STATENS VÄGINSTITUT · STOCKHOLM
The National Road Research Institute, 114 28 Stockholm, Sweden

INTERVIEW INVESTIGATION OF ROAD
TRAFFIC ACCIDENTS

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P-O Roosmark and R Fräki

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DIAGRAMS

1. INTRODUCTION

According to the official accident statistics, about 60 000 road traffic accidents notified to the police occur in Sweden every year. No appreciable variations in this figure have been observed in recent years. Experience has shown that these accidents constitute but a part of the total number of road traffic accidents. As is seen from Fig. 1, the number of cases of damage caused by motor traffic accidents which have been notified to insurance companies has increased at a considerably higher rate than the number of motor traffic accidents notified to the police. This development is probably due to several concurrent factors.

As the data on the accidents reported to the police often serve as a basis for traffic safety investigations of various types, it is required to have more detailed information about the relations between the accidents reported to the police and the whole accident population.

Information on the actual number of road traffic accidents which have occurred during a given year is a prerequisite to the calculations of costs of accidents which have frequently to be taken into account in dealing with various questions, e.g. road design and construction problems. It is urgently necessary that the accidents notified to the police should be studied more closely in order to find out to what extent they are representative in respect of the level of severity or the type of accident. Time and again, it has been pointed out that the data on the accidents reported to the police may be supposed to cover a small fraction of the total number of accidents, and that it may therefore possibly be advisable to replace them by data on the accidents notified to insurance companies. The question is how far the latter accidents are representative in various respects of the total accident population.

In order to shed light on the above-mentioned problems, the National Swedish Road Research Institute, Stockholm, has carried out the investigation which is described in the present paper. This investigation may also be regarded as a methodological study.

In undertaking an investigation with this object in view, it is conceivable that we have to choose among different frames of reference for sample

selection. Thus, it is possible to utilise records of motor car repair shops, as well as the central register of motor vehicles. The present investigation is based on interviews with persons who were selected from census papers.

2. DESCRIPTION OF SAMPLE

The population comprised all those persons registered in Sweden for census purposes who had been born during the period from 1895 to 1948. The individual was chosen as a sample unit. The census papers for 1964 were used as a frame of reference. The random selection resulted in a self-weighting random sample, which consisted of 2 988 persons.

The questionnaire employed for the interviews contained questions about the road traffic accidents which the interviewees stated to have experienced during the years 1963 and 1964. The interviews were carried out in the spring of 1965.

No interviews were obtained from 266 persons, that is, 8.9 per cent of the whole random sample. The number of persons who had died, or had left the country, amounted to 1.5 per cent, and the remaining 7.4 per cent were not interviewed for various reasons.

In order to increase the scope of the statistical material, both husband and wife were interviewed in the cases where the selected persons was married. The answers of unmarried selected persons were doubled so as to simplify the enumeration procedure. This made it possible to carry out the enumeration in a uniform manner, irrespective of the status of the person. A total number of $2(2\,988 - 266) = 5\,444$ "answers" was obtained by means of this procedure. In what follows, the statements concerning the number of accidents in the sample are based on these partly fictitious figures. Even at this stage, it may already be useful to point out that the above-mentioned procedure influenced the variance. This matter will be dealt with more closely further on.

Since the interviews covered only those persons who had been born during the period from 1895 to 1948, the results include only those accidents which have been experienced by some person aged 15 to 68 in 1963 and 16 to 69 in 1964. Accordingly, the number of accidents was somewhat underestimated, as the sample did not comprise all age groups. This underestimation was greatest in the case of the accidents which involved a motor car and an "unprotected" road user, i.e. a motor cyclist, a bicyclist, or a pedestrian.

A road traffic accident has been defined as an accident

- (a) which has occurred on a public road,
- (b) which has caused personal injury or property damage,
- (c) and which has involved at least one motor vehicle.

A personal-injury accident has been defined as an accident which has caused an injured person to apply for medical treatment.

The total number of accidents included in the interview investigation is given in Table 1.

Table 1. Accidents covered by the interview investigation.
Classification into parking and non-parking accidents per year.

Year	Non-parking accidents	Parking accidents	Total
1963	289	112	401
1964	483	221	704
Total	772	333	1 105

3. CONTROL OF MEMORY FUNCTION

An important question in this connection is how long a period of investigation may be chosen to be without involving an excessively great risk of overestimation or underestimation. In order to study the effect of the memory function, it is desirable to use a relatively short period of observation. In the present case, it has been possible to make comparisons only between two whole years. The question is now whether the whole accident data, i.e. the figures for 1963 and 1964, may be used for the various estimations, or whether some of them must be based on the data for 1964 alone.

It may be supposed that the memory function is in part dependent on the level of severity of the accidents, and on whether the accidents have been notified to the police or not.

Tests have shown that only those accidents which had occurred in 1964 could be used for analyses that included accidents which involved property damage, and which had not been notified to the police. In other cases, it was possible to utilise the data relating to both years in question.

4. PROCEDURE IN ENUMERATION AND IN DETERMINATION OF CONFIDENCE INTERVALS

This chapter contains a brief description which shows how the numbers of accidents of different types which had occurred in Sweden as a whole have been estimated on the basis of the information about the numbers of selected persons who had experienced accidents. The simplifications which have been allowed for purely practical reasons in the determination of the confidence intervals are discussed at the same time. It has not been considered necessary to give a special account of some details, e.g. the procedure used in estimating the costs of repairs and damages, see Chapter 9.

4.1. Determination of Confidence Interval for Number of Accidents

It is required to estimate the total number of accidents on the basis of the answers received from the persons who have been interviewed about their involvement in road traffic accidents.

The first step is to estimate the number of individuals who have been involved in at least one road traffic accident. Let this number be denoted by A , and let the total number of individuals in a given country be designated by N . The reasoning in what follows is based on the assumption that all N individuals are interviewable. We select a random sample comprising n individuals, among whom n_o have experienced a road traffic accident.

An unbiased estimate of $p = \frac{A}{N}$ is $f = \frac{n_o}{n}$.

We use the standardised variable

$$\lambda = \frac{n_o/n - p}{\sqrt{(pq/n)}}, \text{ where } q = 1-p.$$

The probability distribution of this variable is dependent on p . If n is great, then n_o/n is distributed in accordance with the asymptotically normal distribution $N[p, \sqrt{(pq/n)}]$ that is to say, λ is $N(0,1)$.

If n is sufficiently great, then an approximate 95 per cent confidence interval for p can be written

$$f - 1.96 \sqrt{\frac{f(1-f)}{n}} < p < f + 1.96 \sqrt{\frac{f(1-f)}{n}} \quad (1)$$

The next step is to deduce an expression for the number of accidents. For this purpose, it is necessary to take account to the fact that the accidents which involve different numbers of traffic elements have different probabilities of being represented in the selected sample. In order to form an unbiased estimate of the number of accidents, each accident stated by an interviewee must be expressed in the enumeration by the quotient of unity divided by the number of traffic elements involved in this accident. The probability that two or several persons included in the selected sample have experienced the same accident is negligible in this connection. To begin with, for the sake of simplicity, it is assumed that an individual has experienced not more than one accident of the same type in respect of the number of traffic elements involved. First of all, just as in the above, it is necessary to estimate the number of individuals who have experienced an accident of a certain definite type.

We put

Np_1 = the number of individuals who have experienced a single-element accident,

Np_2 = the number of individuals who have experienced a two-element accident,

etc.

It is to be noted that Np_1 is at the same time the number of single-element accidents, while $Np_2/2$ is the number of two-element accidents, and so forth. The total number of accidents is obtained by summation as follows:

$$Np = N \sum_{i=1}^{i_{\max}} p_i/i$$

As estimates of p_i , we choose $f_i = \frac{n_i}{n}$, where n_i is the number of those individuals in the sample who have experienced accidents which involved i traffic elements. In order to estimate a confidence interval for p , we evaluate the variance for $f = \sum f_i/i$. A reasonable assumption is to suppose that f_i and f_j are independent of each other if $i \neq j$.

Then we get

$$\text{var } f = \sum \frac{1}{i^2} \quad \text{var } f_i = \sum \frac{f_i(1-f_i)}{i^2 n} \quad (2)$$

Accordingly, an approximate 95 per cent confidence interval for p can be written

$$\sum \frac{f_i}{i} \pm 1.96 \left[\sum \frac{f_i(1-f_i)}{i^2 n} \right]^{1/2} \quad (3)$$

The deduction of the above expressions is based on the assumption that an individual has experienced not more than one accident of the same type. However, it appears justifiable to generalise these expressions so that they may be applicable without this assumption. An important requirement which must be fulfilled in order that the reasoning below may be valid is that the accidents can be regarded as mutually independent events, and that the probability of being involved in an accident is the same for each individual. Let X_{ij} denote the number of accidents of the type i which have been experienced by the j -th individual. The mean number of accidents of the type i per individual in the sample can be written

$$v_i = \frac{1}{n} \sum_{j=1}^n X_{ij}$$

and can be considered to be an estimate of the mean value, λ_i , for the whole population. On the assumption that the number of accidents per individual is distributed in conformity with a Poisson distribution having a mean value λ_i , we can deduce an expression for an approximate 95 per cent confidence interval for $N\lambda_{i/i}$, viz.,

$$\frac{Nv_i}{i} - 1.96 \frac{N}{ni} \sqrt{(nv_i)} < \frac{N\lambda_i}{i} < \frac{Nv_i}{i} + 1.96 \frac{N}{ni} \sqrt{(nv_i)} \quad (4)$$

4.2. Simplified Calculation of Estimated Confidence Intervals

The interview investigation which has been carried out by the National Swedish Road Research Institute makes it possible in principle to calculate nearly exact confidence intervals. However, the estimated confidence inter-

vals which are given in the present publication have been calculated by using a somewhat simplified procedure. Therefore, the calculated confidence intervals should not be regarded as anything else than confidence intervals which are very approximate, but which nevertheless reflect the relative accuracy in the estimates. The estimates of the confidence intervals are based on the calculation procedure which is outlined in Section 4.1, and which has been supplemented by the simplifications and assumptions stated in what follows.

1. The stratified sample was regarded as a simple random sample.
2. It was assumed that each person had experienced not more than one accident of the same type, as defined by the number of traffic elements involved.
3. The calculations of the variance were simplified. In brief, this implies that $\sum O_i/i^2$ was replaced by $\sum O_i/i$ where O_i is the number of accidents which involved i traffic elements.
4. For married persons, the answers of both husband and wife were utilised, and were treated in the same manner, that is to say, as if they had been selected at random.
5. In order to simplify the enumeration procedure, the answers received from unmarried persons were doubled.

The above simplifications can influence the results in different ways. The effects of the assumptions made under Point 1 and 2 may be expected to be but slight. The simplification of the calculation of the variance stated under Point 3 influences the estimation of the number of accidents involving several traffic elements, so that the confidence interval will be somewhat wider than it would have been if this simplification had not been introduced. The assumption under Point 4 influences the magnitude of the confidence interval as well as its mean value. The degree of this influence is dependent on the correlation between husband and wife. Finally, the simplification mentioned under Point 5 implies that the confidence intervals will be narrower than they would have been in the absence of this simplification.

5. BREAKDOWN OF TOTAL NUMBER OF ACCIDENTS BY LEVEL OF SEVERITY AND TYPE OF NOTIFICATION

Table 2 shows a breakdown of the estimated total number of accidents by level of severity and type of notification. The intervals given in this table are approximate 95 per cent confidence intervals. In other words, the probability that the true value is comprised within these intervals is about 95 per cent.

Table 2. Breakdown of the estimated total number of road traffic accidents in Sweden, 1964 by level of severity and type of notification.

Level of severity	Notified to the police	Notified to insurance companies	Not notified	Total
Accidents involving personal injury	12.450 $\pm$ 4.800	15.300 $\pm$ 5.300	7.700 $\pm$ 3.800	25.500 $\pm$ 7.150
Accidents involving property damage (exclusive of parking accidents)	39.000 $\pm$ 8.500	124.400 $\pm$ 21.400	120.500 $\pm$ 21.300	252.000 $\pm$ 31.200
Parking accidents	14.500 $\pm$ 7.350	39.200 $\pm$ 12.100	68.700 $\pm$ 16.000	110.100 $\pm$ 20.200
Total	65.950 $\pm$ 12.200	178.900 $\pm$ 25.100	196.900 $\pm$ 26.700	387.600 $\pm$ 37.600

As is seen from Table 2, the estimated total number of road traffic accidents which occurred in Sweden in 1964 was 388.000, including 110.000 parking accidents. This total should be compared with about 59.000 accidents, i.e. the figure based on that number of accidents notified to the police which is stated in the official statistics for the same year. It is to be noted that the accidents which involved fatalities and severe personal injury were not included in the last-mentioned figure, since it is obvious that the numbers

of such accidents cannot be estimated in an investigation of this type.

The total number comprises about 66.000 accidents notified to the police, about 180.000 accidents notified to insurance companies, and about 200.000 accidents which have not been notified either to the police or to insurance companies. Some accidents have been counted twice in the first-mentioned two groups.

The estimated number of accidents involving personal injury was 26.000, and the number of accidents involving property damage, exclusive of parking accidents, was estimated at 252.000.

As was to be expected, the frequency of accidents notified to the police in the group of personal-injury accidents was to a marked degree significantly higher than in the group of property-damage accidents (45 and 15 per cent, respectively). Only a good one sixth of the total number of accidents involving property damage, exclusive of parking accidents, have been reported to the police.

As was likewise to be expected, the frequency of personal-injury accidents in the group of accidents notified to the police was significantly higher than in the group of accidents notified to insurance companies. Table 2 shows that about half of the total number of accidents have not been notified at all.

Fig. 2 represents the frequencies of personal-injury and property-damage accidents which have been notified to the police, notified to insurance companies, and not notified.

The accidents in rural areas totalled about 134.000 (35 per cent), and those in urban areas amounted to 254.000 (65 per cent), including 97.000 parking accidents. Neither the respective percentages of accidents notified to the police in rural areas and in urban areas, nor those of accidents notified to insurance companies, differ significantly from the percentages of the total number of accidents in these areas.

The quality of the above estimates can be checked in two respects.

In the first place, the number of accidents notified to the police, as stated in the official statistics, is compared in Fig. 3 with the corresponding number estimated on the basis of the interview investigation. Parking accidents have not been included. This graph shows that the number of accidents reported by the police to the Swedish Central Bureau of Statistics is in all accident groups closely in agreement with the corresponding estimated number obtained from the present investigation.

In the second place, the number of cases of damage caused by motor traffic accidents and notified to insurance companies has also been estimated in order to be used as a check for a comparison with the statistics issued by the Swedish Association of Traffic Insurance Companies. The number of cases of damage notified to insurance companies has been estimated at 310.000, while the corresponding number given in the statistics was 320.000. Thus, the agreement was very close in this instance too.

6. COMPARISONS WITH OFFICIAL ACCIDENT STATISTICS

In Fig. 4, the respective numbers of personal-injury accidents and property-damage accidents in rural areas and urban areas have been brought into relation with the corresponding numbers taken from the official accident statistics. If the respective numbers were equal, then their ratios would be equal to unity.

The estimated total number of personal-injury accidents was significantly higher than the corresponding number recorded by the Central Bureau of Statistics. This result may be regarded as remarkable. The number of personal-injury accidents which have not been notified to the police was as high as 13.000 ± 4.900 . At a level of significance of 5 per cent, at least 8.900 personal-injury accidents were not notified to the police, and at a level of significance of 10 per cent, the corresponding number was at least 9.800. These figures indicate that the statistics of personal-injury accidents collected by the Central Bureau of Statistics exhibit a deficiency, which amounted to about 50 per cent of the official figures at a level of significance of 10 per cent. On account of the relatively large confidence intervals which are obtained when the accidents are distributed between rural areas and urban areas, a significant difference between the estimated and official numbers of personal-injury accidents was to be noted only in rural areas, but not in urban areas.

For the property-damage accidents, the ratio of the estimated number to that given in the official statistics is of course definitely not equal to unity in rural areas as well as in urban areas. A comparison between rural and urban areas has not shown any significant differences in the values of this ratio either for the accidents which involved personal-injury or for those which caused property damage.

The number of accidents has furthermore been estimated with respect to type of accident. For practical reasons which had to do with the interviews, this estimation had to be confined to the types of the traffic elements involved in the accidents. It was not considered to be possible to ask the interviewees whether the accidents had occurred in connection with opposite-direction-vehicles, overtaking and passing, etc. Fig. 5 shows the percentages of single-element accidents in the personal-injury and property-damage accident groups in rural areas. Parking accidents have not been included.

The single-element accidents comprise motor-car and motor-cycle accidents. As is seen from this graph, the percentages of single-element accidents estimated on the basis of the interview investigation were significantly higher than the corresponding figures given in the official statistics. This statement applies to both personal-injury and property-damage accidents. Fig. 5 shows that the percentage of single-element accidents in rural areas estimated with the help of the interview investigation was about twice as high as that which is stated in the official statistics.

In other words, the fact that the official statistics are limited to the accidents which have been notified to the police distorts the true relation between single-element and multi-element accidents.

7. BREAKDOWN OF ACCIDENT FREQUENCY BY DRIVER'S AGE

The data collected by means of interviews covered, among other things, the ages of the interviewees, their driving licences, and the kilometrages travelled in 1964. As estimated breakdown of the accident frequency by driver's age is represented in Fig. 6. These estimates were based on the data concerning nearly 3.000 selected persons who were comprised among the interviewees. This material permits a classification in only two age groups, viz., first, younger than 25, and second, 25 and older.

In all kilometrage classes, the number of motor-car accidents per holder of driving licence in the lower age group was significantly greater than in the higher age group.

These results indicate that young drivers can be exposed to a greater risk of accidents than older ones. However, from these results, we cannot directly draw the conclusion that the above-mentioned differences can be attributed to age. It is also necessary to take into account a large number of other contributing factors. For instance, we cannot exclude the possibility that these differences can largely be ascribed to dissimilarities in driving experience.

8. NUMBER OF RECIPIENTS OF SICKNESS BENEFITS CONNECTED WITH ACCIDENTS

One of the objects of the interview investigation was to afford an empirical basis for estimating the socio-economic costs of accidents. For this purpose it was necessary to know, among other things, the number of persons who had received sickness benefits in connection with accidents and the duration of the sickness benefit period.

The persons who stated that they had applied for medical treatment after an accident have also been asked whether they had received any sickness benefits and what was the duration of the benefit period. In this way, it was possible to segregate the cases of more or less severe personal injury. Since the interview investigation was carried out end of March and early in April, 1965 the probability of interviewing persons who had been hospitalised for more than three months was dependent on the time when the accident had occurred. Consequently, it was primarily the number of days of sickness, and then also the number of recipients of sickness benefits, that have been underestimated in this investigation. The number of persons who had received sickness benefits was 20.300 ± 5.100 .

As it may be suspected that the level of severity of those personal-injury accidents which are not notified to the police is lower than that of the accidents of this type which are reported to the police, a comparison was made between these levels of severity. Among the 20.300 injured persons who had received sickness benefits, 7.800 had been involved in accidents which have not been notified to the police. The number of recipients of sickness benefits was 1.0 per personal-injury accident notified to the police, and 0.6 per personal-injury accident not notified to the police. However, as a consequence of large confidence intervals due to the small size of the sample, this difference is not significant.

9. COSTS OF REPAIRS AND DAMAGES

In order to calculate the costs of accidents, it was also required to have information about the costs of repairs. The interviewees have therefore been asked to state the costs of repairs of their own motor-cars in connection with accidents, as well as the other direct costs which they had incurred on account of damage caused to the property of other persons, e.g. fences, clothes, etc.

Table 3 gives the costs of repairs and damages associated with the accidents notified to the police, notified to insurance companies, and not notified, in rural areas and in urban areas. The cost figures in what follows are dollar equivalents of Swedish kronor.

Table 3. Costs of repairs and damages (million dollars) associated with accidents in rural areas and urban areas.

Type of notification	Non-parking accidents			Parking accidents	Total number of accidents
	Rural areas	Urban areas	Sweden, total		
Accidents notified to the police	26 _{+ 9}	16 ₊₅	42 ₊₁₁	2 ₊₁	46 ₊₁₁
Accidents notified to insurance companies	41 ₊₁₁	36 ₊₅	78 ₊₁₂	5 ₊₁	83 ₊₁₂
Not notified accidents	2 _{+ 1}	2 ₊₁	5 _{+ 2}	2 ₊₁	7 _{+ 2}
Total cost	48 ₊₁₂	46 ₊₉	94 ₊₁₅	7 ₊₂	101 ₊₁₅

The total cost of repairs and damages amounted to about 100 _{+ 15} million dollars. For the accidents notified to the police, these costs were signi-

ificantly lower than those for the accidents notified to insurance companies.

According to the calculations made by the National Swedish Private Insurance Inspectorate, the damages relating to accidents which have been paid by insurance companies in 1964 totalled about 80 million dollars. A comparison with the estimated total cost of repairs and damages for the accidents notified to insurance companies, i.e. 82 million dollars, shows that the agreement was very close.

The costs of repairs and damages per accident in rural areas and urban areas are given in Table 4. The estimated average cost per accident was 400 dollars for accidents in rural areas, and 300 dollars for non-parking accidents in urban areas. The difference between these values is not significant.

Table 4. Costs of repairs and damages (dollars) per accident for accidents in rural areas and urban areas.

Type of notification	Non-parking accidents			Parking accidents
	Rural areas	Urban areas	Sweden, total	
Accidents notified to the police	1100 $\pm$ 400	600 $\pm$ 200	800 $\pm$ 200	110 $\pm$ 10
Accidents notified to insurance companies	800 $\pm$ 200	400 $\pm$ 60	600 $\pm$ 80	130 $\pm$ 40
Not notified accidents	40 $\pm$ 20	40 $\pm$ 15	40 $\pm$ 10	30 $\pm$ 10
Total cost	400 $\pm$ 100	300 $\pm$ 60	330 $\pm$ 50	70 $\pm$ 15

The data collected for this investigation showed that the single-element accidents in rural areas entailed a total cost of 20 $\pm$ 7 million dollars. The cost per single-car accident was 250 $\pm$ 50 dollars, while the cost per

two-car accident was 700 ± 150 dollars. A comparison between the costs per two-car accident for accidents in rural areas and urban areas indicates that the former were significantly higher than the latter.

Fig. 7 shows the relation between the percentage of notified accidents and the cost of repairs per accident. This cost is represented in a logarithmic scale. The percentage of accidents notified to insurance companies increased continuously as the cost of repairs became higher. When this cost exceeded 200 dollars, practically 100 per cent of the accidents were notified. The frequency of accidents notified to the police was on the whole unchanged so long as the cost of repairs was lower than 100 dollars. As the cost became higher than this value, the percentage of notified accidents increased, and finally became constant at about 50 per cent when the cost of repairs exceeded 400 dollars. It is to be regarded as remarkable that the percentage of accidents notified to the police should have been so low for accidents which were relatively severe in respect of cost.

Furthermore, it is seen from Fig. 7 that the percentage of accidents which have not been notified at all was highest when the cost of repairs was low, and that this percentage gradually decreased as the cost became higher. The primary data indicated that the costs of repairs per accident for non-notified accidents were in general lower than 150 dollars.

Figure 1. Motor traffic accidents notified to the police, cases of damage in motor traffic notified to insurance companies, and motor vehicles registered in Sweden during the period from 1954 to 1963. The respective numbers in 1954 were put equal to 100.

Figure 2. Frequencies of personal-injury accidents resp property-damage accidents notified to the police, notified to insurance companies and not notified. The dash lines represent 95 per cent confidence intervals.

Figure 3. Comparison between the number of accidents reported by the police to the Swedish Central Bureau of Statistics and the number of accidents notified to the police, as estimated on the basis of the interview investigation. CBS = Central Bureau of Statistics. Int = Interview investigation. The dash lines represent 95 per cent confidence intervals.

Figure 4. Ratios of the respective numbers of personal-injury accidents and property-damage accidents in rural areas and urban areas estimated on the basis of the interview investigation (Int) to those recorded by the Central Bureau of Statistics (CBS). The dash lines represent 95 per cent confidence intervals.

Figure 5. Comparison between the percentages of single-element accidents among personal-injury accidents and property-damage accidents in rural areas, as recorded by Central Bureau of Statistics (CBS), and those estimated on the basis of the interview investigation (Int). The dash lines represent 95 per cent confidence intervals.

Figure 6. Breakdown of the ratio of the number of motor-car accidents to the number of driving licence holders by driver's age and by annual kilometrage. The dash lines represent 95 per cent confidence intervals.

Figure 7. Relation between the percentage of notified accidents and the cost of repairs per accident. The cost is represented on a logarithmic scale.