DILAX

Quality of
DILAX People Counting Systems

Autor: AFI, PSC, TDE
Version 1.0 vom 27.03.2012

DILAX Intelcom GmbH
Alt-Moabit 96b
10559 Berlin/Germany

Phone: +49 30 773 092 40
Fax: +49 30 773 092 50

E-mail: info@dilax.com
Internet: www.dilax.com

Contents

Version history

Version	Change	Author	Checked	Released	Valid from
0.1	Draft	PSC	UHI, WKL, TDE, TKI, JMA		
0.1.1	Adjustments following first review	PSC	TDE		
2.2	Completion	PSC	ZDE, AFI		
0.3	Changes following review	PSC	TDE, AFI		
0.4	Further changes and additions	PSC	WKL, TDE, AFI		
0.5	Further changes and additions	PSC			
0.6	Changes and corrections	TDE	AFI, JMA, UHI, TKI		
7.7	General revision	AFI	PSC		
0.8	Changes and corrections	PSC	JMA		
0.9	Changes and corrections	AFI	PSC		
0.9.1	Review and changes	AOK	PSC		
1.0	Changes after review by subsidiaries and creation of final version1.0	PSC	AFI, TDE, WKL, JMA	IMA	26-03-2012

1 Introduction

This document provides general guidelines for clients and customers of the DILAX group of companies (DILAX) as well as potential customers and users who are already using automatic people counting (APC) systems. It is also intended to be used as the basis for decision-making and as orientation, the basis of quality audits as well as purely as a source of information.

This document begins with the general market expectations, explains the precise meaning of the DILAX quality statement and shows how this can be statistically verified with the help of comparative counts[1]. Some additional illustrative examples are provided.

The document ends with a summary and suggested further reading.

2 Quality Expectations and Automatic People Counting Systems

The market usually expresses the expected quality of an automatic people counting system as follows:

The automatic people counting system should measure precisely and reliably, and therefore guarantee that the people counting can permanently be deemed to be a controlled operational process.

The accuracy, depending on the provider and customer, is given between 90 and 98 percent. Understanding of the reliability is often unclear. Occasionally statements such as "in nine out of ten cases" are made – or there is no clear quantitative statement at all.

3 The DILAX Quality Statement

For more than two decades, DILAX has been producing highly-accurate systems for automatic people counting. The particular quality of DILAX people counting systems is their reliably high counting accuracy. For DILAX's customers, people counting is therefore a controlled operational process.

In mathematical terms, this is expressed by the following statement.

P1. 1.10.4

P1 1.10.8.5

After they have been correctly and professionally installed and set up, DILAX' automatic people counting systems operate with at least 95% accuracy, with a statistical reliability of at least 90%.

The statements made apply to all DILAX people counting systems – not only to passenger counting systems installed for public transit companies, but also to people counting systems inside and outside buildings. Where industry-specific deviations or additions exist, these are identified accordingly.

The three aspects of the quality statement, i.e. "properly installed and set up", "accuracy" and "statistical reliability" are considered more closely in the following.

[1] Both the quality statement and its verification is based on the requirements of the Association of German Transport Companies ("Verband deutscher Verkehrsunternehmen" – VDV - VDV Leaflet 457, Part B, Chapter 1: *"Comparative counting is to be planned according to the principles of the sampling theory, with a statistical certainty of at least **90%** and a maximum sampling error of **5%**."* Verification of the count accuracy requires an adequately large sample size.

4 Correct Installation and Setup

In order to achieve the expected measuring accuracy of the DILAX people counting system, the system is correctly installed and set up. Experienced DILAX employees analyze the installed counting system, configure it to the customer's specific situation and randomly test the correctness of the measurements.

This involves, for example, optimizing the sensor settings, testing the counting lines and if necessary readjusting them and determining the quality of the counting system on the basis of long-term observations.

The objective is to detect any systematic and random negative effects[2] on measuring accuracy and reliability and to largely eliminate them.

Systematic effects occur regularly and unilaterally affect the measurements, and are mainly responsible for the measuring accuracy.

The following procedures are recommended to avoid systematic effects:

- correct installation of the overall system with all its add-on components
- provision of all the necessary signals (public transit applications)
- precise configuration of the counting system
- testing and, if applicable, performing a functional check after changing the overall system (repairs, new or re-installation, configuration changes)

Random effects occur sporadically and affect the measurements in different ways and to varying extents, and are mainly responsible for the variance (scatter) in the measured values.

5 Quality Verification by Means of Comparative Counts

The purpose of a comparative count is to statistically verify the DILAX quality statement.

In contrast, there are randomly taken measurements, which do not provide any statistical proof, but can give an assessment of the quality.

In both cases, a certain number of measurements are taken. People are counted in both directions (in/out, boarding/alighting). With the statistical accuracy verification, which we consider later, the reference values acquired are related to the measured values of the automatic counting system and the total deviation[3] is determined for each measurement and the arithmetical mean value μ[4] of all total deviations is determined for all measurements.

[2] See DIN 1319-1:1995, Chap. 2, section 3.5 Measurement error

[3] Total deviation = (APC in - Reference in + APC out - Reference out) / (Reference in + Reference out)

[4] $\mu = \frac{1}{n}\sum_{i=1}^{n} x_i$, where x_i is the total deviation of the i th measurement.

5.1 Accuracy

The accuracy of a measuring system is the degree by which the measured value and the correct value correspond. The correct value is usually unknown and is approximated using reference values.[5]

After professional installation and setup, DILAX people counting systems have a maximum deviation of 5%. This applies in most cases, but not in all, which is expressed by the reference to the statistical reliability.

5.2 Statistical Reliability

The statement that the statistical reliability is at least 90% is occasionally misunderstood to mean that only ten comparative measurements have to be taken and a satisfactory result has been achieved if only one of these measurements has a deviation greater than 5%. Such a test is legitimate, but is not a statistical verification.

Before we discuss the quality verification, we will briefly digress into statistics. Correctly installed and set up people counting systems can be described in statistical terms with the help of the normal distribution.

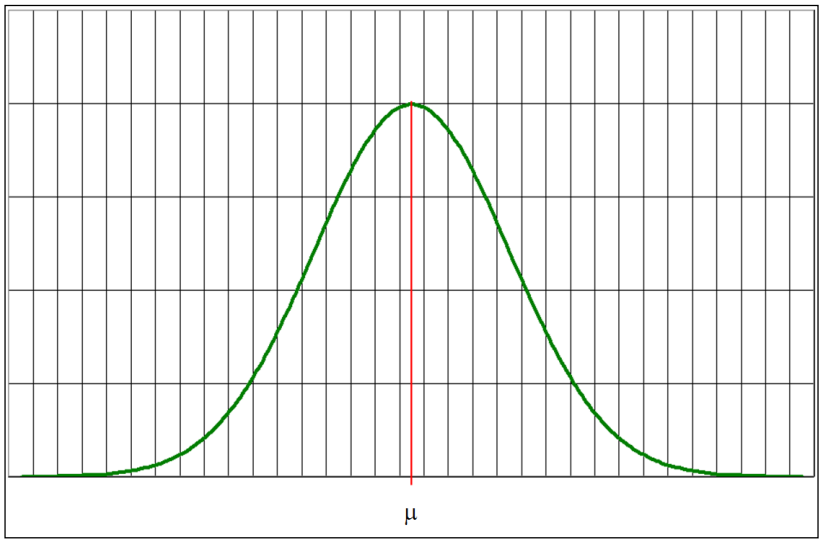

Figure 1: Uniform deviations from the mean value μ with reducing frequency are characteristic for a normal distribution

As shown in the graph, the deviations from the mean value μ are uniformly distributed on both sides with longer observation. The higher the deviation, the more seldom it occurs. Mathematically speaking, the likelihood or probability of occurrence is given by the area under the curve. Therefore, a larger deviation in one direction or the other is very improbable; however, it can occur at any time and is therefore also possible in a comparative count.

[5] See definition in EN 60051 and EN55 350-13 Abs. 2.1

In a normally distributed process, apart from the mean deviation μ, the standard deviation σ [6] is also an important measurement of the scatter. Only if both μ and σ are low, can a counting system be said to be reliably accurate. We will not show the explicit solution of the integral here and instead have taken the following result from the relevant mathematical text books, such as 8.

In a normal distribution, there is a 90% probability that the values lie within the range:

$$[\mu - 1{,}645*\sigma;\ \mu + 1{,}645*\sigma]$$

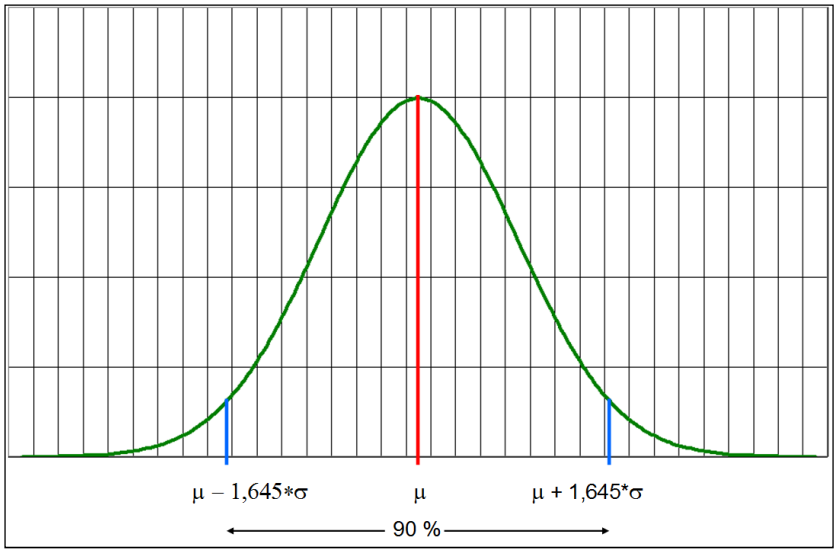

Figure 2: In a normally distributed process, the probability of occurrence depends on the standard deviation σ.

If we want to statistically prove that the installed DILAX people counting system has the reliable accuracy given above, we must prove that the following upper and lower limit values apply:

Lower limit: $\mu - 1{,}645*\sigma > -5\%$

Upper limit: $\mu + 1{,}645*\sigma < +5\%$

When determining the mean total deviation μ and the standard deviation σ with the help of comparative counts, the principles of the sampling theory must be observed.

[6] $\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \mu)^2}$, where x_i is the total deviation of the i th measurement.

5.3 Sample size

5.3.1 Sample size in general

It is understandable that the sample size, i.e. the number of comparative measurements, depends on the scatter of the person counting system to be checked and therefore on the standard deviation σ: the more the values are scattered around the reference value the more samples are required.

From [01], we take the generally applicable guideline from sampling theory:

If the accuracy to be verified is 95% then the sample size n:

$$n >= 4 * (100*\sigma)^2$$

From the previous chapter, if there is no total deviation ($\mu = 0\%$), the maximum allowable value for the standard deviation σ is 3.04%[7], with which the statistical verification can be performed. In this case the sample size is at least 37[8].

If $\mu = 0.5\%$, σ may not exceed 2.735%[9]. In this case the sample size is at least 30[10].

As, in general, at the start of a comparative measurement neither the mean total deviation μ nor the standard deviation σ are known, at least 30 samples must be used.

Therefore, only after taking the comparative measurements is it possible to determine whether an adequate number of samples were taken or not.

[7] Inserting this in $\mu + 1{,}645*\sigma < + 5\%$ gives $\mu = 0\%$: $1.645*\sigma < + 5\%$ and consequently $\sigma < 3.04\%$

[8] Inserting this in $n >= 4 * (100*\sigma)^2$ gives $\sigma = 3.04\%$: $n >= 4 * (3.04)^2 = 37$

[9] Inserting this in $\mu + 1{,}645*\sigma < + 5\%$ gives $\mu = 0.5\%$: $1.645*\sigma < + 4.5\%$ and consequently $\sigma < 2.735\%$

[10] Inserting this in $n >= 4 * (100*\sigma)^2$ gives $\sigma = 2.735\%$: $n >= 4 * (2.735)^2 = 30$

5.3.2 Sample size within local public transport

Especially for local public transit sector, the following formula can be used for calculating of sample size *n*:

$$n = \frac{k^2 * V^2 * N}{k^2 * V^2 + (N-1) * d_r^2}$$

n - sample size (number of trips / tours) during the survey period
V - relative scatter (quotient scatter / mean value)[11]
d_r - max. allowable relative sample deviation [12]
k - table value (depending on the required statistical certainty (confidence level)[13]
N - number of trips / tours during the survey period (population)

If the specific values are set according to the DILAX quality statement, the result is

$$n = \frac{1{,}645^2 * 1{,}5^2 * N}{1{,}645^2 * 1{,}5^2 + (N-1) * 0{,}04^2}$$

The required sample size can be reduced accordingly, for example, by taking a separate measurement for each vehicle door: n can be divided through the count of vehicle doors. The sample design must always be taken into account.

N	n (1 door)	n/2 (doors)	n/3 (doors)	n/4 (doors)	n/6 (doors)	n/8 (doors)
10000	2757	1379	919	689	460	345
5000	2161	1081	720	540	360	270
2500	1509	755	503	377	252	189
1200	912	456	304	228	152	114
1000	792	396	264	198	132	99
800	661	331	220	165	110	83
600	518	259	173	130	86	65
400	362	181	121	91	60	45
200	190	95	63	48	32	24
100	97	49	32	24	16	12
50	49	25	16	12	8	6
25	25	13	8	6	4	3

Figure 3: Required sample sizes depending on the number of vehicle doors

[11] In local public transport V = 150% = 1.5 can be used as planning variable.

[12] An accuracy of 95% implies a maximum total deviation, which is made up of a maximum sample deviation of 4% and measuring errors of max. 1%.

[13] k = 1.645

5.4 Size-proportional sample design

With each measurement, various scenarios occur with differing frequency: individual persons, couples, groups, strollers, children playing in the counting area, luggage, etc. For the comparative measurements to be representative, the individual samples must therefore designed proportional to their size.

In the local public transit sector, from a sampling theory point of view, it can therefore be assumed that representative measurements can be taken in the number of persons in each counting direction (in/out) is at least 1,000.

In buildings such as shops, shopping centers and airports, the number of possible event types is higher, so that from a sampling theory point of view, 1,000 – 2,000 persons per measurement and counting direction (in/out) are assumed.

If the individual measurement is too small, random deviations have a particularly large effect because the measured values are always integers. For example, a dog travelling with a passenger is incorrectly interpreted as being a passenger. If there are 1000 people in the sample, the dog only accounts for 0.1%. However, if the measurement only includes 100 people, the value rises to 1%, which is not usually the proportion of dogs in relation to the total number of passengers.

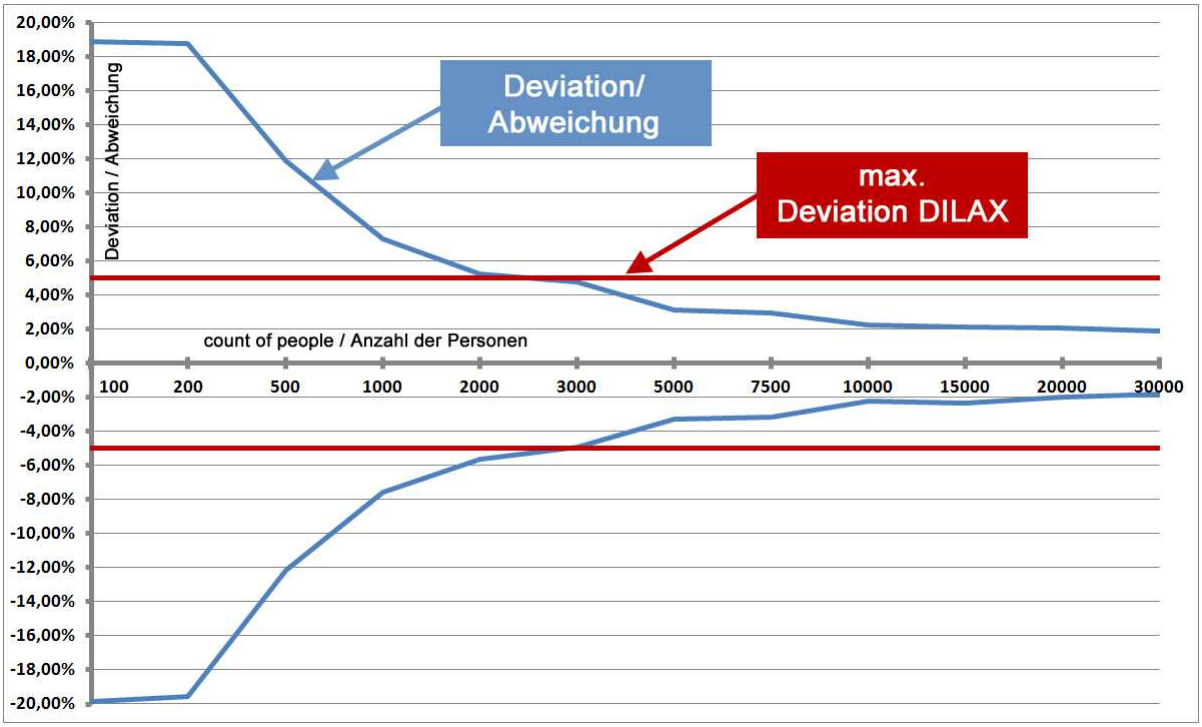

Figure 3: Graph showing the dependence of the percentage deviation on the number of counted objects)

5.5 Quality Requirements and Comparative Counts[14]

Just like with an automatic people counting system, both random and systematic effects can affect the results of the comparative measurement. It is also possible for the results of different teams[15] to differ from each other by so much that it is no longer possible to unequivocally state which result best reflects reality.

If the comparative count is not at least 98.5% correct, it can no longer be used and may not be incorporated in the overall consideration.

A further reason for the unsuitability of a measurement can be that despite careful sample design, such extraordinary occurrences happen during the comparative count that the sample taken can no longer be classified as being representative.

In the case of the automatic people counting system, faults can occur during the comparative measurement for which nobody is to blame and which permanently reduce the quality. For example, a technical fault in the APC system can occur during a comparative measurement in a vehicle due to a defective door signal.

Finally, it is necessary to clarify in advance how particular objects are to be handled:

- Strollers, suitcases, luggage trolleys and other bulky objects
  - In general, these objects should not be counted.
- Umbrellas, placards and other visual obstructions
  - Visual obstructions can prevent a reliable measurement, both by the automatic people counting system and by the comparative count.

The precise criteria for the exclusion of comparative counts must be defined in advance in close consultation between customers and DILAX. Otherwise there is a risk that the results acquired cannot be used and the statistical quality verification of the APC system cannot be provided.

Therefore, as it is possible that not all the measurements can be used for the evaluation, a few measurements more than required should always be taken.

[14] See also VDV leaflet 457, chapter 2.10

[15] Later in the text it is shown that it is essential to measure with several teams in parallel.

5.6 Comparative Counting Methods

In each comparative count, the count values of the automatic people count are compared to count values determined through other means. These, as mentioned above, also have a certain inaccuracy. Therefore, this should be taken into account when choosing the comparative count method and the selection should set the same quality standards for the method.

In the following, the two most important methods are explained with their advantages and disadvantages.

5.6.1 Manual in-situ counting

In a manual in-situ count, selected people count the visitors manually on site. In this case, it should be ensured that

- two or more teams measure the same area (boarding and alighting areas)
- each measuring person (counter) only measures one walking direction at one door
- the results per direction are checked for plausibility[16] and, if necessary, their average used
- another person controls and documents the team's measurement
- the measuring lines (boarding and alighting) are clearly identifiable
- the measuring personnel themselves do not cross the measuring lines
- the measuring personnel does not disrupt normal operations
- each person measures for a maximum period of 30 minutes[17] (people tire very quickly)
- all the watches of the counters are synchronized with the automatic people counting system's time
- fully functioning and tested hand-held counters are used
- all measuring people have been adequately instructed

5.6.1.1 Advantages and disadvantages

Advantages	Disadvantages
+ Tried,tested and accepted method + Multiple counts (two or more teams) provide mostly adequately precise reference values + The more teams there are that measure the same area, the better the quality of the comparative count can be assessed.	- People tire very quickly - No subsequent check possible - Risk of individual areas having an obstructed view - Risk of influencing the customers' behaviour - Measuring lines must be directly marked

[16] If possible, the occupancy per unit of time should also be measured and these values should be used later in the assessment.

[17] In the passenger control in airports, the security officers are relieved after only 20 minutes.

5.6.2 Manual video evaluation

In a manual video evaluation, selected people count the visitors using previously recorded videos. These control videos are usually recorded by the site's video surveillance system. In this case, it must be ensured that

- all relevant areas are visible on the control videos
- the measuring lines (in and out) are clearly identifiable for the persons evaluating the control videos
- the time of the control video recordings are clearly identifiable
- all clocks are synchronized
- two or more teams evaluate the control videos
- each counter only measures one walking direction at one door
- the results per direction are averaged
- overlapping areas in the control videos are taken into account and duplicate counts are calculated and removed accordingly

5.6.2.1 Advantages and disadvantages

Advantages	Disadvantages
+ Tried, tested and accepted method + Multiple counts (two or more teams) provide mostly adequately precise reference values + The more teams there are that measure the same area, the better the quality of the comparative count can be assessed. + Subsequent checking possible + Low risk of influencing customers + Measuring lines can also be marked on freeze frames	- People tire very quickly - Complete video surveillance must be available - Risk of individual areas having an obstructed view - Recording and evaluation are often regulated by data protection provisions

6 Examples

The following examples are purely fictional and are only used for the purpose of illustration.

6.1 Scenarios for Quality Verification in Public Transit and Retail Sectors

Local public transit scenario:

A bus company makes 100 trips within the survey period (N=100). The comparative counts are to be taken in 3-door buses. From the table in chapter 5.3.2 implies a sample size of n = 97. If a measurement team counts the people at each door the sample size can reduced to n = 32. 10% additional counts are planned, so that in total 35 comparative counts are taken.

Retail scenario:

A shop with one entrance door is equipped with a DILAX people counting system. Following careful installation and setup, the quality is to be verified statistically, by filming the entrance area with a video camera and then counting the people in the videos.

Around 500 people per hour enter the shop, so that two hours are set for each comparative count. 35 measurements are taken, so that in total, 70 hours of video, divided into 5 minute segments, are evaluated by two teams. If there are large deviations between the team results, the time segments are counted again. 10% of all time segments are then randomly selected and checked again.

6.2 Evaluation of the Comparative Counts

In the following we assume that three measurements in both scenarios have to be discarded. (due to implausible results). The following table is used as an example for both scenarios. The analysis shows that the deviation of +3.18% and - 2.28% is within the tolerance range of ± 5% and -5%.

No.	Reference		APC		deviation	evaluation	
	In	Out	In	Out			
1	1003	1009	1006	1014	0,40%	Mittelwert:	0,45%
2	1038	1046	1021	1031	-1,54%	Standard-	
3	1072	1048	1020	1096	-0,19%	abweichung:	1,66%
4	988	993	977	1003	-0,05%		
5	997	1012	995	1010	-0,20%	**$\mu + 1{,}645*\sigma$ =**	**3,18% < + 5%**
6	1011	986	1001	993	-0,15%		
7	982	993	972	1021	0,91%	**$\mu - 1{,}645*\sigma$ =**	**-2,28% > - 5%**
8	996	1033	982	997	-2,46%		
9	1043	988	1021	1002	-0,39%		
10	1010	1000	1007	999	-0,20%		
11	976	957	989	962	0,93%		
12	986	1004	984	1008	0,10%		
13	1005	1038	1035	1021	0,64%		
14	949	989	1006	1012	4,13%		
15	1004	1017	1018	1025	1,09%		
16	1070	1021	1078	1017	0,19%		
17	1024	1005	1048	1021	1,97%		
18	1033	995	1020	1002	-0,30%		
19	1006	1035	982	1056	-0,15%		
20	994	1000	976	1008	-0,50%		
21	1032	1021	1024	1038	0,44%		
22	1032	1065	1021	1088	0,57%		
23	987	976	997	996	1,53%		
24	1029	1038	1013	1045	-0,44%		
25	1022	1041	1049	1067	2,57%		
26	985	1017	996	1004	-0,10%		
27	993	1030	1007	1018	0,10%		
28	947	978	993	988	2,91%		
29	996	957	1008	1001	2,87%		
30	985	996	963	968	-2,52%		
31	1047	1034	1100	1075	4,52%		
32	1007	995	980	977	-2,25%		

Figure 5: Data analysis and calculation of the deviations

The DILAX people counting system installed therefore completely fulfils the quality requirements set.

7 Summary

The outstanding feature of the DILAX automatic person counting systems is their reliably high counting accuracy.

After they have been correctly installed and set up, DILAX' automatic people counting systems operate with at least 95% accuracy, with a statistical reliability of at least 90%.

For our customers, this means that they use a people counting system, which continuously operates very accurately and reflects reality as well as is possible. The measurement results deviate rarely and only moderately from the correct values. The people counting is therefore a controlled operational process.

The DILAX employees set the system up correctly and professionally, in order to achieve the best possible results for the customers. No matter whether hardware, software, implementation or service: Each system module must successfully pass through the strict, IRIS certified DILAX quality process before it is released for the market.

DILAX will be pleased to assist you in taking adequate comparative counts.

8 References

[01] Caputo, Fahrmeir, Künstler, Lang, Pigeot, Tutz: Arbeitsbuch Statistik, Springer-Verlag, 2009

[02] Kauermann, Küchenhoff: Stichproben, Springer-Verlag, 2011