,1,M(1,J1),O(1,T0,1,02),J01,1,3,Y,Y8)  ;
      YYDISY2(Y,Y7,Y8,M3/2) ;
      FACT=O(2,T0,2,01)*O(1,T0,2,02)*K(L01,T0,2)/YSEC*K(L02,T0,2)*
           M3/VE*F78 ;
      FOR I1=(1,1,N3) DO BEGIN
      MOVY(3,Y,Y8,-M3)           ; INFLADD(Y,Y7,Y8,Q,Q9) ;
       LECOUNT(Q,Q9,R,R9,J8,E9)  ; RLSTORE(R,R9,FACT,T,TRL,TRH,TLL,TLH) ;
       ONB(L01,T0)=ONB(L01,T0)+FACT ; ONB(L02,T0)=ONB(L02,T0)+FACT ;
      END N3 ;
       END 02 ;
     END 01 ;
       IF L01 NEQ L02 THEN BEGIN
       SONB(L01,T0)=SONB(L01,T0)+ONB(L01,T0) ; OCC=ONB(L01,T0)/2 END ;
       SONB(L02,T0)=SONB(L02,T0)+ONB(L02,T0) ; OCC=OCC+ONB(L02,T0)/2 ;
   END T0=-1,0 ELSE
   BEGIN  INIT(T) ;
     FOR T6=(1,1,T2) DO FOR T7=(1,1,T2) DO BEGIN
             K1=A(T6,1)+A(T7,1)+2*X0  ;  M3=K1/N3 ;
      FOR 01=(1,1,W1) DO BEGIN
      INFLTOYQ(I,T6,1,M(2,T6),O(2,T6,1,01),J02,2,1,Y,Y7) ;
      FOR 02=(1,1,W1) DO BEGIN
      INFLTOYQ(I,T7,1,M(2,T7),O(1,T7,1,02),J01,1,3,Y,Y8) ;
      YYDISY2(Y,Y7,Y8,M3/2) ;
      FACT=O(2,T6,2,01)*O(1,T7,2,02)*K(L02,T6,2)/YSEC*K(L01,T7,2)*
           M3/VE*F78 ;
      FOR I1=(1,1,N3) DO BEGIN
       MOVY(3,Y,Y8,-M3)           ; INFLADD(Y,Y7,Y8,Q,Q9) ;
       LECOUNT(Q,Q9,R,R9,J8,E9)  ; RLSTORE(R,R9,FACT,T,TRL,TRH,TLL,TLH) ;
       ONB(L01,T7)=ONB(L01,T7)+FACT ; ONB(L02,T6)=ONB(L02,T6)+FACT ;
      END N3 ;
      END 02 ;
      END 01 ;
    END T6,T7 ;
    IF L01 NEQ L02 THEN BEGIN
    FOR T7=(1,1,T2) DO BEGIN SONB(L01,T7)=SONB(L01,T7)+ONB(L01,T7) ;
                        OCC=OCC+ONB(L01,T7)/2 END ; END ;
    FOR T6=(1,1,T2) DO BEGIN SONB(L02,T6)=SONB(L02,T6)+ONB(L02,T6) ;
                        OCC=OCC+ONB(L02,T6)/2 END ;
   END T0 NEQ -1,0 ;
   SOCC=SOCC+OCC ;
   END PROCEDURE ME ;
```

```
   PROCEDURE SI(LS,T0,T) ;
   REAL ARRAY T ; INTEGER LS,T0 ;
   BEGIN INTEGER I1,AX,T6,N,J0 ; REAL ARRAY RT(1:2,1:60) ;
    INIT(T) ;
    J0=IF LS EQL 2 THEN -1 ELSE 1 ;
   IF T0 EQL -1 OR T0 EQL 0 THEN BEGIN
      INFLTOYQ(J,J1,1,M(1,J1),1,J0,LS,1,Q,Q9) ;
      LECOUNT(Q,Q9,R,R9,J8,E9) ;
      FOR N=(C(LS,T0,5),1,C(LS,T0,6)) DO BEGIN.
      FACT=X(LS,T0,N)*(K(LS,T0,2)-SONB(LS,T0)) ;
       IF FACT LSS 0 THEN BEGIN WRITE(<<'TOO MANY OVERLAPPINGS',A1>>) ;
       GOTO L99 END ;
      FOR I1=(1,1,R9) DO BEGIN
        RT(1,I1)=R(1,I1)*VAL(N,P1) ;
        RT(2,I1)=R(2,I1)*VAL(N,P1) END I1 ;
      RLSTORE(RT,R9,FACT,T,TRL,TRH,TLL,TLH) ;
      ONB(LS,T0)=ONB(LS,T0)+FACT ;
   END N;
       SONB(LS,T0)=SONB(LS,T0)+ONB(LS,T0) ; OCC=ONB(LS,T0) ;
   END T0=-1,0 ELSE
   BEGIN
     FOR T6=(1,1,T2) DO
     FOR AX=(1,1,M(3,T6)) DO BEGIN
     INFLTOYQ(I,T6,AX,M(2,T6),1,J0,LS,1,Q,Q9) ;
      LECOUNT(Q,Q9,R,R9,J8,E9) ;
      FOR N=(C(LS,T6,5),1,C(LS,T6,6)) DO BEGIN
      FACT=X(LS,T6,N)*H(T6,2,AX)*(K(LS,T6,2)-SONB(LS,T6)) ;
       IF FACT LSS 0 THEN BEGIN WRITE(<<'TOO MANY OVERLAPPINGS',A1>>) ;
       GOTO L99 END ;
      FOR I1=(1,1,R9) DO BEGIN
        RT(1,I1)=R(1,I1)*VAL(N,P1) ;
        RT(2,I1)=R(2,I1)*VAL(N,P1) END I1 ;
      RLSTORE(RT,R9,FACT,T,TRL,TRH,TLL,TLH) ;
      ONB(LS,T6)=ONB(LS,T6)+FACT ;
   END N;
```

```
END T6,AX ;
FOR T6=(1,1,T2) DO BEGIN SONB(LS,T6)=SONB(LS,T6)+ONB(LS,T6) ;
                       OCC=OCC+ONB(LS,T6) END ;
END T0=1 ;
SOCC=SOCC+OCC ;
END PROCEDURE SI ;
---------------------------------------------------------------
PROCEDURE TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
REAL ARRAY T,S ; INTEGER TRL,TRH,TLL,TLH,SRL,SRH,SLL,SLH ;
BEGIN INTEGER I1,I2 ;
 FOR I1=(TRL,1,TRH) DO FOR I2=(TLL,1,TLH) DO S(I1,I2)=S(I1,I2)+T(I1,I2);
 IF TRL LSS SRL THEN SRL=TRL ; IF TRH GTR SRH THEN SRH=TRH ;
 IF TLL LSS SLL THEN SLL=TLL ; IF TLH GTR SLH THEN SLH=TLH ;
END PROCEDURE TADDS ;
---------------------------------------------------------------
PROCEDURE STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
COMMENT T WILL CONTAIN 1-DISTRIBUTION=GTR (NOT GEQ) ;
REAL ARRAY T ; INTEGER TRL,TRH,TLL,TLH ;
BEGIN INTEGER I1,I2 ;
  FOR I2=(TLL,1,TLH) DO FOR I1=(TRH-1,-1,TRL) DO
  T(I1,I2)=T(I1,I2)+T(I1+1,I2) ;
 FOR I1=(TRL,1,TRH) DO FOR I2=(TLH-1,-1,TLL) DO
  T(I1,I2)=T(I1,I2)+T(I1,I2+1) ; COMMENT T(..) NOW CONTAINS GEQ ;
 FOR I1=(TRL,1,TRH) DO FOR I2=(TLL,1,TLH) DO
  T(I1-1,I2-1)=T(I1,I2) ;
 FOR I2=(TLL-1,1,TLH) DO T(TRH,I2)=0 ;
 FOR I1=(TRL-1,1,TRH) DO T(I1,TLH)=0 ; COMMENT T(..) NOW CONTAINS GTR ;
END PROCEDURE STLINSPCONV ;
---------------------------------------------------------------
PROCEDURE INFLTOYQ(J,J1,AX,M1,O,J0,L0,YS,Y,Y78) ;
 REAL ARRAY J,Y ; REAL O ; INTEGER J1,AX,M1,J0,L0,YS,Y78 ;
 BEGIN INTEGER I1,I2,I3,I4 ;
 I1=2*AX-1 ; I2=2*AX ;
  I4=ABS(J1)*SIGN(J0) ;
  FOR I3=(1,1,M1) DO BEGIN
  Y(YS+1,I3)=J(I4,I2,I3)*O ; Y(YS,I3)=J(I4,I1,I3) END ;
 Y78=M1 ;
END PROCEDURE INFLTOYQ ;
---------------------------------------------------------------
PROCEDURE YYDISY2(Y,Y7,Y8,DIST) ;
REAL ARRAY Y; REAL DIST ; INTEGER Y7,Y8 ;
BEGIN INTEGER I1 ; REAL K1 ;
 K1=Y(1,Y7)-Y(3,1)+DIST ;
 FOR I1=(1,1,Y8) DO Y(3,I1)=Y(3,I1)+K1 ;
END YYDISY2 ;
---------------------------------------------------------------
PROCEDURE MOVY(YS,Y,Y8,MOV) ;
REAL ARRAY Y; INTEGER YS,Y8 ; REAL MOV ;
BEGIN INTEGER I1 ;
 FOR I1=(1,1,Y8) DO Y(YS,I1)=Y(YS,I1)+MOV ;
END PROCEDURE MOVY ;
---------------------------------------------------------------
PROCEDURE YQTOYQ(YS1,Y1,Y7,YS2,Y2,Y8) ;
REAL ARRAY Y1,Y2 ; INTEGER YS1,YS2,Y7,Y8 ;
BEGIN INTEGER I1 ;
 FOR I1=(1,1,Y7) DO BEGIN
 Y2(YS2+1,I1)=Y1(YS1+1,I1) ;
 Y2(YS2,I1)=Y1(YS1,I1) END ;
Y8=Y7 ;
END PROCEDURE YQTOYQ ;
---------------------------------------------------------------
PROCEDURE RLSTORE(R,R9,FACT,T,TRL,TRH,TLL,TLH) ;
REAL ARRAY R,T ; REAL FACT ; INTEGER R9,TRL,TRH,TLL,TLH ;
BEGIN INTEGER I1,I2,I3 ;
 FOR I3=(1,1,R9) DO BEGIN
 I1=NBR(ABS(R(1,I3)),W0)  ;  I2=NBR(R(2,I3),Z0)  ;
  RNB(SIGN(R(1,I3)))=RNB(SIGN(R(1,I3)))+FACT    ;
 IF I1 GTR TRH THEN TRH=I1 ; IF I1 LSS TRL THEN TRL=I1 ;
 IF I2 GTR TLH THEN TLH=I2 ; IF I2 LSS TLL THEN TLL=I2 ;
 T(I1,I2)=T(I1,I2)+FACT ;
 END I3 ;
END PROCEDURE RLSTORE ;
---------------------------------------------------------------
PROCEDURE DYNCONV(S,SRL,SRH,SLL,SLH,A1,AM,T,TRL,TRH,TLL,TLH) ;
REAL ARRAY S,T,AM ; INTEGER SRL,SRH,SLL,SLH,A1,TRL,TRH,TLL,TLH ;
BEGIN INTEGER I1,I2,I3,I5,I6 ; REAL K1,K2,K3 ;
INIT(T) ;
 FOR I1=(SRL,1,SRH) DO BEGIN
   K1=VAL(I1,W0) ; K2=K1/2 ;
 FOR I2=(SLL,1,SLH) DO BEGIN
   K3=VAL(I2,Z0) +K2 ;
 FOR I3=(1,1,A1) DO BEGIN
   I5=NBR(K1*AM(1,I3),W0) ;
   I6=NBR(K3-K2*AM(1,I3),Z0) ;
   T(I5,I6)=T(I5,I6)+S(I1,I2)*AM(2,I3) ;
    IF I5 LSS TRL THEN TRL=I5 ; IF I5 GTR TRH THEN TRH=I5 ;
    IF I6 LSS TLL THEN TLL=I6 ; IF I6 GTR TLH THEN TLH=I6 ;
 END I3 ;
 END I2 ;
 END I1 ;
END PROCEDURE DYNCONV ;
---------------------------------------------------------------
PROCEDURE PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,
                 PR,PL) ;
REAL ARRAY T,ONB ; REAL OCC ; STRING TEXT ;
INTEGER TRL,TRH,TLL,TLH,PR,PL,T0 ;
COMMENT LEVEL GREATER THAN OR EQUAL LOWER CLASS LIMIT ;
BEGIN INTEGER I1,I2,I3,I4,I5,I6,I7,I8,I9 ;
REAL K1,K2,K3 ; STRING PLO(25) ;
INTEGER ARRAY C(1:2),LEV(1:2,1:25) ;
 I6=11 ; I7=10 ; I8=16 ; I9=15 ;
 FOR I1=(1,1,2) DO BEGIN IF PR NEQ 1 THEN GOTO L10 ;
 WRITE(<<E1,S80,A1>>,TEXT) ;
 IF I1 EQL 1 THEN
 WRITE(<<'LINSPECTRUM',J15>>) ELSE WRITE(<<'10LOGSPECTRUM',J15>>) ;
 WRITE(<<'OCASSIONS=',I9,J40,'NB. OF RANGES=',I10,A1>>,
         OCC,T(TRL-1,TLL-1)) ;
 WRITE(<<'VEHICLES (AXLES) INVOLVED LANE1',J35>>) ;
  I3=T0 ;
  I4=IF T0 EQL 1 THEN T2 ELSE T0 ;
 WRITE(<<:I4-I3+1:(I9),A1>>,FOR I2=(I3,1,I4) DO ONB(1,I2)) ;
 WRITE(<<'(TYPE 1,2...)',J27,'LANE2',J35>>) ;
 WRITE(<<:I4-I3+1:(I9),A1>>,FOR I2=(I3,1,I4) DO ONB(2,I2)) ;
 FOR I2=(0,IF I1 EQL 1 THEN I6 ELSE I8,200) DO BEGIN
 IF I1 EQL 1 THEN
  I5=IF (TLL-1+I7+I2) GTR TLH THEN TLH ELSE TLL-1+I7+I2 ELSE
  I5=IF (TLL-1+I9+I2) GTR TLH THEN TLH ELSE TLL-1+I9+I2 ;
 WRITE(<<'  GREATER EQUAL  GREATER THAN OR EQUAL LEVEL',A2>>) ;
 WRITE(<<'       RANGE        --TOTALS IN FIRST ROW',A1>>) ;
  IF I1 EQL 1 THEN
```

```
 WRITE(<<J16,:I5-I2+2-TLL:(D10.2),A1>>,FOR I4=(TLL-1+I2,1,I5) DO
       VAL(I4,Z0)+Z0/2) ELSE
 WRITE(<<J16,:I5-I2+2-TLL:(D7.2),A1>>,FOR I4=(TLL-1+I2,1,I5) DO
       VAL(I4,Z0)+Z0/2) ;
FOR I3=(TRL-1,1,TRH) DO BEGIN
WRITE(<<D7.2,'-',D7.2>>,VAL(I3,W0)+W0/2,VAL(I3,W0)+W0*3/2) ;
IF I1 EQL 1 THEN
 WRITE(<<:I5-I2+2-TLL :(I10),A1>>,FOR I4=(TLL-1+I2,1,I5) DO
       T(I3,I4)) ELSE
 WRITE(<<:I5-I2+2-TLL:(D7.4),A1>>,FOR I4=(TLL-1+I2,1,I5) DO
       LN(MAX(T(I3,I4),0.01))/LN(10)) ;
  IF I1 EQL 1 THEN
   BEGIN IF T(I3,TLL-1+I2) LEQ 0 THEN GOTO L8 END ELSE
   IF T(I3,TLL-1+I2) LEQ 0.01 THEN GOTO L8 ;
END I3 ;
L8: IF I5 EQL TLH THEN GOTO L9 ;
END I2 ;
L9:END I1 ;
L10: COMMENT PLOT  ROUTINE BEGINS HERE ;
IF PL EQL 0 THEN GOTO P9 ;
COMMENT I9=1 LIN.PLOT   =2 LOG.PLOT      LESS THAN 25 CURVES ;
FOR I9=(1,1,2) DO BEGIN
LEV(I9,1)=TLL-1 ; I2=TLL ; C(I9)=1 ;
 FOR I1=(2,1,PL) DO BEGIN
 IF I9 EQL 1 THEN BEGIN
 K1=(PL+1-I1)/PL*T(TRL-1,TLL-1) ; K2=(PL-I1)/PL*T(TRL-1,TLL-1) END ELSE
 BEGIN K1=(PL+1-I1)/PL*LN(T(TRL-1,TLL-1))/LN(10) ;
       K2=(PL-I1)/PL*LN(T(TRL-1,TLL-1))/LN(10) END ;
P1:K3=IF I9 EQL 1 THEN T(TRL-1,I2) ELSE
       LN(MAX(T(TRL-1,I2),0.01))/LN(10) ;
   IF K3 GEQ K1 THEN BEGIN I2=I2+1 ; IF I2 EQL TLH+1 THEN GOTO P21
                                       ELSE GOTO P1 END
       ELSE IF K3 GEQ K2 THEN
       BEGIN C(I9)=C(I9)+1 ; LEV(I9,C(I9))=I2 END ;
P2:END I1 ;
P21:END I9 ;
PLO(1,25)='ABCDEFGHIJKLMNOPQRSTUVXYZ' ;
MARGIN('M,72,0,0.') ;
FOR I9=(1,1,2) DO BEGIN I5=0 ;
WRITE(<<:132:('-'),A3>>) ;
WRITE(<<S80,A1>>,TEXT) ;
IF I9 EQL 1 THEN
 WRITE(<<'LINSPECTRUM',J15>>) ELSE WRITE(<<'10LOGSPECTRUM',J15>>) ;
 WRITE(<<'OCASSIONS=',I9,J40,'NB. OF RANGES=',I10,A1>>,
         OCC,T(TRL-1,TLL-1)) ;
 WRITE(<<'VEHICLES (AXLES) INVOLVED LANE1',J35>>) ;
  I3=T0 ;
  I4=IF T0 EQL 1 THEN T2 ELSE T0 ;
 WRITE(<<:I4-I3+1:(I9),A1>>,FOR I2=(I3,1,I4) DO ONB(1,I2)) ;
 WRITE(<<'(TYPE 1,2...)',J27,'LANE2',J35>>) ;
 WRITE(<<:I4-I3+1:(I9),A1>>,FOR I2=(I3,1,I4) DO ONB(2,I2)) ;
WRITE(<<:132:('-'),A1>>) ;
WRITE(<<'I',J7,'RANGE',J18,'I',J65,'GREATER THAN OR ECUAL RANGE'>>) ;
 IF I9 EQL 1 THEN WRITE(<<J95,'LIN(%)',J119,'I GR.EC  LEVEL',A1>>) ELSE
 WRITE(<<J95,'10LOG(*10)',J119,'I GR.EC  LEVEL',A1>>) ;
FOR I1=(TRH,-1,TRL-1) DO BEGIN I5=I5+1 ;
WRITE(<<'I',D7.2,'-',D7.2,' I'>>,VAL(I1,W0)+W0/2,VAL(I1,W0)+W0*3/2) ;
WRITE(<<J19,:9:('          I')>>) ;
IF ENTIER(I5/10)*10 EQL I5 THEN
WRITE(<<J19,:9:('---------+'),'----------'>>) ;
I2=1 ;I4=-1 ;
P3:I3=IF I9 EQL 1 THEN
   ENTIER(T(I1,LEV(I9,I2))/T(TRL-1,TLL-1)*100+0.999999) ELSE
   ENTIER(LN(MAX(T(I1,LEV(I9,I2)),0.01))/LN(10)*10+0.999999) ;
   IF I3 GTR 100 THEN I3=100 ; IF I3 LEC 0 THEN GOTO P4 ;
   IF I3 EQL I4 THEN WRITE(<<J(I3+18),'*'>>) ELSE
    WRITE(<<J(I3+18),S1>>,PLO(I2)) ;
P4:IF I2 NEQ C(I9) THEN
   BEGIN I2=I2+1 ; I4=I3 ; GOTO P3 END ;
  IF I5 LEQ C(I9) THEN
  WRITE(<<J119,'I  ',S1,' =',D7.2,A1>>,PLO(I5),VAL(LEV(I9,I5),Z0)+Z0/2)
  ELSE WRITE(<<J119,'I',A1>>) ;
END I1 ;
WRITE(<<'I',:16:('-'),'+',:20:('---->'),'I',A1>>) ;
WRITE(<<J20,:20:(I5),A1>>,FOR I1=(5,5,100) DO I1) ; I5=I5+1 ;
  IF I5 LEQ C(I9) THEN
  FOR I1=(I5,1,C(I9)) DO
  WRITE(<<J119,'I  ',S1,' =',D7.2,A1>>,PLO(I5),VAL(LEV(I9,I5),Z0)+Z0/2);
END I9 ;
MARGIN('M,66,6,3.') ;
P9:END PROCEDURE PRINTST ;
```

```
COMMENT ---------------------------------------------------------------
  MAX. 70 CLASSES IN G(..)
       90 CLASSES IN X(...)
       10 VEHICLE TYPES
       5 (MIN 2) AXLES PER VEHICLE
       12 POINTS IN INFLUENCE LINE 4
       6 OVERLAP DISTRIBUTION CLASSES
       25 PLOTTED CURVES
       10 DYNAMIC AMPLIFICATION FACTOR CLASSES
```

```
COMMENT +++++ VEHICLE SPECIFICATIONS +++++ ;
COMMENT  AT LEAST 2 AXLES PER VEHICLE AND MAX. 5 ;
VEIN: READ(T2) ; IF T2 EQL 0 THEN GOTO LOIN ;
  WRITE(<<E1,'** VEHICLE SPECIFICATIONS **',A1>>) ;
  WRITE(<<I4,' VEHICLE TYPES',A1>>,T2) ;
  FOR T1=(1,1,T2) DO BEGIN
   READ(V(T1,1),M(3,T1)) ;
   READ(FOR I1=(2,1,V(T1,1)) DO A(T1,I1)) ;
   READ(FOR I1=(1,1,V(T1,1)) DO B(T1,I1)) ;
    K1=B(T1,1) ; A(T1,1)=0 ; FOR I2=(2,1,V(T1,1)) DO BEGIN
               K1=K1+B(T1,I2) ; A(T1,1)=A(T1,1)+A(T1,I2)   END ;
   FOR I2=(1,1,V(T1,1)) DO B(T1,I2)=B(T1,I2)/K1 ;   H2=M(3,T1) ;
   READ(FOR I1=(1,1,H2) DO H(T1,2,I1)) ;  K2=H(T1,2,1) ;
   FOR I1=(2,1,H2) DO K2=K2+H(T1,2,I1) ;
   FOR I1=(1,1,H2) DO H(T1,2,I1)=H(T1,2,I1)/K2 ;
   READ(FOR I1=(1,1,H2) DO H(T1,1,I1)) ;
                    END T1 ;
   WRITE(<<'TYPE AXLES  AXLEDIST.(M)/LOADDISTR. ON AXLES',J53,
         'AXLEDISTFACTOR/DISTR',A2>>) ;
   FOR T1=(1,1,T2) DO BEGIN H2=M(3,T1) ;
   WRITE(<<2I4,J14,:V(T1,1)-1:(D6.2)>>,
        T1,V(T1,1),FOR I1=(2,1,V(T1,1)) DO A(T1,I1)) ;
    WRITE(<<J40,'TOT=',D6.2,J52,:H2:(D6.3),A2>>,
         A(T1,1),FOR I1=(1,1,H2) DO H(T1,2,I1)) ;
   WRITE(<<J10,:V(T1,1):(D6.3)>>,FOR I1=(1,1,V(T1,1)) DO B(T1,I1)) ;
    WRITE(<<J52,:H2:(D6.3),A1>>,FOR I1=(1,1,H2) DO H(T1,1,I1)) ;
                    END T1 ;
```

```
COMMENT +++++ LOAD SPECTRA INPUT +++++ ;
LOIN: WRITE(<<E1,'** LOAD DENSITY FUNCTIONS **',A2>>) ;
COMMENT T1 -1:Ø:1... = TOTAL AXLE TYPE
        IF T2 EQL Ø READ TOTAL AXLE LOADS
        IF T2 GEQ 1 READ TYPE LOADS (TOTAL AXLE CALCULATED) ;
  READ(PR,PL) ;
  READ(Y1,RE,YØ); WRITE(<<'LOAD ID=',D8.2,'   REGION=',D8.4,
      '   YEARS=',I4,A1>>,Y1,RE,YØ) ;
    FOR I1=(-1,1,T2) DO FOR I2=(1,1,7Ø) DO G(I1,I2)=Ø ;
  FOR T1=((IF T2 GEQ 1 THEN 1 ELSE -1),1,T2) DO BEGIN K1=Ø ;
   READ(P1,C(1,T1,3),C(1,T1,4),K(1,T1,2)) ;
    FOR I1=(C(1,T1,3),1,C(1,T1,4)) DO BEGIN READ(G(T1,I1)) ;
        K1=K1+G(T1,I1) END ;
        FOR I1=(1,1,C(1,T1,4)) DO G(T1,I1)=G(T1,I1)/K1   END T1 ;
    IF T2 GEQ 1 THEN BEGIN
       I5=Ø ; I4=1000 ;    K1=K2=Ø ;
       FOR I1=(-1,1,Ø) DO FOR I2=(1,1,7Ø) DO G(I1,I2)=Ø ;
       FOR T1=(1,1,T2) DO FOR N=(C(1,T1,3),1,C(1,T1,4)) DO BEGIN
       G(-1,N)=G(-1,N)+G(T1,N)*K(1,T1,2) ; K1=K1+G(T1,N)*K(1,T1,2) ;
        FOR I1=(1,1,V(T1,1)) DO BEGIN
        I3=NBR(VAL(N,P1)*B(T1,I1),P1) ;
         G(Ø,I3)=G(Ø,I3)+G(T1,N)*K(1,T1,2) ; K2=K2+G(T1,N)*K(1,T1,2) ;
        IF I3 LSS I4 THEN I4=I3 ; IF I3 GTR I5 THEN I5=I3 ;
        END I1 ;
       END T1,N ;
       K(1,-1,2)=K1 ; K(1,Ø,2)= K2 ;
       C(1,-1,3)=MIN(FOR T1=(1,1,T2) DO C(1,T1,3)) ;
       C(1,-1,4)=MAX(FOR T1=(1,1,T2) DO C(1,T1,4)) ;
       C(1,Ø,3)=I4 ; C(1,Ø,4)=I5 ;
       FOR T1=(-1,1,Ø) DO FOR I3=(C(1,T1,3),1,C(1,T1,4)) DO
        G(T1,I3)=G(T1,I3)/K(1,T1,2) ;
    END TOTAL-AXLE CALC ;
  WRITE(<<'   LOAD-CLASS',J18,'TOTAL(%) AXLE(%)',:T2:('  TYPE',I3),
      A2>>,FOR I3=(1,1,T2) DO I3) ;
  FOR T1=(-1,1,T2) DO BEGIN K(1,T1,2)=K(2,T1,2)=K(1,T1,2)*YØ ;
    C(2,T1,3)=C(1,T1,3) ; C(2,T1,4)=C(1,T1,4) END ;
  WRITE(<<'** TOT=',J16,:T2+2:(I9),A1>>,FOR T1=(-1,1,T2) DO
      K(1,T1,2)) ;
  FOR N=(1,1,MAX(FOR I3=(-1,1,T2) DO C(1,I3,4))) DO BEGIN
  K1=VAL(N,P1)-P1/2 ; K2=K1+P1 ;
  WRITE(<<D7.2,'-',D7.2,:T2+2:(D9.5),A1>>,
      K1,K2,FOR T1=(-1,1,T2) DO G(T1,N)*100 ) END ;
PRINTLSP(1,1,PR,PL) ;
```

```
LINF: COMMENT +++++ LATERAL INFLUENCE SPECIFICATIONS +++++ ;
COMMENT F MUST BE GREATER/EQUAL Ø ;
COMMENT TO ELIMINATE LATERAL TRACK DISTR. INFLUENCE - PUT F3=Ø
        Y4 SHALL ALWAYS BE NOT EQUAL Ø ;
  READ(PR,PL) ;
  READ(Y4,Y5,Y6) ;
  READ(F1,F3,F2,F4) ;
  WRITE(<<E1,'** LATERAL INFLUENCE DATA **',A2>>) ;
  IF  (Y5+Y6) GTR 1 THEN BEGIN WRITE('FAULT IN LATINFL.DISTR. INPUT') ;
                             GOTO L99 END ;
  WRITE(<<'LAT.TRACK DISTR EACH LANE: WIDTH(M)=',D7.2,'  FLAT PORTION=',
        D6.3,A1>>,Y4,Y5) ;
  WRITE(<<'   SLANTING PORTION (IF NEG TOWARDS F2-F4 LANE2)=',D6.3,A1>>,
        Y6) ;
  WRITE(<<'  LANE 1 (MIDDLE FACTOR)=',D7.3,'  +F3=',D7.3,
      '  -F3=',D7.3,A1>>,F1,F1+F3,F1-F3) ;
  WRITE(<<'  LANE 2 (MIDDLE FACTOR)=',D7.3,'  +F4=',D7.3,
      '  -F4=',D7.3,A1>>,F2,F2+F4,F2-F4) ;
```

```
EQCA: COMMENT +++++ EQUIVALENT LOAD SPECTRA CALCULATIONS +++++ ;
  FOR I1=(1,1,2) DO FOR I2=(-1,1,10) DO FOR I3=(1,1,90)
                 DO X(I1,I2,I3)=Ø;
  FOR LØ=(1,1,2) DO BEGIN FØ=IF LØ EQL ! THEN F1 ELSE F2 ;
                          FD=IF LØ EQL 1 THEN F3 ELSE F4 ;
   FOR T1=(-1,1,T2) DO BEGIN
    FOR N=(C(LØ,T1,3),1,C(LØ,T1,4)) DO BEGIN
    K3=VAL(N,P1)*(FØ-FD) ; I1=NBR(K3,P1) ;
    K3=VAL(N,P1)*(FØ+FD) ;  I2=NBR(K3,P1) ; K3=VAL(N,P1) ;
    IF I1 EQL I2 THEN BEGIN X(LØ,T1,I1)=X(LØ,T1,I1)+G(T1,N) ;
                         GOTO E3 END ;
     K2=VAL(I1,P1)+P1/2 ;  YL=Ø ; YH=(K2/K3-(FØ-FD))/2/FD*Y4 ;
     X(LØ,T1,I1)=X(LØ,T1,I1)+G(T1,N)*LATINT(Y4,Y5,Y6,YL,YH,LØ) ;
E1: I1=I1+1 ; IF I1 EQL I2 THEN GOTO E2 ;
    K2=VAL(I1,P1)+P1/2 ;
    YL=YH ; YH=(K2/K3-(FØ-FD))/2/FD*Y4 ;
     X(LØ,T1,I1)=X(LØ,T1,I1)+G(T1,N)*LATINT(Y4,Y5,Y6,YL,YH,LØ) ;
    GOTO E1 ;
E2:  YL=YH ; YH=Y4 ;
     X(LØ,T1,I1)=X(LØ,T1,I1)+G(T1,N)*LATINT(Y4,Y5,Y6,YL,YH,LØ) ;
E3: END N ;
   C(LØ,T1,6)=I2 ; K3=VAL(C(LØ,T1,3),P1)*(FØ-FD) ;C(LØ,T1,5)=NBR(K3,P1);
    END T1 ;
   END LØ ;

COMMENT ----- K(2,T1,2) COULD BE CHANGED HERE ;

   FOR LØ=(1,1,2) DO BEGIN
   WRITE(<<'** EQUIVALENT LOAD DENS. FUNC. LANE',I2,' **',A3.1>>,LØ) ;
   WRITE(<<'   LOAD-CLASS',J18,'TOTAL(%) AXLE(%)',:T2:('  TYPE',I3),
       A2>>,FOR I3=(1,1,T2) DO I3) ;
   WRITE(<<'** TOT=',J16,:T2+2:(I9),A1>>,FOR T1=(-1,1,T2) DO
SYSTEM WARNING - MAX PAGES
       K(LØ,T1,2)) ;
   FOR N=(1,1,MAX(FOR I3=(-1,1,T2) DO C(LØ,I3,6))) DO BEGIN
   K1=VAL(N,P1)-P1/2 ; K2=K1+P1 ;
    WRITE(<<D7.2,'-',D7.2,:T2+2:(D9.5),A1>>,K1,K2,FOR T1=(-1,1,T2) DO
          X(LØ,T1,N)*100)    END N;
   END LØ ;
 PRINTLSP(2,1,PR,PL) ;
 PRINTLSP(2,2,PR,PL) ;
```

```
COMMENT +++++ STRUCTURAL POINT. INFLUENCE LINE +++++ ;
SINF: READ(J1,XØ) ; WRITE(<<E1,'** INFLUENCE LINE SPEC. **',A2>>) ;
  WRITE(<<'INFLINE TYPE',I2,' TOTAL LENGTH(M)=',D7.2,A1>>,J1,XØ) ;
  IF J1 NEQ 1 THEN GOTO INF2 ; READ(X6,X7,X8) ;
  WRITE(<<'SLOPE:TOP:INNERSLOPE X-RELATIONS',D5.1,':',D5.1,':',D5.1,
        A1>>,X6,X7,X8) ;
  K1=X6+X7+X8 ; X6=X6/K1/2 ; X7=X7/K1/2 ; X8=X8/K1/2 ; M(1,1)=7 ;
  J(1,2,1)=J(1,2,7)=J(1,2,4)=Ø ; J(1,2,2)=J(1,2,3)=J(1,2,5)=J(1,2,6)=1;
  J(1,1,4)=Ø ; J(1,1,7)=X3=XØ/2 ;        J(1,1,1)=-X3 ;
              J(1,1,6)=X2=(X7+X8)*XØ ; J(1,1,2)=-X2 ;
              J(1,1,5)=X1=X8*XØ ;      J(1,1,3)=-X1 ;      GOTO EINF ;
 INF2: IF J1 NEQ 2 THEN GOTO INF3 ;  READ(X6,X7) ;
  WRITE(<<'SLOPE:TOP X-RELATIONS',D5.1,':',D5.1,A1>>,X6,X7) ;
  K1=2*X6+X7 ; X8=X6/K1 ; X6=X8 ; X7=X7/K1 ;   M(1,2)=4 ;
   J(2,2,1)=J(2,2,4)=Ø ; J(2,2,2)=J(2,2,3)=1 ;
```

```
  J(2,1,3)=X1=X0/2*X7 ; J(2,1,2)=-X1 ;
  J(2,1,4)=X2=X0/2    ; J(2,1,1)=-X2 ;                         GOTO EINF ;
INF3: IF J1 NEQ 3 THEN GOTO INF4 ;
      READ(X6,X7,X8) ;
  WRITE(<<'SLOPE1:SLOPE2 X-RELATIONS,INNERHEIGHT',D5.1,':',D5.1,D5.1,
        A1>>,X6,X7,X8) ;
  K1=X6+X7 ; X6=X6/K1/2 ; X7=X7/K1/2 ; M(1,3)=6 ;
  J(3,2,1)=J(3,2,6)=0 ; J(3,2,2)=X8/2 ; J(3,2,5)=-X8/2 ;
                         J(3,2,3)=.5   ; J(3,2,4)=-.5 ;
  J(3,1,6)=X2=X0/2 ; J(3,1,1)=-X2 ; J(3,1,5)=X1=X7*X0 ; J(3,1,2)=-X1 ;
  J(3,1,4)=J(3,1,3)=0 ;
  IF NOT((X6 LSS .0001) AND (X8 LSS .0001)) THEN GOTO EINF ;
    M(1,3)=4 ;  FOR I1=(2,1,4) DO FOR I2=(1,1,2) DO
                J(3,I2,I1)=J(3,I2,I1+1) ;
 GOTO EINF ;
 INF4: IF J1 NEQ 4 THEN BEGIN WRITE(<<' FAULT INFL. INPUT',A1>>) ;
                               GOTO L99 END ;
  READ(M(1,4)) ;
  IF M(1,4) GTR 12 THEN BEGIN
  WRITE(<<'TOO MANY POINTS IN INFL.LINE 4',A1>>) ; GOTO L99 END ;
  K1=K2=0 ;
  FOR I1=(1,1,M(1,4)) DO BEGIN
   READ(J(4,1,I1),J(4,2,I1)) ;
   IF J(4,2,I1) GTR K2 THEN K2=J(4,2,I1) ;
   IF J(4,2,I1) LSS K1 THEN K1=J(4,2,I1) ;
  END I1 ;
  IF (K2-K1) GTR 1 THEN BEGIN
    WRITE(<<'VARIATION INFL.LINE 4 TOO BIG',A1>>) ; GOTO L99 END ;
X0=J(4,1,M(1,4))-J(4,1,1) ;
WRITE(<<' NEW CALCULATED LENGTH=',D7.2,A1>>,X0) ;
WRITE(<<'INFL.VALUE=',:M(1,4):(D8.4),A1>>,FOR I1=(1,1,M(1,4))
                                          DO J(4,2,I1)) ;
WRITE(<<'   X-VALUE=',:M(1,4):(D8.2),A1>>,FOR I1=(1,1,M(1,4))
                                          DO J(4,1,I1)) ;
 GOTO EINF ;
EINF:
 COMMENT CALCULATE MEETING INFL.LINE ;
 FOR I1=(1,1,M(1,J1)) DO BEGIN
  J(-J1,2,I1)= J(J1,2,M(1,J1)+1-I1) ;
  J(-J1,1,I1)=-J(J1,1,M(1,J1)+1-I1) END I1 ;
COMMENT  DO A LECOUNT ON THE INFLUENCE LINE AND PRINT THE RESULT ;
WRITE(<<'LECOUNT ON J1 AND -J1 (MEETING)  RANGE/LEVEL',A2>>);
FOR I1=(1,-2,-1) DO BEGIN
INFLTOYQ(J,J1,1,M(1,J1),1,I1,1,1,Q,Q9) ; LECOUNT(Q,Q9,R,R9,1000,0) ;
WRITE(<<'RANGE=',:R9:(D7.3),A2>>,FOR I2=(1,1,R9) DO R(1,I2)) ;
WRITE(<<'LEVEL=',:R9:(D7.3),A1>>,FOR I2=(1,1,R9) DO R(2,I2)) ; END I1 ;
COMMENT END $INF ;
-----------------------------------------------------------------------
COMMENT +++++ CALCULATION OF VEHICLE TYPE INFLUENCE LINES +++++ ;
VINF: IF T2 EQL 0 THEN GOTO OVDI ;
FOR I1=(-10,1,10) DO FOR I2=(1,1,6) DO FOR I3=(1,1,60) DO I(I1,I2,I3)=0;
  FOR T1=(-T2,1,T2) DO BEGIN IF T1 EQL 0 THEN GOTO V2 ;
  N8=ABS(T1) ; N9=J1*SIGN(T1) ;
   FOR I3=(1,1,M(3,N8)) DO BEGIN
   I1=2*I3-1 ; I2=2*I3 ; D3=0 ;
   M(2,N8)=Y7=Y8=M(1,J1) ;
    FOR I5=(1,1,M(2,N8)) DO BEGIN
    Y(2,I5)=I(T1,I2,I5)=J(N9,2,I5)*B(N8,1) ;
    Y(1,I5)=I(T1,I1,I5)=J(N9,1,I5) END I5 ;
   IF V(N8,1) EQL 1 THEN GOTO V1 ;
    FOR I4=(2,1,V(N8,1)) DO BEGIN
    D3=D3+A(N8,I4)*H(N8,1,I3) ;
     FOR I5=(1,1,Y8) DO BEGIN
     Y(4,I5)=J(N9,2,I5)*B(N8,I4) ;
     Y(3,I5)=J(N9,1,I5)+D3 END I5 ;
    INFLADD(Y,Y7,Y8,Q,Q9) ;  Y7=M(2,N8)=Q9 ;
     FOR I5=(1,1,Y7) DO BEGIN
     Y(2,I5)=I(T1,I2,I5)=Q(2,I5) ;
     Y(1,I5)=I(T1,I1,I5)=Q(1,I5) END I5 ;
    END I4 ;
V1:END I3 ;
V2:END T1 ;
FOR I2=(1,1,MAX(FOR T1=(1,1,T2) DO M(3,T1))) DO BEGIN
 WRITE(<<'** VEHICLE TYPE INFLUENCE LINES AND LECOUNT **',A3>>) ;
 WRITE(<<'** AXLE FACTOR NB.',I2,A1.1>>,I2) ;
 WRITE(<<' POINT: FRONT WHEEL POS. REL. MIDPOINT BRIDGE',A1>>) ;
 WRITE(<<' VALUE: VEHICLE WEIGHTS ARE PUT TO UNITY',A1>>) ;
 WRITE(<<'  RANGE:/LEVEL: FROM LECOUNT',A1>>) ;
FOR L0=(1,-2,-1) DO BEGIN
IF L0 EQL 1 THEN WRITE(<<' --LANE1--',A2>>)
               ELSE WRITE(<<' --LANE2 MEETING--',A2>>) ;
 WRITE(<<:T2:('  VEH.TYPE',I3),A2>>,FOR T1=(1,1,T2) DO T1) ;
 WRITE(<<:T2:(' POINT  VALUE'),A1>>) ;
 FOR I1=(1,1,MAX(FOR T1=(1,1,T2) DO M(2,T1))) DO
  WRITE(<<:T2:(D6.2,D7.3),A1>>,
  FOR T1=(L0,L0,T2*L0) DO (I(T1,2*I2-1,I1),I(T1,2*I2,I1))) ;
FOR T1=(1,1,T2) DO BEGIN
INFLTOYQ(I,T1,I2,M(2,T1),1,L0,1,1,Q,Q9) ; LECOUNT(Q,Q9,R,R9,1000,0) ;
WRITE(<<'TYPE',I3,' RANGE=',:R9:(D7.3),A2>>,T1,FOR I1=(1,1,R9) DO
                                                  R(1,I1)) ;
WRITE(<<'        LEVEL=',:R9:(D7.3),A1>>,FOR I1=(1,1,R9) DO
                                                  R(2,I1)) ; END T1 ;
END L0 ;
END I2=AXLEFACTOR COUNT ;
-----------------------------------------------------------------------
OVDI: COMMENT +++++ OVERLAP DISTRIBUTION INPUT +++++ ;
  READ(W1) ;
  WRITE(<<E1,'** OVERLAP DISTRIBUTION INPUT **',A2.1>>) ;
  WRITE(<<'NB. OF CLASSES',I2,' WITH THE FOLLOWING DISTRIBUTION',
        ' (APPROX.)',A1>>,W1) ;
  WRITE(<<'  (LESS THAN 7 CLASSES)   DISTRIBUTION ABSOLUTE',A1>>) ;
COMMENT --INPUT W1-1 CLASSES. THE LOWEST (FIRST) ARE CALCULATED ;
  READ(FOR I1=(2,1,W1) DO W(I1)) ;  K1=0 ;
  FOR I1=(2,1,W1) DO K1=K1+W(I1) ; W(1)=1-K1 ;
  IF SIGN(W(1)) LSS 0 THEN BEGIN
               WRITE('FAULT IN OVERLAP DIR.') ; GOTO L99 END ;
  WRITE(<<'IN DISTR.',:W1:(D7.3),A1>>,FOR I1=(1,1,W1) DO W(I1)) ;
-----------------------------------------------------------------------
OVCA: COMMENT +++++ CALCULATION OF EQUIVALENT OVERLAP LOAD SPECTRA ++++;
  WRITE(<<'** EQUIVALENT OVERLAP LOAD DENSITY FUNCTIONS **',A2.1>>) ;
  WRITE(<<'  --  % ( LC      - HC          )',A2>>) ;
  WRITE(<<'  --LOAD (LOW CLASS-HIGH CLASS )',A1.1>>) ;
  FOR T1=(-1,1,T2) DO BEGIN
  IF T1 EQL -1 THEN WRITE(<<'TOTAL',J9>>) ELSE IF T1 EQL 0 THEN
   WRITE(<<'AXLE',J9>>) ELSE WRITE(<<'TYPE ',I2,J9>>,T1) ;
   FOR L0=(1,1,2) DO BEGIN WRITE(<<J9,'LANE',I2,J16>>,L0) ;
   I2=C(L0,T1,6)+1 ;
    FOR I3=(W1,-1,2) DO BEGIN
    K1=0 ; I2=I2-1 ; I1=I2 ; K2=0 ; IF I2 EQL 0 THEN GOTO 02 ;
01: K1=K1+X(L0,T1,I2) ;    K2=K2+X(L0,T1,I2)*VAL(I2,P1) ;
```

```
IF K1 LSS W(I3) THEN BEGIN I2=I2-1 ; IF I2 EQL Ø THEN GOTO 02
                                                 ELSE GOTO 01 END ;
 O(LØ,T1,2,I3)=K1 ; O(LØ,T1,1,I3)=K2/K1 ;
 Y(1,I3)=I2 ; Y(2,I3)=I1 ;
 END I3 ;
 Y(1,1)=1   ;  Y(2,1)=I2-1 ; K1=K2=Ø ;
 FOR I4=(1,1,I2-1) DO BEGIN K1=K1+X(LØ,T1,I4) ;
                           K2=K2+X(LØ,T1,I4)*VAL(I4,P1) END I4 ;
 IF K1 LSS Ø.ØØØ1 THEN GOTO 02 ;
  O(LØ,T1,2,1)=K1  ; O(LØ,T1,1,1)=K2/K1 ;
 K1=Ø ; FOR I1=(1,1,W1) DO K1=K1+O(LØ,T1,2,I1) ;
 WRITE(<<:W1:(D7.2,' % (LC-HC)')>>, FOR I1=(1,1,W1) DO
       O(LØ,T1,2,I1)*1ØØ) ;
  WRITE(<<'  TOT=',A2>>) ;
 WRITE(<<J16,:W1:(D8.3,'  (',I2,'-',I2,')')>>,FOR I1=(1,1,W1) DO
  (O(LØ,T1,1,I1),Y(1,I1),Y(2,I1))) ;
 WRITE(<<I1Ø,A1>>,K1*K(LØ,T1,2)) ;
END LØ ;
END T1 ;
GOTO TRIN ;
02:WRITE('TOO MANY OVERLAP CLASSES') ; GOTO L99 ;
```

```
TRIN: COMMENT +++++ TRAFFIC DATA INPUT +++++ ;
READ(VE,TE,F8,F7) ;
READ(T9,SØ,S1,F9) ;
WRITE(<<E1,' ** TRAFFIC DATA **',A2.1>>) ;
WRITE(<<'VEH.SPEED(M/S)=',D5.1,'  EQUIVALENT TIME=',D6.2,' FACTOR ON',
      ' MEET.PROB.=',D5.2,A1>>,VE,TE,F8) ;
WRITE(<<'FACTOR ON OVERTAKING PROB.=',D5.2,A1>>,F7) ;
WRITE(<<'QUEUE CRITICAL TIME DISTANCE=',D7.2,A1>>,T9) ;
WRITE(<<'MIN-MAX QUEUEDIST.',2D7.2,' FACTOR ON QUEUE PROB.',D5.2,A1
      >>,SØ,S1,F9) ;
 S2=(SØ+S1)/2 ;
WRITE(<<'AVERAGE QUEUEDIST.=',D7.2,A1>>,S2) ;
IF S1 GTR XØ AND F9 GTR Ø.ØØØ1 THEN BEGIN
 F9=F9*(XØ-SØ)/(S1-SØ) ; S1=XØ ; IF F9 LEQ Ø OR F9 GTR 1 THEN BEGIN
      F9=Ø ; SØ=S1 END ;
 WRITE(<<'NEW MIN-MAX QUEUED',2D7.2,' NEW QUEUE FACTOR  =',D5.2,A1>>,
       SØ,S1,F9) END ;
 YSEC=YØ*365*24*36ØØ*TE ;
```

```
LEDI: COMMENT +++++ LOADEFFECT CALCULATION DIRECTIVES +++++ ;
READ(L1,TØ) ;
READ(WØ,ZØ,A9,QQSW) ;
READ(N3,S4,S4QM) ;
READ(PR,PL,PRT,PLT) ;
INFLTOYQ(J,J1,1,M(1,J1),1,1,1,1,Q,Q9) ; LECOUNT(Q,Q9,R,R9,1ØØØ,Ø) ;
 IF N3 LEQ Ø THEN BEGIN
  N3=INT(ABS(N3)*R9*2*(1+
     (IF TØ EQL 1 THEN MAX(FOR T1=(1,1,T2) DO A(T1,1)) ELSE Ø)/XØ))+1;
  IF N3//2+1 NEQ (N3+1)//2 THEN N3=N3+1 ; END ;
 IF S4 LEQ Ø THEN S4=INT(ABS(S4)*R9*(S1-SØ)/XØ)+1 ;
 IF S4QM LEQ Ø THEN S4QM=INT(ABS(S4QM)*R9*(S1-SØ)/XØ)+1 ;
RNB(-1)=RNB(Ø)=RNB(1)=Ø ;
IF ABS(L1) GTR 2 OR L1 EQL Ø OR L1 EQL -1 OR ABS(TØ) GTR 1 THEN BEGIN
WRITE(<<' WRONG L1 OR TØ VALUES IN INPUT',A1>>) ; GOTO L99 END ;
IF TØ EQL 1 AND T2 EQL Ø THEN BEGIN
WRITE(<<'TYPE LOAD NOT READ AND TØ=1',A1>>) ; GOTO L99 END ;
COMMENT L1=1,2,-2 SINGLE,PARALLELL, MEETING LANES
        TØ=-1,Ø,1 TOTAL,AXLE AND TYPE WEIGHTS
        N3=NB.MEET.POINTS  S4=NB.QUEUEING POINTS
        S4QM=NB.QUEUING POINTS IN QUEUEMEETING
        QQSW=Ø OVERLAY QUEUE MEETING QUEUE CASE
        A9=MAXIMUM AMPLIFICATION FACTOR ;
 I1=I2=Ø ;
 I1=MAX(FOR T1=(1,1,T2) DO C(1,T1,6)) ;
 I2=MAX(FOR T1=(1,1,T2) DO C(2,T1,6)) ;
LSR=LSL=Ø ;
HSR=HSL=
 IF TØ EQL -1 THEN MAX(
  IF F8 GTR Ø.ØØØ1 AND F9 GTR Ø.ØØØ1 AND L1 EQL -2 THEN
   2*C(2,-1,6)+2*C(1,-1,6) ELSE Ø,
  IF F7 GTR Ø.ØØØ1 AND F9 LSS Ø.ØØØ1 AND L1 NEQ 1 OR
     F8 GTR Ø.ØØØ1 AND L1 EQL -2 THEN C(1,-1,6)+C(2,-1,6) ELSE Ø,
  IF F9 GTR Ø.ØØØ1 AND L1 EQL -2 THEN 2*C(2,-1,6) ELSE Ø,
  IF F9 GTR Ø.ØØØ1 AND L1 NEQ  2 THEN 2*C(1,-1,6) ELSE Ø,
  IF L1 EQL -2 THEN C(2,-1,6) ELSE Ø,
  C(1,-1,6)) ELSE
 IF TØ EQL Ø THEN MAX(
  IF F7 GTR Ø.ØØØ1 AND F9 LSS Ø.ØØØ1 AND L1 NEQ 1 OR
     F8 GTR Ø.ØØØ1 AND L1 EQL -2 THEN C(1,Ø,6)+C(2,Ø,6) ELSE Ø,
  IF L1 EQL -2 THEN C(2,Ø,6) ELSE Ø,
  C(1,Ø,6)) ELSE
 IF TØ EQL 1 THEN MAX(
  IF F9 GTR Ø.ØØØ1 AND L1 EQL -2 THEN 2*I2 ELSE Ø,
  IF F9 GTR Ø.ØØØ1 AND L1 NEQ  2 THEN 2*I1 ELSE Ø,
  IF F7 GTR Ø.ØØØ1 AND F9 LSS Ø.ØØØ1 AND L1 NEQ 1 OR
     F8 GTR Ø.ØØØ1 AND L1 EQL -2 THEN I1+I2 ELSE Ø,
  IF L1 EQL -2 THEN I2 ELSE Ø,
  I1) ELSE Ø ;
HSR=HSR*P1/WØ+2 ; HSL=HSL*P1/ZØ+2 ;
LTR=LSR ; HTR=HSR*A9 ;
LTL=LSL-(HTR-HSR)/2*WØ/ZØ-2 ; HTL=HSL ;
K1=Ø ;
FOR I1=(1,1,M(1,J1)) DO IF J(J1,2,I1) LSS K1 THEN K1=J(J1,2,I1) ;
  I1=HTL-LTL ;  HTL=HTL+I1*K1+2 ; LTL=LTL+I1*K1-2 ;
  I2=HSL-LSL ;  HSL=HSL+I2*K1+2 ; LSL=LSL+I2*K1-2 ;
WRITE(<<'** COMPUTED DIMENSIONS OF ARRAYS T AND S **',A3.1>>) ;
WRITE(<<'   T(',I4,':',I4,',',I4,':',I4,')',A1>>,LTR,HTR,LTL,HTL) ;
WRITE(<<'   S(',I4,':',I4,',',I4,':',I4,')',A1>>,LSR,HSR,LSL,HSL) ;
WRITE(<<'  (RANGE INCR.=',D6.2,')   (LEVEL INCR.=    ',D6.2,')',A2>>,
     WØ,ZØ) ;
WRITE(<<'  (NB MEET POINTS=',I3,')   (NB QUEUING POINTS=',I3,')',A2>>,
     N3,S4) ;
WRITE(<<'  (NB. QUEUING POINTS IN QUEUE MEETING=',I3,')',A2.1>>,S4QM) ;
```

```
BEGIN COMMENT ----- LE. CALCULATION BLOCK ----- ;
 REAL ARRAY T(LTR:HTR,LTL:HTL),S(LSR:HSR,LSL:HSL) ;
```

```
IF TØ EQL -1 THEN TEXT(36,25)='TOTALWEIGHTS (TØ=-1)' ELSE
IF TØ EQL Ø  THEN TEXT(36,25)='AXLEWEIGHTS  (TØ=Ø)' ELSE
                  TEXT(36,25)='VEHICLE TYPES (TØ=1)' ;
IF L1 EQL 1  THEN TEXT(61,2Ø)='JUST ONE LANE (1)' ELSE
IF L1 EQL -2 THEN TEXT(61,2Ø)='MEETING LANES     ' ELSE
                  TEXT(61,2Ø)='PARALLEL LANES' ;
FOR I1=(LSR,1,HSR) DO FOR I2=(LSL,1,HSL) DO S(I1,I2)=Ø ;
SRL=HSR ; SRH=LSR ; SLL=HSL ; SLH=LSL ;
FOR I1=(1,1,2) DO FOR I2=(-1,1,1Ø) DO SONB(I1,I2)=Ø ;
SOCC=Ø ; J8=1ØØØ ; E9=Ø ;
```

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LECA: COMMENT +++++ LOADEFFECT CALCULATIONS +++++ ;
 IF L1 EQL -2 AND T0 EQL -1 AND F8*F9 GTR 0.00000001 THEN BEGIN
 IF QQSW EQL 1 THEN BEGIN
   TEXT(1,35)='LANE2 QUEUES MEET LANE1 QUEUES *' ;
  QQ(T) ;        TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,PR,PL) ;
 END QQSW ;
  TEXT(1,35)='LANE2 QUEUES MEET LANE1 SINGLES *' ;
  QM(2,1,T) ;   TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,PR,PL) ;
  TEXT(1,35)='LANE1 QUEUES MEET LANE2 SINGLES *' ;
  QM(1,2,T) ;   TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,PR,PL) ;
    END 2,2 2,1 1,2 ;
 IF L1 EQL -2 AND(T0 EQL -1 OR T0 EQL 1)AND F9 GTR 0.0001 THEN BEGIN
  TEXT(1,35)='LANE2 QUEUES *' ;
  QU(2,T0,T) ; TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,PR,PL) ;
    END 2,0 ;
 IF(L1 EQL 1 OR L1 EQL -2)AND(T0 EQL -1 OR T0 EQL 1) AND F9 GTR 0.0001
 THEN BEGIN
  TEXT(1,35)='LANE1 QUEUES *' ;
  QU(1,T0,T) ; TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,PR,PL) ;
    END  0,2 ;
 IF ABS(L1) EQL 2 AND F9 LSS 0.0001 AND F7 GTR 0.0001 THEN BEGIN
  TEXT(1,35)='LANE2 OVERTAKING LANE1 *' ;
  ME(1,1,T0,T) ;   TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,PR,PL) ;
    END ,11 ;
 IF L1 EQL -2 AND F9 LSS 0.0001 AND F7 GTR 0.0001 THEN BEGIN
  TEXT(1,35)='LANE1 OVERTAKING LANE2 *' ;
  ME(2,2,T0,T) ;   TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,PR,PL) ;
    END ,22 ;
 IF L1 EQL -2 AND F8 GTR 0.0001 THEN BEGIN
  TEXT(1,35)='LANE2 SINGLES MEET LANE1 SINGLES *' ;
  ME(2,1,T0,T) ;   TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,PR,PL) ;
    END  1,1 ;
 IF L1 EQL -2 THEN BEGIN
  TEXT(1,35)='LANE2 SINGLES *' ;
  SI(2,T0,T) ; TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,PR,PL) ;
    END 1,0 ;
  TEXT(1,35)='LANE1 SINGLES *' ;
  SI(1,T0,T) ; TADDS(T,TRL,TRH,TLL,TLH,S,SRL,SRH,SLL,SLH) ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,OCC,ONB,TEXT,PR,PL) ;
  TEXT(1,35)='** TOTAL SPECTRUM NO DYN. AMPL. **' ;
  INIT(T) ;
  FOR I1=(SRL,1,SRH) DO FOR I2=(SLL,1,SLH) DO T(I1,I2)=S(I1,I2) ;
  TRL=SRL ; TRH=SRH ; TLL=SLL ; TLH=SLH ;
    STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,SOCC,SONB,TEXT,PRT,PLT) ;
________________________________________________________________________
DYDI: COMMENT +++++ DYNAMIC AMPLIFICATION FACTOR DISTRIBUTION +++++ ;
COMMENT  NOT MORE THAN 10 CLASSES IN AMP.FACTOR DISTRIBUTION ;
 READ(A1) ;
 READ(FOR I1=(1,1,A1) DO AM(2,I1)) ;
 READ(FOR I1=(1,1,A1) DO AM(1,I1)) ;
 IF AM(1,A1) GTR A9 THEN BEGIN
 WRITE('AMP. FACTOR TOO BIG IN INPUT') ; GOTO L99 END ;
READ(PRT,PLT) ;
 K1=0 ;  FOR I1=(1,1,A1) DO K1=K1+AM(2,I1) ;    A2=0 ;
         FOR I1=(1,1,A1) DO BEGIN
         AM(2,I1)=AM(2,I1)/K1 ; A2=A2+AM(1,I1)*AM(2,I1) END I1 ;
 WRITE(<<E1,'** DYNAMIC AMPLIFICATION FACTOR DISTRIBUTION **',A2>>) ;
 WRITE(<<'-- % --',:A1:(D7.3),A2>>,FOR I1=(1,1,A1) DO AM(2,I1)*100) ;
 WRITE(<<' VALUE ',:A1:(D7.3),A1>>,FOR I1=(1,1,A1) DO AM(1,I1)) ;
 WRITE(<<' AVERAGE AMPLIFICATION FACTOR=',D7.3,A1>>,A2) ;
________________________________________________________________________
DYCA: COMMENT +++++ ADJUST LE-DISTRIBUTION FOR DYNAMIC EFFECTS +++++ ;
  DYNCONV(S,SRL,SRH,SLL,SLH,A1,AM,T,TRL,TRH,TLL,TLH) ;
  STLINSPCONV(T,TRL,TRH,TLL,TLH) ;
  TEXT(1,35)='** TOTAL DYN AMPLIFIED SPECTRUM **' ;
    PRINTST(T,TRL,TRH,TLL,TLH,T0,SOCC,SONB,TEXT,PRT,PLT) ;
________________________________________________________________________
COMMENT --- --- CONTINUE --- ;
READ(I1) ;
WRITE(<<'-----NB.OF POS.RANGES=',I12,A3>>,RNB(1)) ;
WRITE(<<'-----        NULLRANGES=',I12,A1>>,RNB(0)) ;
WRITE(<<'-----         NEG.RANGES=',I12,A1>>,RNB(-1)) ;
WRITE(<<'-----                SUM=',I12,A1.1>>,RNB(-1)+RNB(0)+RNB(1)) ;
FOR I2=(1,1,14) DO WRITE(<<:I8:(' GOTO',I2),A1>>,FOR I3=(1,1,18) DO I1) ;
IF I1 EQL 0 THEN GOTO DYDI ;
GOTO JUMP(I1) ;
END CALCULATION T,S BLOCK ;
L99: END OF PROGRAM ;
```

INFLADD

```
BEGIN
PROCEDURE INFLADD(Y,Y7Y,Y8Y,Q,Q9) ;
REAL ARRAY Y,Q ; INTEGER Y7Y,Y8Y,Q9 ;
 BEGIN INTEGER I7,I8,I9,Y7,Y8 ;
    Y7=Y7Y+1 ; Y8=Y8Y+1 ; I7=I8=I9=1 ;
    IF (Y(1,I7) LSS Y(3,I8)) THEN GOTO L2 ;
L1: Q(2,I9)=Y(4,I8) ; Q(1,I9)=Y(3,I8) ; I8=I8+1 ; I9=I9+1 ;
    IF (I8 EQL Y8) THEN GOTO L6 ;
     IF (Y(1,I7) GTR Y(3,I8) OR Y(3,I8) EQL Y(3,I8-1)) THEN GOTO L1
                                                     ELSE GOTO L4 ;
L2: Q(2,I9)=Y(2,I7) ; Q(1,I9)=Y(1,I7) ; I7=I7+1 ; I9=I9+1 ;
    IF (I7 EQL Y7) THEN GOTO L5 ;
    IF (Y(1,I7) LSS Y(3,I8) OR Y(1,I7) EQL Y(1,I7-1)) THEN GOTO L2 ;
L3: Q(2,I9)=Y(4,I8)+Y(2,I7-1)
      +(Y(2,I7)-Y(2,I7-1))*(Y(3,I8)-Y(1,I7-1))/(Y(1,I7)-Y(1,I7-1)) ;
     Q(1,I9)=Y(3,I8) ; I8=I8+1 ; I9=I9+1 ;
    IF (I8 EQL Y8) THEN GOTO L6 ;
    IF (Y(1,I7) GEQ Y(3,I8)) THEN GOTO L3 ;
L4: Q(2,I9)=Y(2,I7)+Y(4,I8-1)
      +(Y(4,I8)-Y(4,I8-1))*(Y(1,I7)-Y(3,I8-1))/(Y(3,I8)-Y(3,I8-1)) ;
     Q(1,I9)=Y(1,I7) ; I7=I7+1 ; I9=I9+1 ;
    IF (I7 EQL Y7) THEN GOTO L5 ;
    IF (Y(1,I7) GTR Y(3,I8)) THEN GOTO L3 ELSE GOTO L4 ;
L5: Q(2,I9)=Y(4,I8) ; Q(1,I9)=Y(3,I8) ; I8=I8+1 ; I9=I9+1 ;
    IF (I8 NEQ Y8) THEN GOTO L5 ELSE GOTO L7 ;
L6: Q(2,I9)=Y(2,I7) ; Q(1,I9)=Y(1,I7) ; I7=I7+1 ; I9=I9+1 ;
    IF (I7 NEQ Y7) THEN GOTO L6 ;
L7: Q9=I9-1
 END PROCEDURE INFLADD ;
```

EXAMPLE OF RUN

** VEHICLE SPECIFICATIONS **
7 VEHICLE TYPES

TYPE	AXLES	AXLEDIST.(M)/LOADDISTR. ON AXLES		AXLEDISTFACTOR/DISTR
1	2	5.10	TOT= 5.10	0.333 0.333 0.333
		0.200 0.800		1.000 0.800 1.200
2	2	5.10	TOT= 5.10	0.333 0.333 0.333
		0.333 0.667		1.000 0.800 1.200
3	3	5.70 7.40	TOT= 13.10	0.333 0.333 0.333
		0.111 0.444 0.444		1.000 0.800 1.200
4	4	5.70 4.70 5.70	TOT= 16.10	0.333 0.333 0.333
		0.091 0.364 0.182 0.364		1.000 0.800 1.200
5	4	5.70 4.70 7.70	TOT= 18.10	0.333 0.333 0.333
		0.111 0.222 0.333 0.333		1.000 0.800 1.200
6	3	4.70 8.40	TOT= 13.10	0.333 0.333 0.333
		0.111 0.444 0.444		1.000 0.800 1.200
7	3	4.70 13.40	TOT= 18.10	0.333 0.333 0.333
		0.200 0.400 0.400		1.000 0.800 1.200

** LOAD DENSITY FUNCTIONS **
LOAD ID= 4.00 REGION= 11.1973 YEARS= 50

LOAD-CLASS	TOTAL(%)	AXLE(%)	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TYPE 6	TYPE 7
** TOT=	9317900	27851550	1506500	1796000	1930500	1810800	1389600	575350	309150
0.00- 10.00	0.00000	4.05580	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10.00- 20.00	0.00000	10.36606	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
20.00- 30.00	1.59739	12.02640	6.98071	0.00000	2.26257	0.00000	0.00000	0.00000	0.00000
30.00- 40.00	1.43314	9.86324	5.47987	0.00000	2.64099	0.00000	0.00000	0.00000	0.00000
40.00- 50.00	2.53602	11.91588	10.48445	0.00000	4.05830	0.00000	0.00000	0.00000	0.00000
50.00- 60.00	2.25141	8.60066	7.75406	0.00000	4.81540	0.00000	0.00000	0.00000	0.00000
60.00- 70.00	2.75720	4.51114	8.09220	0.00000	6.09504	0.00000	0.00000	3.01078	0.00000
70.00- 80.00	7.32554	4.95191	5.83593	23.08492	7.29337	0.00000	0.00000	6.85637	0.00000
80.00- 90.00	4.34098	4.25635	5.34764	3.93800	6.28120	0.00000	0.00000	7.16930	0.00000
90.00- 100.00	2.73222	4.24192	5.29404	1.57050	4.84030	0.00000	0.00000	6.14420	5.76820
100.00- 110.00	3.17266	3.05273	6.79149	1.57050	4.25017	2.23000	0.00000	4.15808	6.06540
110.00- 120.00	3.95064	2.55709	5.01116	1.57050	4.71430	6.83985	0.00000	5.20416	6.33927
120.00- 130.00	4.98023	4.20451	6.76083	1.57050	4.13152	10.15393	3.24803	3.13321	2.37741
130.00- 140.00	4.44514	3.64462	4.11261	1.57050	2.99394	5.66310	2.93106	1.36436	5.76850
140.00- 150.00	3.52253	3.32834	3.01451	1.57050	2.17130	5.79840	5.58815	1.36436	7.17422
150.00- 160.00	3.24914	3.67087	5.47651	1.57050	2.81906	2.60375	5.71891	1.36436	1.03385
160.00- 170.00	2.33895	1.79198	1.24478	1.57050	3.18016	0.95922	5.84154	1.36436	1.03385
170.00- 180.00	2.18538	1.06286	3.49173	1.57050	3.07234	0.95922	2.52556	1.36436	1.03385
180.00- 190.00	1.92535	1.30114	3.57922	1.57050	2.97050	0.95922	0.82861	1.36436	1.03385
190.00- 200.00	1.83972	0.57616	1.73545	1.57050	3.20505	0.95922	0.82861	4.01823	1.03385
200.00- 210.00	2.55422	0.00000	0.00000	9.26030	2.05048	0.95922	0.82861	3.12437	1.03385
210.00- 220.00	2.84382	0.00000	1.07568	7.84989	3.02614	0.95922	0.82861	3.00607	1.03385
220.00- 230.00	2.76714	0.00000	1.21856	7.45808	2.94284	0.95922	0.82861	2.89269	1.03335
230.00- 240.00	2.79437	0.00000	1.21856	7.08330	2.86317	0.95922	0.82861	4.77093	1.03385
240.00- 250.00	2.14025	0.00000	0.00000	5.00000	2.78684	0.95922	0.82861	4.12730	1.03385
250.00- 260.00	1.91996	0.00000	0.00000	5.00000	1.75331	0.95922	0.82861	4.02752	1.03385
260.00- 270.00	0.63593	0.00000	0.00000	0.00000	0.66719	0.95922	0.82861	2.49459	1.03385
270.00- 280.00	1.94841	0.00000	0.00000	5.00000	1.70731	0.95922	0.82861	3.25903	3.60555
280.00- 290.00	1.93619	0.00000	0.00000	5.00000	1.68628	0.95922	0.82861	3.19644	3.48919
290.00- 300.00	0.96065	0.00000	0.00000	0.00000	1.66550	0.95922	0.82861	3.13600	3.37484
300.00- 310.00	1.18729	0.00000	0.00000	0.00000	0.93213	2.94453	0.82861	3.07758	3.26529
310.00- 320.00	1.16038	0.00000	0.00000	0.00000	0.91269	2.86288	0.82361	3.02105	3.15923
320.00- 330.00	0.97253	0.00000	0.00000	0.00000	0.54420	2.78377	0.82861	1.51928	3.05652
330.00- 340.00	1.02475	0.00000	0.00000	0.00000	0.87559	2.70707	0.82861	1.91035	2.28142
340.00- 350.00	1.31820	0.00000	0.00000	0.00000	0.85757	4.24558	0.82861	1.88085	2.28142
350.00- 360.00	1.28738	0.00000	0.00000	0.00000	0.84065	4.11464	0.82861	1.85158	2.28142
360.00- 370.00	1.46882	0.00000	0.00000	0.00000	0.34965	3.34258	3.74521	1.01632	3.78195
370.00- 380.00	1.44221	0.00000	0.00000	0.00000	0.34965	3.29131	3.64504	1.01682	3.73042
380.00- 390.00	0.93239	0.00000	0.00000	0.00000	0.00000	1.77268	3.54754	0.00000	1.77341
390.00- 400.00	1.39105	0.00000	0.00000	0.00000	0.34965	3.19873	3.45252	1.01682	3.63136
400.00- 410.00	1.11567	0.00000	0.00000	0.00000	0.34965	3.14529	1.98707	0.59445	2.98210
410.00- 420.00	1.32798	0.00000	0.00000	0.00000	0.34965	4.28937	1.93916	0.59445	2.89531
420.00- 430.00	1.21616	0.00000	0.00000	0.00000	0.34965	4.24420	1.89239	0.59445	0.00000
430.00- 440.00	1.14620	0.00000	0.00000	0.00000	0.00000	2.64193	3.99698	0.00000	1.10626
440.00- 450.00	0.26875	0.00000	0.00000	0.00000	0.00000	0.00000	1.80206	0.00000	0.00000
450.00- 460.00	0.83356	0.00000	0.00000	0.00000	0.00000	1.10689	3.90868	0.00000	1.10626
460.00- 470.00	0.82719	0.00000	0.00000	0.00000	0.00000	1.10689	3.86597	0.00000	1.10626
470.00- 480.00	0.82095	0.00000	0.00000	0.00000	0.00000	1.10689	3.82416	0.00000	1.10626
480.00- 490.00	0.69605	0.00000	0.00000	0.00000	0.00000	1.10689	2.77288	0.00000	2.06696
490.00- 500.00	0.69007	0.00000	0.00000	0.00000	0.00000	1.10689	2.73279	0.00000	2.06696
500.00- 510.00	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
510.00- 520.00	0.38394	0.00000	0.00000	0.00000	0.00000	1.10689	1.13990	0.00000	0.00000
520.00- 530.00	0.38394	0.00000	0.00000	0.00000	0.00000	1.10689	1.13990	0.00000	0.00000
530.00- 540.00	0.17000	0.00000	0.00000	0.00000	0.00000	0.00000	1.13990	0.00000	0.00000
540.00- 550.00	0.17000	0.00000	0.00000	0.00000	0.00000	0.00000	1.13990	0.00000	0.00000
550.00- 560.00	0.17000	0.00000	0.00000	0.00000	0.00000	0.00000	1.13990	0.00000	0.00000
560.00- 570.00	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
570.00- 580.00	0.17000	0.00000	0.00000	0.00000	0.00000	0.00000	1.13990	0.00000	0.00000
580.00- 590.00	0.17000	0.00000	0.00000	0.00000	0.00000	0.00000	1.13990	0.00000	0.00000
590.00- 600.00	0.17000	0.00000	0.00000	0.00000	0.00000	0.00000	1.13990	0.00000	0.00000

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***** LIN-LOG LOADSPECTRA LANE 1                         TOTAL=  9317900    AXLE= 27851597
  T=TOTAL X=AXLE  TYPES:A=1 B=2 C=3 D=4 E=5 F=6 G=7 H=8 I=9 J=10
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I      LOAD      I                                             GREATER THAN OR EQUAL LOAD    LINSPECTRA (%)          I
I 600.00- 610.00 I         .         .         .         .         .         .         .         .         .         I
I 590.00- 600.00 I*        .         .         .         .         .         .         .         .         .         I
I 580.00- 590.00 I*        .         .         .         .         .         .         .         .         .         I
I 570.00- 580.00 I*        .         .         .         .         .         .         .         .         .         I
I 560.00- 570.00 I*        .         .         .         .         .         .         .         .         .         I
I 550.00- 560.00 I*        .         .         .         .         .         .         .         .         .         I
I 540.00- 550.00 I*        .         .         .         .         .         .         .         .         .         I
I 530.00- 540.00 I *       .         .         .         .         .         .         .         .         .         I
I 520.00- 530.00 ID*       .         .         .         .         .         .         .         .         .         I
I 510.00- 520.00 ID*.................................................................................................I
I 500.00- 510.00 ID*       .         .         .         .         .         .         .         .         .         I
I 490.00- 500.00 I*ET      .         .         .         .         .         .         .         .         .         I
I 480.00- 490.00 I* ET     .         .         .         .         .         .         .         .         .         I
I 470.00- 480.00 IGDET     .         .         .         .         .         .         .         .         .         I
I 460.00- 470.00 IGD ET    .         .         .         .         .         .         .         .         .         I
I 450.00- 460.00 IGD E T   .         .         .         .         .         .         .         .         .         I
I 440.00- 450.00 IGD  ET   .         .         .         .         .         .         .         .         .         I
I 430.00- 440.00 IG D E  T .         .         .         .         .         .         .         .         .         I
I 420.00- 430.00 I* D  E  T.         .         .         .         .         .         .         .         .         I
I 410.00- 420.00 I*..D.E...T.........................................................................................I
I 400.00- 410.00 I*   DE   .T        .         .         .         .         .         .         .         .         I
I 390.00- 400.00 I*   D E  .  T      .         .         .         .         .         .         .         .         I
I 380.00- 390.00 I*     DE .   T     .         .         .         .         .         .         .         .         I
I 370.00- 380.00 I*    D E .    T    .         .         .         .         .         .         .         .         I
I 360.00- 370.00 I*     DE .     T   .         .         .         .         .         .         .         .         I
I 350.00- 360.00 I*       *.       T .         .         .         .         .         .         .         .         I
I 340.00- 350.00 I*G      *.        T.         .         .         .         .         .         .         .         I
I 330.00- 340.00 I*G      *.         T         .         .         .         .         .         .         .         I
I 320.00- 330.00 IF*      ED         .T        .         .         .         .         .         .         .         I
I 310.00- 320.00 IF*......ED...........T.............................................................................I
I 300.00- 310.00 I *      E.D        .  T      .         .         .         .         .         .         .         I
I 290.00- 300.00 I *      E.D        .   T     .         .         .         .         .         .         .         I
I 280.00- 290.00 IB*C     E.D        .     T   .         .         .         .         .         .         .         I
I 270.00- 280.00 I *C     E.D        .       T .         .         .         .         .         .         .         I
I 260.00- 270.00 I *C      E D       .        T.         .         .         .         .         .         .         I
I 250.00- 260.00 I G*C     E D       .         .T        .         .         .         .         .         .         I
I 240.00- 250.00 I GF*     E D       .         .  T      .         .         .         .         .         .         I
I 230.00- 240.00 IAGF CB   E D       .         .     T   .         .         .         .         .         .         I
I 220.00- 230.00 IAGF C B  E D       .         .        T.         .         .         .         .         .         I
I 210.00- 220.00 IA.GF.C..BE..D...........................T..........................................................I
I 200.00- 210.00 IA GF C   * D       .         .         .   T     .         .         .         .         .         I
I 190.00- 200.00 I* GF  C  EB D      .         .         .     T   .         .         .         .         .         I
I 180.00- 190.00 I *GF   C .* D      .         .         .       T .         .         .         .         .         I
I 170.00- 180.00 I A*F   C .* D      .         .         .         T         .         .         .         .         I
I 160.00- 170.00 I  *FX   C.BED      .         .         .         . T       .         .         .         .         I
I 150.00- 160.00 I  G*    XC BED     .         .         .         .    T    .         .         .         .         I
I 140.00- 150.00 I  G*     C *E D    .         .         .         .        T.         .         .         .         I
I 130.00- 140.00 I  GFA    .CB  E*   .         .         .         .         .  T      .         .         .         I
I 120.00- 130.00 I  G FA   .C B E  D X         .         .         .         .       T .         .         .         I
I 110.00- 120.00 I..G.F.A...CB..E....D..X.................................................T..........................I
I 100.00- 110.00 I   GF  A .  * E    D     X   .         .         .         .         .     T   .         .         I
I  90.00- 100.00 I   G F  A.   *E    D         X         .         .         .         .       T .         .         I
I  80.00-  90.00 I   G F  A.    *C   D         .   X     .         .         .         .         .  T      .         I
I  70.00-  80.00 I   G F   A    E C  *         .        X.         .         .         .         .         T         I
I  60.00-  70.00 I   G  F  . A  E  C *         .         .   X     .         .         .         .         . T       I
I  50.00-  60.00 I   G  F  .  A E   C*         .         .         . X       .         .         .         .   T     I
I  40.00-  50.00 I   G  F  .    *    *         .         .         .         .   X     .         .         .     T   I
I  30.00-  40.00 I   G  F  .    EA   *C        .         .         .         .         .   X     .         .       T I
I  20.00-  30.00 I   G  F  .    E A  *C        .         .         .         .         .         .     X   .        TI
I  10.00-  20.00 I...G..F.......E.A..*C...........................................................................X...TI
I   0.00-  10.00 I   G  F  .    E A  *C        .         .         .         .         .         .         .        *I
I----------------+---->---->---->---->---->---->---->---->---->---->---->---->---->---->---->---->---->---->---->---->I
                      5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100
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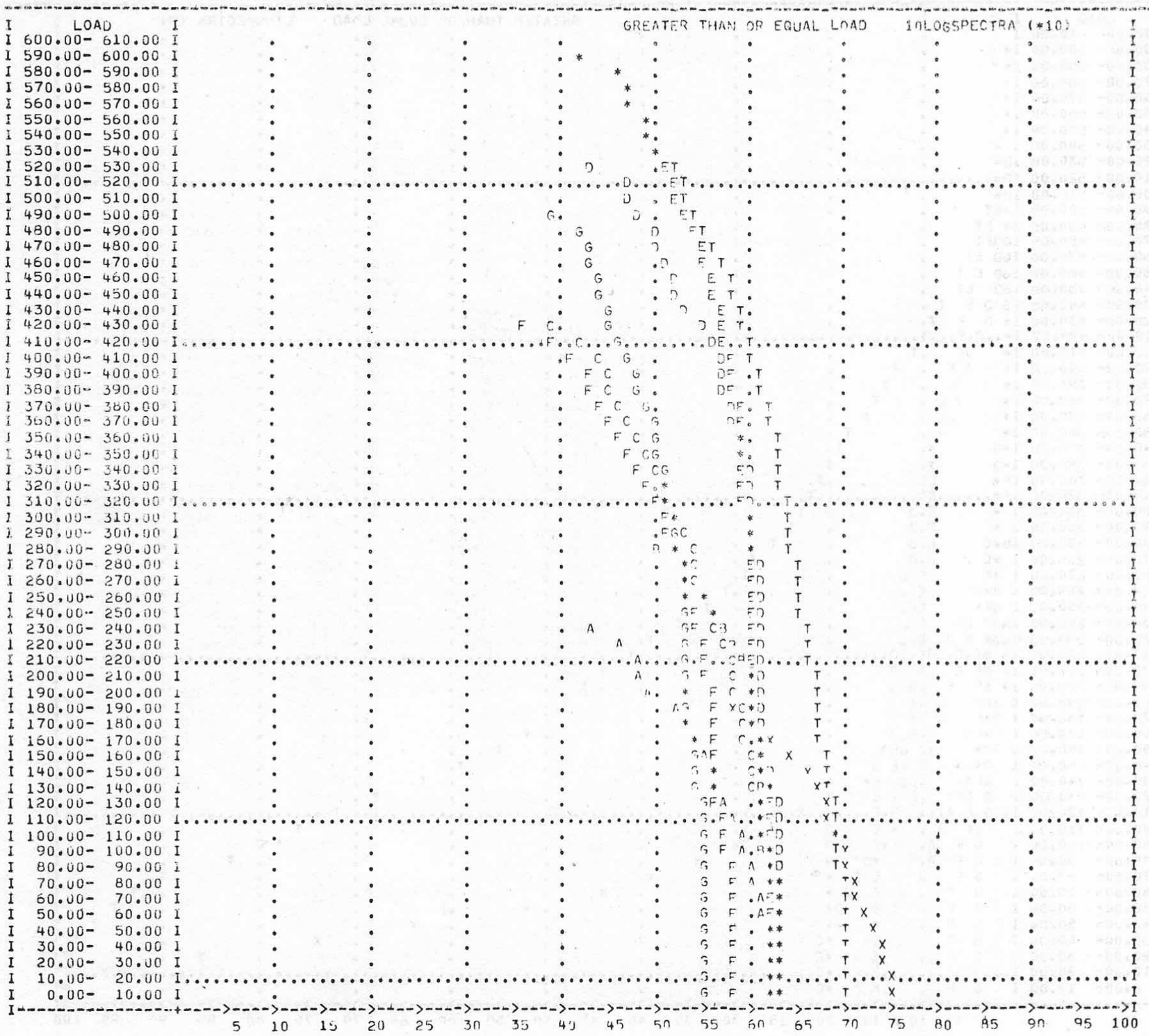
***** LIN-LOG LOADSPECTRA LANE 1 TOTAL= 9317900 AXLE= 27851597
T=TOTAL X=AXLE TYPES:A=1 B=2 C=3 D=4 E=5 F=6 G=7 H=8 I=9 J=10



** LATERAL INFLUENCE DATA **
LAT.TRACK DISTR EACH LANE: WIDTH(M)= 1.00 FLAT PORTION= 1.000
SLANTING PORTION (IF NEG TOWARDS F2-F4 LANE2)= 0.000
LANE 1 (MIDDLE FACTOR)= 0.750 +F3= 0.800 -F3= 0.700
LANE 2 (MIDDLE FACTOR)= 0.600 +F4= 0.650 -F4= 0.550

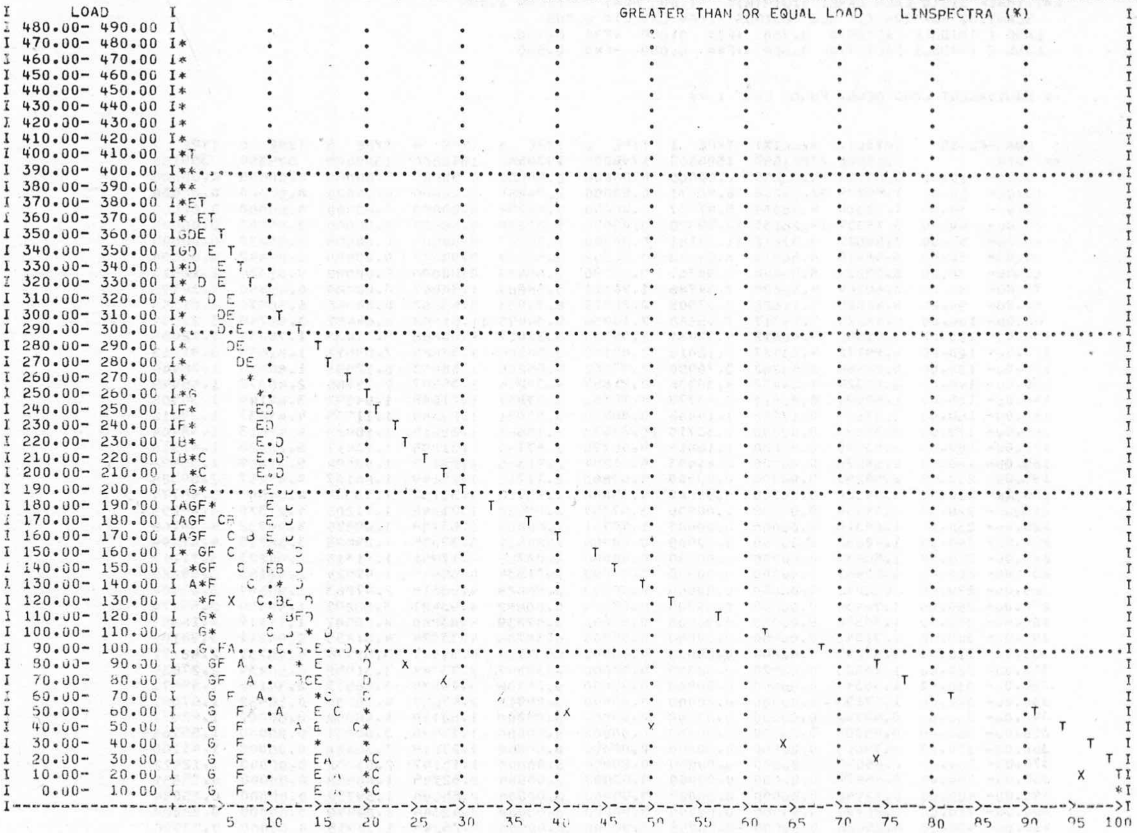
** EQUIVALENT LOAD DENS. FUNC. LANE 1 **

LOAD-CLASS	TOTAL(%)	AXLE(%)	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TYPE 6	TYPE 7
** TOT=	9317900	27851550	1506500	1796000	1930500	1810800	1389600	575350	309150
0.00- 10.00	0.00000	4.05580	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10.00- 20.00	1.59739	22.39246	6.98071	0.00000	2.26257	0.00000	0.00000	0.00000	0.00000
20.00- 30.00	1.43314	9.88324	5.47987	0.00000	2.64098	0.00000	0.00000	0.00000	0.00000
30.00- 40.00	3.15004	14.26151	12.59920	0.00000	5.37220	0.00000	0.00000	0.00000	0.00000
40.00- 50.00	3.54622	9.37812	11.24161	0.00000	7.72267	0.00000	0.00000	2.08438	0.00000
50.00- 60.00	8.42926	6.56918	8.64040	23.61362	9.52902	0.00000	0.00000	8.20442	0.00000
60.00- 70.00	5.09224	5.55044	6.98351	9.03790	7.69499	0.00000	0.00000	9.01029	2.12513
70.00- 80.00	3.68964	4.56890	7.54786	1.96410	5.68809	1.38047	0.00000	6.45460	7.39790
80.00- 90.00	5.46825	4.11622	8.07905	2.20975	6.34033	8.53062	0.64965	6.50976	8.01353
90.00- 100.00	6.48224	5.29317	7.95568	2.16936	5.34495	11.61988	6.64457	3.96749	5.31697
100.00- 110.00	5.01352	4.40612	4.73421	2.00328	3.32017	7.00666	9.71433	1.74034	7.72408
110.00- 120.00	4.19172	4.23427	5.12010	2.09140	3.58506	4.33885	7.59511	1.81689	3.91763
120.00- 130.00	3.24466	2.55262	3.76090	2.07262	4.05200	1.68953	6.12095	1.80058	1.36440
130.00- 140.00	2.90324	1.64272	4.39236	2.21859	4.32204	1.35507	2.74786	2.40372	1.46049
140.00- 150.00	2.58591	0.85812	2.43775	4.10365	3.57831	1.21085	1.04597	3.64144	1.30506
150.00- 160.00	3.37606	0.17728	1.14468	8.80990	3.65051	1.29348	1.11735	4.41037	1.39412
160.00- 170.00	3.70493	0.00000	1.32710	10.23538	3.78563	1.28414	1.10928	4.41013	1.38404
170.00- 180.00	3.53895	0.00000	1.16018	9.08790	3.87780	1.31295	1.13417	5.26428	1.41510
180.00- 190.00	2.68576	0.00000	0.41483	6.41294	2.91305	1.25712	1.08594	5.31009	1.35492
190.00- 200.00	2.08240	0.00000	0.00000	4.63663	2.11718	1.25149	1.08107	4.47267	2.09328
200.00- 210.00	2.04300	0.00000	0.00000	4.35688	1.93710	1.31162	1.13302	4.24807	3.48774
210.00- 220.00	2.01454	0.00000	0.00000	3.57257	2.02628	1.71046	1.11206	4.21310	4.45295
220.00- 230.00	1.68318	0.00000	0.00000	1.40351	1.66065	2.63738	1.09879	3.99732	4.38166
230.00- 240.00	1.42052	0.00000	0.00000	0.00000	1.24531	3.37035	1.09425	3.38715	4.07499
240.00- 250.00	1.50839	0.00000	0.00000	0.00000	1.08769	4.17951	1.11318	2.94223	3.71117
250.00- 260.00	1.60463	0.00000	0.00000	0.00000	1.01534	4.64815	1.49024	2.42183	3.59229
260.00- 270.00	1.69241	0.00000	0.00000	0.00000	0.86028	4.63318	2.47263	2.00504	3.65402
270.00- 280.00	1.74434	0.00000	0.00000	0.00000	0.60602	4.43421	3.60297	1.48850	3.85274
280.00- 290.00	1.70546	0.00000	0.00000	0.00000	0.42839	4.03060	4.20587	1.11119	4.14657
290.00- 300.00	1.71042	0.00000	0.00000	0.00000	0.38786	4.33774	4.01859	0.90211	3.98109
300.00- 310.00	1.57245	0.00000	0.00000	0.00000	0.34138	4.31951	3.51974	0.68731	2.86171
310.00- 320.00	1.43523	0.00000	0.00000	0.00000	0.30597	3.93744	3.31952	0.58434	2.27639
320.00- 330.00	1.30348	0.00000	0.00000	0.00000	0.20106	3.29670	3.66577	0.34182	1.59671
330.00- 340.00	1.17193	0.00000	0.00000	0.00000	0.09912	2.47657	4.18536	0.16852	1.07087
340.00- 350.00	0.99742	0.00000	0.00000	0.00000	0.00000	1.50118	4.40052	0.00000	1.48971
350.00- 360.00	0.85308	0.00000	0.00000	0.00000	0.00000	1.15986	3.86231	0.00000	1.55768
360.00- 370.00	0.79603	0.00000	0.00000	0.00000	0.00000	1.27019	3.36846	0.00000	1.41180
370.00- 380.00	0.65649	0.00000	0.00000	0.00000	0.00000	1.15197	2.65082	0.00000	1.12422
380.00- 390.00	0.46478	0.00000	0.00000	0.00000	0.00000	0.82745	1.86958	0.00000	0.75851
390.00- 400.00	0.32492	0.00000	0.00000	0.00000	0.00000	0.55690	1.39732	0.00000	0.25054
400.00- 410.00	0.26490	0.00000	0.00000	0.00000	0.00000	0.42346	1.22449	0.00000	0.00000
410.00- 420.00	0.25026	0.00000	0.00000	0.00000	0.00000	0.25245	1.34915	0.00000	0.00000
420.00- 430.00	0.17444	0.00000	0.00000	0.00000	0.00000	0.00000	1.16967	0.00000	0.00000
430.00- 440.00	0.13654	0.00000	0.00000	0.00000	0.00000	0.00000	0.91556	0.00000	0.00000
440.00- 450.00	0.09945	0.00000	0.00000	0.00000	0.00000	0.00000	0.66683	0.00000	0.00000
450.00- 460.00	0.08719	0.00000	0.00000	0.00000	0.00000	0.00000	0.58468	0.00000	0.00000
460.00- 470.00	0.05182	0.00000	0.00000	0.00000	0.00000	0.00000	0.34746	0.00000	0.00000
470.00- 480.00	0.01714	0.00000	0.00000	0.00000	0.00000	0.00000	0.11495	0.00000	0.00000

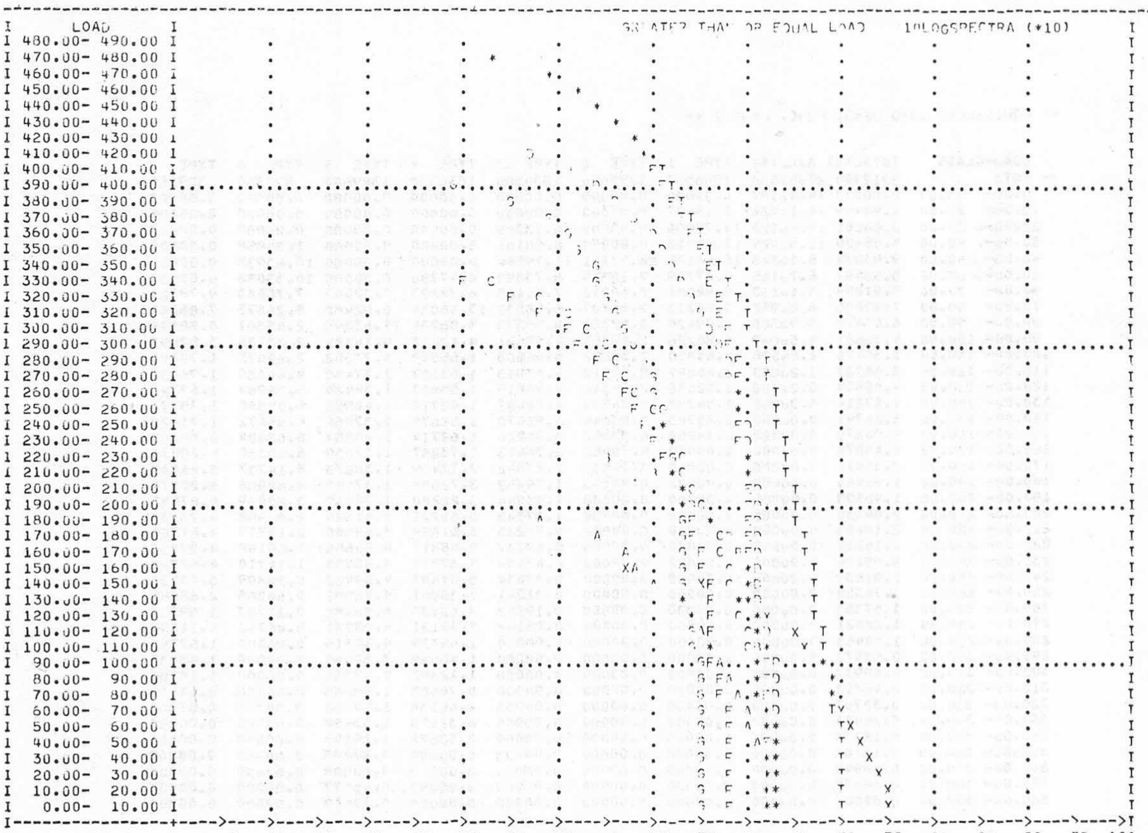
** EQUIVALENT LOAD DENS. FUNC. LANE 2 **

LOAD-CLASS	TOTAL(%)	AXLE(%)	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TYPE 6	TYPE 7
** TOT=	9317900	27851550	1506500	1796000	1930500	1810300	1389600	575350	309150
0.00- 10.00	0.00000	14.42187	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10.00- 20.00	1.90449	14.14424	8.15497	0.00000	2.82850	0.00000	0.00000	0.00000	0.00000
20.00- 30.00	3.66205	19.68128	14.79006	0.00000	6.13385	0.00000	0.00000	0.00000	0.00000
30.00- 40.00	4.05420	11.55024	13.04512	0.00000	8.80161	0.00000	0.00000	1.96858	0.00000
40.00- 50.00	9.93974	8.13343	10.68176	26.52151	11.79564	0.00000	0.00000	10.63938	0.00000
50.00- 60.00	5.58997	6.73155	9.07709	7.16914	8.73898	0.47786	0.00000	10.33088	6.00539
60.00- 70.00	5.81298	5.10133	9.92881	2.60213	7.41165	6.78223	0.32482	7.76683	9.78222
70.00- 80.00	7.57000	6.02952	9.28213	2.60107	6.56532	13.46034	6.92482	5.26075	7.06340
80.00- 90.00	6.47490	5.93308	6.79429	2.62301	4.49375	9.06234	11.63245	2.45561	8.80924
90.00- 100.00	4.90821	4.56049	5.86286	2.69051	4.89681	4.12073	9.14352	2.33736	3.57093
100.00- 110.00	3.55178	2.24528	4.64810	2.58532	5.06608	1.65849	4.77300	2.62025	1.70191
110.00- 120.00	3.58727	1.23083	3.66047	5.55112	4.87913	1.63327	1.77450	4.44030	1.76034
120.00- 130.00	4.08934	0.21702	1.52680	10.54316	4.46615	1.55613	1.34424	5.28764	1.67720
130.00- 140.00	4.57214	0.00000	1.54793	12.26970	4.82087	1.62712	1.40556	6.05886	1.75371
140.00- 150.00	3.66741	0.00000	0.85703	9.03844	3.95070	1.58675	1.37069	6.45672	1.71020
150.00- 160.00	2.96870	0.00000	0.14260	6.83852	3.06226	1.62714	1.40557	6.03504	2.85187
160.00- 170.00	2.40074	0.00000	0.00000	4.70002	2.36613	1.73287	1.37039	5.20330	4.28578
170.00- 180.00	2.35428	0.00000	0.00000	3.34530	2.27842	2.73434	1.38673	5.14737	5.46807
180.00- 190.00	1.92464	0.00000	0.00000	0.92105	1.79452	3.72808	1.37143	4.42908	5.20871
190.00- 200.00	1.90599	0.00000	0.00000	0.00000	1.43064	5.20800	1.38969	3.80839	4.67443
200.00- 210.00	2.04130	0.00000	0.00000	0.00000	1.17548	5.66221	2.41447	2.91958	4.73332
210.00- 220.00	2.10285	0.00000	0.00000	0.00000	0.92233	5.51858	3.69580	2.18779	4.61305
220.00- 230.00	2.16210	0.00000	0.00000	0.00000	0.69737	5.48817	4.56656	1.69190	4.99053
230.00- 240.00	2.09196	0.00000	0.00000	0.00000	0.49098	5.37717	4.83403	1.14710	4.62723
240.00- 250.00	1.91539	0.00000	0.00000	0.00000	0.37634	5.01403	4.69462	0.78899	3.44132
250.00- 260.00	1.70350	0.00000	0.00000	0.00000	0.31261	4.30981	4.53091	0.60365	2.65855
260.00- 270.00	1.57053	0.00000	0.00000	0.00000	0.19248	3.62139	4.96481	0.32723	1.99718
270.00- 280.00	1.28821	0.00000	0.00000	0.00000	0.05142	2.34131	5.09721	0.08742	1.71804
280.00- 290.00	1.00463	0.00000	0.00000	0.00000	0.00000	1.49739	4.42315	0.00000	1.62762
290.00- 300.00	0.90572	0.00000	0.00000	0.00000	0.00000	1.48049	3.82044	0.00000	1.45435
300.00- 310.00	0.69937	0.00000	0.00000	0.00000	0.00000	1.12892	2.97356	0.00000	1.10106
310.00- 320.00	0.46712	0.00000	0.00000	0.00000	0.00000	0.76503	1.99265	0.00000	0.64131
320.00- 330.00	0.32707	0.00000	0.00000	0.00000	0.00000	0.46238	1.57436	0.00000	0.07307
330.00- 340.00	0.28933	0.00000	0.00000	0.00000	0.00000	0.31123	1.53454	0.00000	0.00000
340.00- 350.00	0.18278	0.00000	0.00000	0.00000	0.00000	0.02621	1.19148	0.00000	0.00000
350.00- 360.00	0.13108	0.00000	0.00000	0.00000	0.00000	0.00000	0.87895	0.00000	0.00000
360.00- 370.00	0.08949	0.00000	0.00000	0.00000	0.00000	0.00000	0.60008	0.00000	0.00000
370.00- 380.00	0.06872	0.00000	0.00000	0.00000	0.00000	0.00000	0.46077	0.00000	0.00000
380.00- 390.00	0.02001	0.00000	0.00000	0.00000	0.00000	0.00000	0.13419	0.00000	0.00000

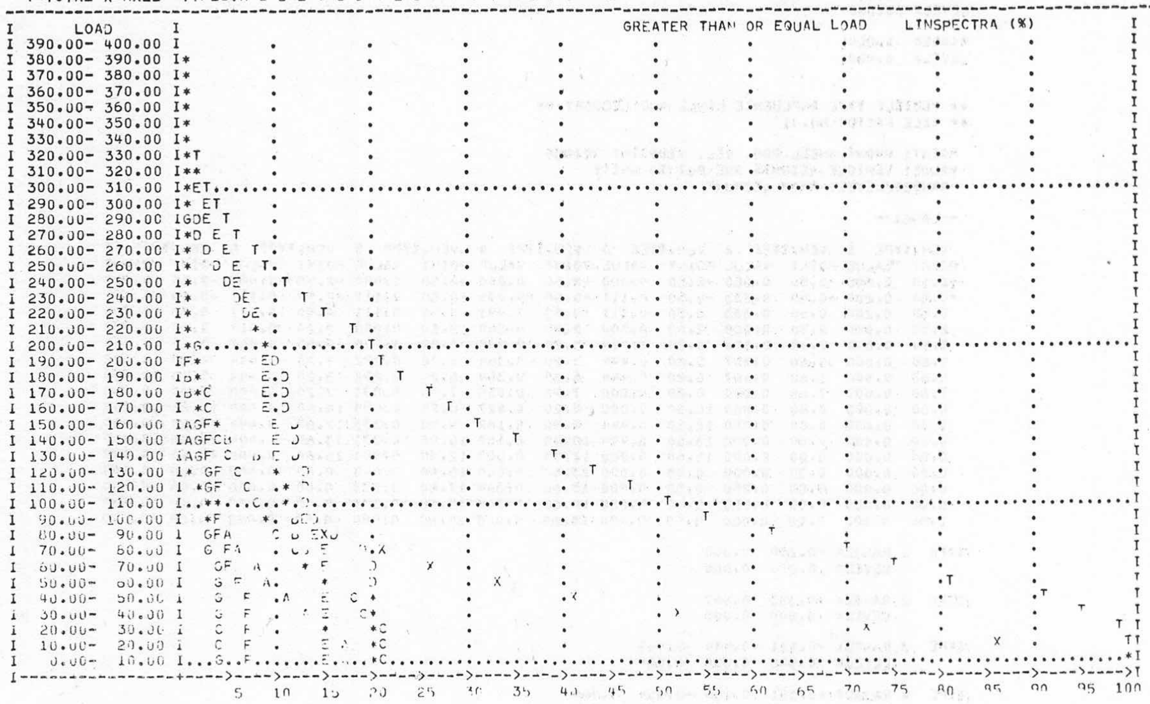
***** LIN-LOG EQUIVALENT LOADSPECTRA LANE 1 TOTAL= 9317900 AXLE= 27851597
T=TOTAL X=AXLE TYPES:A=1 B=2 C=3 D=4 E=5 F=6 G=7 H=8 I=9 J=10



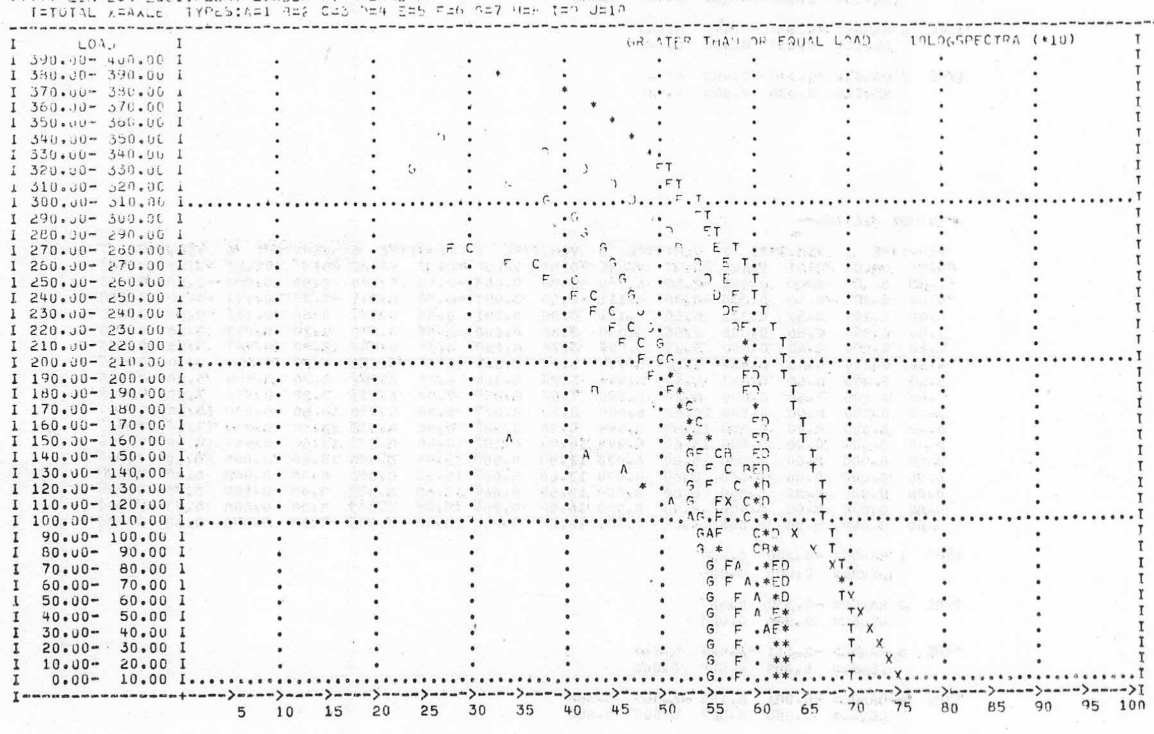
***** LIN-LOG EQUIVALENT LOADSPECTRA LANE 1 TOTAL= 9317900 AXLE= 27951597
T=TOTAL X=AXLE TYPES:A=1 B=2 C=3 D=4 E=5 F=6 G=7 H=8 I=9 J=10



***** LIN-LOG EQUIVALENT LOADSPECTRA LANE 2   TOTAL= 9317900   AXLE= 27851597
T=TOTAL X=AXLE TYPES:A=1 B=2 C=3 D=4 E=5 F=6 G=7 H=8 I=9 J=10



***** LIN-LOG EQUIVALENT LOADSPECTRA LANE 2   TOTAL= 9317900   AXLE= 27851597
T=TOTAL X=AXLE TYPES:A=1 B=2 C=3 D=4 E=5 F=6 G=7 H=8 I=9 J=10



** INFLUENCE LINE SPEC. **
INFLINE TYPE 2 TOTAL LENGTH(M)= 5.00
SLOPE:TOP X-RELATIONS 2.0: 1.0

LECOUNT ON J1 AND -J1 (MEETING) RANGE/LEVEL

RANGE= 1.000
LEVEL= 0.000

RANGE= 1.000
LEVEL= 0.000

** VEHICLE TYPE INFLUENCE LINES AND LECOUNT **
** AXLE FACTOR NB. 1

POINT: FRONT WHEEL POS. REL. MIDPOINT BRIDGE
VALUE: VEHICLE WEIGHTS ARE PUT TO UNITY
RANGE:/LEVEL: FROM LECOUNT

--LANE1--

VEH.TYPE 1		VEH.TYPE 2		VEH.TYPE 3		VEH.TYPE 4		VEH.TYPE 5		VEH.TYPE 6		VEH.TYPE 7	
POINT	VALUE	POINT	VALUE	POINT	VALUE	POINT	VALUE	POINT	VALUE	POINT	VALUE	POINT	VALUE
-2.50	0.000	-2.50	0.000	-2.50	0.000	-2.50	0.000	-2.50	0.000	-2.50	0.000	-2.50	0.000
-0.50	0.200	-0.50	0.333	-0.50	0.111	-0.50	0.091	-0.50	0.111	-0.50	0.111	-0.50	0.200
0.50	0.200	0.50	0.333	0.50	0.111	0.50	0.091	0.50	0.111	0.50	0.111	0.50	0.200
2.50	0.000	2.50	0.000	2.50	0.000	2.50	0.000	2.50	0.000	2.20	0.017	2.20	0.030
2.60	0.000	2.60	0.000	3.20	0.000	3.20	0.000	3.20	0.000	2.50	0.067	2.50	0.060
4.60	0.800	4.60	0.667	5.20	0.444	5.20	0.364	5.20	0.222	4.20	0.444	4.20	0.400
5.60	0.800	5.60	0.667	6.20	0.444	6.20	0.364	6.20	0.222	5.20	0.444	5.20	0.400
7.60	0.000	7.60	0.000	8.20	0.000	7.90	0.055	7.90	0.033	7.20	0.000	7.20	0.000
0.00	0.000	0.00	0.000	10.60	0.000	8.20	0.027	8.20	0.050	10.60	0.000	15.60	0.000
0.00	0.000	0.00	0.000	12.60	0.444	9.90	0.182	9.90	0.333	12.60	0.444	17.60	0.400
0.00	0.000	0.00	0.000	13.60	0.444	10.90	0.182	10.90	0.333	13.60	0.444	18.60	0.400
0.00	0.000	0.00	0.000	15.60	0.000	12.90	0.000	12.90	0.000	15.60	0.000	20.60	0.000
0.00	0.000	0.00	0.000	0.00	0.000	13.60	0.000	15.60	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000	15.60	0.364	17.60	0.333	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000	16.60	0.364	18.60	0.333	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000	18.60	0.000	20.60	0.000	0.00	0.000	0.00	0.000

TYPE 1 RANGE= -0.200 0.800
LEVEL= 0.000 0.000

TYPE 2 RANGE= -0.333 0.667
LEVEL= 0.000 0.000

TYPE 3 RANGE= -0.111 -0.444 0.444
LEVEL= 0.000 0.000 0.000

TYPE 4 RANGE= -0.091 0.155 -0.364 0.364
LEVEL= 0.000 0.027 0.000 0.000

TYPE 5 RANGE= -0.111 -0.189 -0.333 0.333
LEVEL= 0.000 0.033 0.000 0.000

TYPE 6 RANGE= -0.094 -0.444 0.444
LEVEL= 0.017 0.000 0.000

TYPE 7 RANGE= -0.170 -0.400 0.400
LEVEL= 0.030 0.000 0.000

--LANE2 MEETING--

VEH.TYPE 1		VEH.TYPE 2		VEH.TYPE 3		VEH.TYPE 4		VEH.TYPE 5		VEH.TYPE 6		VEH.TYPE 7	
POINT	VALUE	POINT	VALUE	POINT	VALUE	POINT	VALUE	POINT	VALUE	POINT	VALUE	POINT	VALUE
-2.50	0.000	-2.50	0.000	-2.50	0.000	-2.50	0.000	-2.50	0.000	-2.50	0.000	-2.50	0.000
-0.50	0.200	-0.50	0.333	-0.50	0.111	-0.50	0.091	-0.50	0.111	-0.50	0.111	-0.50	0.200
0.50	0.200	0.50	0.333	0.50	0.111	0.50	0.091	0.50	0.111	0.50	0.111	0.50	0.200
2.50	0.000	2.50	0.000	2.50	0.000	2.50	0.000	2.50	0.000	2.20	0.017	2.20	0.030
2.60	0.000	2.60	0.000	3.20	0.000	3.20	0.000	3.20	0.000	2.50	0.067	2.50	0.060
4.60	0.800	4.60	0.667	5.20	0.444	5.20	0.364	5.20	0.222	4.20	0.444	4.20	0.400
5.60	0.800	5.60	0.667	6.20	0.444	6.20	0.364	6.20	0.222	5.20	0.444	5.20	0.400
7.60	0.000	7.60	0.000	8.20	0.000	7.90	0.055	7.90	0.033	7.20	0.000	7.20	0.000
0.00	0.000	0.00	0.000	10.60	0.000	8.20	0.027	8.20	0.050	10.60	0.000	15.60	0.000
0.00	0.000	0.00	0.000	12.60	0.444	9.90	0.182	9.90	0.333	12.60	0.444	17.60	0.400
0.00	0.000	0.00	0.000	13.60	0.444	10.90	0.182	10.90	0.333	13.60	0.444	18.60	0.400
0.00	0.000	0.00	0.000	15.60	0.000	12.90	0.000	12.90	0.000	15.60	0.000	20.60	0.000
0.00	0.000	0.00	0.000	0.00	0.000	13.60	0.000	15.60	0.000	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000	15.60	0.364	17.60	0.333	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000	16.60	0.364	18.60	0.333	0.00	0.000	0.00	0.000
0.00	0.000	0.00	0.000	0.00	0.000	18.60	0.000	20.60	0.000	0.00	0.000	0.00	0.000

TYPE 1 RANGE= -0.200 0.800
LEVEL= 0.000 0.000

TYPE 2 RANGE= -0.333 0.667
LEVEL= 0.000 0.000

TYPE 3 RANGE= -0.111 -0.444 0.444
LEVEL= 0.000 0.000 0.000

TYPE 4 RANGE= -0.091 0.155 -0.364 0.364
LEVEL= 0.000 0.027 0.000 0.000

TYPE 5 RANGE= -0.111 -0.189 -0.333 0.333
LEVEL= 0.000 0.033 0.000 0.000

TYPE 6 RANGE= -0.094 -0.444 0.444
LEVEL= 0.017 0.000 0.000

TYPE 7 RANGE= -0.170 -0.400 0.400
LEVEL= 0.030 0.000 0.000

⋮

```
** OVERLAP DISTRIBUTION INPUT **

NB. OF CLASSES 5 WITH THE FOLLOWING DISTRIBUTION (APPROX.)
  (LESS THAN 7 CLASSES)   DISTRIBUTION ABSOLUTE
IN DISTR.  0.814  0.150  0.030  0.005  0.001

** EQUIVALENT OVERLAP LOAD DENSITY FUNCTIONS **

  --  %  ( LC        - HC          )
  --LOAD (LOW CLASS-HIGH CLASS )

TOTAL   LANE 1   79.38 % (LC-HC)  16.45 % (LC-HC)   3.36 % (LC-HC)   0.66 % (LC-HC)   0.16 % (LC-HC)  TOT=
                111.920  ( 1-24) 291.228  (25-35) 373.236  (36-41) 426.289  (42-45) 460.514  (46-48)   9317900

        LANE 2   79.03 % (LC-HC)  16.78 % (LC-HC)   3.40 % (LC-HC)   0.60 % (LC-HC)   0.18 % (LC-HC)  TOT=
                 89.190  ( 1-19) 232.063  (20-28) 299.730  (29-33) 342.376  (34-36) 371.101  (37-39)   9317900

AXLE    LANE 1   76.68 % (LC-HC)  18.11 % (LC-HC)   4.18 % (LC-HC)   0.86 % (LC-HC)   0.18 % (LC-HC)  TOT=
                 33.780  ( 1- 8)  99.869  ( 9-12) 128.934  (13-14) 145.000  (15-15) 155.000  (16-16)  27851596

        LANE 2   74.66 % (LC-HC)  17.06 % (LC-HC)   6.83 % (LC-HC)   1.23 % (LC-HC)   0.22 % (LC-HC)  TOT=
                 25.673  ( 1- 6)  75.487  ( 7- 9)  98.289  (10-11) 115.000  (12-12) 125.000  (13-13)  27851597

TYPE  1 LANE 1   75.51 % (LC-HC)  18.01 % (LC-HC)   4.91 % (LC-HC)   1.16 % (LC-HC)   0.41 % (LC-HC)  TOT=
                 54.647  ( 1-10) 119.338  (11-14) 152.738  (15-17) 175.000  (18-18) 185.000  (19-19)   1506500

        LANE 2   74.96 % (LC-HC)  20.97 % (LC-HC)   3.07 % (LC-HC)   0.86 % (LC-HC)   0.14 % (LC-HC)  TOT=
                 43.625  ( 1- 8)  97.468  ( 9-12) 130.034  (13-14) 145.000  (15-15) 155.000  (16-16)   1506500

TYPE  2 LANE 1   70.53 % (LC-HC)  20.14 % (LC-HC)   4.36 % (LC-HC)   3.57 % (LC-HC)   1.40 % (LC-HC)  TOT=
                100.473  ( 1-17) 182.790  (18-20) 205.000  (21-21) 215.000  (22-22) 225.000  (23-23)   1796000

        LANE 2   75.16 % (LC-HC)  15.88 % (LC-HC)   4.70 % (LC-HC)   3.35 % (LC-HC)   0.92 % (LC-HC)  TOT=
                 64.020  ( 1-14) 149.307  (15-16) 165.000  (17-17) 175.000  (18-18) 185.000  (19-19)   1796000

TYPE  3 LANE 1   78.89 % (LC-HC)  16.87 % (LC-HC)   3.30 % (LC-HC)   0.65 % (LC-HC)   0.30 % (LC-HC)  TOT=
                 84.844  ( 1-17) 201.358  (18-25) 269.885  (26-30) 309.727  (31-32) 328.302  (33-34)   1930500

        LANE 2   76.08 % (LC-HC)  19.70 % (LC-HC)   3.29 % (LC-HC)   0.69 % (LC-HC)   0.24 % (LC-HC)  TOT=
                 65.564  ( 1-13) 157.252  (14-20) 216.533  (21-24) 249.537  (25-26) 267.108  (27-28)   1930500

TYPE  4 LANE 1   78.82 % (LC-HC)  16.69 % (LC-HC)   3.25 % (LC-HC)   0.98 % (LC-HC)   0.25 % (LC-HC)  TOT=
                177.135  ( 1-30) 322.833  (31-36) 373.639  (37-39) 390.319  (40-41) 415.000  (42-42)   1810800

        LANE 2   79.04 % (LC-HC)  15.29 % (LC-HC)   4.11 % (LC-HC)   1.23 % (LC-HC)   0.34 % (LC-HC)  TOT=
                141.852  ( 1-24) 257.152  (25-28) 294.103  (29-31) 318.767  (32-33) 335.777  (34-35)   1810800

TYPE  5 LANE 1   76.08 % (LC-HC)  18.77 % (LC-HC)   4.10 % (LC-HC)   0.93 % (LC-HC)   0.11 % (LC-HC)  TOT=
                199.865  ( 1-34) 366.500  (35-41) 427.195  (42-45) 458.728  (46-47) 475.000  (48-48)   1389600

        LANE 2   75.32 % (LC-HC)  19.88 % (LC-HC)   3.60 % (LC-HC)   1.06 % (LC-HC)   0.13 % (LC-HC)  TOT=
                158.596  ( 1-27) 293.523  (28-33) 343.181  (34-36) 369.343  (37-38) 385.000  (39-39)   1389600

TYPE  6 LANE 1   75.75 % (LC-HC)  18.97 % (LC-HC)   4.19 % (LC-HC)   0.93 % (LC-HC)   0.17 % (LC-HC)  TOT=
                119.766  ( 1-21) 235.726  (22-27) 286.882  (28-31) 318.691  (32-33) 335.000  (34-34)    575350
        LANE 2   76.86 % (LC-HC)  18.49 % (LC-HC)   3.63 % (LC-HC)   0.60 % (LC-HC)   0.41 % (LC-HC)  TOT=
                 96.809  ( 1-17) 190.983  (18-22) 232.511  (23-25) 255.000  (26-26) 267.108  (27-28)    575350

TYPE  7 LANE 1   77.47 % (LC-HC)  17.42 % (LC-HC)   4.09 % (LC-HC)   0.76 % (LC-HC)   0.25 % (LC-HC)  TOT=
                161.572  ( 1-28) 306.359  (29-35) 363.941  (36-38) 385.000  (39-39) 395.000  (40-40)    309150

        LANE 2   75.67 % (LC-HC)  19.43 % (LC-HC)   3.08 % (LC-HC)   1.10 % (LC-HC)   0.71 % (LC-HC)  TOT=
                126.904  ( 1-22) 243.558  (23-28) 289.719  (29-30) 305.000  (31-31) 316.023  (32-33)    309150


** TRAFFIC DATA **

VEH.SPEED(M/S)= 18.0  EQUIVALENT TIME=  1.00 FACTOR ON MEET.PROB.= 0.00
FACTOR ON OVERTAKING PROB.= 1.00
QUEUE CRITICAL TIME DISTANCE=    6.00
MIN-MAX QUEUEDIST.  20.00  40.00 FACTOR ON QUEUE PROB. 0.00
AVERAGE QUEUEDIST.=  30.00

** COMPUTED DIMENSIONS OF ARRAYS T AND S **

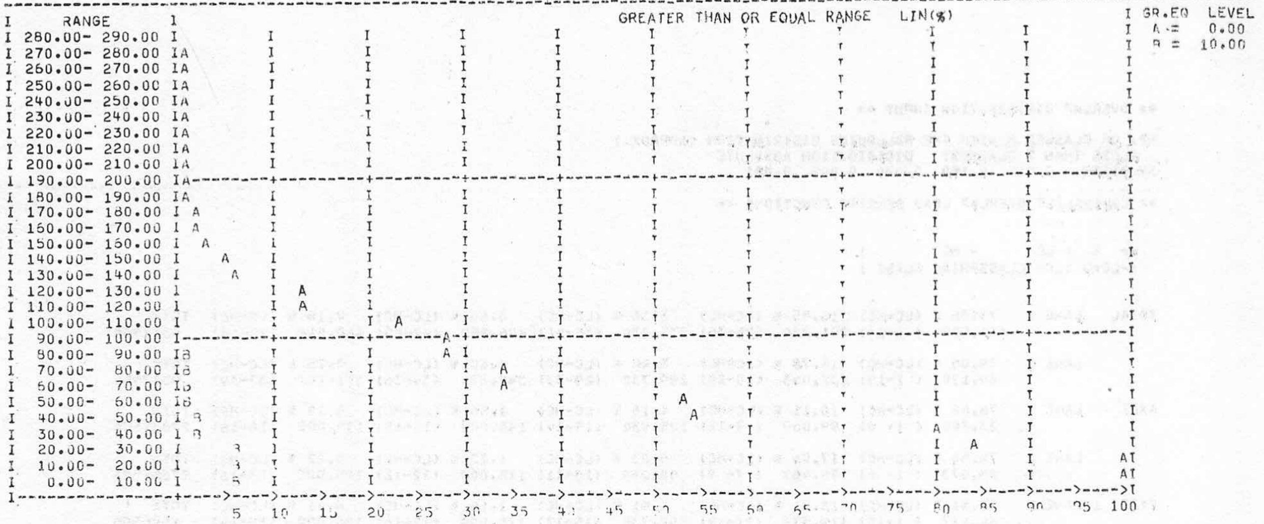
  T(   0:  43,  -10:  33)
  S(   0:  31,   -2:  33)

 (RANGE INCR.= 10.00)    (LEVEL INCR.=     10.00)

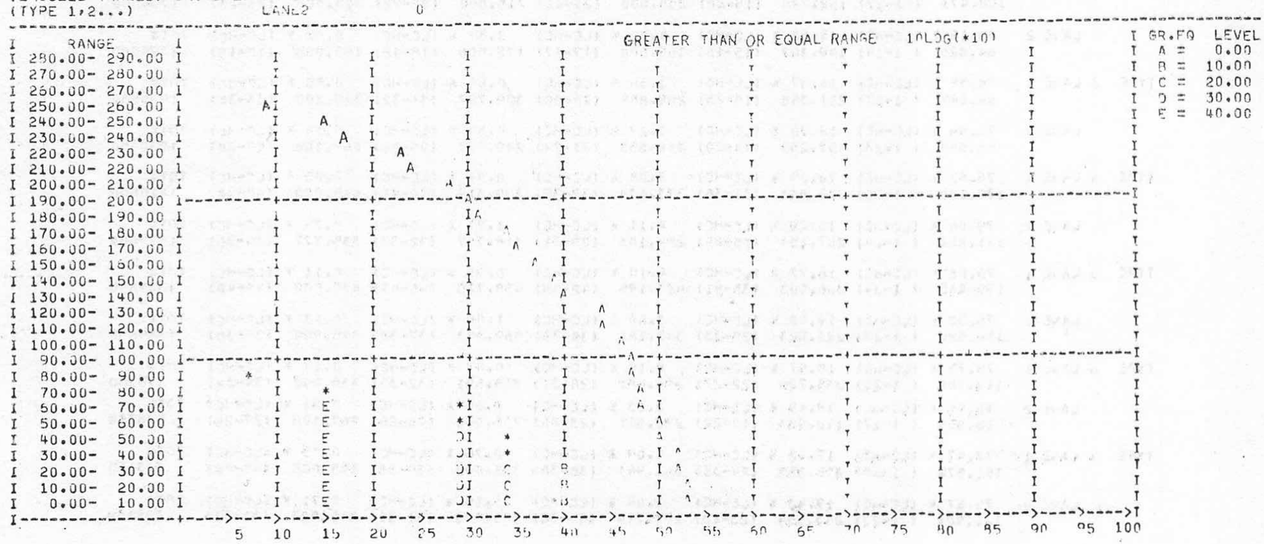
 (NB MEET POINTS=  7)    (NB QUEUING POINTS= 13)

 (NB. QUEUING POINTS IN QUEUE MEETING= 13)
```

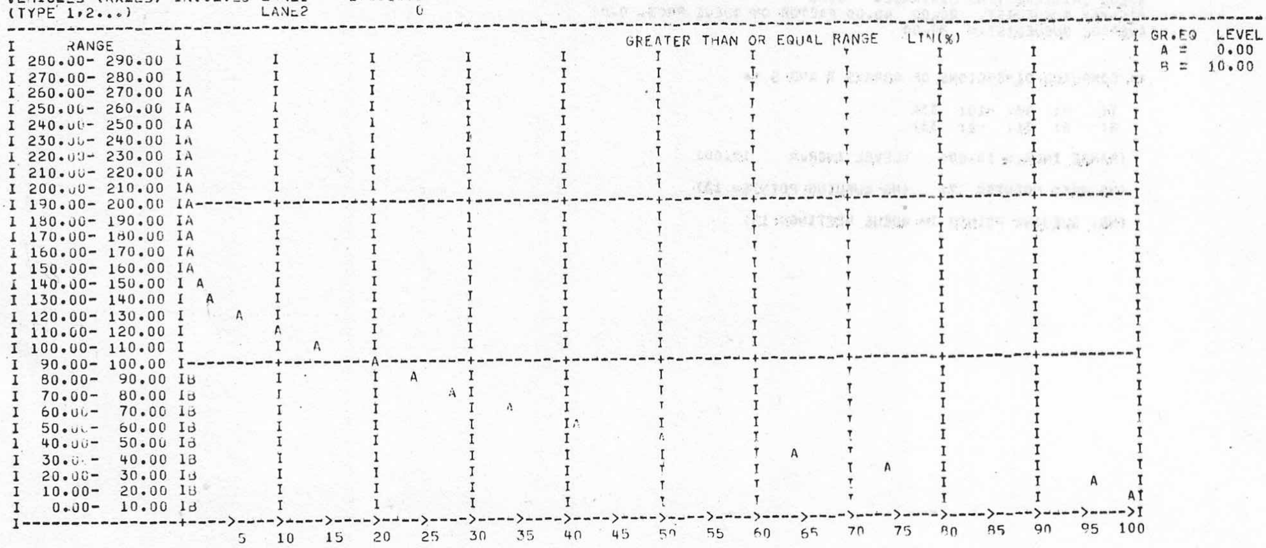
```
LANE2 OVERTAKING LANE1 *         AXLEWEIGHTS  (T0=0)      PARALLEL LANES
LINSPECTRUM   OCASSIONS=    136653      NB. OF RANGES=    175697
VEHICLES (AXLES) INVOLVED LANE1        273307
(TYPE 1,2...)                LANE2           0
```



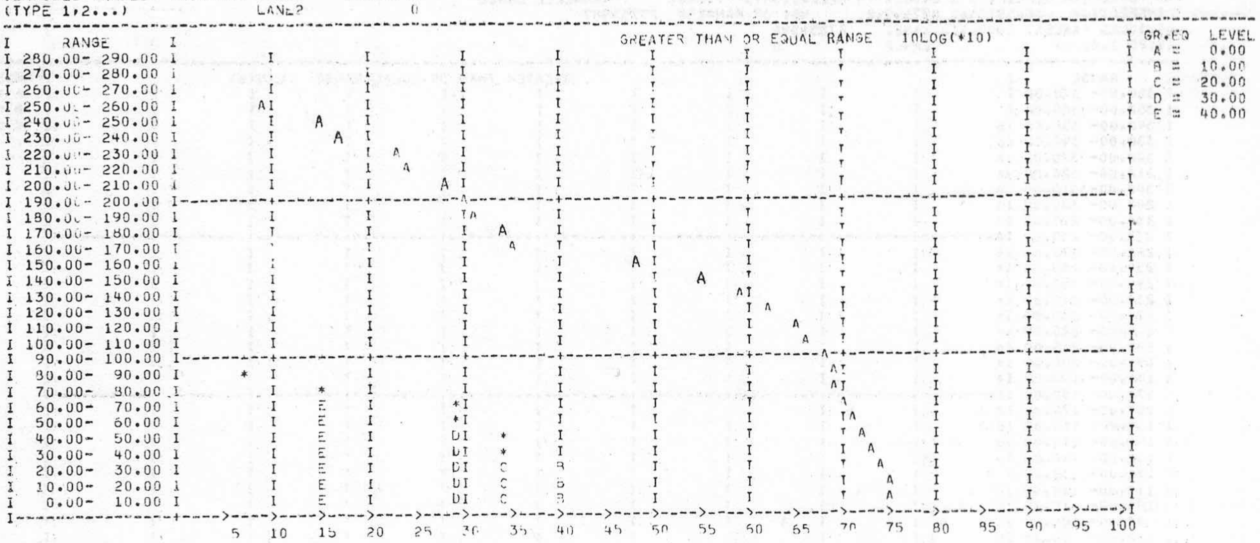

```
LANE2 OVERTAKING LANE1 *         AXLEWEIGHTS  (T0=0)      PARALLEL LANES
10LOGSPECTRUM OCASSIONS=    136653      NB. OF RANGES=    175697
VEHICLES (AXLES) INVOLVED LANE1        273307
(TYPE 1,2...)                LANE2           0
```



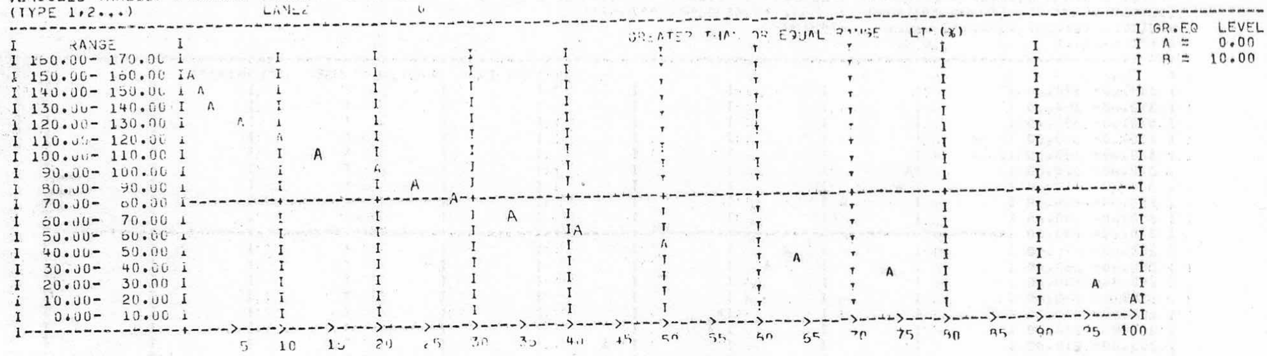

```
** TOTAL SPECTRUM NO DYN. AMPL. ** AXLEWEIGHTS  (T0=0)      PARALLEL LANES
LINSPECTRUM   OCASSIONS= 27714942      NB. OF RANGES=  27753987
VEHICLES (AXLES) INVOLVED LANE1       27851596
(TYPE 1,2...)                LANE2           0
```



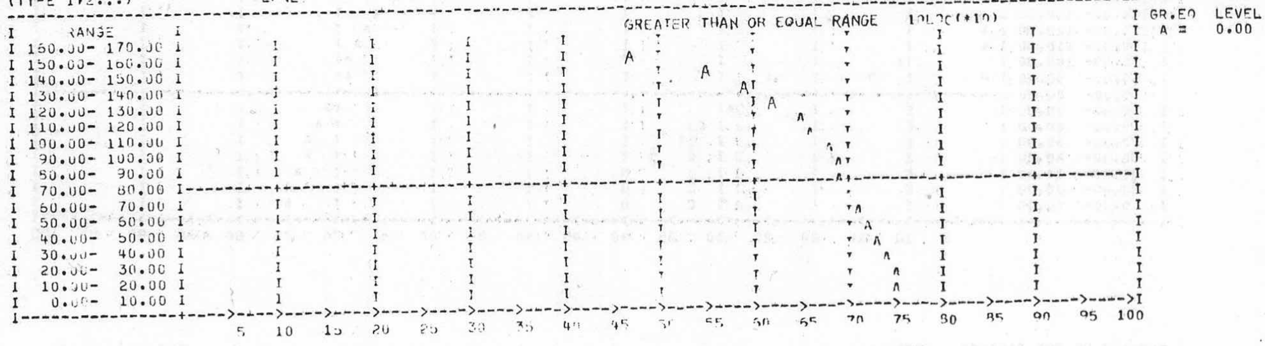
** TOTAL SPECTRUM NO DYN. AMPL. ** AXLEWEIGHTS (T0=0) PARALLEL LANES
10LOGSPECTRUM OCASSIONS= 27714942 NB. OF RANGES= 27753987
VEHICLES (AXLES) INVOLVED LANE1 27851596
(TYPE 1,2...) LANE2 0



LANE1 SINGLES * AXLEWEIGHTS (T0=0) PARALLEL LANES
LINSPECTRUM OCASSIONS= 27576289 NB. OF RANGES= 27576290
VEHICLES (AXLES) INVOLVED LANE1 27576289
(TYPE 1,2...) LANE2 0



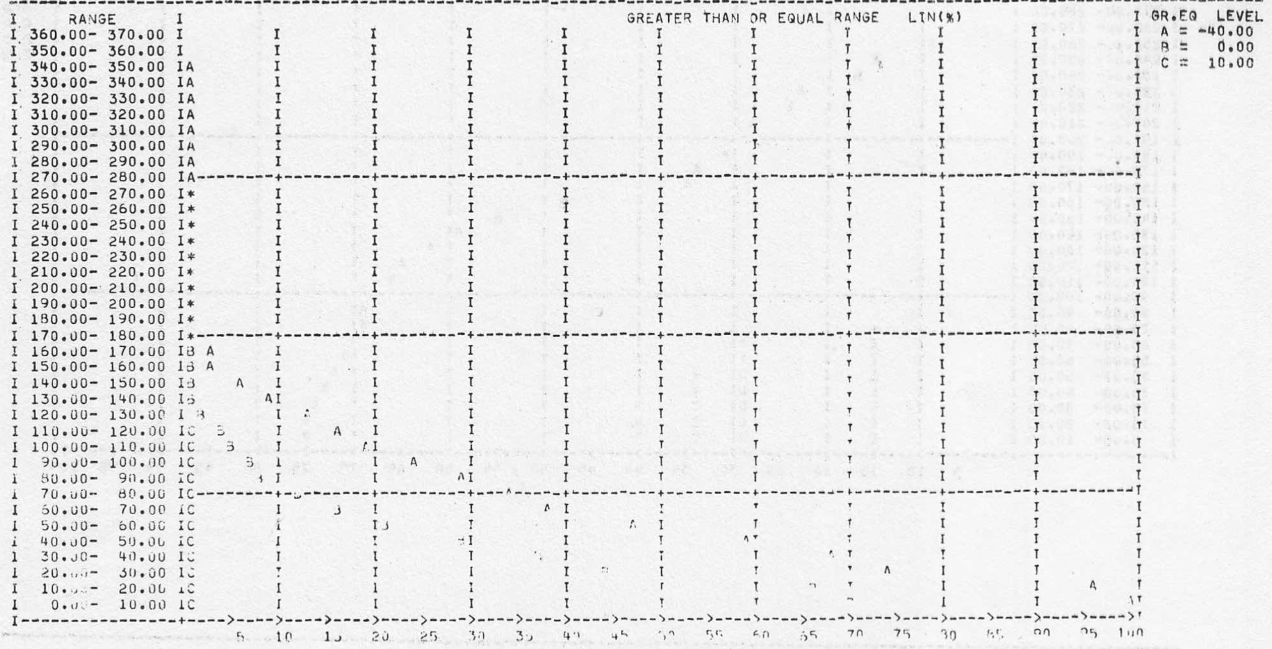
LANE1 SINGLES * AXLEWEIGHTS (T0=0) PARALLEL LANES
10LOGSPECTRUM OCASSIONS= 27576289 NB. OF RANGES= 27576290
VEHICLES (AXLES) INVOLVED LANE1 27576289
(TYPE 1,2...) LANE2 0



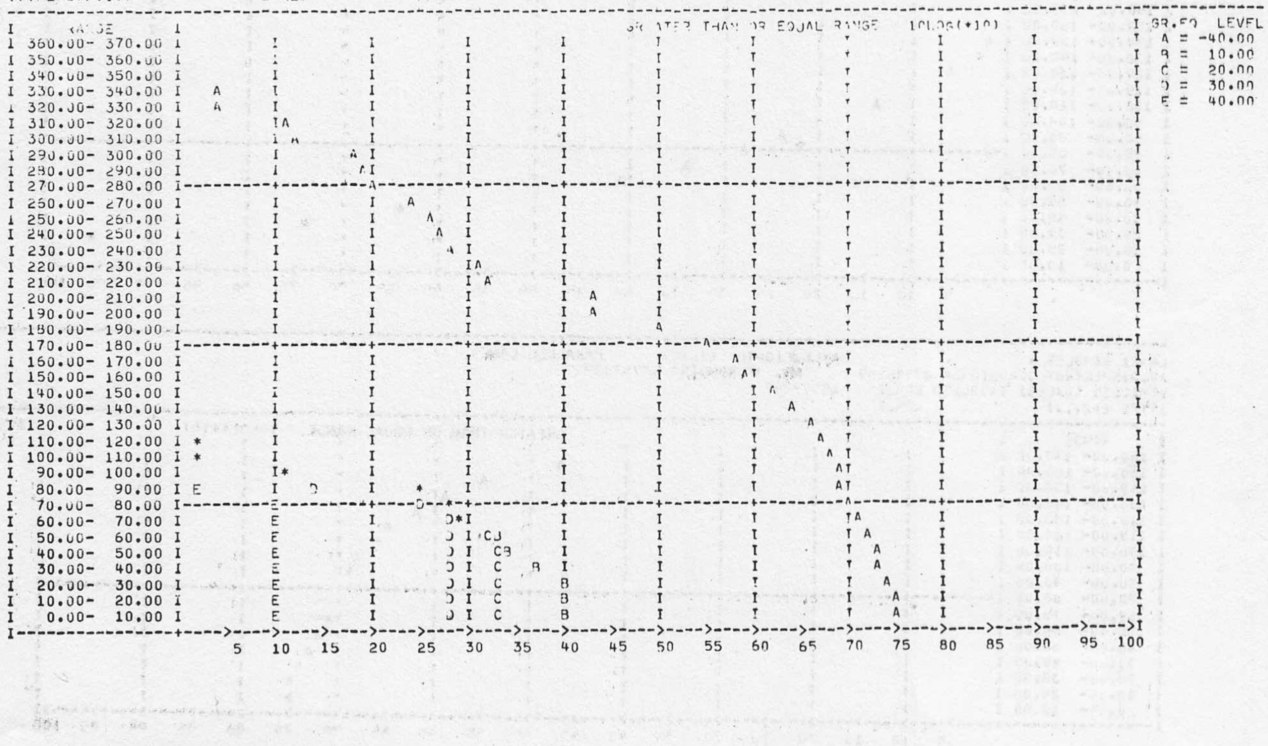
** DYNAMIC AMPLIFICATION FACTOR DISTRIBUTION **

```
-- % -- 33.333 33.333 33.333
 VALUE   1.000  1.150  1.300
 AVERAGE AMPLIFICATION FACTOR=  1.150
```

```
** TOTAL DYN AMPLIFIED SPECTRUM ** AXLEWEIGHTS  (T0=0)        PARALLEL LANES
LINSPECTRUM   OCASSIONS= 27714942       NB. OF RANGES=  27753987
VEHICLES (AXLES) INVOLVED LANE1     27851596
(TYPE 1,2...)                LANE2          0
```




```
** TOTAL DYN AMPLIFIED SPECTRUM ** AXLEWEIGHTS  (T0=0)        PARALLEL LANES
10LOGSPECTRUM OCASSIONS= 27714942       NB. OF RANGES=  27753987
VEHICLES (AXLES) INVOLVED LANE1     27851596
(TYPE 1,2...)                LANE2          0
```




```
-----NB.OF POS.RANGES=    27734466
-----     NULLRANGES=            0
-----     NEG.RANGES=        19522
-----           SUM=      27753988
```