EURODATA COUNCIL

Symbology comparison of

Two-dimensional Symbologies

with focus on EDI messages on transport labels

rev. 2007-10-22

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
global office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

EURODATA COUNCIL

Symbology comparison of

Two-dimensional Symbologies

with focus on EDI messages on transport labels

Symbologies being compared: PDF 417, Aztec, QR, Data Matrix

Summary:

The comparison undertaken below proofs that two-dimensional symbols perform in a comparable manner if the parameters are set to produce comparable results:

- If symbology parameters are set for comparable space consumption, the reading distances become nearly the same for any of the tested codes.
- If symbology parameters are set for same smallest dot size, size of matrix codes gets reasonably smaller than for a stacked PDF 417 but reading distances for the matrix codes gets lower as well.

Additionally the test results show, that different scanning devices perform differently according its optics and decoding software.

In essence, the choice of the 2D symbology does not influence the scanning performance to a major extend if the parameters are set in a comparable manner. Where the symbol parameters enable the basic features the choice of the scanners is decisive for the final performance of an application.

The study below will illustrate the performance of 4 different 2d-dymbols and a variety of different image scanners. Laser scanners have not been considered because laser scanner do not perform for matrix type codes regularly.

Any input for completion and potential update of the study is appreciated.

Contact: Heinrich.Oehlmann@Eurodatacouncil.org

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3

Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

EURODATA COUNCIL

Symbology comparison of

Two-dimensional Symbologies

with focus on EDI messages on transport labels

1 Introduction

Two-dimensional symbols are in use for small data elements but also for carrying complete messages as used in B2B communication via EDI. Code PDF 417 was introduce in the 90th as the optimum code for long messages but experiences have been made with other symbologies as well in different applications in the meantime. The study shall supply answers to questions how the different symbologies may perform carrying an UN/EDIFACT message with transport information. The study was specifically required by DHL World Wide Net for updating purposes. Since some of the 2D-Symbols have been considered for use in transport environment by the ISO 15394 Transport Label, some not, the study shall be submitted to the ISO 15394 maintenance committee as well. The study was prepared by the TC of Eurodata Council in co-operation with experts of AIM-Germany and DIN NA043-01-31AA. The target of the study is to get a picture about the performance of the different symbologies but not to be used for selection of scanning products. The scanners chosen for the test have been selected stochastically not on specific purposes, but the samples printed may be used for comparison with other scanner in the market. Contact for questions and input for potential updates: Heinrich.Oehlmann@Eurodatacouncil.org

Selected 2D Symbols for comparison

As symbologies the following codes have been selected, being in use widely and performing for global use

- PDF417
- Aztec
- QR
- Data Matrix

Criteria for use on a transport label

1. What is the possible reading distance for each of these codes, assuming the same resolution/space is used?
2. What is the minimum vertical space consumption for a message of maximum size, on a label with a width of 10 to 11 cm?
3. We would like to know the average decoding time for each 2D code per scanner type, both in single-code mode and if configured to read all 4 codes alternatively?
4. Where is each of these symbologies primarily in use today?
5. To which extent is each of these symbologies standardised globally?
6. What are further relevant constraints, strengths and weaknesses per symbology?
7. We also need to know how sensitive each of the codes is to single dot failures, print head dot failures (vertical white lines) and general dirt coverage or damages.

Beyond that, the dependency on different barcode reader technologies (laser scanner, image scanner), and the costs associated with it shall be addressed.

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

Common symbology parameters and settings for this 2D-study

- Reference data string encoded in conformity to ISO 15434 Transfer Syntax.

  Format header “02” for full UN/EDIFACT messages is used.

  []><RS>02
  UNH+67231540+IFTMIN:D:96B:UN+DHL3.1.1/OPSETE32'
  BGM+787+A9272109+9'
  DTM+186:20010123:102'
  TSR+ZCD:153+Z01+02'
  MOA+22:1960.00:EUR'
  TOD+Z01++CPT'
  NAD+OS+08927437'
  NAD+CN+++MARANS SYSTEMVIEW AG+BUNDESKANZLERPLATZ:2:-
  10+BONN++53113+DE'
  GID+0+1'
  MEA+WT++KGM:45'
  PCI+ZZ1+JD00001123451234567'
  UNT+12+67231540'
  <RS><EOT>

- X-dimension: Smallest Dot size for the selected symbols: 15mil / 0,38mm per dot for 200 dpi printers but 13mil / 0,33mm per dot (300dpi printer) but upward adjusted dot size for the matrix codes for the comparison by space.
  Specific parameter for the stacked PDF417: Horizontal to vertical bar ratio1 to 3

- Error correction levels:
  -PDF417: error correction level 4 of 8
  -Aztec: automatic setting
  -QR: error correction level 2of4, 3of4
  -Data Matrix: automatic setting

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

2 Questions and answers

2.1 What is the possible reading distance?

Answer: Table 1 shows comparable scanning performance depending on the scanning device used and in case of comparable symbol sizes.
The tests using same dot size result in smaller space for matrix symbols of approx. 25% but also smaller reading distances of 25% in average. See details below.

2.1.1 Comparison of symbols with equalized space consumption (200dpi)

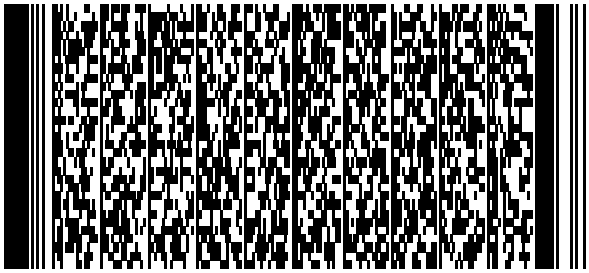
To reach nearest comparable symbol size the matrix codes have been printed with X = 30mil/0,76mm per dot.
Symbol parameter setting for 200 dpi printers:

- PDF 417 with smallest Dot size of 15mil / 0,375mm per dot, horizontal to vertical: 1 to 3
- Matrix Codes adjusted closely to the size 2695 sqmm of PDF 417 with dot size 15mil using 30mil for the Matrix Codes.

Table 1 Reading distances (cm) with symbols of comparable sizes achieved by different scanners

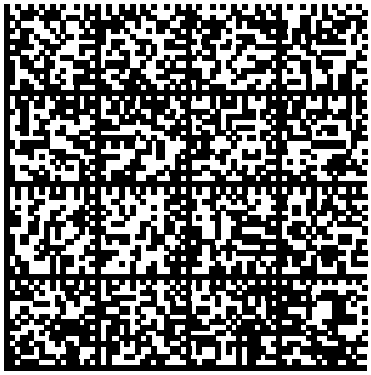
symbology square mm	EMAH 120	EMAH 200	EMS1690	OPI2002	HP4410 LR	Fixmount HF CCD	
PDF 417, 2695	24	39	35	22	24	120	
Aztec, 1849	24	38	30	23	27	120	
QR, sec 2, 2401	22	39	30	27	28	120	
QR, sec 3, 3364	22	39	30	27	28	120	
DataMatrix, 2401	22	41	30	25	26	120	

Samples of symbols adjusted to the size of the PDF 417 sample



PDF417,15mil, 35x77mm (2695sqmm)

Aztec 30mil, 43x43mm (1849 sqmm)



QR 30mil, 49x49mm, sec. standard 2401sqmm)

Datamatrix 30mil, 49x49mm (2401sqmm)

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

2.1.2 Comparison of scanning distances with symbols of equal dot size of 15mil

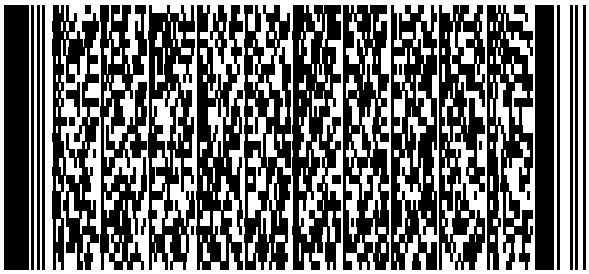
Matrix symboles of 15mil become about 25% of the size of a PDF 417 but reading distances get approx. 25% less.
See table 2 and illustrations below.

Parameter setting for 200dpi printers
- Smallest Dot size: 15mil / 0,38mm per dot (200dpi), PDF 417: X horizontal to vertical: 1 to 3
- Error correction levels:
  -PDF417: error correction level 4 of 8
  -Aztec: automatic setting
  -QR: error correction level 2 of 4
  -Data Matrix: automatic setting

Table 2 Reading distances (cm), assuming the same resolution of 15mil/0,38mm per dot is used for each of the codes

symbology X=15mil	EMAH 120	EMAH 200	EMS1690	OPI2002	HP4410 LR	Fixmount HF CCD	
PDF 417	24	39	35	21	24	120	
Aztec	17	29	17	15	16	90	
QR, sec 2	16	29	18	18	16	90	
Data Matrix	16	29	19	17	16	90	

Samples of the 4 selected symbologies
with equal dot size of 15mil/0,38mm per dot



PDF 417, 15mil
70x35mm / 2450 sqmm

Aztec
22x22mm / 484sqmm
20% of PDF4 417

QR, Sec. level 2 - standard
24 x 24 mm / 576 sqmm
24% of PDF 417

Data Matrix 24x24mm
24 x 24 mm / 576 sqmm
24% of PDF 417

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

2.1.3 Comparison scanning distances with symbols of equal dot size of 13mil

Matrix symboles of 13mil become about 17% of the size of a PDF 417 but reading distances get approx. 30% less in average.
See table 3 and illustrations below.

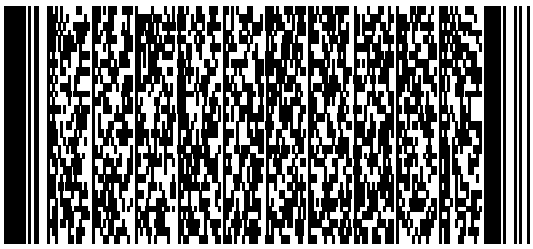
Parameter setting for 300dpi printers

- Smallest Dot size for the selected symbols: 13mil / 0,33mm per dot (300dpi printer)
  Additional parameter for the stacked PDF417-Horizontal to vertical: 1 to 3
- Error correction levels:
  -PDF417: error correction level 4 of 8
  -Aztec: automatic setting
  -QR: error correction level 2 of 4
  -Data Matrix: automatic setting

Table 3 Reading distances (cm), assuming the same resolution of 13mil/0,33mm per dot is used for each of the codes?

symbology	EMAH 120	EMAH 200	EMS1690	OPI2002	HP4410		
PDF 417	25	37	29	21	24		
Aztec	17	27	16	15	16		
QR	19	27	17	18	16		
Data Matrix	12	27	19	17	16		

Samples of the 4 selected symbologies
with equal dot size of 13mil/0,33mm per dot



PDF 417
70x40mm / 2800 sqmm

Aztec
20x20mm / 400 sqmm
15% of PDF417

QR sec. level 2
22x22mm / 484 sqmm
17 % of PDF417

Data Matrix
22x22mm / 484 sqmm
17 % of PDF417

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

2.2 What is the minimum vertical space consumption for a message of maximum size, on a label with a width of 10 to 11 cm?

Table 4 Space consumption

symbology	printing parameters X=13mil 300dpi	printing parameters PDF 417X=15mil 200dpi	printing parameters PDF 417X=15mil but Matrix codes 30mil
	symbol height x length	symbol height x length	symbol height x length
PDF 417	30mm x 70mm	35mm x 70mm	35mm x 70mm
Aztec	20mm x 20mm	22mm x 22mm	43mm x 43mm
QR, sec 2	22mm x 22mm	24mm x 24mm	49mm x 49 mm
Data Matrix	22mm x 22mm	24mm x 24mm	49mm x 49 mm

2.3 We would like to know the average decoding time for each 2D code per scanner type, both in single-code mode and if configured to read all 4 codes alternatively.

Table 5 Average decoding time for each 2D code per scanner type, both in single-code mode and if configured to read all 4 codes alternatively or linear codes.

symbology	**single code setting**	**all code setting & linear**
	time for 10 scans each	time for 10 scans each
PDF 417	4,5 sec	5 sec
Aztec	6,5 sec	7 sec
QR	5,5 sec	6 sec
Data Matrix	5,5 sec	6 sec

Note: As scanner one of the other test models was selected only, because the test shall show the relation of the decoding time between a single code setting and “all codes setting” but shall not test different software performances. But the table may be used for comparison with other scanners as well.

2.4 Where is each of these symbologies primarily in use today?

Table 6 shows a selection of areas where each of these symbologies are in use today primarily

symbology	Direct Marking	Product Labelling	Transport Labelling	domains
PDF 417		+	++	automotive, electronics
Aztec				Ticketing, special in house applications
QR	+	+	+ (Asia)	automotive, health care, special applic.
Data Matrix	++	++	+	industry & health care

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

2.5 To which extent is each of these symbologies standardised globally?

The selected symbologies are recognised by the ISO/IEC committee JTC 1/SC 31 and its national normalisation bodies. The references for access to the specifications are:

- PDF417 ISO/IEC 15438
- Aztec ISO/IEC spec. in preparation within ISO/IEC JTC 1/SC 31/WG 1
- QR ISO/IEC 18004
- Data Matrix ISO/IEC 16022

2.6 What are further relevant constraints, strengths and weaknesses per symbology?

Table 7

symbology	constrains	strength	weakness
PDF 417	2D scanner	Linear scanners available, read. distance	large size
Aztec	Image scanner	no quiet zone around symbol	new for many
QR	Image scanner	wide usage in ASIA	
Data Matrix	Image scanner	wide usage US and Europe	

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

2.7 Sensitivity for each of the codes is to single dot failures, print head dot failures (vertical white lines) and general dirt coverage.

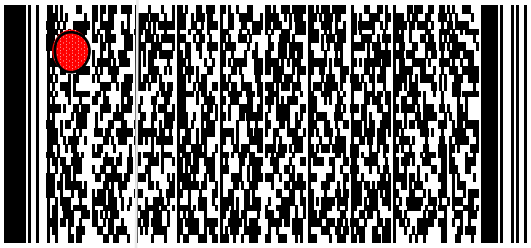
2.7.1 Spot damages and print head failure

Table 8 Spot damages nor single line print head failures cause cause problems

symbology	a) spot damage	b) print head failure (vertical lines)
PDF 417	**read**	**read**
Aztec	**read**	**read**
QR	**read**	**read**
Data Matrix	**read**	**read**

7.1 Spot damage and print head failuer used for the test

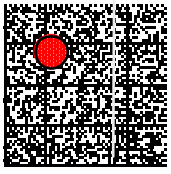
PDF 417



Aztec

QR

Data Matrix



EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

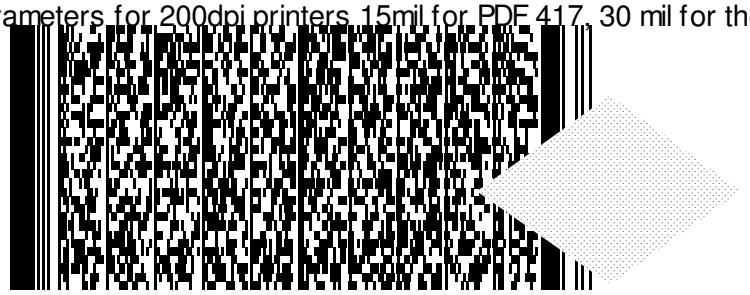
2.7.2 7.2 Test: Area damages

7.2.1 Area damage simulation level A: **Every tested scanner reads every code**

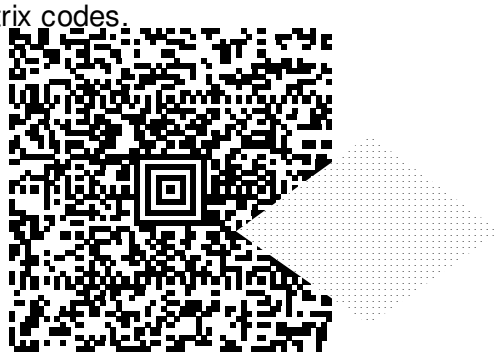
Table 9 shows no reading problems in case of illustrated area damages

symbology	EMAH 120	EMAH 200	EMS1690	OPI2002	HP4410 LR	Fixmount HF CCD	
PDF 417	YES	YES	YES	YES	YES	YES	
Aztec	YES	YES	YES	YES	YES	YES	
QR, sec 2	YES	YES	YES	YES	YES	YES	
QR, sec 3	YES	YES	YES	YES	YES	YES	
Data Matrix	YES	YES	YES	YES	YES	YES	

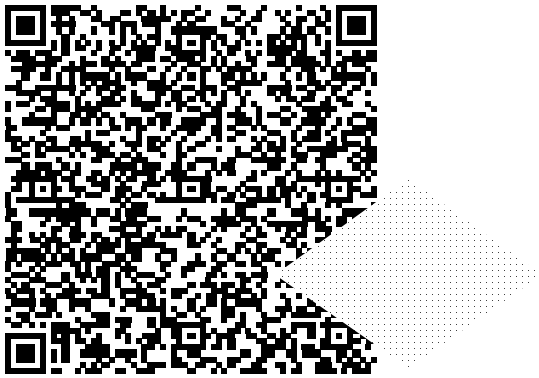
Samples from for damage simulation level A:
Parameters for 200dpi printers 15mil for PDF 417, 30 mil for the matrix codes.



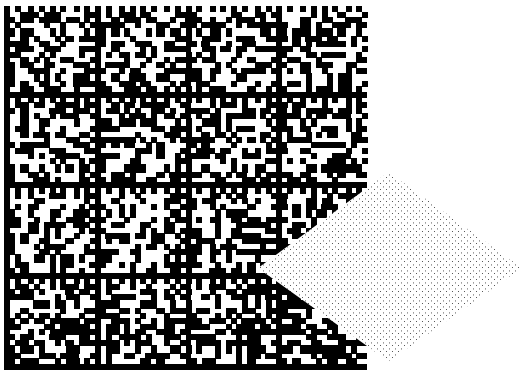
PDF 417 sec. level 4 of 8



Aztec



QR, sec. level standard (2 of 4)



Data Matrix

QR, sec. level 3 of 4

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

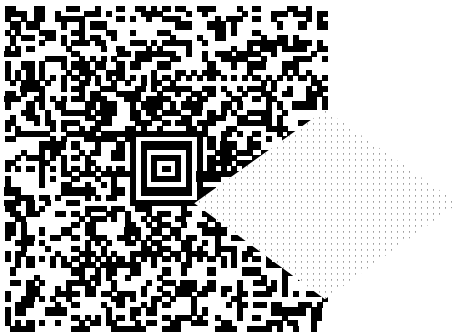
2.7.3 Test: Area damage simulation level B

Table 10 shows some reading problems in case of area damages C

symbology	EMAH 120	EMAH 200	EMS1690	OPI2002	HP4410	Fixmount	
PDF 417	YES	YES	YES	YES	**NO**	YES	
Aztec	**NO**	**NO**	**NO**	**NO**	YES	YES	
QR, sec 2	YES	YES	YES	**NO**	YES	YES	
QR, sec 3	YES	YES	YES	YES	YES	YES	
Data Matrix	YES	YES	**NO**	YES	**NO**	YES	

Samples with area damage simulation level B used for the test:

PDF 417 sec. level 4 of 8



Aztec

QR, sec. level Standard (2 of 4)

Data Matrix

QR, sec. level 3 of 4

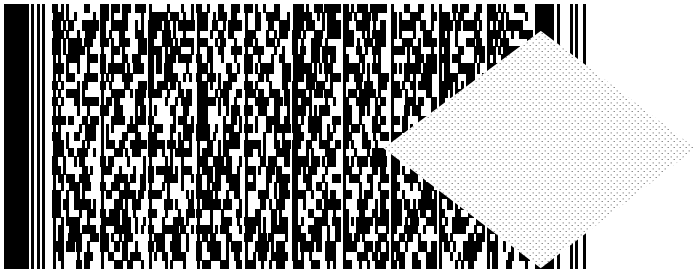
EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

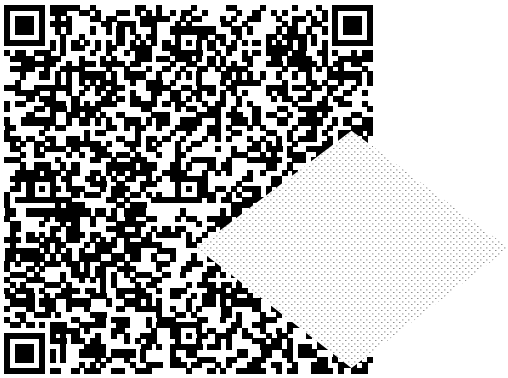
2.7.4 Test: Area damage simulation level C

Table 11 shows some reading problems in case of area damages C

symbology	EMAH 120	EMAH 200	EMS1690	OPI2002	HP4410	Fixmount	
PDF 417	YES	YES	YES	YES	**NO**	YES	
Aztec	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	
QR, sec 2	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	
QR, sec 3	YES	YES	YES	YES	YES	YES	
Data Matrix	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	

Samples with area damage simulation level B used for the test:

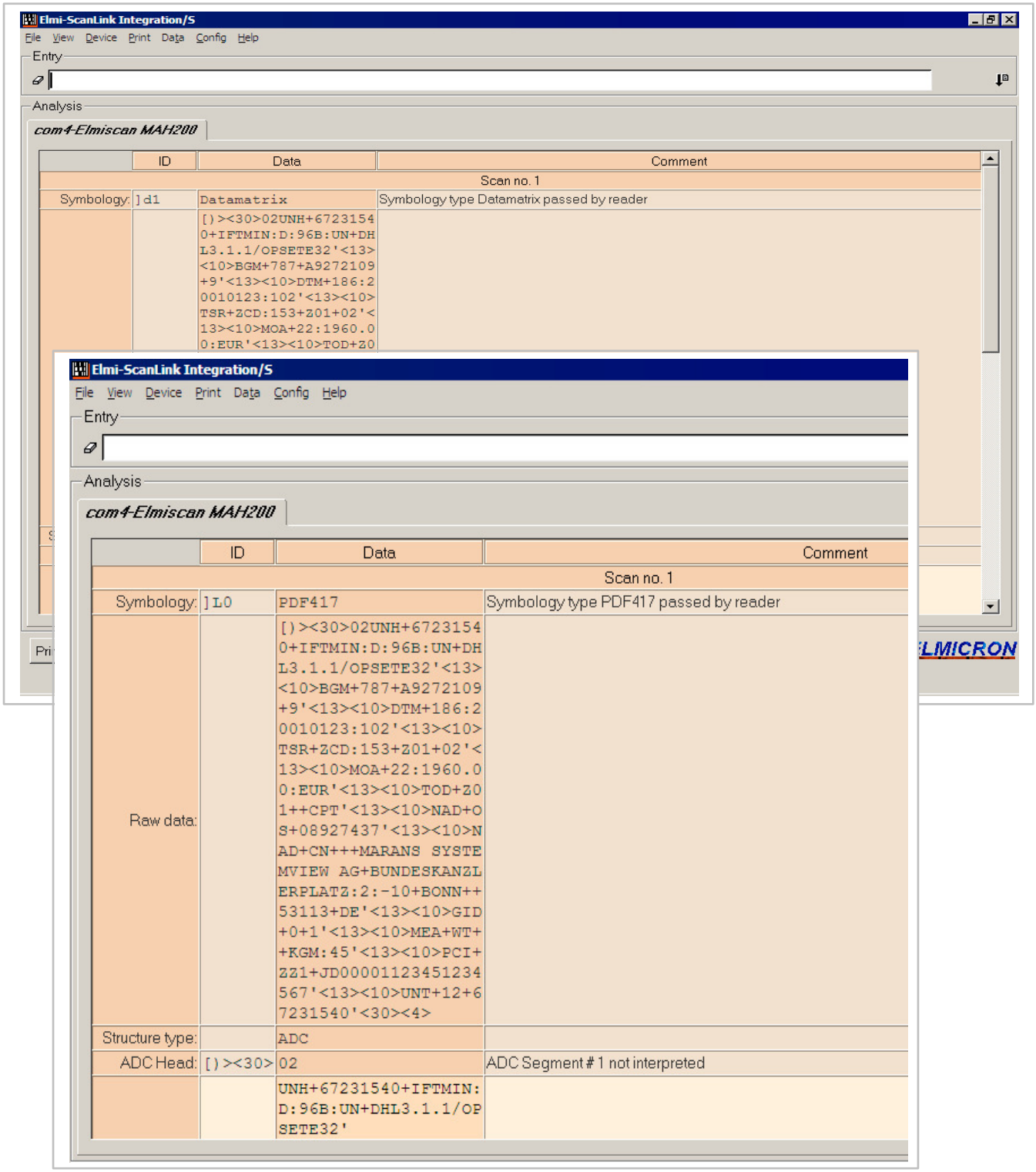




EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

3 Annex Scan diagnostic

The diagnostic screen below shows the data content of the symbols. It shows the conformity to ISO/IEC 15434 Syntax for High Capacity Media



EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org

4 Annex Selection of scanners

Dependency on different barcode readers and the costs associated.

Table 12 Selection of reading devices (to be completed)

SCANNER	market price (€URO)	for the test prepared by	Laser/ Imager	linear Barcode	PDF 417	Aztec	QR	Data Matrix
EMAH120	450,-	*ELMICRON	Imager	√	√	√	√	√
EMAH200	800,-	*ELMICRON	Imager	√	√	√	√	√
EMS1690	450,-	*ELMICRON	Imager	√	√	√	√	√
OPI2002	450,-	OPTICON	Imager	√	√	√	√	√
HP4410 LR		HHP	Imager	√	√	√	√	√
Fixmount	4.200,-	ACCUSORT	Camera	√	√	√	√	√

**www.emicron.de*

EURODATA COUNCIL Stichting European Council for Applied Information Technologies and Data Logistics, NL-2596 AN Den Haag, Jozef Israelslaan 3
Global Office D-06618 Naumburg, Koesener Str. 85, phone:+49(0)3445 78116 0, Fax +49(0)3445 770 161, info@EurodataCouncil.org