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APPLICATION NOTE

Validating a DynaPCN Installation

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Technical assistance

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Revision history

Revision	Description	Date
1-1	First release	13 January 2010
2-0	Updated document layout	12 October 2011
2-1	Removed chapter "DynaPCN Characterization" Complete document update	14 May 2012
2-3	Updated 4th cover	20 October 2013
2-4	Updated paragraph "Product overview"	21 June 2016
3-0	Complete document review	1 March 2018
3-1	Corrected errors Inserted section "Rapid and worthwhile measurement of Accuracy"	21 March 2018

Contents

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1 Scope of this document

Eurotech DynaPCN people and passengers counters are compact and autonomous devices based on stereoscopic vision technology.

They are designed for passenger counting above the doorways of buses and rolling stocks, as well as to count people as they enter or leave buildings or any area with restricted access.

Figure 1. The Eurotech DynaPCN

This document outlines the steps to validate the accuracy of DynaPCN installations on transport vehicles.

Refer to the product documentation[1] for details about the DynaPCN technology and how it operates.

When correctly installed, configured and operated, the DynaPCN can provide a real life operating **Accuracy** of 98% (refer to $A_B^{tot,S}\%$ and $A_B^{tot,S,D}\%$ definitions).

[1] DynaPCN User Manual and related Application Notes and Technical Datasheets are downloadable from the Eurotech website (http://www.eurotech.com/en/products/devices/people+passenger+counters). They contain important product information and details which you should carefully check before using the product.
Anyhow, Eurotech Technical Support Team (https://support.eurotech.com) is always available for further information and support.

2 Validate the accuracy of a DynaPCN installation

The installation of the DynaPCN shall follow the recommendations defined in the User Manual.

Depending on the installation, the DynaPCN parameters shall be tuned with the dedicated SW tools (WinClient).

Due to the characteristics of the statistical variables associated to people counting systems, e.g. shapes of traffic, height of persons, speed, ambient lights, …, the accuracy of DynaPCN counting systems must be validated across a representative sample of population and people traffic situations.

This document defines the reference variables and methods to define and evaluate the accuracy/error of DynaPCN systems.

The counts made by the DynaPCN automatically are defined as **measured**.

The manual counts are defined as **real**.

The comparison, by the definitions and formulas on the following sections, between measured and real counts, gives the Errors of a counting system.

The Accuracy (percentage) is defined as 100 - Error (percentage).

The **measured** counts can be automatically collected by a gateway/master system connected to the DynaPCN (RS485, Ethernet, USB).

The **real** counts should be collected by visual inspection of gates/doors.

A representative statistical population should be composed of at least 1000 real passages, under various real people traffic shapes.

3 Variables definition

- $C_i^{in,m}$ Measured count of incoming people, at stop i (all doors)
- $C_i^{in,r}$ Real count of incoming people, at stop i (all doors)
- $C_i^{out,m}$ Measured count of outgoing people, at stop i (all doors)
- $C_i^{out,r}$ Real count of outgoing people, at stop i (all doors)

- $C_{i,j}^{in,m}$ Measured count of incoming people, at stop i and at door j
- $C_{i,j}^{in,r}$ Real count of incoming people, at stop i and at door j
- $C_{i,j}^{out,m}$ Measured count of outgoing people, at stop i and at door j
- $C_{i,j}^{out,r}$ Real count of outgoing people, at stop i and at door j

- $C_P^{in,m}$ Measured count of incoming people, all period[2] (all doors)
- $C_P^{out,m}$ Measured count of outgoing people, all period[2] (all doors)

- S_0 Total number of stops with no people income or outgone
- S_x Total number of stops with at least one people income or outgone
- $S = S_0 + S_x$ Total number of stops

- D Number of doors considered in the installations

- $E_U^{in,S}$ Unbalanced error on incoming people for S stops and one door
- $E_U^{out,S}$ Unbalanced error on outgoing people for S stops and one door
- $E_U^{tot,S}$ Unbalanced total Error (incoming + outgoing) for S stops and one door
- $A_U^{tot,S}$ Unbalanced Accuracy (incoming + outgoing) for S stops and one door

[2] The term **period** means, for example, the entire daily service, where the vehicle leaves and arrives without passengers (for example: a bus leaves the depot without passengers, and arrives to the depot without passengers).

- $E_U^{in,S,D}$ Unbalanced error on incoming people for S stops and all doors
- $E_U^{out,S,D}$ Unbalanced error on outgoing people for S stops and all doors
- $E_U^{tot,S,D}$ Unbalanced total Error (incoming + outgoing) for S stops and all doors
- $A_U^{tot,S,D}$ Unbalanced Accuracy (incoming + outgoing) for S stops and all doors

- $E_B^{in,S}$ Balanced error on incoming people for S stops and one door
- $E_B^{out,S}$ Balanced error on outgoing people for S stops and one door
- $E_B^{tot,S}$ Balanced total Error (incoming + outgoing) for S stops and one door
- $A_B^{tot,S}$ Balanced Accuracy (incoming + outgoing) for S stops and one door

- $E_B^{in,S,D}$ Balanced error on incoming people for S stops and all doors
- $E_B^{out,S,D}$ Balanced error on outgoing people for S stops and all doors
- $E_B^{tot,S,D}$ Balanced total Error (incoming + outgoing) for S stops and all doors
- $A_B^{tot,S,D}$ Balanced Accuracy (incoming + outgoing) for S stops and all doors

- $E_{R,P}^{tot}$ Rapid Error (incoming + outgoing) for all period and all doors
- $A_{R,P}^{tot}$ Rapid Accuracy (incoming + outgoing) for all period and all doors

4 Errors and Accuracy definitions

4.1 Unbalanced Error and Accuracy on one door

This error gives the probability that a measure differs from the real value, without balancing possible statistical fluctuations on in/out measurements.

$$E_U^{in,S} = \frac{1}{S}\left(\sum_i^{S_x}\left(\frac{\left|C_i^{in,m} - C_i^{in,r}\right|}{C_i^{in,r}}\right) + \sum_i^{S_0}\left(\frac{\left|C_i^{in,m}\right|}{\overline{C^{in}}}\right)\right) \quad (1)$$

$$E_U^{out,S} = \frac{1}{S}\left(\sum_i^{S_x}\left(\frac{\left|C_i^{out,m} - C_i^{out,r}\right|}{C_i^{out,r}}\right) + \sum_i^{S_0}\left(\frac{\left|C_i^{out,m}\right|}{\overline{C^{out}}}\right)\right) \quad (2)$$

$$\overline{C^{in}} = \frac{1}{S}\sum_i^{S} C_i^{in}$$

$$\overline{C^{out}} = \frac{1}{S}\sum_i^{S} C_i^{out}$$

$$E_U^{tot,S} = \frac{1}{2}\left(E_U^{in,S} + E_U^{out,S}\right)$$

$$E_U^{tot,S}\% = E_U^{tot,S} \cdot 100$$

$$\boldsymbol{A_U^{tot,S}\% = 100 - E_U^{tot,S}\%}$$

4.2 Unbalanced Error and Accuracy on more than one door

When considering the error related to more than one door, (e.g. trains, buses etc.), the formulas (1) and (2) are still valid, but the C_i values must be calculated as follows:

$$C_i^{in,m} = \sum_j^D C_{i,j}^{in,m}$$

$$C_i^{in,r} = \sum_j^D C_{i,j}^{in,r}$$

$$C_i^{out,m} = \sum_j^D C_{i,j}^{out,m}$$

$$C_i^{out,r} = \sum_j^D C_{i,j}^{out,r}$$

Hence:

$$E_U^{in,S,D} = \frac{1}{S}\left(\sum_i^{S_x}\left(\frac{\left|C_i^{in,m} - C_i^{in,r}\right|}{C_i^{in,r}}\right) + \sum_i^{S_0}\left(\frac{\left|C_i^{in,m}\right|}{\overline{C^{in}}}\right)\right)$$

$$E_U^{out,S,D} = \frac{1}{S}\left(\sum_i^{S_x}\left(\frac{\left|C_i^{out,m} - C_i^{out,r}\right|}{C_i^{out,r}}\right) + \sum_i^{S_0}\left(\frac{\left|C_i^{out,m}\right|}{\overline{C^{out}}}\right)\right)$$

Where:

$$\overline{C^{in}} = \frac{1}{S}\sum_i^S C_i^{in}$$

$$\overline{C^{out}} = \frac{1}{S}\sum_i^S C_i^{out}$$

$$E_U^{tot,S,D} = \frac{1}{2}\left(E_U^{in,S,D} + E_U^{out,S,D}\right)$$

$$E_U^{tot,S,D}\% = E_U^{tot,S,D} \cdot 100$$

$$\boldsymbol{A_U^{tot,S,D}}\% = \mathbf{100} - \boldsymbol{E_U^{tot,S,D}}\%$$

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4.3 Balanced Error and Accuracy on one door

This error gives the probability that a measure differs from the real value, balancing possible statistical fluctuations on in/out measurements.

$$E_B^{in,S} = \left(\frac{\left|\sum_i^S C_i^{in,m} - \sum_i^S C_i^{in,r}\right|}{\sum_i^S C_i^{in,r}}\right) \quad (3)$$

$$E_B^{out,S} = \left(\frac{\left|\sum_i^S C_i^{out,m} - \sum_i^S C_i^{out,r}\right|}{\sum_i^S C_i^{out,r}}\right) \quad (4)$$

$$E_B^{tot,S} = \frac{1}{2}\left(E_B^{in,S} + E_B^{out,S}\right)$$

$$E_B^{tot,S}\% = E_B^{tot,S} \cdot 100$$

$$\boldsymbol{A_B^{tot,S}}\% = \boldsymbol{100 - E_B^{tot,S}}\%$$

4.4 Balanced Error and Accuracy on more than one door

When considering the error related to more than one door, (e.g. trains, buses etc.), the formulas (3) and (4) are still valid, but the C_i values must be calculated as follows:

$$C_i^{in,m} = \sum_j^D C_{i,j}^{in,m}$$

$$C_i^{out,m} = \sum_j^D C_{i,j}^{out,m}$$

$$C_i^{in,r} = \sum_j^D C_{i,j}^{in,r}$$

$$C_i^{out,r} = \sum_j^D C_{i,j}^{out,r}$$

Hence:

$$E_B^{in,S,D} = \left(\frac{\left| \sum_i^S C_i^{in,m} - \sum_i^S C_i^{in,r} \right|}{\sum_i^S C_i^{in,r}} \right) \tag{5}$$

$$E_B^{out,S,D} = \left(\frac{\left| \sum_i^S C_i^{out,m} - \sum_i^S C_i^{out,r} \right|}{\sum_i^S C_i^{out,r}} \right) \tag{6}$$

$$E_B^{tot,S,D} = \frac{1}{2}\left(E_B^{in,S,D} + E_B^{out,S,D} \right)$$

$$E_B^{tot,S,D}\% = E_B^{tot,S,D} \cdot 100$$

$$\boldsymbol{A_B^{tot,S,D}}\% = \mathbf{100} - \boldsymbol{E_B^{tot,S,D}}\%$$

4.5 Rapid and worthwhile measurement of Accuracy

This method allows you to evaluate the accuracy of the PCN, only using **measured** counts (i.e. the counts made by the DynaPCN automatically).
It does not require an operator to manually count the real passages.

Consider a period of time, for example the entire daily service, where the vehicle leaves and arrives without passengers (for example: a bus leaves the depot without passengers, and arrives to the depot without passengers).

Sum together all the INs of the period (of all the doors).

Sum together all the OUTs of the period (of all the doors).

The error is given by the ratio of the difference between In's an OUTs, and the sum of the INs and OUTs, according to the following formulas:

$$E_{R,P}^{tot} = \left(\frac{\left| C_P^{in,m} - C_P^{out,m} \right|}{C_P^{in,m} + C_P^{out,m}} \right)$$

$$E_{R,P}^{tot}\% = E_{R,P}^{tot} \cdot 100$$

The accuracy is given by the following formula:

$$\boldsymbol{A_{R,P}^{tot}}\% = \mathbf{100} - \boldsymbol{E_{R,P}^{tot}}\%$$

5 How to Evaluate the Accuracy

The following diagram outlines the procedure to evaluate the accuracy of a vehicle operating PCN device.

This procedure references to one vehicle, but it can be easily extended to more than one vehicle.

The procedure needs:

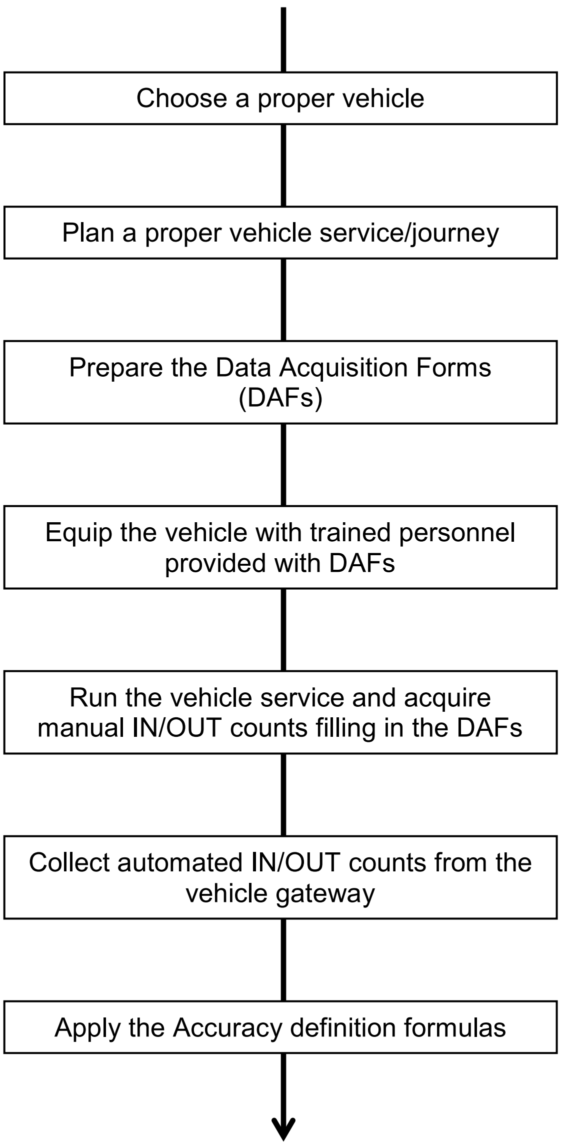
- One or more vehicles equipped with PCNs systems
- Trained personnel to be available at each door

In this procedure are used:

- **Real** collected counts
- **Measured** counts (by the DynaPCN), automatically collected by a gateway.

Prerequisites:

- A vehicle is equipped with one or more PCN devices installed above the doors
- The PCN devices are connected to a bus (Ethernet or RS485) and managed by a gateway
- The gateway is equipped with a proper software that stores the INs and OUTs counts collected from the PCN devices.



5.1 Choose a proper vehicle

A vehicle provided with different door types could be better suited to evaluate the accuracy of a PCN system.

An example could be a bus provided with front, middle and rear doors, with different sizes.

5.2 Plan a proper vehicle service/journey

A vehicle usually performs its service from terminus-to-terminus trips, several times a day.

Given that the accuracy evaluation is a statistical variable, a service that includes a meaningful shape of passenger traffic is necessary. A good service/journey should include a representative traffic of passenger, avoiding both trips that are only poorly populated and trips that are only highly jammed.

5.3 Prepare the Data Acquisition Forms (DAFs)

Each door is assisted by an operator, that records on a form (DAF) the INs and OUTs during the service.

Forms are prepared in order to speed up the recording process.

The going trip can be different from the return one.

Two different DAFs can better cope with going and return trips.

Two examples of DAFs are hereafter, first is for the going trip, the second is for the return trip.

	Vehicle:			
	Date			
	Trip Num:			
	Door:			
	Stop	**Real (manual) Count**		
		IN	**OUT**	**Notes**
1	Cockfosters			
2	Oakwood			
3	Southgate			
4	Arnos Grove			
5	Manor House			
6	Finsbury Park			
7	Arsenal			
8	Holloway Road			
9	Caledonian Road			
10	King's Cross			
11	Russel Square			
12	Holborn			
13	Hickenham			
14	Hillingdon			
15	Uxbridge			
	Total			

Vehicle	
Date	
Trip Num:	
Door:	

	Stop	Real (manual) Count		
		IN	OUT	Notes
1	Uxbridge			
2	Hillingdon			
3	Hickenham			
4	Holborn			
5	Russel Square			
6	King's Cross			
7	Caledonian Road			
8	Holloway Road			
9	Arsenal			
10	Finsbury Park			
11	Manor House			
12	Arnos Grove			
13	Southgate			
14	Oakwood			
15	Cockfosters			
	Total			

5.4 Equip the vehicle with trained personnel provided with DAFs. Run the vehicle service and acquire manual IN/OUT counts filling in the DAFs

The operator must fill in the forms while inspecting the flow of passengers through the doors.

The field “note” should report also the case in which, given a crowded situation, the operator is uncertain of the counts. That stop should be then excluded from the statistics when evaluating the accuracy.

The count reporting at the terminus shall indicate the OUTs at the last stop of a trip.

The count reporting at the terminus shall indicate the INs at the first stop of a trip.

A representative statistical population should be composed of at least 1000 real INs and 1000 real OUTs.

5.5 Collect automated IN/OUT counts from the vehicle gateway

The count collected from the system gateway must be downloaded. The gateway program must have been previously validated to assure the correct reporting of PCN counts.

5.6 Apply the accuracy definition formulas

To evaluate the accuracy, use the formulas (5) and (6), and complete the following procedure:

1. Look at all the DAFs reporting the number of INs and OUTs, similar to the tables above.
2. Sum all the INs and OUTs related to the same doors (INs separately from OUTs).
3. Sum all the counts related to stops (INs separately from OUTs).
4. Apply the formulas (5) and (6).

Example

The following example shows a door that is monitored on the going/return trips of a service.

The first DAF is the going trip, the second DAF is the return trip.

Vehicle	Train 8527
Date	27th Apr 2015
Trip Num:	12
Door:	4/5

	Stop	Real (manual) Count		PCN Count	
		IN	OUT	IN	OUT
1	Cockfosters	16	0	15	0
2	Oakwood	3	8	3	8
3	Southgate	7	7	7	6
4	Arnos Grove	4	2	4	2
5	Manor House	7	0	7	0
6	Finsbury Park	1	3	1	3
7	Arsenal	0	1	1	1
8	Holloway Road	2	8	2	7
9	Caledonian Road	0	4	0	4
10	King's Cross	4	4	4	4
11	Russel Square	0	0	0	0
12	Holborn	8	3	9	3
13	Hickenham	2	3	2	3
14	Hillingdon	4	3	4	3
15	Uxbridge	0	12	0	13
	Total	**58 (A)**	**58 (B)**	**59 (C)**	**57 (D)**

	Vehicle	Train 8527			
	Date	27th Apr 2015			
	Trip Num:	13			
	Door:	4/5			
	Stop	**Real (manual) Count**		**PCN Count**	
		IN	**OUT**	**IN**	**OUT**
1	Uxbridge	13	0	14	0
2	Hillingdon	2	3	2	3
3	Hickenham	8	3	8	3
4	Holborn	3	8	3	9
5	Russel Square	6	0	5	0
6	King's Cross	1	2	1	2
7	Caledonian Road	0	1	1	1
8	Holloway Road	4	1	4	1
9	Arsenal	0	4	0	4
10	Finsbury Park	3	1	3	1
11	Manor House	0	0	0	0
12	Arnos Grove	5	3	5	3
13	Southgate	5	6	5	5
14	Oakwood	3	2	4	2
15	Cockfosters	0	21	0	20
	Total	**53 (E)**	**55 (F)**	**55 (G)**	**54 (H)**

In this case the Error is:

$$E_B^{in,30,1} = \frac{|(A+E)-(C+G)|}{(A+E)} = 0.027$$

$$E_B^{out,30,1} = \frac{|(B+F)-(D+H)|}{(B+F)} = 0.018$$

$$E_{TOT}^{out,30,1} = 0.5\left(E_B^{in,30,1} + E_B^{out,30,1}\right) = 0.023$$

$$E_{TOT}^{out,30,1}\% = 2.3\%$$

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Notes

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