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1. Abbreviations

AA       Active Authentication
ABC gates Automated Border Control. Also referred to as e-Gates or electronic gates
ABC4EU   Automated Border Control Gates for Europe
ABIS     Automated Biometric Identification System
AFIS     Automated Fingerprint Identification System
AVG      Average
BAC      Basic Access Control
BCP      Border Crossing Point
BG       Border Guard
BMS      Biometric Matching System
BSI      Bundesamt für Sicherheit in der Informationstechnik
BVA      Biometric Vulnerability Assessment
CA       Certification Authority
CdG      Charles de Gaulle
CI       Chip facial image
CMC      Cumulative Matching Characteristic Curve
COTS     Commercial Off The Shelf
COTW     Clock On The Wall
CRL      Control Revocation List
CSCA     Country Signing Certificate Authority
DET      Detection Error Trade-off
DG2      DataGroup 2
DS       Data Structure
DMZ      Demilitarised Zone
EAC      Extended Access Control
EDPS     European Data Protection Supervisor
EES      Entry-Exit System
EF       Elementary Files
eGate    Electronic gate
eMRTD    Electronic MRTD (see below MRTD)
ENISA    European Union Agency for Network and Information Security
EP       European Parliament
EU       European Union
eu-LISA  European Agency for the operational management of large-scale IT systems in the area of freedom, security and justice
FAR      False Acceptance Rate
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>FBI</td>
<td>Federal Bureau of Investigation</td>
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<tr>
<td>FI</td>
<td>Facial Image(s)</td>
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<tr>
<td>FMR</td>
<td>False Match Rate</td>
</tr>
<tr>
<td>FNIR</td>
<td>False Negative Identification Rate</td>
</tr>
<tr>
<td>FNMR</td>
<td>False non-Match Rate</td>
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<tr>
<td>FP</td>
<td>Fingerprint(s)</td>
</tr>
<tr>
<td>FpVTE</td>
<td>Fingerprint Vendor Technology Evaluation</td>
</tr>
<tr>
<td>FPIR</td>
<td>False Positive Identification Rate</td>
</tr>
<tr>
<td>FRA</td>
<td>European Union Agency for Fundamental Rights</td>
</tr>
<tr>
<td>FRONTEX</td>
<td>European Agency for the Management of Operational Cooperation at the External Borders of the Member States of the European Union</td>
</tr>
<tr>
<td>FRR</td>
<td>False Rejection Rate</td>
</tr>
<tr>
<td>FTA</td>
<td>Failure to Acquire</td>
</tr>
<tr>
<td>FTE</td>
<td>Failure to Enrol</td>
</tr>
<tr>
<td>FPIR</td>
<td>False Positive Identification Rate</td>
</tr>
<tr>
<td>FpVTE</td>
<td>Fingerprint Vendor Technology Evaluation</td>
</tr>
<tr>
<td>GdN</td>
<td>Gare du Nord</td>
</tr>
<tr>
<td>HTER</td>
<td>Half Total Error Rate</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
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<tr>
<td>ICD</td>
<td>Interface Control Document</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>IREX</td>
<td>Iris Exchange</td>
</tr>
<tr>
<td>IS</td>
<td>Inspection System</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organisation for Standardisation</td>
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<tr>
<td>LDS</td>
<td>Logical Data Structure</td>
</tr>
<tr>
<td>LED</td>
<td>Light-Emitting Diode</td>
</tr>
<tr>
<td>LI</td>
<td>Live facial image</td>
</tr>
<tr>
<td>LTV</td>
<td>Limited Territorial Validity</td>
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<tr>
<td>MRTD</td>
<td>Machine Readable Travel Document</td>
</tr>
<tr>
<td>MRZ</td>
<td>Machine Readable Zone of a Machine Readable Travel Document</td>
</tr>
<tr>
<td>MS</td>
<td>Member State(s)</td>
</tr>
<tr>
<td>NDPA</td>
<td>National Data Protection Authority</td>
</tr>
<tr>
<td>NFIQ</td>
<td>NIST Fingerprint Image Quality</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>NISTIR</td>
<td>NIST Internal/Interagency Reports</td>
</tr>
<tr>
<td>NUI</td>
<td>National Uniform Interface</td>
</tr>
<tr>
<td>OCR</td>
<td>Optical Character Recognition</td>
</tr>
</tbody>
</table>
OCSP  Online Certificate Status Protocol
OWASP  Open Web Application Security Project
PA    Passive Authentication
PACE  Password Authenticated Connection Establishment
PID   Project Initiation Document
PKD   Public Key Directory
PKI   Public Key Infrastructure
PM    Project Manager
PoC   Proof of Concept
QA    Quality Assurance
QC    Quality Control
ROC   Receiver Operating Characteristic
RT    Registered Traveller
RTP   Registered Traveller Programme
SAC   Supplemental Access Control
SBC   Schengen Border Code
SLA   Service Level Agreement
SMS   Short Message Service
SOD   Document Security Object
SIS   Schengen Information System
SIS II Schengen Information System of the 2nd Generation
TAR   True Acceptance Rate
TC    Test Case
TCN   Third Country National
TCNVE Third Country National - Visa Exempt
TCNVH Third Country National - Visa Holder
TDN   Travel Document Number
ToR   Terms of Reference
TPIR  True Positive Identification Rate
UPS   Uninterruptible Power Supply
VE    Visa Exempt
VH    Visa Holder
VIS   Visa Information System
VSN   Visa Sticker Number
# 2. Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABIS</strong></td>
<td>Automated system capable of capturing, storing, comparing, and verifying biometric data.</td>
</tr>
<tr>
<td><strong>AFIS</strong></td>
<td>ABIS dealing only with fingerprints.</td>
</tr>
<tr>
<td><strong>Automated Border Control (ABC) system</strong></td>
<td>An automated system, which authenticates the eMRTD, establishes that the traveller is the rightful holder of the document, queries relevant systems and automatically determines eligibility for border crossing according to predefined rules.</td>
</tr>
<tr>
<td><strong>APC</strong></td>
<td>Automated Passport Control.</td>
</tr>
<tr>
<td><strong>Basic Access Control</strong></td>
<td>Challenge-response protocol where a machine reader must create a symmetric key in order to read the contactless chip by hashing the data scanned from the MRZ.</td>
</tr>
<tr>
<td><strong>Biometrics</strong></td>
<td>Measurable, physical characteristic or personal behavioural trait used to recognise the identity, or verify the claimed identity of a person previously enrolled.</td>
</tr>
<tr>
<td><strong>Border check</strong></td>
<td>The checks carried out at Border Crossing Points, to ensure that persons, including their means of transport and the objects in their possession, may be authorised to enter the territory of the Member States or authorized to leave it. [Schengen Borders Code, Article 2.10]</td>
</tr>
<tr>
<td><strong>Border Crossing Point (BCP)</strong></td>
<td>Any crossing-point authorised by the competent authorities for the crossing of external borders. [Schengen Borders Code, Article 2.8].</td>
</tr>
<tr>
<td><strong>BCU</strong></td>
<td>Backup Central Unit.</td>
</tr>
<tr>
<td><strong>Capture</strong></td>
<td>Process of collecting biometric sample from the end user.</td>
</tr>
<tr>
<td><strong>Clock On The Wall (COTW)</strong></td>
<td>A timekeeper (border guard or assisting personnel) manually measuring the time, using a stopwatch or specific software.</td>
</tr>
<tr>
<td><strong>CU</strong></td>
<td>Central Unit.</td>
</tr>
<tr>
<td><strong>DB</strong></td>
<td>Database.</td>
</tr>
<tr>
<td><strong>De-duplication</strong></td>
<td>Elimination of redundant data.</td>
</tr>
<tr>
<td><strong>DoS</strong></td>
<td>Denial of Service.</td>
</tr>
<tr>
<td><strong>eMRTD / e-passport</strong></td>
<td>Machine Readable Travel Document (e.g. passport) containing a Contactless Integrated Circuit (IC) chip within which data from the MRTD data page, a biometric measure of the passport holder, and a security object to protect the data with PKI cryptographic technology is stored, and which conforms to the specifications of ICAO DOC 9303, Part 1.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Enrolment</td>
<td>Process of collecting biometric samples and subsequent preparation and storage of biometric reference templates representing that person’s identity</td>
</tr>
<tr>
<td>End to end duration</td>
<td>Time required for the entire border crossing process, from the moment the traveller cross the yellow line until the border crossing.</td>
</tr>
<tr>
<td>ES</td>
<td>Spain.</td>
</tr>
<tr>
<td>ESTA</td>
<td>Electronic System for Travel Authorisation.</td>
</tr>
<tr>
<td>ETA</td>
<td>Electronic Travel Authorisation.</td>
</tr>
<tr>
<td>Extended Access Control</td>
<td>Protection mechanism for additional biometrics included in the eMRTD. The mechanism will include State’s internal specifications or the bilateral agreed specifications between States sharing this information.</td>
</tr>
<tr>
<td>External borders</td>
<td>Schengen countries’ land borders, including river and lake borders, sea borders and their airports, river ports and lake ports, provided they are not internal borders.</td>
</tr>
<tr>
<td>Failure To Acquire (FTA)</td>
<td>Failure of a biometric system to capture and extract biometric data.</td>
</tr>
<tr>
<td>Failure To Enrol (FTE)</td>
<td>Proportion of a specified set of biometric enrolment transactions that resulted in a failure to enrol (ISO/IEC 2382).</td>
</tr>
<tr>
<td>False Acceptance Rate (FAR)</td>
<td>Probability that a biometric system incorrectly identifies an individual or fails to reject an impostor.</td>
</tr>
<tr>
<td>False Rejection Rate (FRR)</td>
<td>Probability that a biometric system fails to identify or verify the legitimate claimed identity of an enrolled individual.</td>
</tr>
<tr>
<td>False Negative Identification Rate (FNIR)</td>
<td>Probability that a biometric system does not return the user’s correct identity when looking for users enrolled in the system.</td>
</tr>
<tr>
<td>False non-Match Rate (FNMR)</td>
<td>Probability that a biometric system does not find a user enrolled in the system.</td>
</tr>
<tr>
<td>FI</td>
<td>Finland.</td>
</tr>
<tr>
<td>First Line Check</td>
<td>The border check conducted at the location at which all travellers are checked. See also “Second Line Check”.</td>
</tr>
<tr>
<td>FR</td>
<td>France.</td>
</tr>
<tr>
<td>FP scanner</td>
<td>Device used to capture the fingerprints of an individual.</td>
</tr>
<tr>
<td>Identification (1:n)</td>
<td>Process of comparing a biometric sample with a previously stored reference template.</td>
</tr>
<tr>
<td>Kiosk</td>
<td>Self-service data collection station, configurable to perform different functionality, such as biometric enrolment and verification, or document reading.</td>
</tr>
<tr>
<td>LES</td>
<td>Light-emitting sensor</td>
</tr>
<tr>
<td>Live capture</td>
<td>Capturing a biometric sample by an interaction between an end user and a biometric system.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>LTV visa</td>
<td>Limited territorial validity visa.</td>
</tr>
<tr>
<td>Manual verification</td>
<td>A manual verification is made by a person and includes, in most cases, ocular inspection of a picture, from the travel document or displayed from another source, and comparing this picture to the person being checked.</td>
</tr>
<tr>
<td>Matching</td>
<td>Successful comparison a biometric sample against a previously stored template, which implies that the level of similarity exceeds a given threshold.</td>
</tr>
<tr>
<td>MEV</td>
<td>Multiple Entry visa.</td>
</tr>
<tr>
<td>MRTD</td>
<td>Official document, conforming with the specifications contained in Doc 9303, issued by a State or organisation which is used by the holder of international travel (e.g. passport, visa,) and which contains mandatory visual (eye readable) data and a separate mandatory data summary in a format which is capable of being read by a machine.</td>
</tr>
<tr>
<td>Minutiae</td>
<td>Specific points in a finger image.</td>
</tr>
<tr>
<td>MoU</td>
<td>Memorandum of Understanding.</td>
</tr>
<tr>
<td>Multimodal biometrics</td>
<td>Combination of information from two or more biometric measurements. It is also known as “Fusion” and “multibiometrics”.</td>
</tr>
<tr>
<td>NFIQ score</td>
<td>Fingerprint quality metric introduced in 2004 with an updated and improved version currently being developed.</td>
</tr>
<tr>
<td>Pilot</td>
<td>Small scale preliminary study conducted in order to evaluate different aspects in order to predict and help organizing the actual large-scale project in terms of feasibility, time, cost, adverse events, etc.</td>
</tr>
<tr>
<td>Quality Score</td>
<td>Value that indicated the level of quality for a biometric identifier collected.</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency Identification.</td>
</tr>
<tr>
<td>RO</td>
<td>Romania.</td>
</tr>
<tr>
<td>Schengen visa</td>
<td>Uniform short stay visa that entitles the holder to stay in the territories of all Schengen States for a period of maximum of 90 out of 180days and that may be issued for the purpose of single or multiple entries.</td>
</tr>
<tr>
<td>Second line check</td>
<td>A further check that may be carried out in a special location away from the location where all travellers are checked (first line). (Schengen Borders Code, Article 2.12)</td>
</tr>
<tr>
<td>SIEM</td>
<td>Security incident and Event management.</td>
</tr>
<tr>
<td>Third Country National (TCN)</td>
<td>Any person who is not a Union citizen within the meaning of Article 20(1) of the Treaty on the Functioning of the European Union and who is not covered by the definition of persons enjoying the Community right of free movement outlined in Article 2.5 of the Schengen Borders Code. [Schengen Borders Code, Article 2.6].</td>
</tr>
</tbody>
</table>

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1 Fingerprint Image Quality, NISTIR 7151, August 2004.
<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Threshold</strong></td>
<td>Decision threshold: the acceptance or rejection of biometric data depends on the quality or matching score falling above or below the threshold. The threshold is adjustable so that the biometric system can be more or less strict.</td>
</tr>
<tr>
<td><strong>True Positive Identification Rate (TPIR)</strong></td>
<td>Probability of that a biometric system returns the user’s correct identity when looking for users enrolled in the system.</td>
</tr>
<tr>
<td><strong>USB</strong></td>
<td>Universal Serial Bus.</td>
</tr>
<tr>
<td><strong>Verification (1:1)</strong></td>
<td>Process of comparing a biometric sample with a previously stored reference template.</td>
</tr>
<tr>
<td><strong>VEVO</strong></td>
<td>Visa Entitlement Verification Online.</td>
</tr>
</tbody>
</table>
3. Methodology

This chapter describes the methodologies used during the pilot project set-up and execution. Throughout the work, standardised approaches were taken at technical, operational and organisational levels to ensure that meaningful and relevant results that could be included in the final report were obtained and subsequently used to draw legitimate and reasonable conclusions, while complying with data protection rules and the applicable administrative and legal framework.

The chapter includes information on how the project was planned and then managed during execution and how stakeholders were consulted when appropriate and necessary. At the technical level, the metrics used for quantitative and qualitative assessment of result outcomes are also described in some detail.

3.1. Overall approach

In order to tackle the objectives of the pilot in the most appropriate and effective manner while fully respecting operational and legal constraints, two different approaches were taken, namely operational testing and desk research.

a. Operational testing

The goal of operational testing was to examine the overall feasibility of deployed systems and the performance and effectiveness of such systems, as well as the associated processes in the application environment with the actual end-user community - third country national travellers entering or exiting the Schengen Area. This approach was used when reasonably possible and when Member States could provide the necessary resources to perform the adequate adaptations and measurements (e.g. human resources, infrastructure, required time).

For the purpose of the present report, feasibility is defined based on ISO/IEC/IEEE 29148:2011 as being composed of:

- Being technically achievable;
- Not requiring major technology advances;
- Fitting within system constraints (e.g., cost, schedule, and technical, legal, regulatory);
- With acceptable risk (not addressed with the exception of iris where it is partially addressed via spoofing).

Operational testing variably involved:

1. Operational integration of the test steps into the existing border crossing processes. In this regards, testing was undertaken in two different ways: integrated or standalone processes, as depicted in the figure below.
2. Technical integration of the equipment or systems used in testing into the existing border management technical solution;

3. Use of test devices in an operational environment, by border guards, but without full technical or operational integration.

Operational and technical integration of test devices and systems provides the most realistic data in terms of how the tested solutions would function in a full operational environment. In addition, it also allows the measurement of the end-to-end duration of existing processes (i.e. baseline measurement) and the process including pilot tests, making it possible to calculate the difference between the existing process and the new process in terms of duration. However, existing resource or capability limitations or operational constraints sometimes meant that testing was executed according to the third approach listed above.

In order to ensure that the testing environments and the processes in which test systems would be deployed were representative of the variety of Schengen border conditions (e.g. border types, ABC gate types, vehicle types), it was planned that operational testing would be undertaken at 18 different border crossing locations, covering air, land and sea borders in 12 volunteering Member States. It was also ensured that a variety of biometric devices would be used to investigate different set-ups at different location types, in different environments and under different conditions, with the provision that all devices used were already available on the market. Thus, the tests assessed technology existing today.

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2 End-to-end covers in general all process steps involved in the border check - from the moment the traveller arrives at the booth (crosses the yellow line), until the moment he/she leaves the border control post.

3 Each Member States expressing a will to participate in the tests was offered the possibility to propose one or more Border Crossing Points (BCP) for the tests. In order to achieve good representativeness of all test cases, an initial proposal was made by eu-LISA to perform one or more specific test cases given the different BCPs, taking into account as much as possible BCP constraints and desired schedule.
b. Desk research

Aspects for which it was impractical or non-feasible (e.g. because of timeline, budget, legal constraints) to perform full operational testing were explored via desk research. This approach was applied for the following specific topics as specified by the Terms of Reference (ToR):

- Fall-back options (chapter 3.1);
- VIS border check using travel document number (chapter 3.2);
- Web services for travellers and carriers (chapter 3.3);
- Equipment and costs (chapter 3.4);
- Spoofing vulnerability of iris enrolment and counter-measures (chapter 3.5);
- Reading chips in e-passports, extraction of the facial image for use and execution of passive authentication (chapter 3.6).

Desk research included literature review, interviews and workshops with stakeholders (e.g. FRONTEX, ABC Working Group, FRA, MS and industry), reflections on experiences and consultations with those involved in previous and/or similar projects (e.g. ABC4EU, FastPass, Tabula Rasa).

The following approaches were used to address the pilot’s objectives:

**Table 1 Coverage of the two types of methodologies by test case**

<table>
<thead>
<tr>
<th>Test case</th>
<th>Operational testing at BCP</th>
<th>Desk research</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC1: Enrol 4 fingerprints at first-line border check</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TC2: Enrol 8 fingerprints at first-line border check</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TC3: Enrol 10 fingerprints at first-line border check</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TC4: Enrol live facial image</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TC5: Enrol iris pattern</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TC6: Capture Facial Image from eMRTD</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TC7: Verification of F1 captured from eMRTD against a live facial image</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TC8: Searching VIS by Travel Document Number</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>TC9: Automated Exit Checks of TCNs</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TC10: Use of Self-Service kiosks</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TC11: Pre-border checks at Land Borders</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TC12: Fall-back options</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>TC13: Web-interfaces to the carriers and to the travellers</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

3.2. Consultations with stakeholders

The objective of the Smart Borders pilot is to deliver evidence-based information for further decision-making that involves many different stakeholders. It was therefore a priority for the project to ensure that all stakeholders were kept informed and involved.

The following stakeholders were involved and consulted during the Smart Borders pilot project:

- European Commission (DG Home);
- Member States;
- European Parliament (LIBE);
• EU Council (relevant working groups);
• Frontex;
• European Union Agency for Fundamental Rights (FRA);
• European Union Agency for Network and Information Security (ENISA);
• Industry actors within the field of the tests;
• Vendors involved in the tests.

Besides the abovementioned stakeholders, consultations on technical matters took place with authorities and agencies from non EU countries, e.g. with the Australian Department of Immigration and Border Protection, and the United States Department of Homeland Security. For further details on how stakeholders were involved, please refer to the Project Management methodology section 3.9.

3.3. Metrics for biometric quality assessment

This section presents the parameters chosen to assess the different biometric identifiers tested in the project, and describes the collection and analysis methods used.

It should be noted that biometric quality when used in this report should be interpreted as defined in ISO/IEC 29794-1: 2009 - a predictor of a matcher’s performance. In the context of the pilot project, performance prediction is sought for automated comparison methods. Practically, quality assessment of biometric samples always involves the calculation of a numeric score for a particular sample, which should provide an accurate indication of the usefulness of the sample for biometric comparison.

Quality of the different biometric identifiers was assessed in the pilot as a basis for making predictions on the likely performance of a future automated biometric identification system (ABIS) containing biometrics enrolled at the various border crossing points at the external borders of the Schengen Area. This approach was necessary because the applicable legal and data protection framework for the pilot project precluded any storage of biometric data collected from pilot participants or comparison of collected images against a database of reference samples that could have provided direct performance results.

Quality assessment was also, where possible, undertaken at the point of capture in order to determine whether re-enrolment of samples was necessary, i.e. quality thresholds were applied in order to assess whether the quality was sufficient for use in an automated system. If the sample was judged to be of low quality, more attempts were, in general, made to enrol a better quality image. Rejection of low quality samples in this manner is applied in many biometric systems as a means of improving ABIS performance.

It may be noted that biometric sample quality can be influenced by a range of factors: devices used and their ergonomics, the environment in which the enrolment takes place, the users - both the person in charge of the enrolment process and his/her level of knowledge, training and supervision of the process, and the traveller’s physical and physiological capabilities as well as his/her knowledge of and familiarity with appropriate enrolment processes, or other process related factors. These variables were not controlled in operational testing; rather, the variability was one reason for undertaking tests at diverse locations.

3.3.1. Fingerprints

Within the pilot, the feasibility of enrolling 4, 8 and 10 fingerprints (i.e. test cases 1, 2 and 3 respectively) was assessed at different border types and using different types of equipment. Enrolment sensors included: optical sensors requiring contact to be made between the traveller’s fingers and the glass plate of the device, contactless scanners, devices enrolling 1, 2 or 4 fingers in a single step, light-emitting sensor devices and mobile devices.

3.3.1. Quality indices collected

Part of the feasibility assessment involved examination of the quality of prints enrolled at the different locations. During the preparatory phase of the project, it was decided in collaboration with Member States and vendors
participating in expert meetings that fingerprint quality would be assessed using the NIST Fingerprint Image Quality (NFIQ) metric and also by counting the number of minutiae detectable in each print.

The NFIQ metric was first introduced in 2004\(^4\) with an updated and improved version currently being developed. However, as this upgraded version was not available publically at the time of testing, the original version 1 metric was used to ‘score’ the quality of every fingerprint collected individually at all locations irrespective of the device type or the vendor providing the device.

A fingerprint minutia is a characteristic locus in a print image. Examples of common minutiae are ridge endings and bifurcations. Data on minutiae including their locations and directions is typically used in manual and many automated systems as the basis of image comparisons. A comparison based on a high number of high quality minutiae should be more reliable than one based on fewer or lower quality loci. The number of minutiae present can thus be considered to indicate the usefulness of the print for comparison. It should be noted that the number of minutiae in a print is in fact one element on which NFIQ is based, even if NFIQ also considers the reliability of the minutiae identified as well as other quality aspects and could therefore be considered more sophisticated.\(^5\)

In some locations, supporting vendors also provided quality scores based on their own quality measures. While these sometimes aided aspects of vendor support and were used as a basis for quality thresholds that defined when re-enrolment was necessary, these scores were not used for performance prediction and are typically not described in this report. Quality thresholds and re-enrolment is described further below.

3.3.1.2. **Why NFIQ and how to use the metric to compare results**

The NFIQ metric is a publically known and well-understood quality metric developed by the US National Institute of Standards and Technology (NIST)\(^6\). Over the years, it has become a *de facto* standard for assessing fingerprint quality. In fact, its computation is mandatory in the ANSI/NIST ITL 1-2007 standard that defines the ‘NIST’ format for storage of fingerprint images and associated data. The source code for the algorithm is freely available. Thus, it could be provided by all supporting vendors and provided as a means to compare the quality obtained at different locations and with different devices and set-ups at different times. The metric ranges from 1 to 5, with lower values indicating higher quality prints. Biometric quality as described by NIST in their article introducing this metric entirely fits the purposes of the work conducted under the pilot project, as the article indicates that good quality fingerprint images would result in high matcher performance, and vice versa, the matcher performing poorly for poor quality fingerprints.\(^7\)

In order to allow comparison of NFIQ scores between locations or from different device configurations or to estimate quality over time, values computed across all samples can be condensed into a single value representing a quality index of the enrolled set. In NISTIR 7422,\(^8\) it is recommended that NFIQ scores for a set of fingerprints be condensed into a single representative score, \(Q\), according to the following calculation:

\[
Q = 102.75 - 2.75 p_1 - 5.37 p_2 - 14.38 p_3 - 42.25 p_4 - 102.75 p_5
\]

where \(p_i\) is the proportion of the fingerprints with quality \(i = 1 \ldots 5\). The score scales between 0 and 100, with higher values indicating better quality prints in the dataset. The weights reflect the point made previously that prints with NFIQ scores of 4 or 5 can be considered of very poor quality, thus their strong negative weighting. Plain averaging is clearly inappropriate when using NFIQ scores.

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\(^5\) Ibid.

\(^6\) The NIST agency collaborates with FBI’s Biometric Center of Excellence to develop open testing procedures, metrics and requirements in order to back the certification and inclusion of contactless fingerprint tools in the list of Government Certified Products.

\(^7\) Towards NFIQ II Lite, NISTIR 7973, December 2013.

3.3.1.3. Performance prediction

Leading vendors active in the field of AFIS design and development were provided with general distributions of NFIQ scores obtained from testing in various locations and using different equipment. All information related to device type or location was removed in advance to remove any contextual information that might have biased results. Vendors were able to provide predictions for 1:n performance per location/device combination and also for an AFIS system containing fingerprints of the qualities enrolled throughout testing in all locations. The assumptions were the following:

- Identification transactions would be run against a database of 100 million travellers;\(^9\)
- All cases in which fingerprint enrolment failed were counted as ‘misses’ and therefore negatively impacted performance rates provided below;
- Parameterisation would be such that false positive identification rates (i.e. false alarms) would be very low (i.e. several orders of magnitude below 1%).

Performance is reported in the quality section of the “Fingerprints chapter” in the main report (chapter 2.1) of this report with true positive identification rate (TPIR) figures. This figure indicates how frequently the correct match will be ranked at the top of an output list of candidates when a fingerprint set is provided as a query and run against a dataset containing a sample for the person being identified. It is equivalent to 100% minus the false negative identification rate (FNIR) (or in cases of de-duplication queries, false rejection rate, i.e. the duplicate is not detected.)

When considering performance predictions made, it should be borne in mind that the relationship between a quality metric and AFIS performance will vary with algorithms used. Even if NFIQ scores are something of a consensus score, having been developed using combined results from a number of commercial algorithms available at the time of development, it is non-optimal as a predictor for any single given AFIS but allowed predictions to be made by the different approaches of all vendors.

The accuracy of predictions made will also depend on the devices used. As referenced in the fingerprint chapter, the NFIQ metric was developed based on prints enrolled from optical contact scanners only. Thus, its validity as a predictor of AFIS performance in a database of prints enrolled from other scanner types is unclear. Initial results in the literature seem to suggest that the NFIQ metric is in fact not suitable for assessing the quality of prints from contactless scanners, for example.\(^10\)

3.3.1.4. Acquisition process

It is desirable to assess quality at the time of enrolment so that poorly enrolled prints can be recaptured while the person presenting the sample is still present. The practice of applying a quality threshold with which the enrolled fingerprints must comply is common in systems worldwide and has been suggested as best practice for fingerprint enrolment in the VIS, for example. In NISTIR 7973, it is demonstrated that efficient rejection of low-quality samples using the NFIQ metric results in improved performance. Within the pilot and after consultation with experts from Member States, enrolment thresholds were set such that prints from the thumb, index finger, middle finger and ring finger should have NFIQ scores of 1 or 2 and those from the little finger scores 1, 2 or 3. Usually, up to 3 enrolment attempts were made as necessary.

It is important to note that in some instances, due to the realities of operational testing, there were some deviations from this global approach to thresholding and re-enrolment. In cases of such deviation, the differences are noted in the individual BCP chapters. This must be considered in the analysis of results as acceptance of lower quality

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\(^9\) The performance of identification typically decreases as the database size increases, with the relationship between mated match performance and gallery size typically following a power law, as noted, for example, in NISTIR 7577. Such a law was used to scale vendor predictions to the gallery size of 300M when necessary, in order to allow for convenient comparison of results.

\(^10\) See, for example, the article ‘Neural-based Quality Measurement of Fingerprint Images in Contactless Biometric Systems, Labati RD, Piuri, V and Scotti, F, 2010 International Joint Conference on Neural Networks, 2010.'
fingerprints will possibly lead to quicker enrolment processes but will negatively impact AFIS matching performance. Conversely, implementation of more stringent thresholds typically leads to higher Failure to Enrol (FTE) rates. Finally, in some cases, time and resource constraints meant that re-enrolment rules could not be practically implemented despite fingerprints being enrolled below threshold. In all cases, however, the number of enrolment attempts made is recorded in the output dataset.

Some enrolment devices used incorporated auto-capture functionalities. This involves the use of real-time or close to real-time assessment of the quality of prints being captured while the finger is in contact with the glass plate, examining multiple sequentially captured fingerprint images and selecting the best as the enrolled sample. It should be noted that quality need not be calculated as an NFIQ score. Indeed in most cases of devices used in the pilot, auto-capture was based on vendor metrics including ridge separation, image contrast and number of minutiae.

Most cases included the provision of real time feedback to either the border guards’ interface, or the travellers, by means of green LEDs in the sensor. This feedback has been proven to be useful and increases the user experience and the quality of the enrolment.

3.3.2. Facial Image

Within the pilot, the feasibility of enrolling the live facial image of travellers, retrieving the facial image stored in their eMRTD chip and performing a biometric verification based on these two sources (i.e. test cases 4, 6 and 7 respectively) was assessed at different border types and using different types of equipment. Enrolment sensors included: standard web-cameras, specific fixed devices and specific mobile devices.

From a border management perspective, the aim of the tests was foremost to assess whether the identity of travellers can reliably be verified at the border by means of using the facial image as a biometric identifier.

For this purpose, various vendors were requested to set-up devices that could perform the above-mentioned operations, including automated verification of the traveller. This process entails two opposing concepts: the system needs to reject as many impostors as possible (meaning that the false acceptance rate (FAR) is as low as possible), while accepting as many persons presenting their genuine passport as possible (meaning that the false rejection rate (FRR) is as low as possible).

Operationally, this translates on the set-up of a maximum false acceptance rate, i.e. how many impostors it is acceptable to label as the genuine bearers of the passport. At this fixed level, the false rejection rate, i.e. how many people are wrongly rejected, then depends on several factors. These include the quality of the algorithm, the quality of the images used in the verification process and other factors affecting the face over time, like ageing or surgery.

Therefore each vendor set an acceptable false acceptance rate for the pilot and the verification scores, i.e. the confidence of the algorithm that the person on the two images is indeed the same, are then measured to assess the success rate of identity verification at the border based on the facial image biometric modality.

Other objectives included the measurement of the quality of the biometrics captured, the duration of the process and the users’ feedback of the process.

While these tests were performed at manual booths, the use of facial image as a biometric identifier was also tested at ABC gates and with kiosks. However, these cases are analysed separately because of the different conditions in which they take place (e.g. assistance and action of border guard at manual booth, compared to simple supervision at ABC gates and kiosks).

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3 The false acceptance rates used during the pilot were between 0.1% and 1%, meaning that at most this percentage of impostors would be wrongly flagged as genuine passport bearers by the verification system. This does not preclude additional checks which can confirm/confirm the verification outcome.

4 It was assumed during the pilot that 100% of participating travellers were presenting their genuine passport, and as such, a theoretical 100% of travellers should have their identity verified in optimal conditions and with a perfect matching algorithm.
The figure below presents the verification of a live facial image stored in the eMTRD chip:

![Verification process for facial image](image)

**Figure 2 Verification process for facial image**

### 3.3.2.1. Quality indices collected

Based on the above-mentioned objectives and on consultations with experts and participating Member States, the following objectively verifiable indicators were selected to serve as a basis for the assessment:

- The quality scores of the facial images (live and from the chip) based on vendor proprietary algorithms;
- Selected ICAO 9303 image properties results;
- Verification scores (i.e. quantitative outcome of the verification process), along with the conditions in which the verification was performed (i.e. matching device and software used, false acceptance rate threshold used) in order to qualify the results.

The quality scores obtained from vendor proprietary algorithm were used to compare the quality of both facial images (captured live or retrieved from the eMRTD chip) and therefore understand which one had the most impact on the verification process.

ICAO 9303\(^{13}\) defines the standard for machine-readable travel documents. For the quality requirements of the image imbedded in the visual inspection zone or stored in the electronic chip of a passport, ICAO 9303 refers to and imposes the quality requirements defined in ISO standard 19794-5.

As live images were enrolled for the purposes of comparison with a reference taken from the document in most test cases, controls at the points of capture to enforce compliance with the afore-mentioned standards were generally not implemented. Thus, ICAO quality indicators were normally considered less appropriate than some vendor algorithms for assessing the quality of live images obtained and in some cases were not recorded. ICAO quality indicators were obtained and considered in instances when used as a basis for thresholds or when efforts were made to enrol ICAO compliant images at the BCP.

Further to the consultation of experts from the industry and from Member States, the following indicators have been selected from the ICAO Document 9303 and, where possible, collected during the pilot test execution:

- ICAO 9303 indicators of the digitalised facial image:
  - Face characteristics: roll nose axis, mouth closed, eye distance, colour space, greyscale density and colour saturation;

---

Different retry policies (e.g. up to three attempts, unlimited reattempts with a timeout);
- Different vendor specific verification thresholds (from 0.1% to 1%);
- Verification score;
- Ratios: head width/image width, head height/image height;
- Position: vertical position of the face, horizontally centred face.

The results of these ICAO indicators were analysed transversally across test BCPs, and more importantly across passport-issuing countries, in order to assess the level of compliance of Member States to ISO/IEC 19794-5:2005, which defines acceptable values for the indicators outlined in ICAO Doc 9303 and measured during the pilot.

### 3.3.2.2. Performance

The approach to analyse the results of the tests (involving the facial image biometric mode) was different compared to the other biometric modes. Rather than using quality scores as a predictor of ABIS performance, verification performance was directly assessed by measuring how often travellers started the process outlined above but could not be automatically verified based on their facial image at the set threshold.

For this purpose, the verification score allowed to compute the success rate of the facial image verification. The success rate of the entire process, i.e. capture of live facial image, retrieval of facial image from the eMRTD chip and verification thereof, was computed taking into account the failure to perform each of these individual steps. Thus, errors along the process were recorded: the failure to enrol a live facial image, the errors in reading the eMRTD chip and subsequently retrieving the facial image, and finally errors during the verification process.

The final success rate obtained is a clear and measured performance indication of the entire process in the operational environment at various EU BCPs.

### 3.3.2.3. Acquisition process

In order to be representative of the different conditions of border-crossing points across Europe, various set-ups and processes were tested during the pilot. These set-ups and processes are listed in the “Facial image chapter” of the main report (chapter 2.2.) dealing with the findings of the pilot on facial image and they cover:

- Various types of equipment for live facial image capture (e.g. standard web-cameras, mobile equipment, fixed equipment);
- Various types of equipment for eMRTD chip facial image capture (e.g. flatbed readers, swipe readers);
- Various types of verification algorithms;
- Different vendor specific verification thresholds (from 0.1% to 1%);
- Different live image capture success criteria (e.g. assessment based on the quality of the live image or on the verification score);
- Different retry policies (e.g. up to three attempts, unlimited reattempts with a timeout);
- Different types of feedback provided to the border guard and/or traveller (e.g. live feedback of the ongoing capture to travellers and border guards, or to only one of them, or to none of them).

#### 3.3.3. Iris

Within the pilot, the feasibility of enrolling the iris patterns of travellers (i.e. test case 5) was assessed at different border types and using different types of equipment. Enrolment sensors included mobile and fixed short-acquisition-distance (c. 20 cm) equipment fixed medium-acquisition-distance (c. 60 cm) devices and fixed long-acquisition distance (c. 120 cm) equipment. Equipment that could capture the iris patterns and a facial image simultaneously was also tested.

One of the main aims in evaluating the quality of the iris enrolled was to obtain reliable and robust estimates with regards to the likely performance of an ABIS for both verification and identification against a database of iris patterns at a certain set level of quality. In brief, the higher the quality of a biometric modality enrolled into a database, in this case iris patterns, the higher the likelihood of success for 1:1 verification or 1:n identification.

In the figure below, the process of enrolling two iris images and, when applicable, a facial image, is shown.
The subsequent sections provide a description of the quality indicators used and elements that were taken into consideration for assessing the feasibility of using the iris as a biometric identifier in the context of border checks.

3.3.3.1. **Quality indices collected**

Based on the above-mentioned objectives and on consultations with experts and participating Member States, the following objectively verifiable indicators were selected to serve as a basis for the assessment:

- The quality scores of the iris patterns (left and right) based on vendor proprietary algorithms;
- Selected NISTIR 7820 image property results: usable iris area, iris pupil contrast, pupil shape, iris sclera contrast, gaze angle and sharpness.

The quality scores obtained from vendor proprietary algorithms were used to predict performance on a large-scale database and to understand whether there was a difference between the quality of the left iris and the right iris when taken at the border. Not all vendors could provide such information and therefore prediction was made based on the results of one vendor.

ISO/IEC 29794-6:2015, the standard which defines actionable measurement methods for the indicators outlined in NISTIR 7820, was only recently published. As it was unavailable at the time of the design of the tests, it was not possible to enforce any specific quality threshold across different vendors and set-up, thus limiting the comparability of the results obtained.

3.3.3.2. **Performance prediction**

Performance prediction with iris was carried out by one vendor based on the results obtained at the BCPs for which they provided equipment. The prediction was made based on results obtained by the vendor with their own database. By isolating database samples corresponding to the same quality distribution as was obtained in the tests, and measuring performance based on these, a false rejection rate was measured. The assumptions were the following:

- Database of 100 million people;
- False acceptance rate of 0.01% (similar than for the prediction on fingerprints);
- Identification based on both irises.

3.3.3.3. **Acquisition process**

In order to be representative of the different conditions of border-crossing points across Europe, various set-ups and processes were tested during the pilot. These set-ups and processes are listed in the “Iris chapter” of the main report (Volume 1 - Chapter 2.3) dealing with the findings of the pilot on iris, which cover:

- Various types of equipment for iris pattern capture (e.g. short-range or long-range equipment, mobile equipment, fixed equipment);
- Different image capture success criteria;
- Different retry policies (e.g. up to three attempts, unlimited reattempts with a timeout);
- Different types of feedback provided to the border guard and/or traveller (e.g. feedback of the capture to
travellers and border guards, or to only one of them, or to none of them); • Different methods of iris localisation (e.g. manually by border guard, or automatically by camera tracking the face and eyes); • Different biometric combinations (e.g. simultaneously with facial image capture, alone); • Different traveller situation conditions (e.g. inside a car, inside a moving train, at a self-service enrolment station).

In those cases where the BCPs where the iris and facial image were captured almost simultaneously, a quality threshold was only implemented for the iris and not for the facial image. Therefore the re-attempt policy (of up to three captures) was based on the success to enrol iris at the required level of quality.

In the other case the re-attempt policy was based on the vendor specific index.

3.3.4. Correlation assessment - Facial Image and Iris Pattern

Where possible, processes were set up to allow the capture of both facial image and iris at the same time. This dual capture was performed almost simultaneously on fixed or mobile multimodal device sensors:

• On the fixed devices, the camera used for capturing live facial was designed to locate the irises as opposed to capturing a high-quality facial image;
• For the mobile device, it was not possible to capture both facial image and iris at the same time. These two types of capture were made in the context of two different tests.

Although the scores were above the thresholds defined by the vendor, it was considered that the information recorded on the quality of the facial image was not fully appropriate to make the correlation computation of iris and facial image quality.

However in these cases, the quality indicators that have been recorded are those mentioned above for facial image and iris.

3.4. Time measurement

The duration of the border control processes and of their respective atomic steps was measured according to the following methodologies (or a combination thereof), depending on the test case and on the specific set-up at the different BCPs:

• Time-stamped log files: the software operating the different devices (e.g. FP scanners) recorded the events in a log file with a time stamp;
• Clock On The Wall (COTW): a timekeeper (border guard or assisting personnel) manually measures the time, using a stopwatch or specific desktop application.

Remark: Unless explicitly stated otherwise, the unit used throughout the report is the second.

Measured durations

The objective of measuring durations during the pilot was to assess the impact of adding biometric capture and checks at the border, compared to a situation where there is none.

To achieve this objective, the following durations were measured, when possible.

• All test cases:
  o Duration of the tested end-to-end process\(^{16}\).
• Fingerprints related test cases:

\(^{16}\) End-to-end covers in general all process steps involved in the border check - from the moment the traveller arrives at the booth (crosses the yellow line), until the moment he/she leaves the border control post.
- Duration of fingerprint capture.

- Facial image related test cases:
  - Duration of the live capture of a facial image;
  - Duration of the retrieval of the facial image from the eMRTD chip;
  - Duration of the verification of the images;
  - Duration of the passive authentication of the eMRTD.

- Iris related test cases:
  - Duration of the enrolment of the iris.

On top of these durations obtained during the tests, the baseline duration (i.e. the duration of the process as it is currently implemented for regular BCP operations) was measured in order to provide a comparison point and to understand the relative impact of the durations added by biometrics-related processes.

### 3.5. Environmental conditions and other constraints

Tests were performed under various environmental conditions. In particular in the case of sea, road and train border-crossing points, the naturally changing conditions throughout the testing phase impacted the tests as they would during actual live operations. The following conditions were considered as having a potential impact on BCP operations, and as a consequence were recorded when possible, using a dedicated device:

- Light (one measure every 15 minutes);
- Temperature (one measure every hour);
- Humidity (one measure every hour);
- Motion (one measure every minute).

Data analysis did not provide any new information compared to what had already been identified by border guards.

Therefore the environmental data loggers were used only to support important findings such as issues with devices occurring in hot temperatures or in specific lighting condition (shade, direct sun). Where relevant, information such as minimal, maximal, average value of a given index (e.g. temperature, humidity) is mentioned in this report.

Other constraints such as constrained environments (e.g. in trains, in cars) have also been identified during the tests, and were assessed qualitatively by means of border guards’ feedback and observations on the field.

### 3.6. Sample size selection

The overall principle for the initial choice of sample size was finding the right balance between the available resources for the test, traveller throughput per BCP and the desired confidence to make conclusions about the population from the sample. All participating travellers gave their consent and participation was voluntary. Participating Member States were offered promotional material (poster, leaflets and gadgets) to trigger participation at their BCPs.

During the execution of the tests, the amount of travellers by test case at each BCP was monitored and compared against the target minimum sample size. This allowed the testing team to make any necessary adjustments during the execution (e.g. add extra staff, improve information/incentive activities, make some necessary adjustments to set-up or prolong the testing phase). Overall, the sample size was reached for the majority of test cases.

When the sample size could not be reached at a particular BCP within the original timeline of the tests, a decision was taken between eu-LISA and the MS PM to address the issue. In some cases, no remedies could be found and therefore the achieved sample size is lower than the targeted one. While the confidence in the results was therefore lower, the observations that could be made from the tests remained in most cases still relevant nonetheless and were therefore also reported.
During the data analysis phase, cleaning was also performed on the data (e.g. to remove duplicates, or test data) and therefore the final sample size can be slightly lower than the total number of travellers who took part in the tests. The target sample size was as follows:

**Table 2 Target sample size by test case**

<table>
<thead>
<tr>
<th>Test case</th>
<th>TC1</th>
<th>TC2</th>
<th>TC3</th>
<th>TC4</th>
<th>TC5</th>
<th>TC6</th>
<th>TC7</th>
<th>TC9</th>
<th>TC10</th>
<th>TC11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target sample size</td>
<td>600</td>
<td>1000</td>
<td>1550</td>
<td>1550</td>
<td>1550</td>
<td>1600</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>

### 3.7. Users’ perception

Users’ perception of the test process was also measured during the pilot in order to assess the human impact of the process. Two target populations were identified: the border guards performing the controls, and the travellers undergoing the tests.

The perception of border guards was collected via two means: written questionnaires and debriefing sessions. Border guards participating in the tests were invited to reflect and share their experience on five topics:

1. The added-value of the new equipment;
2. Its usability;
3. Possible improvements;
4. Perceived acceptance of travellers;
5. Issues encountered (related to process, travellers or equipment).

Border guards’ feedback was sought to be qualitative, given their extended experience with the test processes. Each questionnaire and debriefing meeting session minutes were analysed and compiled in observations for each BCP and TC. The statements made by border guards were also cross-checked against data, to either strengthen the confidence in the relevance of their feedback or to identify cases of dubious feedback. In the majority of cases however, border guards’ feedback correlated to other observations. It is important to note that results should be put into perspective, since the implemented processes generated additional workload on top of regular duties and the deployed equipment was not always fit for use or purpose. Nevertheless, qualitative observations can be made that reinforce findings derived from the technical analysis of the fingerprint test-case results.

In addition to border guards, participating travellers were asked to express their opinion about the tests after taking part in them. Travellers could register their opinion on a tablet by means of a simple survey on the device. The traveller had the possibility to choose one out of five smiley faces: ranging from very unsatisfied to very satisfied.

Travellers’ feedback was kept at a minimum and as short as possible, to avoid disrupting the operations at the BCP. Therefore, a simple scale of 1 to 5 was chosen, and results were analysed purely quantitatively based on the TC (either for individual TCs or a combination of TCs) and BCP. These results were also cross-checked with border guards’ perception of traveller’s acceptance, as well as observations of travellers’ reactions made in the field.

Finally, a survey conducted on non-participating travellers was made by the European Union Agency for Fundamental Rights at seven BCPs where the pilot was carried out. The two main methodological differences between the two surveys were that the respondents of the pilot survey had actually participated in the tests, and therefore could provide an actual account of their experience in taking part of the tests. However in terms of representativeness, the pilot survey only comprised respondents who elected to participate in the tests, and who might therefore be more accepting of new processes and technology than the overall population.

### 3.8. Data collection and protection

Adequate data protection measures were put in place to guarantee the confidentiality of all data collected during the pilot. No personal data was collected for storage in the tests; only quality indicators, error codes and similar data were stored for further analysis. The data collected for the test was therefore depersonalised and saved only locally (i.e. kept separately from any other information that would make it possible to match the data with a person’s
identity) and the retention of that data was limited to the time necessary to produce the relevant statistics and analysis.

In order to have personal data processed, the travellers were informed of the type of data collected, the purpose of the processing and the controller’s identity. The traveller was explicitly and freely given his/her consent to participate in the test and was also informed of his/her right as a data subject in accordance with data protection law.

The data collection and analysis process, as presented in the figure below, is based on the six following automated steps:

1. Collecting raw data from BCPs (this step was done manually);
2. Mapping the original data to the pilot’s specifications;
3. Cleaning the mapped data, by identifying and removing data samples that were clearly not relevant (e.g. duplicates, records outside of expected boundaries);
4. Merging all cleaned data into a single data file;
5. Analysing the cleaned data with statistical methods;

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vendors’ raw data</td>
<td>Reference file of mapping rules (created by BCP Coordinators)</td>
<td>Reference file of cleaning rules – technical and business (created by BCP Coordinators)</td>
<td>MS Access DB</td>
<td>Analysis questions to answer (created by BCP Coordinators)</td>
<td>Visualising the cleaned data and statistical analysis for reporting.</td>
</tr>
<tr>
<td>Raw data files</td>
<td>Mapping Function</td>
<td>Cleaning Function</td>
<td>Mapped data</td>
<td>Cleaned data</td>
<td>Analysed Data</td>
</tr>
<tr>
<td></td>
<td>Mapped</td>
<td>Mapped</td>
<td>Mapped</td>
<td>Mapped</td>
<td>Analysed</td>
</tr>
</tbody>
</table>

**Automated process based on scripts in R, Python, Tableau**

*Figure 4 Data collection and analysis workflow*

Due to the general nature of the findings, when presenting quantitative data, rounding was made to the closest integer. This can create situations where the sum of percentages in a graph is 99%, or 101%. This may occur in situations where the total is divided into three or more items, as in the examples below.

**Table 3 Rounding methodology example 1**

<table>
<thead>
<tr>
<th>Non-rounded</th>
<th>33.30</th>
<th>33.30</th>
<th>33.40</th>
<th>Sum = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rounded</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>Sum = 99</td>
</tr>
</tbody>
</table>

**Table 4 Rounding methodology example 2**

<table>
<thead>
<tr>
<th>Non-rounded</th>
<th>32.60</th>
<th>33.70</th>
<th>33.70</th>
<th>Sum = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rounded</td>
<td>33</td>
<td>34</td>
<td>34</td>
<td>Sum = 101</td>
</tr>
</tbody>
</table>
3.9. Project Management

The pilot was based on the Terms of Reference (ToR) for the pilot prepared by the Commission and enclosed as technical annex of the delegation agreement with eu-LISA. In order to manage and track the scope, budget, resources, benefits, risks and issues, and the quality, the methodology used throughout the entire project was Prince2®.

Timeline

The pilot was organised around 3 main phases with milestones.

1. Preparation Phase
   - A Project Initiation Document (PID) was produced in October 2014 and approved in January 2015. This document entailed success criteria for the project, governance definition, resources identification and planning, communication and reporting strategy, a quality assurance and control strategy and a preliminary risk assessment as well as tolerances and escalation paths;
   - A Project Strategy - “Overview” was produced. This document entailed a first outline of use cases and test cases, stakeholders' identification, precisions on the scope of the project and risks, and inventories of Member States capabilities and vendors' possible contribution;
   - A project Roadmap published in February 2015 which elaborated use cases and test cases, expected test input and outcomes, details on the timeline and technical aspects of tests;
   - Test Case set up sheets communicated to Member States individually with specific instructions and requirements for the test cases.

2. Execution Phase
   - An Interim Report with interim findings of Test Cases in Member States sent to the European Commission on 15 July 2015 as an intermediate project deliverable.

3. Reporting Phase
   - The deadline for the Final Report and Executive Summary delivery was 30 November 2015.

Milestones were achieved on time and within defined tolerances.

Scope, risk and issue management

Scope as given in the Terms of Reference was monitored throughout the project identifying all the questions raised and the way the final report addresses them.

A project register was produced and maintained on a weekly basis both at BCP and central project levels. In addition, risk assessment was performed on a weekly basis in the project management weekly dashboard review.

The main risk identified and mitigated was the request from the European Commission to deliver a draft final report one month earlier than the final delivery date. The whole reporting phase was thus shifted and resources were strengthened. As a result, the project could deliver on time.

The project defined and tracked tolerances, success criteria and benefits.
Communication Strategy

A communication strategy was set at the beginning of the project and refined over time. The objective of the communication strategy was to keep all the stakeholders informed on a regular basis and ensure active participation. For instance, participating Member States were asked to appoint project managers (MS PMs). They were the single point of contact for eu-LISA in the MS, centralising all the information and results from the BCPs. During the execution phase, MS PMs participated in weekly bilateral calls with eu-LISA BCP coordinators to debrief on test cases progression. At the end of tests, Member States have also been involved in the review of results and were given a chance to provide comments.

For the information and involvement of other stakeholders various forms of meetings and communications were used, as follows:

- Weekly progress meetings with the European Commission;
- Monthly status report (Monthly Update to Stakeholders and monthly PM meetings or webinars with all participating MS);
- Participation in stakeholders’ meetings with Member States (e.g. the Frontier working party of the Council, meetings of the LIBE committee in the European Parliament);
- Individual meetings with stakeholders (e.g. meeting with FRA and Frontex);
- Workshops e.g. with Member States on subject matters in the desk research, with Industry actors, with vendors involved in the tests.

End stage reporting and lessons learnt

Each phase was closed with an End Stage report to prepare the next phase, entailing:

- Project Manager’s Report;
- Review of the Business Case;
- Review of Project Objectives;
- Review of Stage Objectives;
- Review of Team Performance;
- Lessons Report;
- Forecast;
- Review of products.
4. Air borders BCP results

4.1. Arlanda – Facial image

4.1.1. Test description

In this chapter, the testing executed at Arlanda airport near Stockholm, Sweden, within the Smart Borders pilot is described. Arlanda airport is an international airport with the most frequent non-Schengen flights arriving and departing from North America and Asia.

Within the pilot, testing was executed between May and August 2015 at manual booths on the arrivals side. The tests carried out focussed on use of automated facial recognition at manual border controls in an airport environment. Specifically, the aims were to examine the enrolment of live facial images from travellers (TC4), the extraction of the facial image from the electronic chip of the travellers’ e-passport (TC6) and to compare both images using automated facial recognition software as a method for bearer verification (TC7). In general, the overall feasibility of the processes was assessed taking into account the quality of images obtained, the performance of the verification and the duration and user-acceptance of introduced processes.

A standard web-camera was used for live facial image enrolment. The facial image from the chip was obtained using a newly installed flatbed document scanner and automated facial image matching software compared both images.

4.1.1.1. Set-up and configuration

An overview of the test set up and the configuration of testing equipment is provided in the table below:

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Air - Stockholm Arlanda Airport is the main international airport in Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td></td>
<td>• TC4: Enrolling a live facial image</td>
</tr>
<tr>
<td></td>
<td>• TC6: Capturing the facial image from an eMRTD</td>
</tr>
<tr>
<td></td>
<td>• TC7: Verifying the facial image captured from the eMRTD against the enrolled live facial image</td>
</tr>
<tr>
<td>Test location</td>
<td>At a single manual booth in the arrivals (entry) area of the airport Terminal 5 (Pier F)</td>
</tr>
</tbody>
</table>
### Staff involved
24 in total
- 20 border guards were trained and participated in the test to varying degrees depending on their work schedules
- 2 Technicians supported the tests as required
- 2 hosts sometimes guided travellers to the pilot queue

### Total duration
3 months in total with one month of interruption necessary due to operational conditions at the BCP

### Timetable
- From 20.05.2015 to 15.06.2015 (3 weeks)
- From 17.07.2015 to 26.08.2015 (5 weeks)

### Sample size (target / actual)
- Facial image
- TC6, TC4 and TC7: 1550 / 1795

### Process layout
- Dedicated test lane

### Integration within the regular border-crossing process
- Integrated
  Tests were performed as a separate step in the normal BCP process and using the same manual booth as for the regular checks

### Technical integration
- Standalone

### Type of device
- TC4: New fixed single-shot web camera
- TC6: New eMRTD reader, Fixed, Full-page
- TC7: Matching software provided by the vendor

### Quality thresholds
- TC4: No specific enrolment threshold was applied. Warnings were displayed on screen during live image enrolment according to various ICAO 9303-type quality measures. However, they were only used to support the border guard’s decision whether to re-enrol, and no automatic re-enrolment was enforced
- TC6: ICAO 9303 quality measures were provided for the chip facial image
- TC7: A verification threshold of 2800 was advised by the supporting vendor, corresponding to an indicative verification false acceptance rate (FAR) of 0.01%. Unlike with ABCs, passage through the control was not dependent on reaching the set threshold, and therefore no retesting was mandated in case that the threshold was not reached; any decision to re-test was at the discretion of the border guard

### Environmental device
- N/A

### Travellers’ feedback
- After test completion: Self-service tablet

### Data protection
- Formal, verbal consent requested

---

#### 4.1.1.2. Workflow

The test cases were executed sequentially and as a combined process according to the following sequence of three steps:

1. TC6 (first part) - Passport inspection (including Passive Authentication) and retrieval of the facial image from the eMRTD;
2. TC4 - Enrolment of the live facial image (photos) from the TCN;
3. TC7 - Verification of the facial image captured from the eMRTD against the live facial image enrolled from the TCNs.
A standard web-camera was used for live facial image enrolment. Automated and manual focussing was possible, set based on the preferences of the border guard. The software automatically zoomed and cropped the obtained image in order to enforce ICAO-type results, and various quality measures were taken and displayed automatically on-screen. The border guard had the possibility to re-enrol the live image in case of significant quality warnings or if it appeared to be of low quality visually. Otherwise, it was passed to the matching algorithm. The facial image from the chip was obtained using a newly-installed flatbed document scanner.

4.1.1.3. Participation and sample characteristics

Overall, an almost equal proportion of male and female travellers participated. 43% of travellers were between 31 and 50 years old. Chinese nationals were the most represented in the dataset, with ~15% of those participating coming from China. High participation of travellers also from the USA (15%), Russia (13%) and from Thailand and Australia (around 10%) was noted.

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15 The country codes used in the graph are the three-letter country codes defined in ISO 3166-1: http://www.nationsonline.org/oneworld/country_code_list.htm.
4.1.2. Test cases operational and technical results

4.1.2.1. Facial Image (TC6, TC4, TC7)

Success / failure

Various measures of success could be used to characterise testing results at Arlanda airport. One metric to measure success is the percentage of successful verification attempts. During the performance of the tests, a vendor metric was used to assess verification success. The figure below shows the success rate at this threshold corresponding to 0.1% FAR. The success rate for the verification of the image (matching) was 39%.

![Figure 10: Arlanda - F1 related test cases success and failure rate](image)

Chip reading worked very well with no errors encountered in 97% of cases. (Note that this does not include errors due to failure of passive authentication (PA). As PA is important for authenticating that the chip has not been modified and that the document is legitimate and therefore processes can be implemented such that PA failures precludes chip reading, this is not technically necessary. Thus, for our purposes herein, PA failure did not imply chip reading failure). For the few other samples, most errors were due to failure to retrieve the image from the chip (1.34%) or due to access control failures (1%).

![Figure 11: Arlanda - TC6 chip reading outcome](image)

Quality

No rigid thresholds were applied for image enrolment in the test, although quality measures based on ICAO Document 9303 specifications were reported in the dataset produced allowing post-analysis of results. The vendor reported values of 2 or 0 for each of these metrics according to whether they were above or below that vendor’s own thresholds respectively. More than 94% of the live image scores and around 72% of scores for the chip image were above the threshold set for the global quality measure provided, as shown in figure 7 below. Scores for other metrics are provided in figures 8 and 9. It may be observed that post-processing of the live image obtained to enforce compliance with ICAO quality parameters was only moderately successful in some instances. Simultaneous adjustments of height and width ratios cannot be achieved without introducing distortions, for example, and thus it is
clear that stronger controls at the point of capture sometimes may need to be applied to enforce correct distance from the camera. In post-analyses, image frontalness, shown in the figure below, seemed to be important for success in the case of this vendor’s algorithm, with the frontalness score being above the vendor-defined threshold significantly more frequently when the image verification was successful than when not. This highlights the need for cooperative traveller behaviour as well as the ability to communicate instructions to travellers alluded to in later sections of this chapter. Additionally, automatic height adjustment of the camera would help to ensure minimisation of pitch angle, an important determinant of verification success in studies. It was also noted that the number of pixels between the eyes (data not shown) in the live image enrolled was a reasonable predictor of verification success, further highlighting the importance of the traveller’s distance from the camera during photo capture. Finally, it may be noted that chip images were also below the vendor’s advised quality in different aspects.

![Figure 12 Arlanda - quality score and frontalness comparison between live and chip facial image based on vendor’s algorithm](image1)

![Figure 13 Arlanda - TC4 ICAO 9303 results for the live facial image](image2)

![Figure 14 Arlanda - TC6 ICAO 9303 results for the chip facial image](image3)
Duration

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader;</td>
<td>1. To the result of the eMRTD FI acquisition (success or failure), including the time to perform the passive authentication;</td>
</tr>
<tr>
<td>2. From the start of the live image enrolment;</td>
<td>2. To the successful enrolment of live image or timeout (if relevant);</td>
</tr>
<tr>
<td>3. From the start of the facial image verification.</td>
<td>3. To the outcome of the facial image verification.</td>
</tr>
</tbody>
</table>

Tests demonstrated that TCs 6, 4 and 7 could be combined in a single border-crossing process in an efficient manner. The total time required from document placement to display of the verification score on the screen was in almost all cases (95.97%) less than 30 seconds and in 86% of cases was between 5 and 15 seconds. When looking at the total duration of the three steps it should be noted that the combination of TCs 4, 6 and 7 includes several steps that may individually or in combination be considered necessary in future border control systems, including enrolment of a live photo and also document bearer verification.

**Figure 15 Arlanda - FI related test cases process duration (in seconds)**

The graphs below show durations per TC, i.e. per sub-step of the overall process. It can be observed that in the vast majority (93.73%) of cases live FI enrolment took less than 15 seconds and retrieval of the facial image from DG2 of the chip generally (i.e. in 69% of cases) took less than 5 seconds. Passive authentication was complete in less than 6 seconds in 87% of cases.

Execution of facial image verification software added negligibly to the overall process, never taking more than 2 seconds to complete.
4.1.3. Users’ perception

4.1.3.1. Travellers’ feedback

In total, 930 entries (corresponding to around 52% of the participating travellers) were recorded. Travellers’ feedback was not recorded individually for the different test cases but rather reflects traveller responses to the process incorporating all three test cases analysed at Arlanda airport. Respondents generally expressed satisfaction with the process to which they submitted, professing to be either satisfied or very satisfied in about 84% of cases. Negative feedback was provided by 12% of respondents. More details about the feedback are provided in the figure below.

Arlanda - TC4, TC6, TC7

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very satisfied / Satisfied</td>
<td>84%</td>
</tr>
<tr>
<td>Neutral</td>
<td>4%</td>
</tr>
<tr>
<td>Very unsatisfied / Unsatisfied</td>
<td>12%</td>
</tr>
</tbody>
</table>

In discussions following test completion, some border guards indicated a lack of trust in the traveller feedback results. One reason provided was that the lane in which testing was carried out was also open to non-participant travellers and some of these had been seen to select options on the tablet device. Some also suggested that the question might not have been fully understood.
4.1.3.2. Border guards’ feedback

4 individual border guards replied to the survey distributed following completion of testing. Their replies have been aggregated with feedback provided by the national project manager in the final testing questionnaire and comments from the end of testing visit from the eu-LISA Smart Borders team in the dashboard below

*Table 6 Arlanda - border guards’ feedback*

<table>
<thead>
<tr>
<th>Process</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most border guards (4/4) felt more confident with the new step/process.</td>
<td>Negative: 2/4</td>
<td>All claimed that the travellers were ‘mostly enthusiastic’ regarding the new step/process.</td>
</tr>
<tr>
<td>Neutral: 1/4</td>
<td>The majority indicated that the equipment could be more user-friendly, better integrated into the process and better positioned.</td>
<td></td>
</tr>
<tr>
<td>Impediments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Language - border guards suggested that they sometimes had difficulty both explaining the tests and guiding travellers when no common language was available.</td>
<td>Several noted issues with the camera, particularly the need for awkward manual camera adjustment and adjustment of traveller positions depending on their height.</td>
<td>The travellers sometimes had to move forward or back to be appropriately seen within the camera frame.</td>
</tr>
<tr>
<td>Some suggested that they would welcome more guidance regarding similar future deployments.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>As above, some border guards wanted more guidance on how to best use the equipment.</td>
<td>Most suggested that the equipment should be better integrated and more ergonomic.</td>
<td>Generally, it was suggested that the positioning of the equipment could be better.</td>
</tr>
<tr>
<td>One border guard suggested that a hand-held camera could have worked better.</td>
<td>Automatic camera adjustment would be beneficial.</td>
<td>Guidance to travellers could have been at an earlier point in their approach to the control, to get the right persons participating control, to get the right persons participating.</td>
</tr>
</tbody>
</table>
Key findings

• Border guards expressed annoyance regarding technical problems encountered related to reading/using the chips in eMRTDs from certain countries (USA, China). It could not be determined if these were related to the chips themselves, the quality of the photo on the chip or related to the passport reader. Although the rate of document reading error disclosed above was low, it was often apparent that several attempts had to be made to read the document prior to that successful - these were filtered out during cleaning due to the ultimate success of the process, although clearly the delay was annoying for the border guard. Furthermore, in instances where reading completely failed, no data was likely output and therefore such errors don't appear in the final dataset analysed. Based on the feedback from border guards, we assume that the above-mentioned error rates are an underestimation;

• Guards also reported how control of lighting conditions had caused difficulty. Reduced lighting had been observed to impact verification success; a desk office lamp had been introduced to try to mitigate the issues with some success;

• Border guards also reported that they would prefer an easier means to adjust the camera. Whenever the persons were unusually short/tall, it was difficult to get a good facial image capture despite efforts to adjust the camera direction up and down. Language issues had prevented explanations to the traveller to move forward or back into the frame of view in some cases;

• Those providing feedback suggested that this kind of verification of identity should be an essential part of future border management systems. It was suggested that a triangular check (printed photo to chip photo to live photo) would be very useful if it could be implemented;

• BGs indicated they would favour use of both facial image and fingerprint matching in a future Smart Borders set-up. When asked about the use of automated facial recognition alone for an RTP-type program, they considered this appropriate. The verification could be against an enrolled photo or otherwise involve local verification of the document photo against the live image. In the latter case, however, they suggested that a verification of an enrolled photo against the document photo should already have been carried out and be trusted.

4.1.4. Constraints

4.1.4.1. Environmental conditions

Initially problems were noted in obtaining a good light for taking the live photo. This was solved by orienting the desk lamp of the officer outwards towards the traveller - a workaround for testing rather than any form of proposed long-term solution for such a set-up. No other issues associated with environmental conditions were noted or recorded. All tests were made in indoor conditions.

4.1.5. Main observations

• In general, tests worked well. It showed that simple web-cameras could be deployed an airport to record live facial images of reasonable quality that were sufficient for successful automated document bearer verification;

• The overall process was seen to be quick and efficient, in most cases taking less than 15 seconds to complete. At a verification threshold corresponding to an FAR of 0.1%, matching was successful in 46% of instances. Given the fact that automated facial recognition at a manual booth will be confirmed manually by the border guard, one might suggest that a less stringent threshold could be used in such instances, in which case the success rate would obviously be higher;

• Some problems were noted, mainly related to the ease of use of the camera. These could likely be overcome quite easily with more time available to integrate the devices into the overall workflow;

• Border guards favoured an automated approach whereby image capture was automated and ran in the background without any specific actions on their part and such a set-up could be likely provided given such time. If an installation were to be permanent, better solutions for lighting would be sought;

• Border guards saw great value in the automated facial recognition process as a support for decision making on document bearer veracity. The border guards paid heed to the matching scores during testing and were generally keen to know if the verification reached provided threshold values;
In discussions on biometric use in future systems, most suggested that both face and fingerprint be used. Fingerprints were somewhat preferred as a biometric identifier because they are already used (for visa holders) and have been seen to work well at Arlanda airport.

The main area of concern was the frequent problems encountered when reading eMRTD chips. At least some of these issues were not surprising for technical support officers in Sweden who had implemented workarounds in the Swedish system to deal with some of the problems encountered in testing with documents that do not conform to typical standards. This suggested that at least some, though certainly not all, of the chip reading problems would probably be overcome in a fully rolled-out system. In any case, it was stated that all chip reading issues would have to be solved before the implementation of any future EES/RTP.
4.2. Charles de Gaulle – Fingerprint, facial image and ABC gates

4.2.1. Test description

This chapter describes the tests executed at Charles de Gaulle airport, France, within the Smart Borders pilot. Charles de Gaulle airport is the biggest airport in the Schengen Area in terms of both traveller numbers and aircraft movements, with flight connections to destinations worldwide. The busiest intercontinental routes in terms of traveller numbers are to the USA, Canada and the UAE. In total, 62 million passengers transit the airport annually, leading to more than 35.5 million crossings of the borders of the Schengen Area at the airport.

Testing in the pilot was undertaken at Terminal 2E. 39 million passengers travel through the 22 manual booths and 3 ABC gates at the terminal each year and 18 million Schengen border crossings are typically made. The tests focussed on the use of automated facial recognition and fingerprints enrolment at manual border controls in an airport environment, and on the use of ABC gates at exit, including both facial recognition and fingerprints verification.\(^{37}\)

4.2.1.1. Set-up and configuration

The execution and organisation of the test case at Charles de Gaulle airport are set up as follows.

Table 7 CdG - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Air - CdG is the busiest international airport in the Schengen Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Map of Europe showing key cities and countries.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TC2: Enrolling 8 fingerprints</td>
</tr>
<tr>
<td></td>
<td>TC6: Capturing the facial image from an eMRTD</td>
</tr>
<tr>
<td></td>
<td>TC4: Enrolling a live facial image</td>
</tr>
</tbody>
</table>

The verification of fingerprints is outside the scope of the pilot and was performed by France in the frame of the national pilot. Therefore, it will not be analysed in this report.
<table>
<thead>
<tr>
<th>Test location</th>
<th>Terminal T2E - entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff involved</td>
<td>1 border guard was trained and was in charge of the test. 1 assistant to guide travellers.</td>
</tr>
<tr>
<td>Total duration</td>
<td>8 weeks in total</td>
</tr>
</tbody>
</table>

### Timetable

| TC2: | Contact 4FP scanner: From 15.09.2015 to 21.09.2015 (1 week)  
       | Contactless 4FP scanner: From 18.08.2015 to 31.08.2015 (2 weeks) |
| TC4, TC6, TC7: | From 03.08.2015 to 30.09.2015 (8 weeks) |
| TC9: | From 03.08.2015 to 23.09.2015 (8 weeks) |

### Sample size (target / actual)

- Fingerprints
  - TC2: contactless 4FP scanner **1000 / 878**
  - TC2: contact 4FP scanner **1000 / 350**
- Facial image
  - TC4: **1550 / 3817**
  - TC6: **1550 / 3067**
  - TC7: **1600 / 2852**
- ABC gates
  - TC9: **1000 / 2487**

### Process layout

Simulated manual booth and dedicated ABC gate next to the actual manual booths at entry

### Integration within the regular border-crossing process

**Not integrated:** the tests were performed independently of the actual border check process

### Technical integration

**Standalone**

- **New manual booth** equipped with fingerprint scanner, eMRTD reader and camera. The booth incorporates a screen that provides real time instructions and feedback to the travellers.
- **New ABC gate** with integrated eMRTD reader, fingerprint scanner (**1FP contact** or **4FP contactless**) and 3 video cameras for Fi capture and verification with lighting system. The ABC gate contains integrated screens to provide real time instructions and feedback to the traveller. Supervision is made from the manual booth by means of an application

### Quality thresholds

- Fingerprints
  - TC2 (both scanners): Vendor based, similar to VIS
  - TC4: The live facial image is considered successfully captured when it is verified
against the FI contained in the passport’s chip. - A threshold for the verification algorithm was agreed together with the integrator, similar to the one used at the FR consular posts

- TC6: N/A
- TC7: Matching threshold is vendor based, corresponding to 1% FAR

ABC gate (TC9)

- Fingerprints: vendor based
- Facial image: matching threshold is vendor based, corresponding to 0.1% FAR

| Environmental device | Available - used as a probe for airport environment in general
| Monitoring temperature, light, humidity and movement conditions (carried by the border guard in the train) |
| Travellers' feedback | After test completion (after the ABC gate): Self-service tablet |
| Data protection | Formal, written consent requested |

4.2.1.2. Workflow

TCNs holding either MRTDs or eMRTDs participated in the testing. MRTD holders could however only participate in the tests aimed at capturing fingerprints at the manual booth. Therefore, the data presented in this document include only participating TCNs holding an eMRTD, with the exception of the FP enrolment (TC2), which includes as well participating TCNs holding a MRTD.

Fingerprints enrolment

8 fingers were enrolled at the manual booth, using either fixed contact scanner or fixed contactless scanner. In CdG, reattempts were made systematically for the slab if any of the related fingers failed to reach the threshold with a maximum of 3 attempts (i.e. up to 3 attempts to successfully enrol all fingers of the right hand followed by, if applicable, up to 3 attempts to successfully enrol all fingers of the left hand). This means that there were a maximum total of 6 acquisitions for TC2 (3 attempts with the right-hand and 3 for the left-hand). Whenever an attempt was successful or after 3 failed attempts, the testing would continue with the next set of acquisitions until completion of the test case.

Guidance and real time feedback was provided to travellers via a screen on top of the device.

1. TC2: Enrolment of 8 fingerprints (index, middle, ring and little fingers for both hands) with contact scanner

The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were firstly captured followed by those of the left hand (4-4 method).

2. TC2: Enrolment of 8 fingerprints (index, middle, ring and little fingers for both hands) with contactless scanner

The device was mounted on the manual booth at a height below the Border Guard sight; he could not visually supervise the enrolment. The traveller was invited to swipe their right hand horizontally and pass it through a gap in the device, followed by the same process for the left hand.
Facial image related test cases

This process was parallelized with the FP enrolment to the extent it was possible.

- eMRTD reading and extraction of the FI

  The eMRTD is placed in a flatbed document reader, which performs the following operations:
  
  - Extract the alphanumeric information from the document to consult all relevant databases;
  - Perform Passive Authentication of the chip to verify the certificate;
  - Retrieve the picture / facial image from the chip;
  - Measure the quality of that picture according to both ICAO and vendor specific algorithms.

- FI acquisition

  The live capture of a traveller’s facial image is done using of a web camera that takes a video flow of images. The camera is fixed to the manual booth on top of the screen that provides instructions to the traveller, and could eventually be manually adjusted. The system automatically captures a live facial image. If this capture does not match with the chip portrait, the process is repeated up to three times. Finally, the quality scores of the last acquired live facial image are computed for post-analysis purposes.

- Verify FI captured from eMRTD against live facial image

  The photo captured from the eMRTD of volunteering TCNs is compared with the live facial image and the relative verification score is recorded.

ABC gates

The ABC gate in operation was set up in a two-step process with man-trap configuration: the gate initiates the process of reading and verification of the document to confirm the traveller’s eligibility to use the system at the first stage; then the traveller moves to a second stage where a biometric verification (including the verification of the live FI against the image retrieved from the eMRTD and the fingerprint capture) is carried out.

Figure 24: CdG - ABC gates test case (TC9) set-up (two-step process with man-trap)\(^8\)

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\(^8\) Source: Best Practice Operational Guidelines for Automated Border Control (ABC) Systems, FRONTEX 2012.
The specific process steps performed at the ABC gates were the following:

1. Passport chip reading and authentication\(^{19}\);
2. Capture of the facial image from the chip contained eMRTD;
3. Acquisition of the live facial image with sufficient quality to succeed the verification against the facial image contained in the chip of the eMRTD. The capture of the facial image was done through a video stream which analysed the best candidate snapshot for facial recognition;
4. Computer verification of the facial image from the chip of the eMRTD against the live facial image;
5. Acquisition of fingerprints (right index contact or right slap contactless); up to three attempts are systematically performed - based on vendor specific algorithm.

### 4.2.1.3. Sample characteristics

The graphs below show the main characteristics of the sample, consisting of approximately 4000 participating travellers:

**Figure 25** CdG - sample distribution by gender  
**Figure 26** CdG - sample distribution by age

96% of travellers were between 18 years old and 70 years old, with a good representativeness of all age groups in this range. The 4% remaining were minors, older than 12. There were more women than men participating in the tests.

Overall the test included a wide range of travellers’ nationalities. USA was the most represented with 54% of participants.

**Figure 27** CdG - sample distribution by nationality

\(^{19}\) The passport-reading step entails the placement of the passport on the document reader.
4.2.2. Test cases operational and technical results

4.2.2.1. Fingerprints (TC2)

Success / failure

Thresholds based on vendor specific algorithm were used during the enrolment process so that re-attempts were systematically performed when the required quality threshold was not reached, up to three attempts.

The enrolment of the fingerprints was considered successful if each finger in one slap reached the threshold within three attempts - considering that the reattempt recaptured all four fingers from the slap.

Looking at the different travellers participating:

- 901 travellers performed one attempt;
- 96 travellers performed two attempts;
- 213 travellers performed three attempts.

The following charts illustrate the different results obtained for both the contactless and contact 4FP scanner.

**Figure 28** CdG - TC2 success and failure rate with contact device at vendor threshold

Out of approximately 330 samples, 94% of prints were captured above the threshold after a maximum of three attempts using contact devices.

**Figure 29** CdG - TC2 success and failure rate with contactless device at vendor threshold

Out of approximately 876 samples, 85% of prints were captured above the threshold after a maximum of three attempts using contactless device. We can observe that this is a lower performance if compared to contact device.

When looking at each hand individually and its four fingers, no difference in success/failure ratio could be identified between the left and the right hand with contact devices prints. With contactless devices prints, the right hand performed better than the left hand, with 94% success for the right hand compared to 88% for the left hand.

Quality

NFIQ results

Percentages of NFIQ score occurrences and amount of minutiae per each corresponding finger are presented in the graphs below, presenting only the results observed for the first attempt.
Figure 30 CdG - TC2 NFIQ scores per finger at the first attempt with contact scanner

On average around 60% of fingerprints captured presented NFIQ scores of 1 or 2, except for the little finger which presented lower scores. Low NFIQ scores (4 and 5) were few, between 12% and 27% in case of the little fingers.

Figure 31 CdG - TC2 NFIQ scores per finger at the first attempt with contactless scanner

The NFIQ results with contactless scanners were noticeably lower than with the contact scanner, with only 17% to 34% of fingerprints with a NFIQ quality of 1 or 2. The majority of fingerprints, between 32% and 54%, had low NFIQ scores of 4 and 5.
Minutiae results

**Figure 32** CdG - TC2 minutiae amount per finger at the first attempt with contact scanner

On average between 65% and 86% of fingerprints presented between 30 and 60 minutiae. A minority presented more, or less, than these amounts, with the little fingers presenting the least and the ring and middle finger the most.

**Figure 33** CdG - TC2 minutiae amount per finger at the first attempt with contactless scanner

The amount of minutiae captured with a contactless scanner were significantly higher than with the contact scanner, with between 52% and 65% of fingerprints presenting more than 60 minutiae, and only a fraction of them presenting less than 30 minutiae.

**Duration**

The duration of fingerprint enrolment is measured in order to assess the added duration compared to the current situation where no biometric identifier is enrolled. Time-stamped log files, produced by FP scanners, were used for calculating the duration.
The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the FP.</td>
<td>1. The successful capture with a maximum of 3 attempts or the end of the third attempt.</td>
</tr>
</tbody>
</table>

The figures below illustrate the duration of fingerprints enrolment.

**Figure 34** CdG - TC2 duration with contact scanners (in seconds)

With contact devices, 62% of attempts at capturing four fingerprints were completed in less than 15 seconds, 86% in less than 30 seconds, and 4% of them completed in more than 60 seconds. The average duration was about 16 seconds.

**Figure 35** CdG - TC2 duration with contactless scanners (in seconds)

With contactless devices, 85% of attempts at capturing four fingerprints were completed in less than 15 seconds, 98% in less than 30 seconds, and less than 1% completed in more than 60 seconds. The average duration was about 6 seconds while 50% of captures only took 1 second.

4.2.2. **Facial image (TC4, TC6, TC7)**

Regarding facial image the following test cases were performed as one process:

- Retrieval of the facial image from the eMRTD chip (TC6);
- Acquisition of a live facial image (TC4);
- Comparison, verification of the two above (TC7).

This section will analyse the results of the process as a whole, although analysis of specific aspects related to
individual test cases is performed when relevant.

**Success / failure**

The purpose of the facial image test scenario is to perform local automated bearer verification at the border based on the facial image biometric identifier, by comparing (TC7) the facial image captured from the passport chip (TC6) with the facial image captured live (TC4). Therefore, the success condition for all three test cases considered as a whole test scenario is the successful one to one verification of the facial image comprising the following elements:

a) The facial image could be accessed and retrieved from the chip of the eMRTD without errors (passive authentication errors will be addressed separately, as they affect only the authenticity of the document itself);

b) The acquisition of the live facial image is successful: the live facial image could be matched against the facial image contained in the chip of the eMRTD;

c) The verification score was above the set threshold of 1% FAR.

The graph below presents the overall success rate for overall facial image related test cases at CdG airport, i.e. the proportion of travellers who could perform all the steps under the conditions outlined above. A failure in the passive authentication process did not prevent the rest of the procedure to take place.

![Image](image.png)

**Figure 36 CdG - FI related test cases success and failure rate**

The graph below presents the overall success rate for overall facial image related test cases at CdG airport.

![Image](image.png)

**Figure 37 CdG - TC6 passive authentication outcome**

The following observations can be made regarding the figures presented above:

- For the majority of cases the FI verification was successful (86%) and in 7% of the cases, an error earlier in the process occurred that prevented the verification to be attempted;

- The passive authentication succeeded in 72% of cases. The failures are usually related to the fact that some certificates are not properly published in the masterlist.
Retrieved and live FI quality
The quality of the facial image was evaluated based on both vendor specific and ICAO quality index\(^{20}\). The graph below presents the quality score results, both for the facial images retrieved from the eMRTDs and the live facial image captured at the manual booth.

![Quality Score Graph](image)

**Figure 38** CDG - TC4 and TC6 quality score comparison between live and chip facial image based on vendor’s algorithm
The quality of the facial images on chips is in general better than the live facial image. The higher quality can probably be explained by the controlled environment in which pictures used for passports issuance are taken and by the fact that the chip picture is meant to meet the ICAO criteria for enrolment, while the live picture is captured up to 3 times until it matches with the chip picture but is not acquired with the aim of maximising its quality. Additionally the live picture is acquired in the variable and less optimal environment at the border and in this test case, without any specific setting entailing for instance a high resolution camera and dedicated lighting.

**Duration**
The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader;</td>
<td>1. To the result of the eMRTD FI acquisition (success or failure), including the time to perform the passive authentication;</td>
</tr>
<tr>
<td>2. From the start of the live image enrolment;</td>
<td>2. To the successful enrolment of live image or timeout (if relevant);</td>
</tr>
<tr>
<td>3. From the start of the facial image verification.</td>
<td>3. To the outcome of the facial image verification.</td>
</tr>
</tbody>
</table>

The overall duration of the facial image related test cases can be analysed by estimating the duration of each individual step. The combination of the individual time of these steps will depend on the specific process workflow which are here made in parallel:

\(^{20}\) Specific vendor scores will not be analysed, and they are presented only for the purpose to allow comparison of the quality scores between the live and chip facial image. Absolute values of the scores will not be assessed.
1. Extract facial image form the eMRTD;
2. Perform Passive Authentication of the chip;
3. Acquisition of the live facial image;
4. Verification of live and chip facial image.

The following figures show the distribution of durations obtained for each of the above steps:

**Figure 39** CdG - TC6 facial image from the chip retrieval duration for eMRTD holders (in seconds)

**Figure 40** CdG - TC4 live facial image enrolment duration for eMRTD holders (in seconds)

**Figure 41** CdG - TC7 facial image verification duration for eMRTD holders (in seconds)

**Figure 42** CdG - TC6 passive authentication duration for eMRTD holders (in seconds)

The following observations can be made:

- In most cases, 80% of the participants, the extraction of the facial image from the chip can be done in less than 4 seconds;
- For 94% of the participants, the acquisition of the live facial image is made in less than 15 seconds;
- The passive authentication and the facial image verification take less than 2 seconds for all of the participants.
4.2.2.3. **ABC gates**

**Success / failure**

The purpose of the ABC gate testing was to assess whether it is possible to perform local automated bearer verification at the border based on the facial image biometric identifier, by matching the facial image retrieved from the passport chip and the facial image captured live. Therefore, the success condition for the test case is the successful verification of the facial image - which depends on the following steps:

a) The facial image could be accessed and retrieved from the chip of the eMRTD without errors (passive authentication errors are addressed separately as they do not prevent the FI to be extracted from the chip and used for an eventual verification with the live facial image);

b) The acquisition of the live facial image was successful;

c) The verification score for the comparison between the live facial image and the photograph extracted from the chip of the eMRTD was above the set threshold. This threshold is based on vendor algorithm and it was chosen to ensure a performance of 0.1% FAR.

The graph below presents the overall success rate for ABC gates at Charles de Gaulle, based on the results obtained with eMRTDs holders only.

![Graph showing success and failure rate for ABC gates]

**Figure 43 CdG - TC9 success and failure rate for the entire bearer verification process based on the facial image modality**

It can be seen that 89% of travellers’ identity was successfully verified at ABC gates based on the facial image modality. 11% of attempts resulted in a matching score lower than the threshold corresponding to 0.1% FAR, and in less than 1% of cases, verification did not occur for other reasons.

Looking only at the PA itself, the following figure shows the amount of cases where the PA was successful and the reason for failure otherwise.

![Graph showing PA success and failure]

**Figure 44 CdG - TC9 passive authentication outcome**

The passive authentication was successful in 74% of the cases.
Quality

The quality distribution between the live facial image and the image capture from the eMRTD chip are presented below for comparison purposes. The quality score is obtained from the vendor’s algorithm\(^{21}\).

![Quality comparison chart](image_url)

**Figure 45** CdG - TCg quality score comparison between live and chip facial image based on vendor’s algorithm

In general, it can be seen that the chip facial image is better than the live facial image, which can probably be explained by the controlled environment in which pictures used for passports issuance are taken, and by the fact that the chip picture is meant to meet the ICAO criteria for enrolment, while the live picture is captured up to 3 times until it matches with the chip picture but is not acquired with the aim of maximising its quality. Additionally the live picture is acquired in the variable and less optimal environment at the border.

Duration

This section describes the time it takes a given traveller to pass through the ABC gate. The duration is calculated by using time-stamped log files produced by the ABC gate itself.

The duration only presents the cases where the traveller was able to actually enter the gate.

In Charles de Gaulle airport, the time recorded in the logs regarding the duration values also covers the time to acquire and to verify one fingerprint with a contact device (for 1508 samples) or four fingerprints with a contactless device (for 972 samples) inside the gate, with a matching score above the vendor’s threshold including up to three systematic attempts.

The duration of this capture is therefore included in the overall duration presented in the figures below.

The capture of one fingerprint with the contact device was on average 6 seconds longer than the capture of four fingers with a contactless scanner.

The measurement points for the duration of the test cases were as following:

---

\(^{21}\) Specific vendor scores will not be analysed, and they are presented only for the purpose to allow comparison of the quality scores between the live and chip facial image. Absolute values of the scores will not be assessed.
In 60% of cases, a traveller spent less than 30 seconds to use the ABC gate, including facial image biometric verification and capture of one or four fingerprints. In 37% of cases, it took between 30 to 60 seconds, with some rare occurrences of lower and higher values recorded. The average crossing time per traveller was around 30 seconds.

On top of the overall duration, the duration of the passive authentication is presented below:

The passive authentication was very fast and stable, with an average of 1.5 seconds needed for the process.

### 4.2.2.4. Duration impact on the end to end process

The purpose of this section is to compare how the introduction of biometric enrolment steps at the manual booth as well as use of ABC gates with biometric verification steps analysed above might affect the duration of the border check process, in comparison to the current average duration of the border check process at Charles de Gaulle airport.
Values are provided in the following table:

**Table 8 CdG - duration impact on the end to end process**

<table>
<thead>
<tr>
<th>Aspect under measurement</th>
<th>Average duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline exit(^{22})</td>
<td>25 seconds</td>
</tr>
<tr>
<td>8 fingerprint enrolment with 4FP contact scanner at manual booth</td>
<td>14 seconds</td>
</tr>
<tr>
<td>8 fingerprint enrolment with 4FP contactless scanner at manual booth</td>
<td>6 seconds</td>
</tr>
<tr>
<td>Facial image capture and verification (including PA) - theoretical time if all steps were done sequentially at manual booth</td>
<td>10 seconds</td>
</tr>
<tr>
<td>ABC gate crossing (including fingerprint verification)</td>
<td>30 seconds</td>
</tr>
</tbody>
</table>

From the values in the table above, it can be observed that in the case of the testing set-up at Charles de Gaulle airport:

- The ABC gate, including biometric capture from two sources and their verification\(^{23}\), was faster than the regular border check process at Charles de Gaulle (11 seconds less);
- The capture of eight fingerprints did not have a substantial impact on the border-crossing time, in particular with the contactless device, which took only six seconds to capture, compared to 14 with the contact device;
- Facial image capture and verification, including passive authentication, was fast even when not taking into account the possibility to parallelise steps of the process, taking 10 seconds in total.

### 4.2.3. Users’ perception

In order to assess the acceptance and perception of the new steps, both travellers and border guards have been consulted.

#### 4.2.3.1. Travellers’ feedback

At Charles de Gaulle airport, participating travellers provided their feedback after going through all the test cases (fingerprints, facial image and ABC gates).

In total, 845 entries (corresponding to around 23% of the participating travellers) were recorded. The overall feedback was very positive, with only 5% of respondents expressing dissatisfaction.

\(^{22}\) Based on 116 samples.

\(^{23}\) Fingerprint capture was also included as a step in the ABC gate as part of the French national pilot.
Charles de Gaulles - TC2, TC4, TC6, TC7, TC9

Very unsatisfied | Unsatisfied  | 5%
Neutral | 4%
Very satisfied | Satisfied | 91%

*Figure 48 CdG - results of the travellers’ survey*

4.2.3.2. Border guards’ feedback

1 border guard replied to the questionnaire in CDG which included the feedback for TC2, TC4, TC6, TC7 and TC9 (all in the same questionnaire).

The results are summarised in the table below.

*Table 9 CdG - border guard’s feedback*

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral: testing was</td>
<td>Negative (this could be due to the dependency between the manual booth and</td>
<td>Positive, quite enthusiastic.</td>
</tr>
<tr>
<td>performed in isolation</td>
<td>the ABC gate added by the national pilot).</td>
<td></td>
</tr>
<tr>
<td>to the actual border</td>
<td></td>
<td></td>
</tr>
<tr>
<td>check.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impediments</td>
<td>Technical disruptions were frequent. This could be due to too frequent</td>
<td>Difficulties to capture finger-</td>
</tr>
<tr>
<td>N/A</td>
<td>change of configuration following the different phases of the national</td>
<td>prints of elderly travellers.</td>
</tr>
<tr>
<td></td>
<td>pilot.</td>
<td></td>
</tr>
<tr>
<td>Improvements</td>
<td>N/A</td>
<td>More guidance to travellers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>needed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More reliable technical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>solution needed.</td>
</tr>
</tbody>
</table>

4.2.4. Constraints

4.2.4.1. Environmental conditions

The tests took place at CdG airport, with indoor conditions. An environmental measurement device was deployed to monitor temperature, humidity and light throughout the entire testing period, in order confirm the postulate that airports are little subject to environmental conditions except in specific conditions.

It was placed in indoor conditions. Border guards did not report about any difficulty with the device that would be linked with environmental conditions. As can be seen in the table below, during the entire testing period, the temperature ranged from a minimum of 23.2° to 30.1° Celsius.
Table 10 CdG - Maximum, minimum and average of temperature, humidity and light

<table>
<thead>
<tr>
<th></th>
<th>Temperature (°C)</th>
<th>Humidity (RH%)</th>
<th>Light (Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>23.2°</td>
<td>28.4%</td>
<td>37.14</td>
</tr>
<tr>
<td>Max</td>
<td>30.1°</td>
<td>54.9%</td>
<td>74.29</td>
</tr>
<tr>
<td>Average</td>
<td>27.21°</td>
<td>38.10%</td>
<td>53.62</td>
</tr>
<tr>
<td>Observations</td>
<td>24° and 29°</td>
<td>30% and 49%</td>
<td>Position of the sensor was not appropriate for recording relevant conditions</td>
</tr>
</tbody>
</table>

4.2.4.2. Others

Assistance to the traveller was often required, in particular with the contactless devices and the ABC gates.

4.2.5. Main observations

Fingerprint enrolment seemed to work well at Charles de Gaulle airport, with a high success rate: 94% with the contact device and 85% with the contactless device. It was also fast compared to the overall process, between 6 and 14 seconds based on the type of device.

Facial image acquisition also worked well, with 76% of travellers successfully verified based on their live facial image and the image from the eMRTD chip, with a 1% FAR threshold. The chip facial image was often better than the live image, highlighting that there is room for improvement to capture the facial image at the border. The process was also fast with 10 seconds in average, not taking into account possibilities for parallelising steps.

Passive authentication was successful in 72% of the cases at the manual booth and 74% at the ABC gate. It was observed that some nationalities fared better at PA than others.

Overall, ABC gates worked well with TCNs and could be successfully applied at Charles de Gaulle airport. 88% of test participants were able to get their identity successfully verified with a 0.1% FAR. The average time to cross the ABC gate was 30 seconds, including bearer verification based on the facial image, fingerprint capture and travel document check.

According to border guards, travellers appreciated the process; however some improvements with the equipment still need to be done. With the exception of some passports being more problematic to read than others (e.g. some Chinese passports), nothing noteworthy seemed to indicate that ABC gates would not be suitable for TCNs at exit.

From the observations on the field, it is noted that ergonomics and integrated assistance with an adequate human interface of the ABC gate play an important role to their acceptability by the user.
4.3. Frankfurt – Fingerprints and ABC gates

4.3.1. Test description

Frankfurt airport, Germany, is the third busiest airport in terms of traveller numbers in Europe, with 59.6 million passengers using the airport in 2014. As well as acting as an entry point for a large region of central Europe, it is a busy transit airport for international flights, with 55.1% of all passengers transferring at the airport and therefore demanding quick passage through border checks. Approximately 36% of flights transiting the airport are intercontinental, with large numbers of flights coming from North America and the Far East.

This chapter describes the tests executed at Frankfurt airport within the Smart Borders pilot. Testing took place at Terminal 2 which handles about 15% of the traffic passing through the airport.

4.3.1.1. Set-up and configuration

The execution and organisation of the test cases at Frankfurt Airport were set up and configured based on characteristics listed in the table below.

Table 11 Frankfurt - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Air - Frankfurt Airport (Flughafen Frankfurt am Main) is the main, busiest, international airport in Germany.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td></td>
<td>• TC1: Enrolling 4 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC2: Enrolling 8 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC3: Enrolling 10 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC9: Using ABC gates for border checks of TCNs</td>
</tr>
<tr>
<td>Test location</td>
<td>TC1, TC2, TC3: Terminal 2 - entry in two locations</td>
</tr>
<tr>
<td></td>
<td>TC9: Terminal 2 - exit</td>
</tr>
<tr>
<td>Staff involved</td>
<td>TC1, TC2, TC3</td>
</tr>
<tr>
<td></td>
<td>• Up to 5 border guards simultaneously at the BC manual booths (from a pool of several hundred trained BGs²⁵)</td>
</tr>
<tr>
<td></td>
<td>• 5 hostesses in total</td>
</tr>
<tr>
<td></td>
<td>TC9</td>
</tr>
<tr>
<td></td>
<td>• 2 border guards dealing with a set of 6 ABC gates, of which two were used for TC9 (from a pool of several hundred BGs)</td>
</tr>
<tr>
<td></td>
<td>• 2 hostesses in total</td>
</tr>
<tr>
<td>Total duration</td>
<td>13 weeks in total</td>
</tr>
<tr>
<td>Timetable</td>
<td>TC1: From 19.08.2015 to 23.09.2015 (5 weeks)</td>
</tr>
<tr>
<td></td>
<td>TC2: From 20.07.2015 to 19.08.2015 and from 15.09.2015 to 21.09.2015 (5 weeks)</td>
</tr>
<tr>
<td></td>
<td>TC3: From 24.06.2015 to 21.07.2015 (4 weeks)</td>
</tr>
<tr>
<td></td>
<td>TC9: From 17.06.2015 to 13.09.2015 (4 weeks)</td>
</tr>
<tr>
<td>Sample size</td>
<td>Fingerprints</td>
</tr>
</tbody>
</table>

²⁵ In Frankfurt, a ‘train the trainer’ approach was used, where 40 border guards received training to further train their colleagues.
| (target / actual) | • TC1: **600 / -1690**  
| | • TC2: **1000 / -1210**  
| | • TC3: **1550 / -1130**  
| | ABC gates  
| | • TC9: **1000 / -6610**  
| **Process layout** | TC1, TC2, TC3: In two locations, an existing manual booth with two stations; (Dedicated lane; done at the regular border guard booth). Later one station added. TC9: Existing ABC gates, two were modified to accept TCNs - two step.  
| **Integration within the regular border-crossing process** | **Integrated**: Process steps were integrated in the normal border-crossing process, i.e. made in the middle of the regular border check procedure.  
| | Process was also integrated in the national system environment (e.g. SIS and VIS checks were included) and - except the ABC gates - connected to an EES simulator. The piloted process followed the concept of the Technical Study on Smart Borders, including a 1:n identification at first entry for VH and different workflows for VH and VE.  
| **Technical integration** | TC1, TC2, TC3: **Integrated**  
| | TC9: **Integrated**  
| **Type of device** | TC1: **New and existing 4FP fixed contact fingerprint scanners** (optical) and **new 4FP contactless scanners**  
| | TC2: **New and existing 4FP fixed contact fingerprint scanners** (optical) and **new 4FP contactless scanner**  
| | TC3: **New and existing 4FP fixed contact fingerprint scanners** (optical)  
| | TC9: **Existing two-step ABC gates**, adapted to accommodate for TCNs  
| **Quality thresholds** | Fingerprints  
| | • TC1:  
| | | • Contact scanners: NFIQ 3·3·3·4  
| | | • Contactless scanners: Vendor specific quality threshold only for the first two attempts. For the third capture, the only criterion was that all fingers have been detected  
| | • TC2:  
| | | • Contact scanners:  
| | | | • 350 samples: NFIQ 3·3·3·4  
| | | | • 150 samples: No threshold  
| | | | • 150 samples: NFIQ 2·2·2·3  
| | | • Contactless scanners:  
| | | | • 50 samples: NFIQ 2·2·2·3  
| | | • 475 samples: Vendor specific quality threshold only for the first two captures. For the third capture, the only criterion was that all fingers have been detected irrespective of the quality  
| | • TC3:  
| | | • Contact scanners: NFIQ 2·2·2·3  

---

55 During the execution of TC2, various set-ups were tested, splitting the total sample into several much smaller groups, lowering the confidence in the results achieved for each individual setting. The sample size for each setting is indicated as results are presented.

56 The sample achieved was below target due to time constraints.
### 4.3.1.2. Workflow

The workflows for fingerprint enrolment were different depending on whether a fixed contact scanner (TC1, TC2, and TC3) or fixed contactless scanner was being used (TC1, TC2).

In Frankfurt, reattempts were made systematically for the slap or pair of thumbs in question if any of the related fingers failed to pass the threshold with a maximum of 3 attempts (i.e. up to 3 attempts to successfully enrol all fingers of the right hand followed by, if applicable (TC2 and TC3), up to 3 attempts to successfully enrol all fingers of the left hand and ending with, if applicable (TC3), up to 3 attempts to successfully enrol both thumbs). This means that there was a maximum total of 3 acquisitions for TC1 (3 attempts with the right-hand), 6 acquisitions for TC2 (3 attempts with the right-hand and left-hand) and 9 acquisitions for TC3 (3 attempts with the right-hand, left-hand and thumbs). Whenever an attempt was successful or after 3 failed attempts, the testing would continue with the next set of acquisitions until completion of the test case.

#### Fingerprint enrolment for fixed contact scanners

Both new and existing 4-FP fingerprint fixed contact scanners were used throughout the tests. Guidance was provided to travellers for the new contact scanner via a screen in front of the device.

1. **TC1: Enrolment of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).**

   The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were captured using a standard optical livescan device.

2. **TC2: Enrolment of 8 fingerprints (index, middle, ring and little fingers for both hands)**

   The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were firstly captured followed by those of the left hand. (4-4 method).

3. **TC3: Enrolment of 10 fingerprints (index, middle, ring, little fingers and thumbs for both hands)**

   The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were captured in the first step, followed by those of the left hand. The thumbs of both hands were captured in the final step of fingerprint enrolment.
Fingerprints enrolment for fixed contactless scanners

New FP fingerprint fixed contactless scanners were used throughout the tests. Guidance was provided to travellers for the new contact scanner via a smartphone placed on a stand in front of the device those this was not implemented until mid-way through the tests.

1. **TC1: Enrolment of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).**

   The device was set in front of the BG station and mounted on the manual booth at a height where the Border Guard could visually supervise the enrolment. The traveller was invited to swipe their right hand horizontally and pass it through a gap in the device while in front of the booth.

2. **TC2: Enrolment of 8 fingerprints (index, middle, ring and little fingers for both hands)**

   The device was set in front of the BG station and mounted on the manual booth at a height where the Border Guard could visually supervise the enrolment. The traveller was invited to swipe their right hand horizontally and pass it through a gap in the device while in front of the booth, followed by the same process for the left hand.

**ABC gates**

The process for the ABC gates was divided in the following steps\(^\text{27}\):  

1. Passport authentication\(^\text{28}\); 
2. Capture of the facial image from the eMRTD chip; 
3. Enrolment of a suitable high-quality live facial image; 
4. Verification of the facial image from the eMRTD against the live facial image; 
5. Stamping, conducted outside the gate.

The ABC gate in operation was a set-up in a two-step process with man-trap.

---

\(^{27}\) The five steps have been defined to permit judgement to be made on whether to allow the traveller to pass without manual intervention and are applicable to all BCPs.  
\(^{28}\) The passport-reading step entails the insertion of the passport in a slot that rolls the passport inside the machine, instead of simply placing it on top of a scanning device. A picture of the passport is scanned, the data from the eMRTD is acquired, and the relevant checks are performed (e.g. National Police, SIS).  
\(^{29}\) Source: Best Practice Operational Guidelines for Automated Border Control (ABC) Systems, FRONTEX 2012.
The gates were set-up in an integrated two-step process. At the first stage, the traveller initiated the verification of the document and the traveller’s eligibility to use the system. Then, if successful, the traveller moved to a second stage where a biometric verification (including the verification of the live FII against the image retrieved from the eMRTD chip) and other applicable checks were carried out.

4.3.1.3. Sample characteristics
The proportion of male to female travellers was balanced, with slightly more male travellers (55%) participating in the tests at Frankfurt Airport. 73% of participating travellers were between 31 and 70 years old. No travellers aged under 18 years old or over 70 years old participated in the tests.

Please note that the spread of nationalities are separate between the test cases covering fingerprints and the test case for ABC gates, as only a limited number of TCN nationalities were allowed to participate in the ABC gate.30

Travellers of American nationality represented the largest share of participants (58% for FP test cases and 30% for the ABC gate test case).

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30 The nationalities allowed to participate were: ARE, ARG, ALJ, AZE, CAN, CHL, CHN, ISR, JPN, KAZ, KOR, MDA, MKD, MYA, NZL, QAT, RUS, SGP, SRB, TGO, THA, TJK, TUR, TUN, USA, VEN. Turkish nationals were excluded from the ABC-at-Exit TC during the pilot phase at a later stage because of transliteration specifics in the MRZ of Turkish passports.

31 FBI EBTS was used as a base for the country codes: see fbibiospecs.org for more details.
4.3.2. Test cases operational and technical results

4.3.2.1. Fingerprint enrolment (TC1, TC2, TC3)

Success / failure

The enrolment of the fingerprints was considered successful if the set threshold for all fingers was reached within three attempts. As mentioned in 1.1 Set-up and configuration, the set threshold differed depending on the Test Case and the type of fingerprint scanner (contact or contactless) deployed.

The graphs below show the success/failure rate for TC1, TC2 and TC3.

TC1 success / failure

Threshold: NFIQ 3-3-3-4

![Graph showing success and failure rate for TC1 with contact device at 3-3-3-4 NFIQ threshold.](Figure 59)

Out of approximately 870 samples, we can see that 78% of prints were captured above the threshold after maximum three attempts. Only in a low percentage of samples (approximately 1%), no values were recorded for one or more fingers.

Threshold: Auto-capture function

![Graph showing success and failure rate for TC1 with contactless device with a vendor quality threshold set only for the 1st two attempts and no threshold for the 3rd attempt](Figure 60)

The vendor specific quality threshold was used for enrolment, but only for the first two captures. For the third capture, the only criterion was that all fingers have been detected. Out of approximately 600 samples, we can see that 93% of prints were successfully captured above the threshold after 3 attempts.
### TC2 success / failure

<table>
<thead>
<tr>
<th></th>
<th>NFIQ 2-2-2-3 (from 20.07.2015 to 27.07.2015: ~ 150 samples)</th>
<th>Auto-capture function (from 28.07.2015 to 02.08.2015: ~ 150 samples)</th>
<th>NFIQ 3-3-3-4 (from 03.08.2015 to 22.09.2015: ~ 350 samples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact</td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
</tr>
<tr>
<td>NFIQ 2-2-2-3</td>
<td>56%</td>
<td>97%</td>
<td>62%</td>
</tr>
<tr>
<td>Auto-capture function</td>
<td>44%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>NFIQ 3-3-3-4</td>
<td></td>
<td></td>
<td>97%</td>
</tr>
</tbody>
</table>

**Figure 61** Frankfurt - TC2 success and failure rate with contact devices at various thresholds

We can see that depending on the threshold used, the success rate varies from 44% for the more stringent NFIQ 2-2-2-3 threshold to 97% for the less stringent threshold applied by the auto-capture function. Across all thresholds, we can see that only in a low percentage of samples no values were recorded for one or more fingers.

<table>
<thead>
<tr>
<th></th>
<th>NFIQ 2-2-2-3 (from 20.07.2015 to 27.07.2015: ~ 50 samples)</th>
<th>Auto-capture function (from 28.07.2015 to 22.09.2015: ~ 475 samples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contactless</td>
<td><img src="image4.png" alt="Graph" /></td>
<td><img src="image5.png" alt="Graph" /></td>
</tr>
<tr>
<td>NFIQ 2-2-2-3</td>
<td>71%</td>
<td></td>
</tr>
<tr>
<td>Auto-capture function</td>
<td>29%</td>
<td>93%</td>
</tr>
</tbody>
</table>

**Figure 62** Frankfurt - TC2 success and failure rate with contactless devices at various thresholds

We can see that the success rate for the contactless device at NFIQ 2-2-2-3 (29%) is lower than that observed for the contact device (44%), at the same threshold, presented previously. Again, we can see that the less stringent auto-capture function results in a much greater success rate (93%). Across both thresholds, we can see that only in a low percentage of samples no values were recorded for one or more fingers.
TC3 success / failure

Threshold: NFIQ 2-2-2-2-3

Out of approximately 1,130 samples, we can see that 54% of prints were successfully captured above the threshold. Comparing the results with those of the contact scanners in TC2 (same NFIQ 2-2-2-2-3 threshold) we observe that the success rate is 10% better for this test case despite the fact that more slaps (right-hand, left-hand and thumbs) were performed and with the same devices being used. This can be attributed to the sample size which is over 7 times larger for TC3 than TC2.

In line with the observations in TC1 and TC2, only in a low percentage of samples no values were recorded for one or more fingers.

Quality

Percentages of NFIQ score occurrences and amount of minutiae for each corresponding finger for TC4, TC2 and TC3 are presented in the graphs below. The set threshold differed depending on the Test Case and the type of fingerprint scanner (contact or contactless) deployed. For more details on the quality indicators used, and in particular the use of NFIQ with contactless devices, please refer to the Methodology chapter.

TC1 quality

NFIQ results

For these tests, enrolment of fingerprints was conducted both on fixed contact optical scanners and fixed contactless scanners. Below the quality distribution based on NFIQ values for the first attempt are presented per type of scanner (contact / contactless).

Threshold: NFIQ 3-3-3-4

NFIQ scores between 1 and 3 were most frequently obtained at the first attempt. And over 80% of fingerprints captured
had a NFIQ value of at least 3. Fingerprints from the little finger presented the lowest scores (as throughout the tests at Frankfurt); those for the index, middle and ring fingers presented similar scores (NFIQ 1 and 2) in around 60% of cases.

Threshold: Auto-capture

Figure 65 Frankfurt - TC1 NFIQ scores per finger with contactless device with a vendor quality threshold set only for the 1st two attempts and no threshold for the 3rd attempt

On average less than 40% of fingerprints captured presented NFIQ 1 and 2 scores. There were very few fingerprints captured with NFIQ 2 and NFIQ 5. On the other hand, the most common value recorded was NFIQ 4. The majority of fingerprints captured had NFIQ scores 3 or 4. There were no NFIQ 5 scores.

TC1 Minutiae results

Threshold: NFIQ 3-3-3-4

Figure 66 Frankfurt - TC1 minutiae amount per finger at the best attempt with contact device at 3-3-3-4 NFIQ threshold

We can see that 60 or more minutiae were recorded in a majority of cases by the contact scanners in TC1. An absolute majority (above 95%) of fingerprints enrolled presented more than 30 minutiae.

As expected, the number of minutiae recorded was the lowest for the little finger. The results for the index finger were also relatively poor with the number of minutiae recorded being only slightly better than those for the little finger.
Threshold: Auto-capture

Figure 67 Frankfurt - TC1 minutiae amount per finger at the best attempt with contactless device with a vendor quality threshold set only for the 1st two attempts and no threshold for the 3rd attempt

The results for the number of minutiae identified with the contactless equipment in TC1 were very high, with almost all fingerprints enrolled presenting more than 60 minutiae. Though the contactless scanners had lower scores to the contact scanner in terms of the NFIQ quality distribution, the number of minutiae recorded was significantly higher. This can be explained partly by the broader surface scanned, but could also be due to issues with correctly identifying reliable minutiae on pictures originating from contactless scanners.

TC2 quality

For these tests, enrolment of fingerprints was conducted both on fixed contact optical scanners and fixed contactless scanners. During the execution of the tests, the threshold for the fixed contact scanners was revised twice and that for the fixed contactless scanners was revised once. The results are presented below per type of scanner and broken down per threshold.

Figure 68 Frankfurt - TC2 NFIQ scores per finger at the first attempt with contact device at 2-2-2-3 NFIQ threshold

Generally, the NFIQ scores of prints from the left hand were comparable to those from the right hand. The ring finger gave the best quality scores. The NFIQ score distribution across fingers obtained was slightly better than the distributions for the fixed contact scanners in TC1 (2% to 5% depending on the finger), except for the right little finger where 9% more attempts had an NFIQ 1 or NFIQ 2 than in results from the 4-fingerprint enrolment.
This can be explained by the higher threshold used in this case (2-2-2-3) over the one used for the fixed contact scanner in TC1 (3-3-3-4).

Auto-capture function (from 28.07.2015 to 02.08.2015)

Though the percentage of prints with scores of 1 and 2 is comparable to those obtained with a set threshold of NFIQ 2-2-2-3, it can be observed that there are slightly less NFIQ 1 records and more NFIQ 5 records when the threshold was set from the auto-capture function embedded in the device.

NFIQ 3-3-3-4 (from 03.08.2015 to 22.09.2015)

Generally, the NFIQ scores of prints from the left hand were comparable to those taken from the right hand except for the left index finger where 12% more attempts presented quality scores of 1 or 2.

Looking at NFIQ 1 and NFIQ 2 records combined, the score distribution across fingers is worse (3% to 10% depending on the finger) than the distribution observed in TC2 for the fixed contact scanner when the threshold was set at NFIQ 2-2-2-3).

The results of the right hand are comparable to those observed in TC1 (fixed contact scanner with the same NFIQ threshold at 3-3-3-4) in the sense that in around 60% of cases the index, middle and ring fingers readings had NFIQ scores of 1 and 2. However, there seems to be slightly more prints of NFIQ score 3 and slightly less prints of NFIQ score 4 and 5 than in TC1.
**Figure 71** Frankfurt - TC2 NFIQ scores per finger at the first attempt with contactless device at 2-2-2-3 NFIQ threshold

Generally, around 50% of prints had NFIQ scores of 1 or 2. There were no NFIQ 5 scores despite the fact that the device did not allow adjustments of positioning of the hand (the hand was swiped through the device in one single motion). This is consistent with the results obtained from the contactless scanners in TC1 (vendor specific threshold) where a very minimal percentage of attempts resulted in NFIQ 5 values.

Auto-capture function (from 28.07.2015 to 22.09.2015)

**Figure 72** Frankfurt - TC2 NFIQ scores per finger at the first attempt with contactless device at vendor specific quality threshold

On average, less than 40% of fingerprints captured had NFIQ scores of 1 or 2. They were very few fingerprints captured with NFIQ 2 and NFIQ 5. On the other hand, the most common record was NFIQ 4. The majority of fingerprints captured had NFIQ scores of 3 or 4.

Again, there were practically no NFIQ 5 scores despite the fact that the device did not allow adjustments of positioning of the hand (the hand was swiped through the device in one single motion). This is consistent with the results of the contactless scanners described throughout this BCP Chapter. This is due to the fact that the same contactless scanner was used throughout.

It can be observed that the score distribution was significantly lower when compared to those resulting from the contactless scanner results for a set NFIQ threshold of 2-2-2-3. This can be explained by the lower threshold used in this case (vendor specific quality threshold) over the one for the fixed contactless scanner using a threshold of 2-2-2-3.
TC2 Minutiae results

**Figure 73** Frankfurt - TC2 minutiae amount per finger at the best attempt with contact device at 2-2-2-3 NFIQ threshold

Auto-capture function (from 28.07.2015 to 02.08.2015)

**Figure 74** Frankfurt - TC2 minutiae amount per finger at the best attempt with contact device with only the auto-capture function

NFIQ 3-3-3-4 (from 03.08.2015 to 22.09.2015)

**Figure 75** Frankfurt - TC2 minutiae amount per finger at the best attempt with contact device at 3-3-3-4 NFIQ threshold
As observed for the contact scanners in TC1, we can see that 60 or more minutiae were recorded in a majority of cases by the contact scanners in TC2. An absolute majority (above 95%) of fingerprints enrolled presented more than 30 minutiae. The number of minutiae recorded were the lowest for the little finger and the results for the index finger were also relatively poor with the number of minutiae recorded being only slightly better than those for the little finger.

The results of the left hand were noticeably better than those for the right hand.

Comparing the results across the different thresholds, we can see that the best results were obtained with the auto-capture function while the worst were obtained with a set threshold NFIQ threshold of 2-2-2-3.

![Figure 76](image)

**Figure 76** Frankfurt - TC2 minutiae amount per finger at the best attempt with contactless device at 2-2-2-3 NFIQ threshold

![Figure 77](image)

**Figure 77** Frankfurt - TC2 minutiae amount per finger with contactless device at the best attempt at vendor specific quality threshold and auto-capture function

As seen for TC1, the results for the number of minutiae identified with the contactless equipment in TC2 were exceptional, with almost all fingerprints enrolled presenting more than 60 minutiae. Though the contactless scanners seemed inferior to the contact scanner in terms of the NFIQ quality distribution, the number of minutiae recorded was significantly higher. This can be explained partly by the broader surface scanned, but could also be due to issues with correctly identifying reliable minutiae on pictures originating from contactless scanners.
TC3 quality

**Figure 78** Frankfurt - TC3 NFIQ scores per finger at the first attempt with contact device at 2-2-2-2-3 NFIQ threshold

Generally, the quality of prints from the left hand was comparable to those from the right hand. Over 80% of fingerprints captured had a NFIQ value of at least 3 and around 60% of prints had a NFIQ value of 1 or 2. The distribution is characterised by the fact that the majority of prints had NFIQ 1 scores.

Without taking the thumbs into account, the score distribution across fingers obtained was noticeably higher than those for the fixed contact scanner in TC2 with the set threshold of NFIQ 2-2-2-3, particularly for the right hand.

**TC3 Minutiae results**

**Figure 79** Frankfurt - TC3 minutiae distribution per finger with contact device at 2-2-2-2-3 NFIQ threshold

The minutiae for the thumbs for TC3 could not be recorded and, as such, are not presented in the results above.

Generally, more minutiae were recorded for the left hand than the right hand. This is comparable to the results obtained for the contact scanners in TC2.

Also, similarly to the results from the contact scanners in TC1 and TC2, we can see that 60 or more minutiae were recorded in a majority of cases by the contact scanners in TC3. An absolute majority (above 95%) of fingerprints enrolled presented more than 30 minutiae. The number of minutiae recorded were the lowest for the little finger and the results for the index finger were also relatively low with the number of minutiae recorded being only slightly better than those for the little finger.

The results were noticeably inferior to those for the fixed contact scanner in TC2 with the set threshold of NFIQ 2-2-2-3.
Duration

The duration of fingerprint enrolment is measured in order to assess the added duration compared to the current situation where no biometric identifier is enrolled. Time-stamped log files, produced by FP scanners, were used for duration measurement.

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the FP;</td>
<td>1. The successful capture with a maximum of 3 attempts or the end of the third attempt;</td>
</tr>
<tr>
<td>2. The start of the successful capture.</td>
<td>2. The successful capture with a maximum of 3 attempts or the end of the third attempt.</td>
</tr>
</tbody>
</table>

The graphs below illustrate the duration of fingerprints enrolment for TC1, TC2 and TC3.

It should be noted that in the case of Frankfurt, retries were systematically performed when the quality threshold was not reached.

**TC1**

Threshold: NFIQ 3:3:3:4

![Figure 80](#) Frankfurt - TC1 duration with contact scanners (in seconds)

With contact devices, 46% of attempts at capturing four fingerprints were completed in less than 15 seconds, 77% in less than 30 seconds, and 6% of them completed in more than 60 seconds. The average duration was around 25 seconds.
Threshold: Auto-capture

With contactless devices, 52% of attempts at capturing four fingerprints were completed in less than 15 seconds, 76% in less than 30 seconds, and 10% of them completed in more than 60 seconds. The average duration was 25 seconds.

Regardless of the threshold used, less than 1% of attempts at enrolling eight fingerprints were completed in less than 15 seconds. Based on the stringency of the threshold, between 24% and 28% of attempts were completed in less than 30 seconds, and between 23% and 42% of them completed in more than 60 seconds.

The threshold change had an impact on duration, noticeable on the average duration: 60 seconds for the most stringent threshold, 53 seconds for the second most stringent threshold, and 52 seconds with the auto-capture function of the equipment.
Only 2% of attempts at capturing eight fingerprints were completed in less than 15 seconds, regardless of the threshold used. When using the auto-capture function for assessing success of the capture, 45% of attempts were taking less than 30 seconds compared to 11% when using the NFIQ threshold. Attempts taking more than 60 seconds were 19% with the auto-capture function, compared to 57% when using the NFIQ threshold.

The average duration was 44 seconds with the auto-capture, and 79 seconds with the NFIQ 2-2-2-3 threshold.

Only around 1% of attempts at capturing ten fingerprints were completed in less than 30 seconds, and more than 60% of them completed in more than 60 seconds. The average duration was 79 seconds.
Impact of attempts on duration and success/failure rate

In Frankfurt, retries were systematically performed when the quality did not reach the required threshold. The impact of subsequent retries can be analysed from the perspective of duration and success, in order to assess what is the marginal benefit of performing each subsequent attempt, and also how much more time it takes.

Impact of attempts on duration

The average time required for fingerprints capture is presented in the tables below. The capture in Frankfurt was done in three different slaps, one for the right hand (thumb excluded), one for the left hand (thumb excluded) and one for the two thumbs. Each of these slaps could be performed up to three times, and therefore the number of acquisitions can reach up to nine (three attempts for each of the three slaps) in the case of TC3.

Table 12 Frankfurt - Duration per acquisition22 for each TC for the contact and contactless scanners

<table>
<thead>
<tr>
<th>Test case</th>
<th>Number of acquisitions</th>
<th>Number of samples</th>
<th>Average duration</th>
<th>Median duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC1</td>
<td>1</td>
<td>757</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>74</td>
<td>32</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>205</td>
<td>41</td>
<td>3</td>
</tr>
<tr>
<td>TC2</td>
<td>2</td>
<td>412</td>
<td>42</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>51</td>
<td>59</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>57</td>
<td>67</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>25</td>
<td>96</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>73</td>
<td>91</td>
<td>7</td>
</tr>
<tr>
<td>TC3</td>
<td>3</td>
<td>429</td>
<td>52</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>137</td>
<td>66</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>147</td>
<td>77</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>68</td>
<td>94</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>126</td>
<td>104</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>57</td>
<td>114</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>152</td>
<td>130</td>
<td>12</td>
</tr>
</tbody>
</table>

As we can see from the tables above, looking at all test cases for both contact and contactless devices, it took on average around 2 to 3 times longer to register 3 attempts when compared to 1 attempt.

Impact of attempts on success/failure rate

To show the impact of attempts on success failure rate, we take the example of TC1 for both the contact and contactless scanners.

![Attempt 1, Attempt 2, Attempt 3](https://example.com/attempt-graph)

22 The number of acquisitions relates to the “steps” that constitute one attempt. For example, the minimum number of acquisitions for TC3 is three, which constitute one attempt, since the steps involve capturing the right hand followed by the left hand followed by the two thumbs.
The purpose of the ABC gate tests was to assess whether it is possible to perform local automated bearer verification at the border based on the facial image biometric identifier, by comparing the facial image captured from the passport chip and the live facial image captured. Therefore, the success condition for the test case is the successful verification of the facial image - which depends on the following steps:

a) The facial image could be accessed and retrieved from the eMRTD without errors (passive authentication errors are addressed separately as they do not prevent the FI to be extracted from the chip and used for an eventual verification with the live facial image);
b) The acquisition of the live facial image was successful;
c) The verification score was above the set threshold of 0.09% FAR (slightly more stringent than the 0.1% FAR proposed as best practice by Frontex.

The graph below presents the overall success rate for overall facial image related test cases at Frankfurt airport, and the causes for failure.
It can be seen that more than three quarters of travellers who attempted to use the ABC gate succeeded in doing so.

The passive authentication was successful in more than 90% of the cases. Quality data regarding the facial and chip image was not recorded in Frankfurt.

**Duration**

The duration was measured by using time-stamped log files produced by the ABC gate itself. The average crossing duration was calculated considering both instances in which passive authentication (PA) was successful and when it failed. During the tests, if PA failed, the traveller was allowed through the gate and further manual control took place.

The duration presented includes only those travellers who managed to enter the gate (i.e. when the chip image was successfully capture) and does not include additional background checks on the TCN nor the time needed to stamp the passport after the ABC gate crossing.

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The traveller starts interacting with the ABC gate by placing his/her passport onto the reader.</td>
<td>1. The moment the man-trap opens to let the traveller through - this includes the manual intervention needed to be performed by the border guard supervising the ABC gates, who has to manually open the gate’s exit barrier following the facial image verification(^\text{33}).</td>
</tr>
</tbody>
</table>

\(^{33}\) By design, ABC gates do not require a manual intervention by the border guard for EU/EEA and CHE citizen. The workflow for the pilot was designed differently, because the same e-gates were used for both user groups, but for the TCN the passport needed to be stamped. Thus the TCN
48% of travellers crossed the ABC gate in less than 30 seconds, and 46% between 30 and 60 seconds. Only around 6% of cases took more than 60 seconds. The average time was 34 seconds.

The duration needed for passive authentication of the eMRTD was also recorded. At Frankfurt airport, the duration only includes the time for performing the cryptographic part of the passive authentication.

The passive authentication was very fast and stable, with an average of 0.1 seconds needed for the process.

### 4.3.2.3. Duration impact on the end to end process

The purpose of this section is to compare how the introduction of the biometric enrolment and verification steps analysed might affect the duration of a standard end to end border check process. We describe herein:

a. A baseline measurement: the average duration of the current border check process;

b. Average times for the individual biometric enrolment and verification steps calculated based on the operational tests undertaken as well as end to end times for the border check with the facial image and fingerprint-based processes;

c. Average times for the crossing of ABC gates;

d. Border-crossing time (end to end) including a simulated 1:n deduplication and individual file creation (approx. 20

could only leave the gate when authorized by the Border Guard, who called the TCN for passport stamping. With an EES in place, this additional step will be obsolete. All checks could then be performed automatically via the ABC gate.
Values are provided in the following table:

**Table 13** Frankfurt - duration impact on the end to end process

| Aspect under measurement | Baseline\(^{34}\) | Average duration (low threshold | high threshold) |
|--------------------------|-----------------|---------------------------------|
| Contact                  |                 |                                 |
| 4 fingerprint enrolment with 4FP scanner | 54 seconds | |
| 8 fingerprint enrolment with 4FP scanner | 23 seconds | |
| 10 fingerprint enrolment with 4FP scanner | 49 | 61 seconds |
| 79 seconds |
| Contactless              |                 |                                 |
| 4 fingerprint enrolment with 4FP scanner | 25 seconds | |
| 8 fingerprint enrolment with 4FP scanner | 44 | 65 seconds |
| Pilot measured end to end |                 |                                 |
| Total border control procedure with 4 FP enrolment | 109 seconds | |
| Total border control procedure with 8 FP enrolment | 155 seconds | |
| Total border control procedure with 10 FP enrolment | 196 seconds | |

From the values in the table above, it can be observed that in the case of the testing set-up at Frankfurt:

- The ABC gate, for those travellers for whom it can be applied (~70% of the tests participants), was (27%) faster than the baseline. While it didn’t include the questions to the travellers, it included biometric capture from two sources and their matching;
- Fingerprints have a noticeable impact on the border-crossing procedure, in particular when taking eight or ten fingerprints. The total border control procedure with fingerprint enrolment increased by 65% for TC1, 140% for TC2 and 200% for TC3.

### 4.3.3. Users’ perception

#### 4.3.3.1. Travellers’ feedback

4410 entries were recorded for TC1 and TC9 (4 fingerprints and ABC gates)\(^{35}\), 2786 entries for TC2 (8 fingerprints) and 1551 entries for TC3 (10 fingerprints).

Travellers expressed moderate satisfaction subsequent to their participation in the pilot. Throughout the testing, between 19% and 33% of the total number of respondents expressed their dissatisfaction with the process. It should be noted however that the German authorities were conducting additional tests at the same time resulting in a

\(^{34}\) The average baseline duration was calculated from a sample of 135 travellers, with data points recorded manually by the border guard using a clock on the wall (from the time traveller left the queue up to arrival at the booth). All other data points were extracted centrally using the border guard’s software log files (from the time the traveller’s passport was placed on the reader to the point where it was given back by the border guard.

\(^{35}\) At Frankfurt airport, the results from TC1 and TC9 were merged due to a technical issue which made it impossible to identify which feedback came from which test case.
process which was rather long. This could explain some of the dissatisfaction. In general, the travellers’ feedback should be seen in the light of the overall set-up for the testing at Frankfurt Airport as explained in this chapter.

**Frankfurt - TC1, TC9**

Very unsatisfied | Unsatisfied: 19%
Neutral: 6%
Very satisfied | Satisfied: 75%

**Frankfurt - TC2**

Very unsatisfied | Unsatisfied: 23%
Neutral: 9%
Very satisfied | Satisfied: 67%

**Frankfurt - TC3**

Very unsatisfied | Unsatisfied: 33%
Neutral: 7%
Very satisfied | Satisfied: 60%

*Figure 91* Frankfurt - results of the travellers’ survey

4.3.3.2. Border guards’ feedback

From the border guards in Frankfurt, 13 responses for TC1, 25 responses for TC2, 33 responses for TC3 and 8 responses for TC9 were received. In addition, 3 Border Guards participated in the end-of-test field visit and also gave their overall observations regarding the 4 different test cases. The results per the relevant test cases are summarised in the tables below.

The border guard feedback should be read in light of the set-up at Frankfurt which was integrated from both a technical and a process perspective; also the German authorities were conducting additional tests at the same time and deployed a new front-end system for the border guard to use during test execution in order to demonstrate the future process according to the Technical Study on Smart Borders.

Therefore some of the border guards’ feedback covered activities outside the scope of the pilot, as it frequently refers to the whole end-to-end process including, and sometimes specifically referring to, the new software. Also, the experience largely depended on the equipment being used by the border guard.
Table 14 Frankfurt - TC1 border guards’ feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive: 3 out of 13</strong></td>
<td><strong>Neutral: 3 out of 13</strong></td>
<td><strong>Neutral: 3 out of 13</strong></td>
</tr>
<tr>
<td><strong>Neutral: 3 out of 13</strong></td>
<td><strong>Neutral: 3 out of 13</strong></td>
<td><strong>Neutral: 3 out of 13</strong></td>
</tr>
<tr>
<td><strong>Negative: 7 out of 13</strong></td>
<td><strong>Negative: 5 out of 13</strong></td>
<td><strong>Negative: 5 out of 13</strong></td>
</tr>
<tr>
<td>Two of the border guards</td>
<td></td>
<td>One border guard commented that most travellers are enthusiastic as they see it as future-oriented.</td>
</tr>
<tr>
<td>commented that though the system didn’t have much value in the testing, they could envisage the benefit of such a system if implemented across MS.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impediments</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process took too long and one border guard commented that there were too many steps in the process.</td>
<td>Equipment ergonomics.</td>
<td>One border guard commented that travellers were overwhelmed by the process and equipment.</td>
</tr>
<tr>
<td></td>
<td>No signal / system problems.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hardware problems.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Improvements</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 15 Frankfurt - TC2 border guards’ feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive: 5 out of 25</strong></td>
<td><strong>Neutral: 5 out of 25</strong></td>
<td><strong>Neutral: 5 out of 25</strong></td>
</tr>
<tr>
<td><strong>Neutral: 5 out of 25</strong></td>
<td><strong>Neutral: 11 out of 25</strong></td>
<td><strong>Neutral: 11 out of 25</strong></td>
</tr>
<tr>
<td><strong>Negative: 15 out of 25</strong></td>
<td><strong>Positive: 8 out of 25</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Neutral: 2 out of 25</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Negative: 11 out of 25</strong></td>
<td></td>
</tr>
<tr>
<td>New contactless fingerprint device was generally perceived to not be ready for operational use.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impediments</td>
<td>Equipment</td>
<td>Traveller</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>The process takes too long.</td>
<td>Equipment ergonomics.</td>
<td></td>
</tr>
<tr>
<td>Border guards feel under pressure as queues grow, and could make mistakes by trying to avoid creating queues.</td>
<td>No signal / system problems.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hardware problems.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvements</td>
<td>Equipment</td>
<td>Traveller</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>N/A</td>
<td>Improve border guard training to be more confident in equipment use.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improve border guard training to be more confident in guiding travellers.</td>
<td></td>
</tr>
</tbody>
</table>
Table 16 Frankfurt - TC3 border guards' feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
</table>
| Positive: 4 out of 33  
Neutral: 11 out of 33  
Negative: 18 out of 33  
Process is immature but can add value if improved. | Positive: 11 out of 33  
Neutral: 9 out of 33  
Negative: 13 out of 33  
Mixed results most probably due to type of scanner used with contact scanner receiving more praise than the contactless. | Positive: 11 out of 33  
Neutral: 11 out of 33  
Negative: 11 out of 33  
Traveller acceptance seemed to depend on the waiting time, they were unenthusiastic if the queues were too long but were happy if they got through quicker than the normal control points. |

<table>
<thead>
<tr>
<th>Impediments</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
</table>
| Process took too long. | Equipment ergonomics.  
No signal / system problems.  
Hardware problems. | Length of process creating long queues.  
They need more guidance. |

| Improvements | | |
|--------------| | |
| Register travellers in EES already when applying for visa. | Fingerprint scanners should be placed within sight of the border guard, so that they can see what is happening directly and support the travellers if needed. | Application demonstrating the process needs to reflect it better. |

Table 17 Frankfurt - TC9 border guards' feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
</table>
| Positive: 4 out of 9  
Neutral: 4 out of 9  
Negative: 1 out of 9  
Overall, border guards found the process comparable to the current experience with EU nationals using ABC gates. | Positive: 7 out of 9  
Neutral: 2 out of 9  
Negative: none | Positive: 6 out of 9  
Neutral: 3 of 9  
Negative: none  
Traveller acceptance was high. Only difficulty was to manage and communicate the manual intervention needed for passport stamping. |

<table>
<thead>
<tr>
<th>Impediments</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
</table>
| The need for manual intervention and stamping sometimes disturbed the flow of EU travellers that were using the same ABC gates. | No signal / system problems.  
Hardware problems.  
Transliteration issues for the MRZ Turkish passports. | Travellers needed more guidance in understanding the need for manual intervention for passport stamping. |

| Improvements | | |
|--------------| | |
| Two border guards commented that it would be desirable with a fully automated process including automated stamping. | N/A | N/A |
4.3.4. Constraints

4.3.4.1. Environmental conditions

The tests in Frankfurt were performed in airport conditions, and no environmental conditions impacted the operations.

4.3.4.2. Specificities of set-up at Frankfurt

As part of the specific set-up in Frankfurt and for the purposes of their national pilot, Germany implemented and introduced a new border control application and process. This requirement impacted the overall performance and the measured statistics, as:

- The border guard had to deal not only with the new technology and the enrolment process but also the new workflow including an Entry-Exit-System;
- Several hundred border guards participated in the tests, so a train-the-trainer approach was necessary given the short timeframe of the pilot;
- The new border control application had to be developed, but also a national integration including real life systems as the VIS, SIS II and an EES “simulator”.

As a consequence the measurements, especially of the duration of the pilot, must be interpreted in this given context. Performance improvement both based on improved training and technical optimisation can be assumed, if more time for the testing had been available.

4.3.5. Main observations

- The threshold used for fingerprints acquisition plays a central role in the speed of capture, however its impact on quality depends on the equipment used. Taking the example of TC2 where several thresholds were used, all other things held constant:
  - With the contact scanner used in the tests in Frankfurt, using a NFIQ threshold of 2-2-2-3 was approximately 20% slower than with the auto-capture function of the scanner, while having comparatively less impact on the quality: 7% additional captures had a NFIQ of 1 or 2;
  - With the contactless scanner used in Frankfurt, the duration when using the vendor specific algorithm was 30% than when using the NFIQ threshold of 2-2-2-3; however the impact on quality was substantial: 50% less captures had a NFIQ of 1 or 2. This could be explained by the fact that the NFIQ quality algorithm is not designed for assessing the quality of readings from contactless scanners, however it still raises questions on the interoperability with fingerprints obtained by contact scanners.

- Retries (performed when the quality was not sufficient) impacted both duration and success rate. Duration was impacted rather linearly (meaning that two attempts took around twice the time for one attempt, and three times for three attempts), however noticeable diminishing returns were observed after the first attempt. In the case of TC2 for example, the second attempt was credited with 6% out of the 76% success/failure ratio, and the third 2% out of 78%. Each second spent in the process is much less beneficial for the second attempt and the third attempt than for the first;

- Out of the fingerprint test cases, only TC1 had a limited impact on the duration of the border control procedure, with half of the attempts taking less than 15 seconds and three quarters of the attempts taking less than 30 seconds. TC2 and TC3 had much more noticeable impact on the border control procedure with a majority of attempts taking more than 30 seconds, and even 60% of attempts taking more than 60 seconds in the case of TC3;

- Contactless fingerprint scanners did not seem to provide noticeable benefits compared to contact scanners, in terms of quality, duration, border guard and traveller feedback. It was also not possible to practically use them for the thumbs, given the angle of this finger compared to the rest of the hand.
4.4. Lisbon - Iris, ABC gates and kiosks

4.4.1. Test Description

This chapter describes the testing undertaken in Terminal 1 of Lisbon airport within the Smart Border pilot project. Lisbon airport is the main international airport in Portugal and a major European hub, handling over 18 million passengers in 2014. A majority of extra Schengen flights arrive at Terminal 1, with an estimated 2500 travellers per day passing through the border crossing at which test systems were deployed, of whom about 750 were TCNs. The airport thus provided a good environment for the testing of systems at a busy location with significant flows of TCNs.

The tests focused on three different aspects: (i) the use of automated border checks for TCNs when leaving Schengen Area; (ii) enrolment of iris at an enrolment station; (iii) enrolment of facial image and 8 fingerprints using a kiosk.

4.4.1.1. Set-up and configuration

The main characteristics of the pilot tests in Lisbon are summarised in the table below:

**Table 18 Lisbon airport - set-Up and configurations**

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Air - Lisbon airport is the main international gateway to Portugal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>![Map of Lisbon and surrounding countries]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- TC5: Enrolling iris pattern</td>
</tr>
<tr>
<td></td>
<td>- TC9: Automated Exit Checks for TCNs</td>
</tr>
<tr>
<td></td>
<td>- TC10: Use of Self-Service kiosks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test location</th>
<th>TC9: Terminal 1 building - exit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TC5 and TC10: Terminal 1 building - entry</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Staff involved</th>
<th>16 in total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shifts of 2 to 3 border guards plus hostess</td>
</tr>
</tbody>
</table>

| Total duration                 | 11 weeks in total                                                              |
| **Timetable** | TC9: From 15.03.2015 to 03.04.2015 (3 weeks)  
TC5: From 13.04.2015 to 04.05.2015 (4 weeks)  
TC10: From 11.05.2015 to 04.06.2015 (4 weeks) |
| **Sample size (target / actual)** | Iris  
TC5: 1550 / 2219  
ABC gates  
TC9: 1000 / 1384  
Kiosk  
TC10: 1000 / 1453 |
| **Process layout** | TC9: Existing ABC gates (two-step integrated): 1 lane at exit dedicated to the testing with TCNs.  
TC5: Enrolment station placed in front of a dedicated manual booth  
TC10: Kiosk placed in front of a dedicated manual booth |
| **Integration within the regular border-crossing process** | TC9: Integrated: Process steps were integrated in the normal border-crossing process, i.e. made as the regular border check procedure.  
TC5 and TC10: Standalone: Process steps were not integrated into the normal border-crossing process, i.e. made before the processing of travellers by border guards at the dedicated lane. |
| **Technical integration** | TC9: Integrated  
TC5, TC10: Standalone |
| **Type of device** | TC5: Standalone enrolment station equipped with single-shot camera for scanning face and iris (not simultaneously).  
TC9: Existing two-step ABC gates, adapted to accommodate for TCNs  
TC10: Stand-alone kiosk with single-shot camera for scanning face and 4FP fixed contact fingerprint scanner (optical) |
| **Quality thresholds** | Iris  
TC5: Vendor’s threshold, different for verification or enrolment purposes.  
ABC gates  
TC9: Vendor’s threshold.  
Kiosk  
TC10:  
- FI: Vendor’s threshold. For the purposes of calculating the verification success rate this has been normalised to value that would correspond to a FAR of 0.1%  
- FP: Auto capture was set to capture 4 fingers from each slap, with a quality score NIFQ 5 at least for all the fingers. |
| **Environmental device** | N/A |
| **Travellers’ feedback** | After test completion: Self-service tablet |
| **Data protection** | Formal, written consent requested |
4.4.1.2. **Workflow**

**ABC gates**

The process for transit through the ABC gates encompassed the following steps:\(^{36}\):

1. Reading of the MRZ and chip of the eMRTD, including: passport authentication, formatting of data for use by the system, and interrogation of national and European databases;
2. Capture of the facial image from the eMRTD’s chip (accomplished within step one but considered herein as a separate process to aid analyses below);
3. Capture of a live Fl;
4. Verification of the facial image from the eMRTD’s chip against the live facial image. If the verification failed (i.e. a result below threshold was obtained), the border guard overseeing the ABC gate(s) would have to open the gate through the control software;
5. Stamping of the document to record the border crossing at a manual booth after crossing the ABC gate.

The ABC gates at Lisbon airport were integrated two-step gates with man-trap.\(^^{37}\) The below figure illustrate the aforementioned workflow.

![Figure 92 Lisbon - TC9 ABC gates workflow](image)

**Iris enrolment**

The iris enrolment station would simulate the process of enrolling the iris at the first arrival at the border. The traveller first presented him-/herself at the station, where the following steps were implemented:

1. Selection of traveller’s preferred language;
2. Placement of eMRTD onto the document reader for reading of the MRZ and chip and electronic document verification;
3. Capture of the live facial image (kiosk would self-adjust in terms of height);
4. Capture of the iris pattern for both eyes (separate camera than the one used to capture Fl). In case the defined quality threshold was not reached, reattempt would take place up to three attempts in total;
5. The traveller would go to a dedicated lane for the manual booth for the actual border clearance procedure.

**Self-Service Kiosk**

The self-service kiosk provided for a simulated semi-automated border check procedure. The traveller first presented him-/herself at the biometric enrolment kiosk, where the following steps were implemented:

---

\(^{36}\) The five steps have been defined to permit judgement to be made on whether to allow the traveller to pass without manual intervention and are applicable to all BCPs.

\(^{37}\) As defined in the Frontex Best Practice Operational Guidelines for Automated Border Control (ABC) Systems, Frontex, 2012.
1. Selection of traveller’s preferred language;

2. Placement of eMRTD onto the document reader for reading of the MRZ and chip and electronic document verification;

3. Enrolment of 8 FPs, using a 4FP contact scanner. The Kiosk would request to perform a re-attempt of the slap under enrolment if the quality of the slap was not NFIQ 5 (for each finger) or better, up to three attempts in total. Only the scores for the last attempt were kept;

4. Capture of the live facial image and its verification against the reference image extracted from the chip of the eMRTD (the timeout for the live facial image capture was set at several minutes);

5. Upon completion, a paper receipt including a low resolution picture and the biographical data would be printed for the travellers;

6. The traveller would go to a dedicated lane for the manual booth for the actual border clearance procedure. In addition, the traveller would enrol 8 FPs and the live facial image. This allowed comparing the enrolment process at the kiosks and at the manual booth.

4.4.1.3. Participation and sample characteristics

The graphs below show the characteristics of the participants in the testing at Lisbon airport.

There were slightly more female participating travellers with a share of 54%, and 46% male participants. The highest percentage of the travellers was between 31 and 50 years of age (37%) and between 51 and 70 years (also =37%). The test for TC9 and TC10 at Lisbon airport did not accept enrolment of children (below 18 years), however for TC5 the limit was 12 years old instead, following the agreement with the national data protection authority. Travellers having a Brazilian nationality constituted the majority with a share of above 53%, followed by a significant share of travellers from US (24%), as illustrated by the graphs below.
4.4.2. Test cases operational and technical results

4.4.2.1. Iris (TC5)

Success / failure

The success condition is the successful capture of the iris pattern with a quality score over a defined threshold. In most cases (73%), only one attempt was required for a successful enrolment. Up to 3 attempts were made in very few cases (1.3%), in case the first attempt failed.

The graph below presents the success rate of iris pattern capture, as well as the conditions of success reached. At Lisbon Airport, two thresholds were defined: “Enrolment Quality” and “Identification Quality”, being the latter lower.

The enrolment threshold would be the recommended quality for enrolling the iris pattern within the central database and allow further identifications. The values were estimated by the vendor on the basis of large-scale tests performed with proprietary datasets so as to ensure that the biometric iris matching performance will conform to what is typically expected.

It can be observed that the capture of both irises simultaneously was possible in the majority of cases (72%), and that in some occasions (28%), the iris pattern could not be enrolled at a good enough quality. Only a small proportion (5% for left iris and 3% for right iris) of the cases was successful but did not reach the threshold for “Identification Quality”.

Very little difference can be seen between the left and the right iris.
Quality

The quality of the iris pattern captured live is evaluated based on one of two criteria depending on the data received from the MS:

- NISTIR 7820 (extract);
- Vendor quality index.

The indicator retained for Lisbon airport is the Vendor quality index.

The graph below presents the quality score results of the iris patterns obtained in Lisbon. The set-up at Lisbon Airport only recorded quality values for the successful enrolments.

![Figure 98 Lisbon - TC5 quality distribution of right and left iris patterns for attempts with a recorded quality score above vendors' threshold](image)

When capture was possible at a sufficient quality for identification, it can be observed that the absolute majority (92% for left iris and 95% for right iris) of the captured iris patterns had very high quality scores.

Duration

At Lisbon airport, a timeout was set for the enrolment of iris patterns, at 40 seconds.

The points of measurement for the duration of the iris pattern capture are:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the iris pattern.</td>
<td>1. The successful capture of the iris pattern.</td>
</tr>
</tbody>
</table>

The graph below presents the time needed for capturing both iris patterns.

![Figure 99 Lisbon - TC5 right and left iris enrolment process duration (in seconds)](image)
From the above graph can be seen that:

- In 62% of cases, the successful enrolment of the pair of iris patterns was taking less than 15 seconds;
- 78% was taking less than 30 seconds;
- No attempts took more than 60 seconds;
- The average duration was about 18 seconds.

### 4.4.2.2. ABC gates (TC9)

#### Success / failure

The purpose of the ABC gate tests was to assess whether it is possible to perform local automated bearer verification at the border based on the facial image biometric identifier, by matching the facial image retrieved from the eMRTD chip and the live facial image captured. Therefore, the success condition for the test case is the successful verification of the facial image - which depends on the following steps:

a) The facial image could be accessed and retrieved from the eMRTD chip without errors (including passive authentication errors as, though they did not prevent the F1 to be extracted from the chip, they prevented an eventual verification with the live facial image);

b) The capture of the live facial image was successful;

c) The verification score for the comparison between the live facial image and the photograph extracted from the chip of the eMRTD was above the set threshold. This threshold is based on vendor algorithm and was chosen to result in a performance of approximately 0.5% FAR. There was a time-out of 30s implemented for the capture of the facial image.

The graph below presents the overall success rate for ABC gates at Lisbon based on a 1% false acceptance rate.

**Figure 100 Lisbon - TC9 success and failure rate for the entire bearer verification process based on the facial image modality at a FAR of approximately 0.5%**

It can be seen that 52% of the attempts at using ABC gates at exit reached the stage of the facial image verification. When verification score was below the threshold, the values were not recorded as the border guard would take control from the software. As mentioned previously, passive authentication errors are included in the failure rate since the process was blocked when they occurred (accounting for approximately 18% of the population of the test).

In order to facilitate the comparability of the results among BCPs, the figure below demonstrates the success-failure when a theoretical threshold of 0.1% is applied to the sample.
As expected, the verification success rate is reduced, decreasing by 18% (from 52% to 34%), across the whole sample. It should be noted that these figures are solely estimates - if such a threshold was applied in reality, live facial images could have been re-enrolled in case of verification failure. Thus, the proportion of successful verifications at 0.1% FAR presented above underestimated the actual success rate if enforced in real life.

**Chip access**

For around 9% of the travellers, an error in accessing the passport chip prevented the retrieval of the facial image from the chip (OPEN_CHIP_BAC and OPEN_CHIP_OTHER). In 3% of cases the error was due to reading the MRZ of the travel document. The 89% of cases for which document reading (DG2) was possible includes samples for which passive authentication failed. These represented 16% of the overall sample meaning that the document could be read without PA errors in 73% of cases. The difference between this result and the 52% success rate (at 1% FAR) can be attributed to other errors, not related to document reading, impacting the success rate.

**Quality**

The comparison between the Chip Image (CI) quality and Live Image (LI) quality in the cases where there were no document errors or passive authentication errors (since the latter blocked the subsequent enrolment and verification steps) is presented below.

The chip image quality was better than the live image quality in 77% of cases. The contrary was true in 23% of cases. This can be attributed to the better conditions under which the chip image was taken (professional photographer,
dedicated set-up at passport issuing authority) compared to the BCP conditions. In less than 1% of cases the quality values registered were the same for CI and LI, this was due to the fact that the quality recorded was zero in these cases.

**Duration**

The duration was measured by using time-stamped log files produced by the ABC gate itself. The total average crossing duration was calculated excluding cases where passive authentication failed (since this resulted in the process being discontinued). It also excludes samples for which evidence of document errors was recorded as well as the time needed to stamp the passport after the ABC gate crossing.

![Figure 104 Lisbon - TC9 ABC gate process duration (in seconds)](image)

6% of travellers crossed the ABC gate in less than 15 seconds, and 66% between 15 and 30 seconds. 28% of cases took more than 30 seconds, though always less than 90. The average time was 26.6 seconds.

The duration specific to the passive authentication is presented below:

![Figure 105 Lisbon - TC9 passive authentication duration (in seconds)](image)

Security

The success rate for passive authentication is presented below:

![Figure 106 Lisbon - TC9 passive authentication outcome](image)
Passive authentication was successful in 82% of cases. Passive authentication failures due to document reading errors are excluded since they would overstate the passive authentication error rate. The results only include the success rate in the cases where document reading was possible.

According to the feedback received from the Portuguese authorities most of the issues are to be attributed to the conformity of the Brazilian certificate which was also one of the most numerous nationalities volunteering for the tests in Lisbon.

4.4.2.3. Kiosks (TC10)

The test performed in Lisbon aimed at studying the feasibility of a self-service kiosk that could take care of the passport check and of the enrolment of 8 fingerprints and facial image. Data related to all of these aspects is reported in this section.

Due to time constraints and due to limitations linked with the national data protection regime, it was not possible to integrate the kiosk with the manual booth system to test a complete system including the use of a token. Nevertheless the kiosk would print a paper receipt of the check which could be potentially used as token to link the operations performed at the kiosk with the remaining checks to be performed at the manual booth.

In addition, 8 FPs and the live facial image were also captured at the manual booth and the durations of the atomic steps performed recorded, to allow the comparison with the kiosk.

A border guard was constantly near the kiosk in order to invite travellers to participate in the tests and to collect their consent form. The border guard would then also assist travellers and supervise the kiosk area.

Success / failure

The kiosk installed in Lisbon was simulating an enrolment kiosk for 8 FPs and FI. Therefore, a successful transaction can be defined as follows:

1) The traveller completed the entire process at the kiosk without cancelling the fingerprint acquisition nor the facial image capture and verification;

2) The facial image verification score was above the set threshold;

3) The fingerprints were captured with a NFIQ quality score (v1.0) within three attempts.

The success rate for both FI and FPs have been calculated and normalised by applying a threshold to the results. The thresholds applied on the data differ from what was enforced in the set-up, specifically:

- FI: the threshold has been increased compared the one used during the capture process in order to make it correspond to FAR 0.1, in line with the FRONTEX’s guideline for ABC gates;
- FP: the threshold was increased from the enrolment threshold of NFIQ 5 or better for all the fingers to a threshold of NFIQ 2 or better for all the fingers, with the exception of the little finger for which the threshold is NFIQ 3 or better.

The below graphs illustrate these conditions and provide the breakdown where failures or errors have occurred. Errors are to be understood as instances for which it was not possible to record either a facial image verification score or the fingerprint quality, the underlying reason being either a technical issue or the traveller cancelling the step or process.
Overall, the majority of the people were able to complete the entire process (71%), meaning that they provided both FI and 8 FP at the kiosk. However, out of these, only 33% could reach the set thresholds for quality of both FI and the 8 FP simultaneously. For 87% of the volunteers, it was possible to capture the live FI and verify it against the reference picture extracted from the chip of the eMRD with an expected FAR of 0.1%. On the other hand, for only 38% of the people proving sets of 8 FPs, the quality of them was above NFIQ 2.2,2.3; this could however be explained by the fact that such threshold was not enforced at the moment of the enrolment. If any quality was accepted, i.e. equal to NFIQ 5, then the success rate would correspond approximately at 85% of the travellers, with the remaining 15% being sets of FPs for which there was an error for one or more fingers and the NFIQ could not be calculated.

Regarding the errors that prevented the process at the kiosk to be completed, most took place during the enrolment and verification of the facial image. A possible explanation could be the location of the kiosk, positioned in front of a window wall. Thus, the kiosk suffered depending on the time of the day from the impact of the environmental light, which, according to the feedback received from the border guards on site, would negatively affect the performance of the live FI capture and subsequent verification.

The combination of multiple biometric characteristics (FP and FI) at the kiosk reduces the overall success rate as each of them becomes a possible source of issues or failures. On the other hand, if the aim would be to have at least one biometric characteristic above the enrolment threshold, then the combination of FI and FP could yield a higher success rate.

Looking at each of the individual steps performed at the kiosk, the details of the success/failure rate of each main individual steps are shown below.

---

38 The FI verification threshold to define the success has been normalised to a value corresponding to FAR 0.1%.
FP enrolment success / failure | FI verification success / failure | Chip reading success / failure
---|---|---
96% | 4% | 

**Figure 108 Lisbon - TC10 success and failure rate for FP enrolment (left), FI verification (middle) and chip reading (right)**

When looking at individual success conditions, the individual success rate for enrolling 8 fingerprints with the set level of quality (NFIQ 2,2,2,3 for each slap) was 31%. Regarding the facial image related steps, the success rate was 66%.

These results highlight that the use case of the kiosk for checking the passport does not seem to pose particular issues, the chip could be read for the vast majority of the travellers. On the other hand the enrolment of 8 FPs seems to be challenging when this level of quality threshold is chosen. However, it is worth noting that:

- The quality threshold NFIQ 2 -2 - 2 - 3 was not enforced during the FP capture by the Kiosk;
- Each individual hand (4FP only) had approximately 50% success rate.

Finally, although FI had significantly better results than the FP enrolment with a success rate of 66%, the percentage of failures and errors is still significant and suggest that the positioning of the kiosk in front of a source of light (window) was probably not ideal.

**Quality of the biometric characteristics**

**Fingerprints**

Eight fingerprints were enrolled with re-attempts done per slap in case the NFIQ score for each finger was not 5 or better.

The figures below show the quality distribution per finger obtained at the last attempt\(^\text{39}\), in terms of NFIQ and amount of minutiae.

\(^{39}\) Differently to other test instances given that in Lisbon only the scores for the last attempt have been stored in the logs.
The following observations can be made regarding the FP quality distribution:

- The majority of fingers have the majority of the NFIQ scores between 1 or 2, with the exception of the little finger that scores mostly values of 2 or 3;
- Most of the fingers have more than 30 minutiae.

**Facial Image**

The quality of both the facial image stored in the chip of the eMRTD and the live facial image has been measured according to the vendor specific algorithm.

The charts below show that the quality for the image from the chip was in general lower than the one captured live, although from the distribution it is possible to see that the distance between the two values was limited. The Kiosk during the acquisition of the facial image would do several attempts to capture a good image, which could explain the good results in the live image relatively to the chip image.
Duration of the kiosk process

Throughout the test, the time spent at the kiosk was recorded for each traveller, as well as the durations of each individual step in order to provide more granularities. More in detail, the duration of each of the following steps are analysed and shown in the figures below:

- Facial image enrolment and verification with a threshold equivalent to an expected FAR of 1%;
- Eight fingerprints enrolment with up to three attempts with a threshold quality of NFIQ 5 or better.

![Figure 111 Lisbon - TC10 quality score comparison between live and chip facial image based on vendor’s algorithm](image)

![Figure 112 Lisbon - TC10 duration of the FP enrolment (in seconds)](image)

When looking at each step individually, the average duration for the enrolment of 8 FP is almost 39 seconds (median 35), while the time required for the FI enrolment is 27 seconds (median 19). In both cases the durations include re-attempts, which in few cases were several. The timeout was set at several minutes (including the re-attempts).

Although the live Fi capture was faster than the FP capture, its duration was longer than the values measured at the ABC gate (TC9), with a difference of the average of approximately 12 seconds. This could be explained by the fact
that both location and set-up of the ABC gates were well studied and optimised, while the kiosk set-up was experimental with a sub-optimal position near a window.

For comparison, the values obtained at the manual booth, where the same steps had been replicated, were 22 seconds for the 8FPs capture (median and average) and 6 seconds for the live facial image capture.

The overall time spent by a given participating travellers’ interacting with the kiosk is shown in the following figure:

![Figure 114 Lisbon - TCt0 time spent at the kiosk (in seconds)](image)

The above durations relate only to travellers which completed the process at the kiosk (i.e. document check, FP enrolment and FI capture and verification). In instances of failure at an enrolment kiosk, the traveller will typically have to proceed to an alternative manual control booth. For the purposes of testing, therefore, it was considered that the time required to be processed should only be reported when the process was completed and not including instances in which the process might have been abandoned at a mid-way point.

The following observations can be made:

- An average traveller spends around 97 seconds in the kiosk to perform all steps;
- In some cases (22%) the durations exceeded the 120 seconds. Possibly due to the long timeout configured and to the several re-attempts recorded in some cases for both FI and FPs.

Security

It was not possible to perform comprehensive security tests to assess the ideal level of security, as it would have required the installation of several kiosks and a simulated use of the kiosk by impostors\(^6\).

With regards to document security and the verification of the data extracted from the passport, the kiosk performed the passive authentication even if its failure did not prevent the process from continuing. The below chart illustrate the error rate recorded during the tests for this process. In the particular case of Lisbon there were a high percentage of travellers from Brazil, with whom there were specific issues related to its signing certificates. Excluding Brazilian

\(^6\) The term “impostors” is to be understood as persons actively attacking or misusing a biometric system, thereby trying to deceive the enrolment process.
travellers from the calculation (for which passive authentication was possible in 21% of the cases only) would result in a success rate of 82%, almost double the overall rate displayed below.

4.4.3. Users’ perception

In order to assess the acceptance and perception of the new steps, both travellers and border guards have been consulted.

4.4.3.1. Travellers’ feedback

In total, 1088 entries (corresponding to around 50% of the participating travellers) were recorded for TC5, 276 entries (corresponding to around 20% of the participating travellers) for TC9 and 1301 entries (corresponding to around 94% of the participating travellers) were recorded.

The vast majority of travellers that participated in any of the TC performed in Lisbon, declared to be very satisfied or satisfied with the experience. The charts below show the breakdown of the answers per TC.

### Lisbon - TC5

- Very unsatisfied | Unsatisfied: 1%
- Neutral: 2%
- Very satisfied | Satisfied: 97%

### Lisbon - TC9

- Very unsatisfied | Unsatisfied: 5%
- Neutral: 2%
- Very satisfied | Satisfied: 93%

### Lisbon - TC10

- Very unsatisfied | Unsatisfied: 2%
- Neutral: 1%
- Very satisfied | Satisfied: 96%
4.4.3.2. Border guards’ feedback

Iris enrolment

11 border guards participated and replied to the questionnaire in Lisbon for the iris enrolment.

The following dashboard represents a summary of the replies.

Table 19 Lisbon - TC5 iris border guards’ feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive: 18 answers</td>
<td>Positive: 21 answers</td>
<td>Positive: 13 answers</td>
<td></td>
</tr>
<tr>
<td>Neutral: 2 answers</td>
<td>Neutral: 5 answers</td>
<td>Neutral: 3 answers</td>
<td></td>
</tr>
<tr>
<td>Negative: 6 answers</td>
<td>Usability of equipment is good.</td>
<td>Good acceptance of travellers</td>
<td></td>
</tr>
<tr>
<td>More confident with new process.</td>
<td></td>
<td>Some people were not aware how retinal scan worked.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impediments</th>
<th>N/A - enrolment station not integrated</th>
<th>Equipment sensible to the environment lighting conditions. Insufficient ergonomics and guidance (i.e. where to stand compared to the enrolment station).</th>
<th>Difficulties were reported acquiring iris from elderly who cannot fully open their eye lids or if they had cataracts. Acquisition appeared to be more difficult with people with bright eyes.</th>
</tr>
</thead>
</table>

| Improvements | N/A | More ergonomic equipment. Better position the enrolment station to avoid the influence of the sunlight. | More guidance to travellers needed: where to look, open the eyes if not fully open, remove the sunglasses, etc. |
ABC gates

11 border guards participated in and replied to the questionnaire in Lisbon for ABC gate, once per week of testing.

*Table 20 Lisbon - TC9 ABC gate border guards’ feedback*

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Impediments</strong></td>
<td>N/A</td>
<td>Issues reading the passport’s chips and with the certificates to perform the passive authentication. Particularly issues were detected with the Brazilian certificates</td>
</tr>
<tr>
<td><strong>Improvements</strong></td>
<td>N/A</td>
<td>A couple of border guards indicated that the equipment should be more ergonomic (i.e. clear indications on where to stand, where to place the passport, etc.) Addition of a one way communication system from the border guard to the traveller to provide assistance to travellers when needed.</td>
</tr>
</tbody>
</table>
Kiosk

11 border guards participated and replied to the questionnaire in Lisbon for Kiosk once per week of testing.

Table 21 Lisbon - TC10 border guards' feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive: 23 answers</td>
<td>Positive: 26 answers</td>
<td>Positive: 26 answers</td>
<td></td>
</tr>
<tr>
<td>Neutral: 3 answers</td>
<td>Negative: 3 answers</td>
<td>Neutral: 3 answers</td>
<td></td>
</tr>
<tr>
<td>Negative: 3 answers</td>
<td>Usability of equipment is good</td>
<td>Good acceptance of travellers</td>
<td></td>
</tr>
</tbody>
</table>

| Impediments | N/A - kiosk not integrated | Difficulty to use: not sufficient guidance on screen. Errors in recognizing right or left hand. Some software glitches required the restart of the kiosk. Several BG reported difficulties enrolling FPs. | Language barrier. Travellers with big hands had difficulties enrolling FPs due to the size of the scanner area. Kiosk not equipped for disabled people of for people missing a hand. |
| Improvements | N/A | Better feedback for the travellers regarding the capture of FPs. More intuitive interface. More languages available for the travellers. | A majority of border guards indicated that more guidance should be provided to travellers, i.e. video instructions. More intuitive user interface. Addition of languages. |

4.4.4. Constraints

4.4.4.1. Environmental conditions

The tests took place at Lisbon airport in indoor conditions.

Some border guards suggested that light coming from a glass wall behind the kiosk and the iris enrolment station caused some difficulty, as the camera was oriented against the light.

4.4.4.2. Others

Assistance and guidance to the travellers is essential, especially at the kiosk. Real time information about the steps to be performed as well as instructions regarding what is expected from the travellers, are required to assure that the process runs smoothly. In particular video instructions on how to use the kiosk would probably help softening the learning curve for the travellers at their first use.

Observations from the field highlighted that the kiosk’s user-friendliness and ergonomics play an important role in reducing the need for guidance from border guards or civil assistance (some travellers were reported to confuse fingerprint scanner and passport scanner for instance) as well as in increasing the travellers’ acceptability and usability.

Border guards reported of issues due to the language barrier with some travellers.

Finally, elderly travellers had more difficulties operating autonomously the kiosk and enrolling FP and iris.
4.4.5. Main observations

Iris (TC5)

- Successful completion of the enrolment process at the self-service kiosks took on average 18.1 seconds, with 11.3 seconds recorded as median duration of successful enrolment. 71% of travellers were able to complete the enrolment process with quality sufficient for enrolment of both iris patterns;
- Light coming from terminal windows was observed affecting negatively the iris pattern enrolment. It was also noted that elderly people and people with Asian ethnicity encountered more issues due to the shape of their eyes;
- Overall, the location of the enrolment station and its ergonomics appear to have a crucial effect on the success.

ABC gates (TC9)

- Successful completion of the exit checks at an ABC gate took in average of 26.6 seconds, with 21.7 seconds recorded as median duration;
- Passive Authentication was successful in 82% of the cases. Most notably the cause of the failure was non-compliance to standards (e.g. passports issued by Brazil);
- Only TCNs from 20 nationalities were able to participate in the test due to lack of necessary certificates (CSCA) which are needed to verify the authenticity of the information contained in the chip of the eMRTD;
- Overall, the ABC gates seem feasible in processing TCNs when leaving Schengen Area.

Self-Service Kiosk (TC10)

- Successful completion of the enrolment process at the self-service kiosks took some 1-2 minutes, with 93 seconds recorded median duration of successful enrolment. However, only 33% of travellers which were able to complete the process could enrol both 8 fingerprint and facial images to the quality set within the pilot;
- Many travellers were not able to navigate the workflow implemented without support. The nearby border guards would have to provide support to the travellers. Further guidance to travellers seemed to be necessary; in particular border guards suggested that video instructions could be useful;
- Environmental light coming from terminal windows negatively affected live facial image enrolment;
- Overall the location of the kiosk and its ergonomics appear to be crucial for the success.
4.5. Madrid – Fingerprint, facial image and kiosks

4.5.1. Test description

Adolfo Suarez Madrid-Barajas airport is the main international airport serving Madrid in Spain. In 2014, more than 41 million passengers passed through the airport, including a large number of travellers arriving and departing on flights to and from Latin America. The busiest intercontinental routes at the airport include flights to Argentina, Brazil, Mexico, Peru and Colombia as well as the USA. The Smart Borders pilot tests described in this chapter were executed at the BCP of Terminal 4, a large area accommodating 10 manual booths for the checking of about 4,000 passengers daily.

The tests focussed on the use of automated facial recognition and fingerprints enrolment at manual border controls in an airport environment, and on the use of self-service kiosks.

4.5.1.1. Set-up and configuration

The execution and organisation of the test cases at Madrid airport are set up and as follows.

Table 22 Madrid - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Air - Madrid is the main international airport in Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td>TC1: Enrolling 4 fingerprints</td>
<td>• With new equipment</td>
</tr>
<tr>
<td>TC7: Verifying the facial image captured from the eMRTD against the enrolled live facial image</td>
<td></td>
</tr>
<tr>
<td>TC10: Use of self-service kiosks</td>
<td></td>
</tr>
<tr>
<td>Test location</td>
<td>TC1, TC4, TC6, TC7, TC10: Terminal 45 - entry</td>
</tr>
</tbody>
</table>
### Staff involved

3 or 4 border guards were trained and participated in the test to varying degrees depending on their work schedules.  
1 or 2 Technicians or supervisors supported the tests as required.  
1 assistant to guide travellers to the pilot queue.

### Total duration

11 weeks in total (with a four-week break)

### Timetable

- TC1 new equipment, TC4, TC6, TC7:  
  From 27.04.2015 to 13.05.2015 (2.5 weeks)
- TC1 existing equipment, TC4, TC6, TC7:  
  From 14.05.2015 to 03.06.2015 (3 weeks)
- TC10: From 06.07.2015 to 17.07.2015 (2 weeks)

### Sample size (target / actual)

- Fingerprints  
  TC1: New equipment 600 / ~1500  
  TC1: Existing equipment 600 / ~1500  
  TC4: 1550 / ~3000  
  TC6: 1550 / ~3000  
  TC7: 1600 / ~3000  
  Kiosks  
  TC10: 1000 / 1380

### Process layout

TC1, TC4, TC6, TC7: Existing manual booth with two stations (Dedicated lane; Done at the regular border guard booth)  
TC10: kiosk place in front of a dedicated manual booth (Dedicated lane; Done at the regular border guard booth)

### Integration within the regular border-crossing process

Integrated: Process steps are integrated in the normal border-crossing process

### Technical integration

TC1, TC4, TC6, TC7: Integrated with the standard border check  
TC10: Integrated with the standard border check with the exception of VIS consultation

### Type of device

- TC1:  
  New 4FP fixed contact fingerprint scanner  
  Existing 2FP contact fingerprint scanner, used as a 1FP scanner  
- TC4: New web camera with continuous video capture, with integrated lighting system  
- TC6: Existing eMRTD reader, Fixed, Full-page  
- TC7: New local facial image matching system  
- TC10: Kiosk with integrated eMRTD reader, 4FP contact scanner and cameras with continuous video capture with integrated lighting system (2 cameras for the capture and 2 for liveness detection) - similar to the existing ABC gates

### Quality thresholds

- Fingerprints  
  TC1: NFIQ 2-2-2-3  
  Facial Image  
  TC4: The live facial image is considered successfully captured when it is verified against the FI contained in the passport’s chip. A threshold for the verification algorithm was agreed together with the integrator, corresponding to a verification FAR of approximately 0.3%.  
  Kiosk
4.5.1.2. Workflow

At a given time, volunteering TCNs over 18 years old, holding an eMRTD, could participate in one of the following test cases:

- TC1 with new equipment, Tc4, Tc6 and Tc7 -> Fingerprints and Facial Image;
- TC1 with existing equipment, Tc4, Tc6 and Tc7 -> Fingerprints and Facial Image;
- TC10 -> kiosks.

Fingerprints enrolment

1. TC1: New 4FP scanner to enrol of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).

Fingerprints for the index, middle, ring and little fingers for the right hand of volunteering TCNs were captured first using a fixed 4FP contact scanner.

The software configuration did not enforce the retry, so only one attempt was made. Real time feedback during the capturing process was incorporated in the device in the form of green lights.

2. TC1: Existing 2FP scanner to enrol 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).

Fingerprints for the index, middle, ring and little fingers for the right hand of volunteering TCNs were captured first using a fixed contact scanner, one finger at a time.

The software configuration did not enforce the retry, so only one attempt was made.

Facial image related test cases

- **Figure 119** Madrid - facial image test cases (TC4, 6 and 7) steps
- **eMRTD reading and extraction of the FI**
  
The eMRTD was placed in a document reader, which triggered the following operations:
  
  - Extract the alphanumeric information from the document to consult all relevant databases;
  - Perform Passive Authentication of the chip to verify the certificate;
  - Retrieve the picture / facial image from the chip;
  - Measure the quality of that picture according to the vendor specific algorithm.

- **FI enrolment**
  
The live capture of a traveller's facial image was done using of a web camera that took a video flow of images. The camera was placed on a small tripod (20 cm tall) on the manual booth, had an external lighting accessory consisting of LEDs that could be switched on and off by the border guards, and could be manually moved to adjust the focus. The system tried to compare these images with the extracted FI from the eMRTD, and finally selected the picture when the matching score reached or exceeded a given threshold, with a timeout of 15.2 seconds. The picture appeared in the interface for the border guard together with a bar indicating the score, so that the border guard could finish the process when an adequate picture was achieved. A specific vendor verification algorithm was used, which was chosen following the operational configuration existing at the ABC gates present at the airport and currently used for EU citizens.

- **Verify FI captured from eMRTD against live facial image**
  
The photo captured from the eMRTD of volunteering TCNs was compared with the live facial image and the relative matching score is recorded.

**Kiosk**

The Kiosk was used in combination with a manual booth as a second step, by using the MRZ from the participant's eMRTD as a token, linking the two steps. The kiosk was fully integrated with the standard border check process and technical solution, with the exception of VIS consultation for visa holders as well as the questioning and stamping - which took place at the manual booth.

An overview of the process steps and workflows both at the kiosk and at the manual booth is shown below:

![Flowchart](image)

*Figure 120 Madrid - TC10 workflow at the kiosk*

The kiosk has integrated a display that showed an interactive interface to instruct the traveller throughout all process steps. The process at the kiosk started when the traveller placed the eMRTD in the document reader. Then the kiosk connected to the chip of the passport, extracted the relevant information (including the facial image stored in the chip), performed the passive authentication and consulted the relevant national and European databases - with the exception of VIS. The passport must be kept on the reader during the next steps and until the end of the process.

After this, the live facial image was captured by means of one of the two available cameras depending on the person's height. As was the case in TC4 above, the capture of the facial image was carried out through a video stream from which the live facial image was compared against the FI extracted from the chip of eMRTD. When the matching
score reached or exceeded a given threshold before a timeout of 14 seconds, the live facial image was captured and its quality, assessed.

Finally, the kiosk asked the traveller to place the slap on the fixed contact scanner, in order to capture the 4 fingers of the right hand. When the fingerprints captured did not reach a defined threshold (NFIS 2-2-2-3), the participant was required to attempt again, up to three times, so that the capture was then repeated for the whole slap (meaning all 4 fingers were recaptured at the same time).

Once both FI and FP were captured at the kiosk, the traveller was asked to proceed to the manual booth to complete the border check process.

![Comparison with the kiosk data](image)

**Figure 121** Madrid - TC10 workflow at the manual booth

At the manual booth, the border guard scanned the eMRTD once again, in order to obtain from the system the information collected at the kiosk - using the MRZ information. The border guard confirmed that FP and FI were captured correctly and stamped the passport after verifying the period of stay.

In case of being a visa holder, the VIS consultation was performed by scanning the visa sticker and capturing one fingerprint.

4.5.3. **Sample characteristics**

The below graphs show the main characteristics of the sample, consisting of approximately 4380 travellers for all tests. Similar distributions were found for the test cases carried out (facial image and fingerprints, or kiosk)

![Madrid - sample distribution by gender](image)

**Figure 122** Madrid - sample distribution by gender

![Madrid - sample distribution by age](image)

**Figure 123** Madrid - sample distribution by age

The proportion of men and women is almost even, and most of them were middle-aged.

Overall the test included a wide range of nationalities. Countries of South America and USA were the most common nationalities among the participating travellers.
4.5.2. Test cases operational and technical results

4.5.2.1. Fingerprints (TC1 with new and existing equipment)

Success / Failure

Thresholds based on NFIQ values (NFIQ ≤2 for index, middle and ring finger; NFIQ≤3 for the little finger) have been applied to the data collected to identify the successful enrolments of 4 FPs. In the case of Madrid, a single capture attempt has been performed, regardless of the quality achieved.

The following charts illustrate the different results obtained for both the new equipment (4FP scanner) and the existing equipment (2FP scanner used to capture only one finger at a time), showing the proportion of travellers for whom it was possible to enrol four fingerprints with the required level of quality at the first attempt, depending on the equipment used.

Figure 124 Madrid - sample distribution by nationality

<table>
<thead>
<tr>
<th>Country</th>
<th>USA</th>
<th>BRA</th>
<th>CHL</th>
<th>AUS</th>
<th>PHI</th>
<th>JPN</th>
<th>KOR</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Success</td>
<td>32%</td>
<td>36%</td>
<td>16%</td>
<td>15%</td>
<td>8%</td>
<td>4%</td>
<td>3%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Figure 125 Madrid - TC1 success and failure rate at the first attempt with contact device at NFIQ 2 - 2 - 2 - 3 threshold

The following observations can be made from the figures above:

- The global success rate for both scanners, overlying the thresholds (NFIQ ≤2 for index, middle and ring finger; NFIQ≤3 for the little finger) is about 30% regardless of the equipment used. It is important to note that the procedure with only one capture attempt and the configuration of the scanner (sensibility and thresholds for when providing visual feedback to the traveller) might have influenced the results;
- In general, the exiting FP scanner performs slightly better.

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43 The country codes used in the graph are the three-letter country codes defined in ISO 3166-1: http://www.nationsonline.org/oneworld/country_code_list.htm.
Quality

Quality measurement of individual fingerprints in Madrid is based on NFIQ, and number of minutiae. The distribution of NFIQ values for each individual finger obtained with a single attempt with each of the equipment is shown below:

2FP SCANNER CAPTURING ONE FINGER AT A TIME

4FP SCANNER

Figure 126 Madrid - TC1 NFIQ scores per finger at the first attempt with contact scanner

In order to complement the indication provided by NFIQ, the figures below illustrate the distribution of minutiae for each individual finger for TC1 with new and existing equipment.

2FP SCANNER CAPTURING ONE FINGER AT A TIME

4FP SCANNER

Figure 127 Madrid - TC1 minutiae amount per finger at the first attempt with contact scanner

The following observations can be made:

- Both equipment present similar results for the NFIQ measurement;
- The amount of minutia is higher when fingers are captured one by one when a 2FP scanner;
- The vast majority of fingers have an NFIQ score of 2 or 3. The defined quality threshold for TC1 is NFIQ ≤2 for index, middle and ring finger; NFIQ≤3 for the little finger;
- For both devices, the little finger seems to have a higher quality than the right index finger.
Duration

The duration of fingerprint enrolment is measured in order to assess the added duration compared to the current situation where no biometric identifier is enrolled\(^2\). Time-stamped log files, produced by FP scanners, were used for duration measurement.

The fingerprint capture at Madrid manual booth did not enforce any re-attempt, meaning that the fingerprint capture was only performed once and no quality threshold was enforced.

The measurement points for the duration of the test case were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The start of FP capture either by placing the slap in the 4FP scanner or an individual finger for the existing equipment.</td>
<td>1. The capture of all four fingers.</td>
</tr>
</tbody>
</table>

The distribution of the process step duration for capturing all four fingers is shown below, for both devices used:

- **2FP Scanner Capturing one finger at a time**
- **4FP Scanner**

\[\text{Figure 128 Madrid - TC1 duration of one attempt with contact scanner (in seconds)}\]

The following observations can be made regarding the duration of this step when no reattempt takes place:

- It takes in average around 6 seconds less to enrol 4 fingerprints with a 4FP scanner than capturing one finger at a time;
- Capturing one finger at a time, the enrolment of four fingers takes between 15 and 30 seconds for the majority of travellers (58%);
- The vast majority of participants (89%) can capture the four fingerprints using a 4FP scanner in less than 15 seconds.

\[4.5.2.2. \text{Facial image (TC4, TC6, TC7)}\]

Regarding facial image the following test cases were performed:

- Retrieval of the facial image from the eMRTD chip (TC6);

\[^2\text{The current process has an average duration measured in Madrid of approximately 63 seconds per traveller. This duration has been measured on a sample of over 500 travellers, considering different border guards, traveller flows and times of the day.}^\]
- Enrolment of a live facial image (TC4);
- Comparison, verification of the two above (TC7).

As all three test cases are highly related to each other, this section will analyse the results from a joint perspective, analysing specific aspects of individual test case when relevant.

**Success / failure**

The purpose of the facial image tests is to perform local automated bearer verification at the border based on the facial image biometric identifier, by image comparing the facial image captured from the passport chip (TC6) and the live facial image captured (TC4). Therefore, the success condition for all three test cases jointly is the successful verification of the facial image:

a) The facial image could be accessed and retrieved from the eMRTD without errors (passive authentication errors are addressed separately, as they do not prevent the FI to be extracted from the chip and used for an eventual verification with the live facial image);
b) The enrolment of the live facial image is successful;
c) The verification score was above the set threshold. The threshold was proposed by the integrator, based on their experience at Madrid airport, and it corresponds to a False Acceptance Rate (FAR) of approximately 0.3%.

The graph below presents the overall success rate for overall facial image related test cases at Madrid airport.

![Graph showing success rates](image)

**Figure 129** Madrid - Fl related test cases success and failure rate at a FAR of 0.3%

**Figure 130** Madrid - Fl related test cases success and failure rate at a FAR of 0.1%

Looking more in detail the cases where there were issues with the reading of the chip contained in the eMRTD, these can be categorized according to the following figure,

![Chip reading outcome](image)

**Figure 131** Madrid - TC6 chip reading outcome

The following observations can be made regarding the figures presented above:

- For the majority of cases the FI verification was successful (88%) and only in 4% of the cases, an error occurred that prevented the verification to be attempted;
- For only 2% of the travellers an error in accessing the passport chip prevented the retrieval of the facial image from the chip.
Quality

The quality of the facial image was evaluated based on the specific vendor quality index\(^{43}\). The graph below presents the quality score results, both for the facial images retrieved from the eMRTDs and the live facial image captured at the manual booth.

![Quality Scores Comparison](image)

**Figure 132** Madrid - TC4 and TC6 quality score comparison between live and chip facial image based on vendor’s algorithm

The following can be observed:

- The quality of the facial images on chips is in general better than the live facial image. The higher quality can partly be explained by the controlled environment in which pictures used for passports issuance are taken, compared to the variable and less optimal environment at the border;
- The distribution of quality scores is more concentrated for the chip facial images, which suggests that the quality of the pictures on the passport is more homogenous compared to live facial image scores.

Duration

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader;</td>
<td>1. To the result of the eMRTD F1 acquisition (success or failure), including the time to perform the passive authentication;</td>
</tr>
<tr>
<td>2. From the start of the live image enrolment;</td>
<td>2. To the successful enrolment of live image or timeout (if relevant);</td>
</tr>
<tr>
<td>3. From the start of the facial image verification.</td>
<td>3. To the outcome of the facial image verification.</td>
</tr>
</tbody>
</table>

The overall duration of the facial image related test cases can be analysed by estimating the duration of each individual step. The combination of the individual time of these steps will depend on the specific process workflow:

\(^{43}\) Specific vendor scores will not be analysed, and they are presented only for the purpose to allow comparison of the quality scores between the live and chip facial image. Absolute values of the scores will not be assessed.
1. Extract facial image from the eMRTD;
2. Perform Passive Authentication of the chip;
3. Enrolment of the live facial image;
4. Verification of live and chip facial image. In Madrid the duration of the verification step is already included in the enrolment step, while the camera is capturing a video stream, and will thus not be analysed separately.

The following figures show the distribution of durations obtained for each of the above steps:

<table>
<thead>
<tr>
<th>Avg</th>
<th>Med</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7</td>
<td>1.4</td>
<td>1.1</td>
</tr>
</tbody>
</table>

**Figure 133** Madrid - TC6 facial image from the chip retrieval duration for eMRTD holders (in seconds)

**Figure 134** Madrid - TC4 live facial image enrolment duration for eMRTD holders (in seconds)

**Figure 135** Madrid - TC6 passive authentication duration for eMRTD holders (in seconds)

The following observations can be made:

- In most cases, 89% of the participants, the extraction of the facial image from the chip can be done in less than 4 seconds;
- For 85% of the participants, the enrolment and verification of the live facial image is made in less than 5 seconds;
- The passive authentication takes less than 2 seconds for 70% of the participants.

**Security**

Passive authentication is recommended as a means to guard against document modification and to verify appropriate document issuance.

During the tests performed in Madrid for up to 23% of the passports, the PA encountered an error. Given the high number of nationalities participating in the test (43 different nationalities were recorded during the tests in Madrid), the failure rate could be due to missing

![Figure 136 Madrid - TC6 passive authentication outcome](image-url)
The issue of spoofing biometric enrolment and verification systems, including those for facial recognition, should also be considered in operational settings. Spoofing was not examined in testing at Madrid airport but is considered from a theoretical viewpoint in the chapter on spoofing vulnerability of iris enrolment and countermeasures (chapter 3.5) of the main report.

Duration impact on the end to end process

It is worth analysing, from a time perspective, how the introduction of the new biometric steps would influence the global duration of the current border check process - where no biometric identifier is involved. For this aim, the estimated duration of the tests cases described above is compared to:

- The baseline measurement: duration of the current border check process;
- The global end to end time for the border check modified by the testing, which includes both facial image and fingerprints.

The following table summarises the average times:

**Table 23 Madrid - duration impact on the end to end process**

<table>
<thead>
<tr>
<th>Aspect under measurement</th>
<th>Average duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline&lt;sup&gt;45&lt;/sup&gt;</td>
<td>63 seconds</td>
</tr>
<tr>
<td>End to end border check process including the execution of FP and FI related test cases&lt;sup&gt;46&lt;/sup&gt;</td>
<td>74 seconds (old equipment) 66 seconds (new equipment)</td>
</tr>
<tr>
<td>Retrieval of the FI from the chip&lt;sup&gt;47&lt;/sup&gt;</td>
<td>3 seconds</td>
</tr>
<tr>
<td>Facial image enrolment and verification</td>
<td>3 seconds</td>
</tr>
<tr>
<td>4 fingerprint enrolment with 4FP scanner</td>
<td>11 seconds</td>
</tr>
<tr>
<td>4 fingerprint enrolment with 2FP scanner one finger at a time.</td>
<td>17 seconds</td>
</tr>
</tbody>
</table>

From the values in the table above, it can be observed:

- The time required for the facial image enrolment and verification is almost one fourth of the time required for the enrolment of 4 fingers, and even less when the 4 fingerprints are captured one by one. The same applies for the time required to extract the FI from the chip;
- The time required for the facial image enrolment and verification is around 4% of the end-to-end time, and overall its impact on the global time seems to be negligible;
- The FP capture amounted to approximately 17% of the average end-to-end duration measured when using the 4FP scanner (66 seconds). On the other hand when using the existing equipment and acquiring individual fingers the weight of the duration compared to the relative end-to-end time is 23% (over an average of 74 seconds);
- The end-to-end times are between 5% and 17% higher than the baseline depending on the devices used. Given the duration of the atomic steps for the FP capture and FI capture, this seem to indicate a certain level of

---

<sup>45</sup> Different methodologies were used for measuring the baseline (COTW) and the end to end (logs), which limits the reliability of the comparison.

<sup>46</sup> The baseline measurement was made using the COTW methodology on a sample of 290 visa holders and 285 visa exempt travellers. It was measured as the time when the person arrives at the booth until the border guard disengages (i.e. gives back the passports). In Spain, for VH only the visa sticker is scanned, saving some time as the passport biometric page is in those cases not scanned.

<sup>47</sup> The end-to-end duration was measured using the system log files, to which was added a duration of 10 seconds to cater for the time for the traveller to approach the border guard and for the passport to be placed on the passport reader, which triggers the start of the automated measurement.

<sup>48</sup> Usually done in parallel with the other steps.
parallelism and the reduction of the time available for other steps of the process (e.g. questions).

4.5.2.3. **Kiosk (TC10)**

The following functionalities were performed by the participating travellers at the kiosk:

- Scanning of eMRTD document;
- Reading the chip of the eMRTD and retrieve the facial image;
- Enrolling 4 fingerprints with a 4 fixed FP scanner;
- Live facial image enrolment;
- Verification of live FI against FI on the chip.

Travellers were constantly supervised by a nearby border guard, ready to assist them if needed. The system would systematically perform up to three attempts to enrol FP at the set NFIQ threshold\(^{46}\), recapturing the whole 4 fingers slap: 50.1% if the participants only performed one attempt, 15.2% two attempts, and 34.5% three attempts.

**Success / failure**

The use of the kiosk by a traveller can be considered successful for its purpose when the following conditions were fulfilled:

i) eMRTD is read and the facial image extracted successfully from the chip, including passive authentication (PA);

ii) Live facial is enrolled with a sufficient quality;

iii) The live facial image captured can be matched against the photograph retrieved from the eMRTD chip;

iv) Four fingerprints are enrolled with the required level of quality within three attempts (NFIQ<3 for index, middle, ring and NFIQ<4 for the little finger).

The following figure shows the percentage of cases where the entire process was completed at the Kiosk (i.e. FP enrolment and FI enrolment) and further breakdown the success/failures when the process was completed and of the source of errors that interrupted the process.

Errors correspond here to missing values in the system logs which are probably related to the fact that a certain step of the process was cancelled.

---

\(^{46}\) Index, middle and ring NFIQ threshold of 2 and of 3 for the little finger.
Overall, the majority of the people were able to complete the entire process (91%), meaning that they were asked by the kiosk to capture for their FP and FI. From those who finished all steps, 56% completed all aspects successfully, while the remaining 44% failed to either enrol the 4FP simultaneously with the required level of quality (30%), to verify the facial image against the facial image contained in the eMRTD chip (9%), or both (5%). Regarding the errors that prevented the kiosk to finish the process, most took place during the enrolment and verification of the facial image.

The combination of multiple biometric characteristics (FP and FI) at the kiosk reduces the overall success rate as each of them becomes a possible source of issues or failures. On the other hand, if the aim would be to have at least one biometric characteristic above the enrolment threshold, then the combination of FI and FP can yield a higher success rate (in this case it would be around 95% instead of 56%).

For the remaining 9% of the participants, an error occurred and all steps could not be performed.

Below the details of the success/failure rate of the FP enrolment and FI enrolment and verification individual steps, when analysed individually.

---

The FI verification threshold to define the success has been normalised to a value corresponding to FAR 0.1%
When looking at individual success conditions, the individual success rate for enrolling 4 fingerprints with the required level of quality with a maximum of three attempts was 64%. Regarding the facial image related steps, the success rate was 80%.

**Quality**

**Fingerprints**

In the case of Madrid, four fingerprints were enrolled and, systematically, retries were enforced up to three attempts. The figures below show the quality distribution per finger obtained at the last and best attempt, in terms of NFIQ and amount of minutiae.

The following observations can be made regarding the FP quality distribution:

- The majority of fingers have an NFIQ score of 1 or 2, with the exception of the little finger that scores mostly values of 2 or 3;
- Most of the fingers have more than 30 minutiae;
- The little finger obtained less quality scores than the index finger.
Facial Image

Regarding the facial image related test cases, the quality of both the facial image contained in the chip of the eMRTD and the live facial image have been measured according to the vendor specific algorithm.

The charts below clearly show that the image stored in the chip of the passport was consistently of a higher quality compared to the quality of the picture taken live by the Kiosk. When looking at facial image testing at the manual booth, the same observation can be made, but in that case the quality of the FI captured at the manual booth were slightly better than at the kiosk.

![Image Quality Chart]

**Figure 141** Madrid - TC10 quality score comparison between live and chip facial image based on vendor’s algorithm

Duration

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The moment the traveller initiates the transaction at the kiosk (e.g. by selecting the language or by placing the document on the reader).</td>
<td>1. The completion of the workflow at the kiosks.</td>
</tr>
</tbody>
</table>

Durations provided in this section relate only to successful enrolment and verification processes. In instances of failure at an enrolment kiosk, the traveller will typically have to proceed to an alternative manual control booth. For the purposes of testing, therefore, it was considered that the time required to be processed should only be reported when the process was completed and not including instances in which the process might have been abandoned at a mid-way point.

Throughout the test, the time spent at the kiosk was recorded for each traveller, as well as the durations of each individual step in order to provide higher granularity. More in detail, the duration of each of the following steps are analysed:

- eMRTD reading and extraction of the facial image from the chip, including PA;
- Facial image enrolment and verification: the live facial image is captured by means of a continuous video flow
which selects the picture when the verification score against the facial image contained in the chip reaches or exceeds a given threshold, with a timeout of 12.5 seconds - based on specific vendor verification algorithm, which chosen following the operational configuration existing at the ABC gates present at the airport and currently used for EU citizens and which corresponds to a FAR of 0.3%.

- Four fingerprints enrolment, considering up to three attempts depending on the quality achieved.

The following figures present the atomic duration of each step performed at the kiosk.

**Figure 142** Madrid - TC10 duration of the FP enrolment for up to three attempts (in seconds)

<table>
<thead>
<tr>
<th>Avg.</th>
<th>Med.</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.6</td>
<td>2.4</td>
<td>1.3</td>
</tr>
</tbody>
</table>

**Figure 143** Madrid - TC10 duration of the FI enrolment and verification (in seconds)

<table>
<thead>
<tr>
<th>Avg.</th>
<th>Med.</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>0.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

**Figure 144** Madrid - TC10 duration of the chip reading and image retrieval (in seconds)

When looking at each step individually, the average duration for the enrolment of FP is almost 15 seconds, while the time required for the FI enrolment is 6 seconds. The duration of the PA is very low (1 second in average), and the extraction of the FI from the chip of the eMRTD, 2.5 seconds. Compared to the durations observed at the manual booth, the FI and FP enrolment at the kiosk need 3 or 4 seconds more in average each; the FP enrolment at the kiosk includes nevertheless systematic reattempts to achieve the required quality, which is not performed at the manual booth.
The time spent by the travellers at the kiosk is shown in the following figure:

**Figure 146** Madrid - TC10 time spent at the kiosk (in seconds)

The following observations can be made:

- The reading of the passport and extraction of the facial image from the chip takes in most cases less than 5 seconds;
- The enrolment and verification of the FI takes usually less than 7 seconds, which is slightly less than half the average time needed to enrol four fingerprints;
- An average traveller spends around 30 seconds in the kiosk to perform all steps, which is more or less the addition of each of the individual steps.

In addition, the global time spent by a given traveller since the moment the kiosk starts operating until the border guard disengages at the manual booth was also captured in order to estimate how long the end-to-end duration of the process would take, and thus enable the comparison with the process at the manual booth. This global total border-crossing time is shown in the graph below:

**Figure 147** Madrid - TC10 time spent for the border-crossing check: kiosk and manual booth (in seconds)

---

56 The duration of the end-to-end process only gives the service time for the check performed and not the actual negative or positive impact on traveller throughput for a given BCP. The throughput also depends on the number of kiosks set up and the combination of that number with the number of manual gates available. This estimation does not take into consideration the cases where the passport could even not be read.
The following observations can be made:

- The time spent alone interacting with the kiosk, represents about half the time required in average for crossing the border, including the manual booth, which is 61 seconds in average;
- The implementation of the kiosk allows performing the border-crossing process almost in the same time as the tests performed at the manual booth, including the enrolment of four fingerprints and facial image verification. This time is analysed observing the time spent in average by each person, without assessing the increase of the travellers’ throughput.

**Security**

Even if in the case of the tests performed at Madrid it did not prevent the process to continue, the passive authentication failed for 28% of the participants.

---

**Figure 148 Madrid - TC10 passive authentication outcome at the kiosk**

On the other hand, it was not possible to perform comprehensive security tests to assess the ideal level of security, as it would have required the installation of several kiosks and a simulated use of the kiosk by impostors\(^5\).

The testing in Madrid was integrated at a technical level with the real border-crossing process, so the use of the kiosk was supervised at all times. No security issues were observed.

4.5.3 Users’ perception

In order to assess the acceptance and perception of the new steps, both travellers and border guards have been consulted.

4.5.3.1 Travellers’ feedback

In total, 2949 entries (corresponding to around 99% of the participating travellers) were recorded for TC1, TC4, TC6 and TC7, and 1316 entries (corresponding to around 96% of the participating travellers) for TC10.

**Fingerprints and Facial Image**

Travellers’ feedback was recorded for all test cases taking place at a given time, and not individually for the different test cases - with the exception of the kiosk. The results collected in Madrid are summarised in the chart below:

---

\(^5\) The term “impostors” is to be understood as persons actively attacking or misusing a biometric system, thereby trying to deceive the enrolment process.
Madrid - TC1, TC4, TC6, TC7

The following observations can be made:

- Respondents were overwhelmingly positively about their experience, even if the test set up was not optimal. Less than two percent of travellers were not satisfied;
- It should be noted that the tests were run in parallel with TC1, using both new and existing equipment. The results shown below are for the combination of the two modalities and therefore the test conditions were more difficult for travellers.

Kiosk

Travellers’ feedback was recorded for the kiosk test case. The results collected in Madrid show very similar results as those obtained for the manual booth.

Madrid - TC10

4.5.3.2. Border guards’ feedback

Fingerprints and facial image

13 border guards participated and replied to the survey from Madrid airport for fingerprint enrolment and facial image related test cases. Regarding fingerprint enrolment, different feedback has been gathered depending on the specific equipment used: new equipment (4FP scanner with slap technology); and existing equipment (two-finger scanner configured to take one finger at a time).

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52 Based on 2461 surveys, approximately 80% of the participants to TC1,4,6,7 (existing and new devices combined).
53 Ibid.
The following dashboard presents a summary of replies[^24].

**Table 24 Madrid - border guards’ feedback**

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process added-value</td>
<td>More confident with equipment (new and existing FP scanner).</td>
<td>Usability of equipment is good (new and existing FP scanner).</td>
</tr>
<tr>
<td>Impediments</td>
<td>15% of replies suggest improving the equipment usability by including integrated and automated cameras.</td>
<td>Ergonomics of the equipment can be improved (29% of the replies for new FP scanner, and 85% for the existing equipment).</td>
</tr>
<tr>
<td>Improvements</td>
<td>N/A</td>
<td>Occasional hardware problems. Seldom system problem.</td>
</tr>
</tbody>
</table>

Based on the qualitative replies, the following observations and conclusions should be highlighted:

- The aim of the pilot was welcomed;
- Human factor and communication are paramount:
  - Travellers felt more confident with border guards explanations and assistance (e.g. process is facilitated when border guards indicate which fingerprints must be given);
  - Difficulty to communicate with some TCNs (language barrier) caused abortion of tests in some cases.
- Equipment is not 100% reliable and stable:
  - Some problems with the camera have been experienced, especially due to backlight;
  - FP reader is sometimes unstable for both new and existing equipment;
  - Real time feedback to travellers provided by the device is useful, especially for FP capture;
  - Passport issuing country can impact the access time to the chip.

**Kiosk**

12 border guards participated and provided feedback for the kiosk testing, whose answers are summarised below.

[^24]: Percentages are calculated per question and are based on the number of replies given. In some cases, BGs have given more than one reply to one question.
Table 25 Madrid - border guards’ feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process added-value</td>
<td>More confident with equipment.</td>
<td>Usability of equipment is good.</td>
</tr>
<tr>
<td>Impediments</td>
<td>N/A</td>
<td>Occasional problems with the equipment; especially with the camera, probably because of the backlight. Some passports (e.g. Australian) often presented problems for the chip reading.</td>
</tr>
<tr>
<td>Improvements</td>
<td>Integrate all steps in the kiosk, minimizing the time spent at the manual booth.</td>
<td>Ergonomics could be improved, as the same hand is used to place the passports as to provide the fingerprints. Camera should be placed to avoid backlight and improve its performance.</td>
</tr>
</tbody>
</table>

4.5.4. Constraints

4.5.4.1. Environmental conditions

The tests took place at Madrid airport, with indoor conditions.

Some Border Guards suggested that light coming from a glass wall in front of the booths caused some difficulty, as the camera was oriented against the light; in fact, in some instances they even activated the light of the camera to obtain more easily a successful enrolment.

Similar problems occurred at the kiosk, as it was positioned also against the light as well. However, the integrated light system in this case helped mitigate those problems.

4.5.4.2. Others

Assistance and guidance to the travellers is essential, especially at the kiosk. Real time information about the steps to be performed as well as instructions regarding what is expected from the travellers are required to assure that the process runs smoothly.

Real time feedback for the capture and enrolment of biometrics is also crucial, both for travellers and border guards if applicable: for fingerprints and for the correct positioning required to capture the facial image.

Observations from the field highlighted that the kiosk’s user-friendliness and ergonomics play also an important role in reducing the need for guidance from border guards or civil assistance as well as in increasing the travellers’ acceptability and usability.
4.5.5. **Main observations**

**Four fingerprints and facial image (TC1, 4, 6 and 7)**

In general, tests worked well. It was clear that simple devices can be deployed at airports to record live facial images of reasonable quality that were sufficient for successful automated document bearer verification, as well as to enrol four fingerprints. The overall process was seen to be quick and efficient.

**Fingerprints**

The quality obtained was rather low, with low success rates according to the set thresholds. This could be explained by the fact that re-attempt in case the required quality was not reached had not been enforced. Additionally, the enhancement of the real time feedback provided to travellers could also be beneficial. According to the feedback received from the border guards, their ergonomics could be improved which could then contribute to increase the usability and the quality.

The device type, seemed showed no meaningful difference on the enrolment rate achieved or on average quality, however, the 4FP scanner allowed time savings: there is an average of 6 seconds of difference, 35% less than the single finger capture.

**Facial Image**

The facial image solution at Madrid proven to be very quick and able to successfully perform the bearer verification in an automated way also at the manual booth

While the live capture of the facial image was successful for the purpose of the verification, the lightning conditions, the background, the variable distance from the camera yield lower quality than the picture from the passport.

**Kiosk**

Kiosks have proven to be efficient and useful for its purpose, potentially reducing the workload on border guards compared to the manual booth. Biometrics with sufficient quality can be captured in a timely manner: 64% of the participants were able enrol their 4FP, while 80% could enrol and verify the FI against the FI extracted from the chip of the eMRTD.

The enrolment of 4 FP and facial image verification at the kiosk can be done with similar level of quality as in the manual booth, and only adding some seconds to the duration of each process when looked at individually. The end to end time needed in average for an individual traveller to cross the border remains similar in both cases, when using 4FP scanner - around one minute.

Optimal set up and configuration needs however to be considered, and needs to be addressed depending on the specific border, in order to maximize the profit from these benefits. In addition, assistance to the travellers shall be guaranteed to facilitate the use of this technology, which will not only improve the user experience but also will speed up the process.

---

55 The enrolment of FP at the manual booth includes systematic retries up to three attempts, which was not the case at the manual booth.
### 4.6. Schiphol - Fingerprints and ABC gates

#### 4.6.1 Test description

#### 4.6.1.1 Set-up and configuration

The execution and organisation of the test cases at Schiphol were set up and configured based on characteristics listed in the table below.

**Table 26 Schiphol - set-up and configuration**

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Air - Schiphol is the main international airport in the Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td></td>
<td>• TC1: Enrolling 4 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC2: Enrolling 8 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC3: Enrolling 10 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC9: Using ABC gates for border checks of TCNs</td>
</tr>
<tr>
<td><strong>Test location</strong></td>
<td>TC1, TC2, TC3: Terminal 4 - exit</td>
</tr>
<tr>
<td></td>
<td>TC9: Terminal 3 - entry</td>
</tr>
<tr>
<td><strong>Staff involved</strong></td>
<td>6 in total</td>
</tr>
<tr>
<td></td>
<td>• 2 to 3 Border Guards (1 at the booth, 1 to 2 to guide the travellers and assist when needed)</td>
</tr>
<tr>
<td></td>
<td>• 2 Hostesses before the test</td>
</tr>
<tr>
<td></td>
<td>• 1 host for travellers’ feedback</td>
</tr>
<tr>
<td><strong>Total duration</strong></td>
<td>12 weeks in total</td>
</tr>
<tr>
<td><strong>Timetable</strong></td>
<td>TC1: From 21.04.2015 to 13.05.2015 (3 weeks)</td>
</tr>
<tr>
<td></td>
<td>TC2: From 21.04.2015 to 18.06.2015 (4 weeks)</td>
</tr>
<tr>
<td></td>
<td>TC3: From 13.05.2015 to 05.06.2015 (3 weeks)</td>
</tr>
<tr>
<td></td>
<td>TC9: From 15.04.2015 to 30.04.2015 (2 weeks)</td>
</tr>
<tr>
<td><strong>Sample size</strong></td>
<td>Fingerprints</td>
</tr>
<tr>
<td>(target / actual)</td>
<td>• TC1: 600 / 1760</td>
</tr>
</tbody>
</table>
### Process layout

- **TC2: 1000 / –500 (impacted by change of vendors)**
- **TC3: 1550 / –1440**
- **ABC gates**
- **TC9: 1550 / –4190**

TC1, TC2, TC3: Single existing manual booth with two stations; (Dedicated lane; Done at the regular border guard booth)

TC9: Existing ABC gates - one step

### Integration within the regular border-crossing process

- Integrated

Process steps were integrated in the normal border-crossing process, i.e. made in the middle of the regular border check procedure

### Technical integration

- TC1, TC2, TC3: Standalone
- TC9: Integrated

### Type of device

- **TC1:** New 4FP fixed contactless fingerprint scanner
- **TC2:** New 4FP fixed contact fingerprint scanner (optical)
- **TC3:** New 4FP fixed contact fingerprint scanner (optical)
- **TC9:** Existing one-step ABC gates, adapted to accommodate for TCNs

### Quality thresholds

<table>
<thead>
<tr>
<th>Fingerprint quality thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC1: NFIQ 3·3·3·4</td>
</tr>
<tr>
<td>TC2: NFIQ 2·2·2·3</td>
</tr>
<tr>
<td>TC3: NFIQ 2·2·2·3·4</td>
</tr>
</tbody>
</table>

The quality threshold was adapted following discussion with vendors and NL

### Environmental device

N/A

### Travellers’ feedback

After test completion: Self-service tablet

### Data protection

Verbal consent requested

### Workflow

#### Fingerprint enrolment

1. **TC1:** Enrolment of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present)

The device was set parallel to the lane, and the traveller was invited to present his hand vertically and pass it through a gap in the device while approaching the booth.

*Figure 15* Schiphol - TC1 (4FPs enrolment) steps
2. TC2: Enrolment of 8 fingerprints (index, middle, ring and little fingers for both hands)

Fingerprints for the index, middle, ring and little fingers for the right hand of volunteering TCNs were captured first using a fixed contact scanner, and then the same was done for the left hand (4-4 method).

3. TC3: Enrolment of 10 fingerprints (index, middle, ring, little fingers and thumbs for both hands)

Fingerprints for the index, middle, ring and little fingers for the right hand of volunteering TCNs were captured all at once first using a fixed contact scanner (identical scanner type used for TC2), followed by the same process for the left hand. The thumbs for both hands were then captured both at once.

ABC gates

The process for the ABC gates was divided in the following steps:56

1. Passport inspection (including Passive Authentication);57
2. Retrieve facial image from the eMRTD;
3. Capture of the live facial image (photo) from the TCN;
4. Verification of the facial image captured from the eMRTD against the live facial image captured from the TCN.

The ABC gate in operation was a set-up in a one-step process with man-trap.

The gates were set-up in a one-step process, in which the traveller entered a mantrap, provided his/her passport and the facial image was captured in one step without requiring the traveller to move to another stage.

The capture of the facial image was done through a video stream which analysed the best candidate image for facial recognition.

The capture of the facial image process started at the moment when the travellers inserts his/her passport and if no adequate image is captured by the time the passport reading has been completed, the traveller is asked to look at the camera and additional instructions are provided, including live feedback from the point of view of the camera.

---

56 The five steps have been defined to permit judgement to be made on whether to allow the traveller to pass without manual intervention and are applicable to all BCPs.
57 Passive Authentication (PA) is used to check if the data on the RF chip of the electronic ID document is authentic and not forged. Further details are available in the chapter on chip reading.
58 Source: Best Practice Operational Guidelines for Automated Border Control (ABC) Systems, FRONTEX 2012.
4.6.1.3. Participation and sample characteristics

Note that demographic characteristics (gender, age range and nationalities) were not recorded for TC1, TC2 and TC3.

The gender of the sample was evenly distributed, with 53% male and 47% of female travellers. 73% of participating travellers were aged between 31 and 70.

The majority (53%) of participants were from the USA.

![Figure 155 Schiphol - sample distribution by gender](image1)

![Figure 156 Schiphol - sample distribution by age](image2)

![Figure 157 Schiphol - sample distribution by nationality](image3)

4.6.2. Test cases operational and technical results

4.6.2.1. Fingerprints (TC1, TC2, TC3)

Success / failure

The enrolment of the fingerprints was considered successful if the set threshold was reached within three attempts. In the majority of the cases however, no retries were done when the first attempt did not reach the desired threshold.

The graphs below show the success/failure rate for TC1, TC2 and TC3.

---

59 The country codes used in the graph are the three-letter country codes defined in ISO 3166-1:
The rate of success for TC1 with the threshold used (despite it being lowered to NFIQ 3·3·3·4) was 61% at the first attempt. Contactless equipment are generally not strongly performing with NFIQ algorithms, and it can be hypothesised that using a threshold based on another quality algorithm would have produced better results.

The right hand showed better quality at enrolment than the left hand, but not noticeably so.

The device was placed in the middle of the booth, so position is unlikely to have played a significant role in this discrepancy.
The overall rate of success for TC3 was 31% with the threshold used (despite it being lowered to 2-2-2-3-4), and even lower than TC2. Indeed only about a third of the travellers succeeded in reaching the threshold at the first attempt. The right hand showed better quality at enrolment than the left hand, but not noticeably so (in line with findings in other BCPs). Some people managed to enrol the right hand but not the left hand, and vice-versa, and therefore the overall success rate for the two hands is around 20% lower than the one of individual hands.

In this case, the results for the right hand are noticeably better than for the left hand, with a 25% increase in success rate. The device was placed in the middle of the booth, so position is unlikely to have played a significant role in this discrepancy.

Quality

Quality measurement of individual fingerprints in Schiphol was based on NFIQ, number of minutiae and the vendor-specific index. The number of minutiae was also recorded to complement quality measurement based on NFIQ.

![Figure 161 Schiphol - TC1 NFIQ scores per finger at the first attempt with contactless scanner](image1)

![Figure 162 Schiphol - TC1 minutiae amount per finger at the first attempt with contactless scanner](image2)

It can be seen that with the contactless device used at Schiphol for TC1, the quality obtained tends to be either very good (NFIQ 1) or very poor (NFIQ 4 and 5), with only little values in between (NFIQ 2 and 3), meaning that either enrolment can be done with very good quality, or be quite problematic.

It can also be seen that in around 50% of the cases, the right index, middle and ring fingerprints were of very good quality. The little finger was more problematic, with around 50% of the cases where the enrolled quality was very poor.

The amount of poor quality results can be explained by the fact that the contactless device used for TC1 required the traveller to swipe his hand through the device in one single motion, not allowing for adjustments on the fly.

The number of minutiae identified with the contactless equipment used for TC1 was quite high, with an absolute majority (above 90%) of fingerprints enrolled presenting more than 30 minutiae. More than 50% of index, middle and ring fingerprints exceeded 60 minutiae. The little finger presented fewer minutiae, which is in line with findings with other equipment and in other BCPs. These good results contrast the mitigated NFIQ results obtained with this equipment.
Quality of fingerprints based on the NFIQ algorithm for TC2 with an optical contact scanner was more spread out than for TC1 done with a contactless scanner. Indeed the amount of very good quality fingerprints (NFIQ1) is not noticeably better, however there is much fewer very poor quality fingerprints enrolled. This can be explained by the fact that the 30 seconds timeout allows the traveller to adjust the position of his/her hand to improve quality. Also, feedback is provided directly on the scanner by means of colour-coded LEDs to notify the traveller which finger’s position needs to be adjusted.

Despite possibility for adjustment, it can be seen that the little finger poses significant challenges in terms of acquiring good quality fingerprints.

Finally, it can be seen that although there is a significant discrepancy between fingers for the highest quality scores, they tend to even out at value NFIQ3, which 90% of fingers achieve, regardless of which finger it is.

The number of minutiae identified with the optical contact equipment used for TC2 was much lower than with contactless equipment for TC1. It can be seen that only a very limited amount of fingerprints enrolled presented a high (>60) number of minutiae, and that only around 50% of little fingers enrolled had more than 30 fingerprints.

![Figure 163 Schiphol - TC2 NFIQ scores per finger at the first attempt with contact scanner](image1)

![Figure 164 Schiphol - TC2 minutiae amount per finger at the first attempt with contact scanner](image2)

![Figure 165 Schiphol - TC3 NFIQ scores per finger at the first attempt with contact scanner](image3)
Quality of fingerprints based on the NFIQ algorithm for TC1 a capacitive contact scanner was overall lower than with the optical scanner. It can be noticed that the fingerprints of the thumbs had noticeably higher quality than the other fingers; indeed the number of thumbs fingerprints with a NFIQ value of 1 was twice as high as for indexes.

Despite the opportunity for the border guard to provide live feedback and guidance to the traveller about their fingers’ placement, between 10% and 20% of the fingerprints present poor quality (NFIQ 4 and 5).

The number of minutiae obtained with capacitive contact equipment used for TC3 was much higher than with optical contact equipment used for TC2, despite the NFIQ values being lower. The thumbs present a much higher number of minutiae compared to other fingers.

The majority (90%) of fingerprints enrolled presented more than 30 minutiae.

**Duration**

The duration of fingerprint enrolment is measured in order to assess the added duration compared to the current situation where no biometric identifier is enrolled. Time-stamped log files, produced by FP scanners, were used for duration measurement.

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the FP;</td>
<td>1. The successful capture with a maximum of 3 attempts or the end of the third attempt. For TC2, a timeout of 30 seconds was put in place.</td>
</tr>
<tr>
<td>2. The start of the successful capture.</td>
<td>2. The successful capture with a maximum of 3 attempts or the end of the third attempt. For TC2, a timeout of 30 seconds was put in place.</td>
</tr>
</tbody>
</table>

The graphs below illustrate the duration of fingerprints enrolment for TC1, TC2 and TC3.

It should be noted that in the case of Schiphol, only a minority of retries were performed when the quality threshold was not reached. Therefore the following results are valid in case one attempt only is performed.
Enrolment of 4 fingerprints with the contactless device used for TC1 in Schiphol had little time impact on the border-check procedure. One out of three attempts was done below 5 seconds, two out of three done in less than 15 seconds, and the absolute majority (94%) in less than 30 seconds. This can be explained by the fact that travellers could enrol their fingerprints on the move, while getting closer to the booth, without stopping. When only one attempt was needed to reach the threshold, then enrolment took only one second.

Overall, enrolment of 4 fingerprints with a contactless device used as the traveller approaches the booth had very limited time impact on the border check procedure, especially when no retry was needed.

In the case of TC2, the recorded duration was the one of the last attempt to be done. A timeout of 30 seconds was configured in the device. Therefore no value exceeds 30 seconds, and all attempts reaching 30 seconds were unsuccessful.

It can be seen that the majority of last enrolment attempts reached the 30 seconds threshold, and the whole procedure had a noticeable time impact on the border check procedure, with only slightly more than one attempt out of three taking less than 30 seconds, and two out of three taking 30 seconds (and would probably take more if there had been no timeout).

Overall, enrolling 8 fingerprints had a sizeable impact on the border check procedure.

In the case of TC3, no hard timeout was enforced, and therefore the duration can be higher than the one for TC2. Also, capturing the two thumbs is taking additional time. It should be noted however that these results are representative for one attempt only, as retries were in 90% of the cases not performed in case the threshold was not reached.

In the majority of cases, TC3 in Schiphol took more than 30 seconds. If the three attempts policy had been enforced, it is likely that the amount of durations over 30 seconds and 60 seconds would be even higher. Overall, enrolling 10 fingerprints had a sizeable impact on the border check procedure.

4.6.2.2. ABC gates (TC9)

Out of the 4051 samples recorded at Schiphol for this test case, 885 were excluded from the analysis because the equipment could not distinguish whether the traveller had an MRTD or an eMRTD.

Regarding travellers with an eMRTD, there were 430 cases where the nationality of the traveller could not be recorded due to errors in reading the travel document. Excluding them would have removed all errors related to the MRZ.
At the border based on the facial image biometric identifier, by matching the facial image retrieved from the passport chip and the live facial image captured. Therefore, the success condition for the test case is the successful verification of the facial image - which depends on the following steps:

a) The facial image could be accessed and retrieved from the eMRTD without errors (passive authentication errors are addressed separately as they do not prevent the FI to be extracted from the chip and used for an eventual verification with the live facial image);

b) The enrolment of the live facial image was successful.

The enrolment score for the comparison between the live facial image and the photograph extracted from the chip of the eMRTD was above the set threshold. This threshold is based on vendor algorithm and was chosen to result in a performance of 1% FAR.

Regarding travellers with an eMRTD, there were 430 cases where the nationality of the traveller could not be recorded due to errors in reading the travel document. Excluding them would have removed all errors related to the MRZ. Attempting to extrapolate an MRZ error rate associated with TCNs when their nationalities are not known, we applied a ratio of EU nationals to TCNs, deduced from the overall sample, on this subset. This resulted in 322 samples (out of the 430) being removed to reflect the 3-to-1 ratio of EU to TCNs calculated from the samples for which a nationality could be recorded.

The graph below presents the overall success rate for ABC gates at Schiphol airport based on a 1% false acceptance rate.

![Figure 170 Schiphol - TC9 success and failure rate for the entire bearer verification process based on the facial image modality at a FAR of 1%](image)

It can be seen that approximately 90% of the attempts at using ABC gates at exit reached the stage of the facial image verification. 79% of attempts resulted in a successful verification (above the 1% FAR threshold), while 9% resulted in an unsuccessful one. Once the verification of live against chip facial images completed (i.e. excluding the errors), it was successful in 90% of cases.

At various locations, a more stringent verification threshold corresponding to a FAR of 0.1% was applied. In order to all comparison with such results, the figure below demonstrates the success-failure at such a threshold.
As expected, the success rate is impacted by the more stringent theoretical threshold resulting in a 17 percentage point reduction of the verification success rate, across the whole sample, from 79% to 62%.

It should be noted that these figures are solely estimates - if such a threshold was applied in reality, live facial images could have been re-enrolled in case of verification failure. Thus, the proportion of successful verifications at 0.1% FAR presented above is undoubtedly an underestimation of what would be seen in reality.

As we can see for 6% of the travellers an error in accessing the passport chip prevented the retrieval of the facial image from the chip (OPEN_CHIP_BAC and OPEN_CHIP_OTHER). In 4% of cases the error was due to reading the MRZ of the travel document.

At Schiphol, no data was collected regarding the errors related to passive authentication.

The comparison between the Chip Image (CI) quality and Live Image (LI) quality in the cases where there were no document errors is presented below.

The chip image quality was better than the live image quality in 56% of cases. The reverse was true in 42% of cases. This can be attributed to the better conditions under which the chip image was taken (professional photographer,
dedicated set-up at passport issuing authority) compared to the BCP conditions. In 2% of cases the quality values registered were the same for CI and LI. This was due to the fact that the quality recorded was zero in these cases.

Duration

The duration was measured by using time-stamped log files produced by the ABC gate itself. The total average crossing duration was calculated including passive authentication (PA). It does not include samples for which evidence of document errors was recorded. It also does not include the time needed to stamp the passport after the ABC gate crossing.

The measurement points for the duration of the test case were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader.</td>
<td>1. To the opening of the doors.</td>
</tr>
</tbody>
</table>

![Figure 174 Schiphol - TC9 ABC gate process duration (in seconds)](image)

72% of travellers crossed the ABC gate in less than 15 seconds, and 23% between 15 and 30 seconds. Only 5% of cases took more than 30 seconds, though always less than a minute. The average time was 14.3 seconds.

On top of the overall duration, the duration of the passive authentication is presented below:

![Figure 175 Schiphol - TC9 passive authentication duration (in seconds)](image)

The passive authentication duration in Schiphol included the full chip reading, and can be seen as taking less than 8 seconds in 72% of the cases.
4.6.2.3. Duration impact on the end to end process

The purpose of this section is to compare how the introduction of the biometric enrolment and verification steps analysed might affect the duration of the border check process. We describe herein both:

a. A baseline measurement: the average duration of the current border check process;

b. Average times for the individual biometric enrolment and verification steps calculated based on the operational tests undertaken as well as end to end times for the border check with the facial image and fingerprint-based processes;

c. Average times for the crossing of ABC gates.

Values are provided in the following table:

Table 27 Schiphol - duration impact on the end to end process

<table>
<thead>
<tr>
<th>Aspect under measurement</th>
<th>Average duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline(^{60})</td>
<td>33 seconds</td>
</tr>
<tr>
<td>Contact</td>
<td></td>
</tr>
<tr>
<td>8 fingerprint enrolment with 4FP scanner</td>
<td>26 seconds</td>
</tr>
<tr>
<td>10 fingerprint enrolment with 4FP scanner</td>
<td>42 seconds</td>
</tr>
<tr>
<td>Contactless</td>
<td></td>
</tr>
<tr>
<td>4 fingerprint enrolment with 4FP scanner</td>
<td>9 seconds</td>
</tr>
<tr>
<td>ABC gate crossing (1-step process)</td>
<td>14 seconds</td>
</tr>
</tbody>
</table>

From the values in the table above, it can be observed that in the case of the testing set-up at Schiphol:

- The ABC gate, for those travellers for whom it can be applied (~80% of the tests participants), was significantly (42%) faster than the baseline. While it didn’t include the questions to the travellers, it included facial image capture from the eMRTD and live, and their matching;
- Capture of four fingerprints with the contactless device used at Schiphol did not have a major impact on the process time (addition of 27% duration, not counting the explanations);
- Capture of eight and ten fingerprints with the contact devices used at Schiphol had a more important impact on the process time, especially with ten fingerprints where the enrolment alone took 42 seconds, i.e. 127% of the regular process time, compared to 79% for eight fingerprints.

\(^{60}\) The average baseline duration was calculated from a sample of 134 travellers, with each datapoint recorded manually using a clock on the wall. It was measured from the time at which the traveller arrived at the booth until the border guard disengaged (i.e. gave back the passport).
4.6.3. Users’ perception

4.6.3.1. Travellers’ feedback

In total, 1500 entries (corresponding to around 36% of the participating travellers) were recorded for TC1 and TC9, and 1219 entries (corresponding to around 85% of the participating travellers) for TC2 and TC3.

Travellers’ feedback was not recorded individually for the different test cases at Schiphol Airport. Two rounds of feedbacks were recorded: one for TC1 and TC9 and the other for TC2 and TC3. Respondents generally expressed satisfaction with the process to which they submitted, professing to be either satisfied or very satisfied in about 90% of cases for TC1 and TC9 and 82% for TC2 and TC3. Negative feedback was provided by 17% of travellers for both collected feedbacks. More details about the feedback are provided in the figures below.

<table>
<thead>
<tr>
<th>Schiphol - TC1, TC9</th>
<th>Schiphol - TC2, TC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very unsatisfied</td>
<td>6%</td>
</tr>
<tr>
<td>Unsatisfied</td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>4%</td>
</tr>
<tr>
<td>Very satisfied</td>
<td>90%</td>
</tr>
<tr>
<td>Satisfied</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 176 Schiphol - results of the travellers’ survey*

4.6.3.2. Border guards’ feedback

Fingerprints enrolment

In total, 4 responses for the feedbacks from the border guards were collected for TC1, 5 responses for TC2 and 3 responses for TC3.

The results per the relevant test cases are summarised in the table below.

They should be put in the perspective that the set-up at Schiphol was completely standalone from a technical perspective (although integrated in the process), and therefore did not provide direct added value to the border guards who saw it only as an additional step in a different environment. Also, given the test conditions, the equipment could not be tailored to the environment. Finally, TC2 and TC3 results could be highly contrasted because they were set side-by-side and as such border guards could feel strongly for one option or another.
Table 28 Schiphol - TC1 border guards’ feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive: 1 out of 4 Neutral: 1 out of 4 Negative: 2 out of 4</td>
<td>Positive: 2 out of 4 Neutral: 2 out of 4 Device was considered hygienic.</td>
<td>Positive: 4 out of 4</td>
<td>All responses claimed that the travellers were overall ‘mostly enthusiastic’ to accept the new step/process.</td>
</tr>
<tr>
<td>Impediments</td>
<td>Need for border guards guidance and instructions. Several re-tries making travellers irritated.</td>
<td>Signal/ System problems. Quality obtained too low. Device was too big.</td>
<td>Issues with big hands. Tall travellers have to bend to use device.</td>
</tr>
<tr>
<td>Improvements</td>
<td>N/A</td>
<td>More guidance to travellers and to border guards, e.g. through live video feedback.</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 29 Schiphol - TC2 border guards’ feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral: 1 out of 5 Negative: 4 out of 5</td>
<td>Negative: 5 out of 5</td>
<td>Negative: 5 out of 5</td>
<td></td>
</tr>
<tr>
<td>Impediments</td>
<td>Language/age constraints. Length of the process.</td>
<td>Difficulty to use the equipment (e.g. apply sufficient pressure on the scanner).</td>
<td>Size is not adequate for large hands. Right hand considered stronger than left hand.</td>
</tr>
<tr>
<td>Improvements</td>
<td>N/A</td>
<td>Ergonomics of the equipment.</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 30 Schiphol - TC3 border guards’ feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive: 1 out of 3 Neutral: 2 out of 3</td>
<td>Positive: 3 out of 3</td>
<td>Positive: 3 out of 3</td>
<td></td>
</tr>
<tr>
<td>Impediments</td>
<td>Too long as compared to 4 fingerprints capture.</td>
<td>Signal/ System problems. Hygiene of contact scanners.</td>
<td>Lot of recapture because travellers do not understand clearly how to proceed.</td>
</tr>
<tr>
<td>Improvements</td>
<td>N/A</td>
<td>N/A</td>
<td>More guidance needed for travellers. Use of audio for clearly instruction on how to proceed.</td>
</tr>
</tbody>
</table>
ABC gates

Feedbacks from 9 border guards were collected for TCg (ABC gates) at Schiphol Airport. The results are summarised in the table below.

The main criticisms seem to be linked to the test set-up rather than the actual use of the ABC gate by TCNs, and to the fact that travellers are not used to the process, which should evolve over time. No point was highlighted about a potential difference between TCNs and Europeans regarding the applicability of ABC gates for border checks.

*Table 31 Schiphol - TCg border guards’ feedback*

<table>
<thead>
<tr>
<th></th>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td>Neutral: 6 out of 9 Negative: 3 out of 9</td>
<td>Positive: 2 out of 9 Neutral: 3 out of 9 Negative: 4 out of 9</td>
<td>Positive: 2 out of 9 Neutral: 3 out of 9 Negative: 4 out of 9</td>
</tr>
<tr>
<td>Impediments</td>
<td>Language/age barrier. Lengthy process especially required providing adequate instructions to travellers.</td>
<td>Potential hardware problems.</td>
<td>Confusion - a lot of travellers walking in the ABC gates without getting a stamp. Difficulties encountered by people with disabilities.</td>
</tr>
</tbody>
</table>

4.6.4. Constraints

4.6.4.1. Environmental conditions

The tests in Schiphol were performed in airport conditions, and no environmental conditions impacted the operations.

4.6.4.2. Others

Difficulties were encountered to enrol some fingerprints, in particular special circumstances such as:

- Problems with fingerprints (wet, scarred, worn, missing/deformed);
- Impossibility to put fingers within the scanner’s frame;
  - Little fingers are less easy to enrol because of the position - quite lower than ring finger, or hands too big;
  - Hands too big thus the 4 fingers (index, middle, ringer and little fingers) did not fit in the frame space.
- Low sensitivity of the scanner to fingerprint quality;
- Unclean scanner platen.

4.6.5. Main observations

TC1

- Although the device was showing some guidance to the traveller were not knowing exactly how to present their hands to the device;
- In some case the capture of hands was depending on how wide the fingers were opened and presented to the device;
- Time to time the traveller were hitting the device;
- Due to the orientation of the hand (vertical) this device is unable to do 5 fingers;
- The sound was also not correlated with the actual quality of the capture i.e. the traveller did not understand why
he has to retry or go. This behaviour was correct from the point of view of the vendor but I was not from the NFIQ perspective.

TC2
- The device was very slow which could be a bias for the pilot, as it was adapted from another solution with a different purpose;
- Despite the touchscreen being aesthetically pleasing, finishing the procedure (in some cases required cancelling the procedure) took longer because of the poor usability. (Successful capture of the fingerprints required the traveller to press quite hard on the screen);
- The screens were not big enough for enrolling bigger fingers. The device captured 4 fingers at the same time before proceeding to the next step and 8 out of 10 times there was error because the index finger and little finger are not accepted/captured;
- The device feedback was not really taken into account by the traveller who in a vast majority of case preferred to interact with the border guard following his guidance.

Fingerprints enrolment
In the testing conditions at Schiphol, TC1 was faster than TC2 and TC3, also partly accentuated by the use of a contactless device for TC1.

The quality of fingerprints showed some dependency to the equipment used, with contact devices still capturing higher quality fingerprints than contactless based on international standards.

The traveller’s acceptance of the process was much better for TC1 than for TC2 and TC3, also potentially accentuated by the use of a contactless for TC1.

From the border guards’ feedbacks, it could be deduced that the level of guidance could affect the speed of the enrolment process, that hygiene considerations were important and that some pieces of equipment were more usable than others.

Overall, although the position of the device was not giving better placement to one or another hand, the right hands presented better results. Thumbs provide the highest quality fingerprints, followed by the index, middle and ring fingers, while the little finger presents generally poor quality fingerprints.

ABC gates
At Schiphol airport, ABC gates could be used by TCNs in 89% of cases. Depending on the threshold applied, between 9% and 17% of the attempts resulting on a lower verification score than requested, and between 79% and 62% resulted in a successful matching of the traveller based on the biometrics stored in his/her travel document.

The algorithm in use is not one that is proprietary to the vendor, instead the vendor used an off-the-shelf algorithm and added a software layer to allow it to communicate with the ABC gate. The algorithm is ICAO-compliant.

The main differences highlighted between the use of ABC gates by EU and TCNs were the quality of the chip image, the success of passive authentication and the potential language barrier.

The process was fast (14 seconds average excluding stamping time), even when considering the one-step process set-up in use at Schiphol airport.
5. Land borders BCP results

5.1. Gare du Nord – ABC gates

5.1.1. Test description

Paris Nord, or the Gare du Nord, is one of the main stations on the French national rail network and the busiest railway station in Europe, with 190 million passengers passing through the station annually. International train services are offered to Belgium, Germany, the Netherlands and the UK; in the final case, travellers to the UK undergo checks for the exit from the Schengen Area at the train station in Paris prior to embarkation.

Approximately 8,000 passengers travel daily across the English Channel having been checked at one of the 5 available booths, of which about 25% are third country nationals, a majority from North America. This chapter describes the tests executed at a new ABC gate deployed for the purposes of the pilot in the area for exit checks.

The tests focussed on the use of ABC gates at exit, including both facial recognition and fingerprint acquisition.

5.1.1.1. Set-up and configuration

The execution and organisation of the test cases at Gare du Nord train station are set up and as follows.

**Table 32 Gare du Nord - set-up and configuration**

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Land: Train - Gare du Nord is the terminal train station for Eurostar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td></td>
<td>• TC9: Using ABC gates for border checks of TCNs</td>
</tr>
<tr>
<td><strong>Test location</strong></td>
<td>Cross-channel terminal - exit</td>
</tr>
<tr>
<td><strong>Staff involved</strong></td>
<td>1 border guard was trained and in charge of the test.</td>
</tr>
<tr>
<td></td>
<td>1 assistant to guide travellers.</td>
</tr>
<tr>
<td><strong>Total duration</strong></td>
<td>6.5 weeks in total</td>
</tr>
<tr>
<td><strong>Timetable</strong></td>
<td>Two different FP scanners were used during the testing</td>
</tr>
</tbody>
</table>
• Contact 1FP scanner:
  From 17.08.2015 to 17.09.2015 (4.5 weeks)
• Contactless 4FP scanner:
  From 17.09.2015 to 29.09.2015 (2 weeks)

<table>
<thead>
<tr>
<th>Sample size (target / actual)</th>
<th>ABC gates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TC9: 1000 / 1735</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process layout</th>
<th>Dedicated ABC gate in the public area</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Integration within the regular border-crossing process</th>
<th>Not integrated: the tests were performed independently of the actual border check process</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Technical integration</th>
<th>Standalone</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type of device</th>
<th>ABC gate with integrated eMRTD reader, fingerprint scanner (4FP contactless or 1FP contact) and 3 continuous video capture cameras with lighting system for Fl capture and verification.</th>
</tr>
</thead>
</table>

The ABC gate contains integrated screens to provide instructions and real time feedback to the traveller, and is monitored from a separate station.

<table>
<thead>
<tr>
<th>Quality thresholds</th>
<th>ABC gate (TC9):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fingerprints: vendor based</td>
</tr>
<tr>
<td></td>
<td>Facial Image: vendor based, corresponding to 0.1% FAR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental device</th>
<th>Available</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monitoring light, humidity and temperature conditions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Travellers’ feedback</th>
<th>After test completion: Self-service tablet</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Data protection</th>
<th>Formal, written consent requested</th>
</tr>
</thead>
</table>

5.1.1.2. Workflow

TCNs holding an eMRTD participated in the testing. The ABC gate in operation was a set-up in a two-step process with man-trap: the traveller initiates the process of reading and subsequently the verification of the document and of the traveller’s eligibility to use the system at the first stage, and then moves to a second stage where a biometric verification (including the verification of the live Fl against the image retrieved from the eMRTD and the fingerprint capture) is carried out.

![Figure 177 Gare du Nord - ABC gates test case (TC9) set-up (two-step process with man-trap)]

The specific process steps performed at the ABC gates were the following:

---

61 Source: Best Practice Operational Guidelines for Automated Border Control (ABC) Systems, FRONTEX 2012.
1. Passport chip reading and authentication\textsuperscript{62};
2. Capture of the facial image from the chip contained in the eMRTD;
3. Capture of the live facial image with sufficient quality. The capture of the facial image was done through a video stream which analysed the best candidate image for facial recognition;
4. Verification of the facial image from the chip of the eMRTD against the live facial image;
5. Capture of fingerprints (1 (right index) or 4 (index, middle, ring and little of the right hand)) depending on the configuration. Up to three attempts are systematically performed in case the fingers captured do not reach a sufficient level of quality - based on vendor specific algorithm. For the case of the 4FP contactless scanner, the whole slap is recaptured.

5.1.1.3. Participation and sample characteristics
The below graphs show the main characteristics of the sample, consisting of approximately 1735 participating travellers:

\textit{Figure 178} Gare du Nord - sample distribution by gender \hspace{1cm} \textit{Figure 179} Gare du Nord - sample distribution by age

96\% of participating travellers were between 18 years old and 70 years old, with a good representativeness of all age groups in this range. The 4\% remaining were minors, older than 13. There was slightly more women than men participating in the tests.

Overall the test included a wide range of nationalities. USA was the most represented nationality with 37\% of participants.

\textsuperscript{62} The passport-reading step entails the placement of the passport on the document reader.
5.1.2. Test cases operational and technical results

5.1.2.1. ABC gates (TC9)

Success / failure

The purpose of the ABC gate test was to assess whether it is possible to perform local automated bearer verification at the border based on the facial image biometric identifier, by matching the facial image retrieved from the eMRTD chip and the live facial image captured. Therefore, the success condition for the test case is the successful verification of the facial image - which depends on the following steps:

1. The facial image could be accessed and retrieved from the chip of the eMRTD without errors (passive authentication errors are addressed separately as they do not prevent the FI to be extracted from the chip and use it for an eventual verification with the live facial image);
2. The acquisition of the live facial image was successful;
3. The verification score for the comparison between the live facial image and the photograph extracted from the chip of the eMRTD was above the set threshold. This threshold is based on vendor algorithm and was chosen to result in a performance of 0.1% FAR.

The graph below presents the overall success rate for ABC gates at Gare du Nord, based on the results obtained with eMRTDs holders only.

Figure 18a Gare du Nord - sample distribution by nationality

Figure 18b Gare du Nord - TC9 success and failure rate for the entire bearer verification process based on the facial image modality

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63 The country codes used in the graph are the three-letter country codes defined in ISO 3166-1: http://www.nationonline.org/oneworld/country_code_list.htm.
It can be seen that 91% of travellers’ identity was successfully verified at ABC gates based on the facial image modality. 9% of attempts resulted in a matching score lower than the threshold corresponding to 0.1% FAR, and in less than 1% of cases, verification did not occur for other reasons.

Looking only at the PA itself, the following figure shows the amount of cases where the PA was successful and the reason for failure otherwise.

![Figure 182 Gare du Nord - TC9 passive authentication outcome](image)

The passive authentication was successful in 84% of the cases. In 5% of the cases, the signature check failed, and in 2%, the time validity check failed.

**Quality**

The quality distribution between the live facial image and the image capture from the eMRTD chip are presented in Figure 183. In general, it can be seen that the chip facial image is better than the live facial image, most probably related to:

- More controlled environment for chip portrait;
- Successful acquisition of live portrait in gate comes directly from a successful match but not assessed on image quality.

Specific vendor scores will not be analysed, and they are presented only for the purpose to allow comparison of the quality scores between the live and chip facial image. Absolute values of the scores will not be assessed.
quality threshold.

Duration

The measurement points for the duration of the test case were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader.</td>
<td>1. To the opening of the doors.</td>
</tr>
</tbody>
</table>

This section describes the time it takes a given traveller to pass through the ABC gate. The duration was measured by using time-stamped log files produced by the ABC gate itself.

The duration only presents the cases where the traveller was able to actually enter the gate.

In Gare du Nord, the time recorded in the logs regarding the duration values covers as well the time to capture one fingerprint with a contact device (for 1326 samples) or four fingerprints with a contactless device (for 320 samples) inside the gate, with a quality value above the vendor’s threshold within three attempts. The duration of this capture is for this reason included in the overall duration presented in the figures below. No noticeable difference in duration was noted between the capture of one fingerprint with a contact device and the capture of four fingerprints with a contactless device.

![Duration Distribution](image_url)

**Figure 184** Gare du Nord - TC9 ABC gate process duration (in seconds)

In three quarters of cases, it took a traveller between 15 and 30 seconds to use the ABC gate, including facial image biometric verification and capture of one or four fingerprints. In the remaining 25% of cases, it took between 30 to 60 seconds, with some rare occurrences of lower and higher values recorded. The average crossing time per traveller was around 27 seconds.
On top of the overall duration, the duration of the passive authentication is presented below:

![Graph](image)

**Figure 185 Gare du Nord - TC9 passive authentication duration (in seconds)**

The passive authentication was very fast and stable, with an average of 1.5 seconds needed for the process.

### 5.1.2.2. Duration impact on the end to end process

The purpose of this section is to compare how the use of ABC gates with biometric verification steps analysed above might affect the duration of the border check process, in comparison to the current average duration of the border check process at Gare du Nord.

Values are provided in the following table:

**Table 33 Gare du Nord - duration impact on the end to end process**

<table>
<thead>
<tr>
<th>Aspect under measurement</th>
<th>Average duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline(^6)</td>
<td>27 seconds</td>
</tr>
<tr>
<td>ABC gate crossing with fingerprints capture</td>
<td>27 seconds</td>
</tr>
</tbody>
</table>

From the values in the table above, it can be observed that in the case of the testing set-up at Gare du Nord:

- The ABC gate was as fast as the current border check process. While the ABC gate did not include the questions (e.g. on subsistence means) to the travellers, it included biometric capture from two sources and their verification.

### 5.1.3. Users’ perception

In order to assess the acceptance and perception of the new steps, both travellers and border guards have been consulted.

#### 5.1.3.1. Travellers’ feedback

In total, 313 entries (corresponding to around 18% of participating travellers) were recorded for TC9 (ABC gates).

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\(^6\) The average baseline duration was calculated from a sample of 105 TCNs, with each datapoint recorded manually by the border guard using a clock on the wall. It was measured from the time at which the traveller arrived at the booth until the border guard disengaged (i.e. gave back the passport).
Overall, respondents were very satisfied with their use of ABC gates at Gare du Nord. Only 1% of respondents expressed dissatisfaction with the process.

**Gare du Nord - TC9**

<table>
<thead>
<tr>
<th>Very unsatisfied</th>
<th>Unsatisfied</th>
<th>Neutral</th>
<th>Very satisfied</th>
<th>Satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td></td>
<td>1%</td>
<td></td>
<td><strong>98%</strong></td>
</tr>
</tbody>
</table>

*Figure 186 Gare du Nord - results of the travellers’ survey*

5.1.3.2. Border guards’ feedback

4 border guards participated and replied to the survey from Gare du Nord. The following dashboard presents a summary of replies.

**Table 34 Gare du Nord - border guards’ feedback**

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td>Positive: 4 out of 4</td>
<td>Positive: 3 out of 4, for young participants</td>
</tr>
<tr>
<td></td>
<td>Negative: 1 out of 4</td>
<td>Neutral: 1 out of 4, especially</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Negative: 1 out of 4</td>
</tr>
<tr>
<td>Impediments</td>
<td>N/A</td>
<td>Travellers have sometimes difficulties in placing the passport correctly on the reader.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Difficulties to capture chip image from eMRTD for some countries (e.g. China).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensitivity of the camera and the scanner to light conditions (when the sun shines directly on the sensors).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Obstruction by traveller’s luggage resulting to ABC gates’ door not closing. Big backpacks were occasionally interpreted as tailgate cases.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Difficult to capture facial image of traveller’s wearing glasses or due to incorrect positioning of the face with regards to the camera.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In some rare cases, difficult verification of chip image against live image due to drastic change of look.</td>
</tr>
<tr>
<td>Improvements</td>
<td>Better guidance to travellers regarding the process especially to first-time users.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
5.1.4. Constraints

5.1.4.1. Environmental conditions

The tests took place at Gare du Nord train station, with indoor conditions. A glass roof is present in some areas, letting natural light shine through.

It was noted by border guards that there was a point during the day when the sun was shining through the glass roof, and directly impacting the functioning of the camera - and in some occasions the passport and fingerprint scanner. During this period the tests had to be stopped.

In Gare du Nord, an environmental measurement device was deployed to monitor temperature and humidity throughout the entire testing period. It was placed in indoor conditions. As can be seen in the table below, during the entire testing period, the temperature ranged from a minimum of 13.5° to 35.3° Celsius.

**Table 35 GdN - maximum, minimum and average of temperature, humidity and light**

<table>
<thead>
<tr>
<th></th>
<th>Temperature (°C)</th>
<th>Humidity (RH%)</th>
<th>Light (Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Min</strong></td>
<td>13.5°</td>
<td>28.6%</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>35.3°</td>
<td>66.9%</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>22.08°</td>
<td>50.29%</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>Vast majority between 18° and 25°</td>
<td>Vast majority between 30% and 69%</td>
<td>Indoor condition</td>
</tr>
</tbody>
</table>

5.1.4.2. Others

The positioning of the traveller inside the gate was found to be important as it affects the quality of the facial image and thus the matching against the photograph contained in the chip of the eMRTD.

The configuration of the gate, which was initially designed for airport traffic, can be problematic when train travellers are carrying big luggage, especially backpacks.

The instructions provided in the screen at the ABC gate play also a very important role as the travellers interact better with the equipment.

5.1.5. Main observations

Overall, ABC gates worked well with TCNs and could be successfully applied at Gare du Nord. 91% of test participants were able to get their identity successfully verified with a 0.1% FAR. Direct light was however extremely impacting the testing, leading to its interruption when the sun was directly shining on the optical captors.

The duration of the crossing procedure was not extended when compared with the current process at a manual booth, even if it included biometric capture and verification.

The border guards expressed satisfaction with the process and the equipment. According to them, travellers also appreciated the process; however some improvements still need to be done. With the exception of some passports being more problematic to read than others (e.g. some Chinese passports), nothing noteworthy seemed to indicate that ABC gates are less applicable to TCNs than to EU citizens.

From the observations on the field, it is noted that ergonomics and integrated assistance of the ABC gate play an important role to their acceptability by the user.
5.2. Iasi - Fingerprintsand facial image

5.2.1. Test description

The BCP is situated in the eastern part of Romania outside the town of Iasi, in a village called Ungheni, on the European external border to Moldova. The BCP is located just after a bridge (designed and build by Gustave Eiffel) across the Prut which flows southeast joining the Danube river. The trains from and to Moldova (Chisinau - Bucharest and vice versa) are stopped for a 1 hours border check, before continuing to their destination. Usually the border guards get in the train to perform the checks on-board of the stand still train using hand-held equipment.

 Mostly the trains contain citizens from Moldova travelling to and from Bucharest for work, studies, etc. In this BCP there are normally no persons with LBT (local border traffic permits) passing.

At this BCP, between 70 up to 300 persons/day are arriving for entry checks. These volumes vary quite a lot depending on season but also with more traffic around weekends.

Traffic at this BCP represents:

- 20 travellers in average per train from Monday to Friday
- 80 travellers in average per train during the weekend
- up to 200 travellers per train during Student holidays

In summer, special holiday trains (Moscow-Bulgaria) runs with up to 56 carriages, 2 times per week. Border guards then stay in the train until Iasi railway station if their controls are not finished in one hour.

Most of the TCNs are Bosnians (17,935), Serbians (2,900) and other (3,924), incl. Chinese and Russians. There is approx. 20% increase in travellers flow per year. TCN VH comprise very marginal share of all travellers.

The tests focused on the enrolment of fingerprints, the use of automated facial recognition and iris enrolment in outdoor conditions (train).

5.2.1.1. Set-up and configuration

The main characteristics of pilot tests at Iasi are summarised in the points below:

**Table 36 Iasi - set-up and configuration**
<table>
<thead>
<tr>
<th>Objectives</th>
<th>Inside a train, evaluate the feasibility, user-acceptance, duration and the delivered quality of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• TC1: Enrolling 4 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC2: Enrolling 8 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC4: Enrolling a live facial image</td>
</tr>
<tr>
<td></td>
<td>• TC6: Capturing the facial image from an eMRTD</td>
</tr>
<tr>
<td></td>
<td>• TC7: Verifying the facial image captured from the eMRTD against the enrolled live facial image</td>
</tr>
<tr>
<td></td>
<td>• TC5: Capture of the iris pattern</td>
</tr>
<tr>
<td>Test location</td>
<td>Ungheni train station</td>
</tr>
<tr>
<td>Staff involved</td>
<td>10 in total</td>
</tr>
<tr>
<td></td>
<td>• Shifts of 2 to 3 border guards</td>
</tr>
<tr>
<td>Total duration</td>
<td>15 weeks in total</td>
</tr>
<tr>
<td>Timetable</td>
<td>TC1: 14.06.2015 to 29.06.2015 (2 weeks)</td>
</tr>
<tr>
<td></td>
<td>TC2: 29.06.2015 to 03.07.2015 (1 week)</td>
</tr>
<tr>
<td></td>
<td>TC5: 06.07.2015 to 12.08.2015 (6 weeks)</td>
</tr>
<tr>
<td></td>
<td>TC4, TC6, TC7: 12.08.2015 to 25.09.2015 (6 weeks)</td>
</tr>
<tr>
<td>Sample size (target / actual)</td>
<td>Fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC1: 1550 / ~435</td>
</tr>
<tr>
<td></td>
<td>• TC2: 1000 /~190</td>
</tr>
<tr>
<td></td>
<td>Facial image</td>
</tr>
<tr>
<td></td>
<td>• TC4: 1550 /~606</td>
</tr>
<tr>
<td></td>
<td>• TC6: 1500 /~606</td>
</tr>
<tr>
<td></td>
<td>• TC7: 1550 /~606</td>
</tr>
<tr>
<td></td>
<td>Iris</td>
</tr>
<tr>
<td></td>
<td>• TC5: 1550 /~1960</td>
</tr>
<tr>
<td>Process layout</td>
<td>Check performed inside the train. Trains were having compartments for 6 travellers.</td>
</tr>
<tr>
<td>Integration within the regular border-crossing process</td>
<td>Not Integrated</td>
</tr>
<tr>
<td>Technical integration</td>
<td>Standalone</td>
</tr>
<tr>
<td>Type of device</td>
<td>Multi modal mobile device:</td>
</tr>
<tr>
<td></td>
<td>• 2 FP readers</td>
</tr>
<tr>
<td></td>
<td>• Iris and Face capturing</td>
</tr>
<tr>
<td></td>
<td>• eMRTD reader</td>
</tr>
<tr>
<td>Quality thresholds</td>
<td>TC1: NFIQ[^67]</td>
</tr>
</tbody>
</table>

[^66]: Tests were stopped due to the complexity of enrolling 8 FP in the train.
[^67]: NFIQ level 1.
5.2.1.2. Workflow

Fingerprints enrolment

1. TC1: Enrolment of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).

   Fingerprints for the index, middle, ring and little fingers for the right hand only of volunteering TCNs were captured using a 2-finger slap scanner. The index and middles fingers were taken first and then the ring and little fingers were captured.

2. TC2: Enrolment of 8 fingerprints (index, middle, ring and little fingers for both hands)

   Fingerprints for the index, middle, ring and little fingers for the right hand of volunteering TCNs were captured first using a 2-finger slap scanner, and then the same was done for the left hand (4-4 method).

Facial Image

TC4, TC6 and TC7 correspond to the use of Facial image in border checks and the order of the process was undertaken in four steps as follows:

1. TC6 - Capture of the facial image from the eMRTD. The eMRTD is placed in a document reader, which performs the following operations:
   o Extract the alphanumeric information (MRZ) from the document to enable the reading of the chip;
   o Perform Passive Authentication of the chip to verify the certificate;
   o Retrieve the picture / facial image from the chip.

2. TC4 - Enrolment of the live facial image (photos) from the TCNs;

3. TC7 - Verification of the facial image captured from the eMRTD against the live facial image enrolled from the TCNs. The photo captured from the eMRTD of volunteering TCNs is compared with the live facial image and the relative matching score is recorded.

---

69 ICAO 9303 is used to evaluate the quality of the Facial Image stored in the eMRTD. For live facial images.

68 Note that Passport inspection (including Passive Authentication) was carried out before TC1, TC2 and TC3. Also, a maximum of 3 attempts were allowed for the fingerprint enrolment.
Iris

Although TC₄ and TC₅ were both done at Iasi, they were not done in parallel. The test therefore only constituted of the capturing of the iris pattern.

5.2.1.3. Participation and sample characteristics

The below graphs show the main characteristics of the sample, consisting of approximately 4,270 travellers:

![Figure 189](image1.png) Iasi - facial image test cases (TC₄, 6 and 7) steps

![Figure 190](image2.png) Iasi - TC₅ (iris enrolment) steps

![Figure 191](image3.png) Iasi - sample distribution by gender

![Figure 192](image4.png) Iasi - sample distribution by age
A higher rate of participation for the test cases at Iasi was recorded for female travellers, which amounted to 68% of the total sample size for all test cases performed.

Participating travellers aged between 50 and 70 years had the highest recorded percentage with a share of 52%. No traveller beyond 70 years of age was recorded.

Moldova was the main nationality of the participating travellers, with a share of approximately 98%.

5.2.2. Test cases operational and technical results

5.2.2.1. Fingerprints (TC1, TC2)  
Success / failure
For TC1 and TC2, the duration was recorded from the moment the border guard initiated the enrolment of fingerprints enrolment until the successful capture with a maximum of 3 attempts or the end of the third attempt.

The enrolment of the fingerprints was considered successful, by the border guards, when the device signalled “OK”, indicating that the fingerprints were properly enrolled. In the graphs below, the recorded NFIQ value has been used to determine the success/failure (NFIQ 3 · 3 · 3 · 3 or better seen is as successful in this calculation).

It should be noted that due to some technical issue with the configuration of the 2 FP slap device used, only the NFIQ values for only the ultimate attempt was recorded i.e. when 2 attempts were made only the quality data for the 2nd attempt was registered but not for the first attempt.

For TC2, the capture of 2 fingers (index and middle) for the right hand was attempted up to three times (upon failure) and in case the third attempt failed, the two other fingers (ring and little) of the right hand were not enrolled. The same applies for the left hand.

For both TC1 and TC2 the success rate could be considered as quite high, over 80% for all cases.

---

\[ \text{Figure 193 Iasi - sample distribution by nationality}\]^{70}

The country codes used in the graph are the three-letter country codes defined in ISO 3166-1: http://www.nationsonline.org/oneworld/country_code_list.htm.
The graphs below show the success/failure for TC1 (right hand) and TC2 (left hand).

It can be seen that both the right and the left hand could be successfully enrolled in the majority of cases (over 83%) during TC1 and TC2.

Quality

The quality of fingerprints enrolled was assessed using both NFIQ scores and the number of minutiae in each print.

The results presented do not take into account fingerprints where no values were recorded (i.e. which failed to reach the minimum evaluated quality range of 1 to 5).

NFIQ results

- Most of the cases scored between 1 and 3 for the NFIQ. As in many other BCPs, it can be seen that fingerprints from the little finger were of the lowest quality as compared to those for the index, middle and ring fingers;
- Approximately two in three fingerprints captured could be considered to be of good quality (NFIQ 1 or 2) and one in three of average quality (NFIQ 3). Only one in ten fingerprints was of poor quality (NFIQ 4 or 5).

Minutiae results

- The number of minutiae identified was relatively high with approximately 50% of fingerprint images having more than 60 minutiae captured and the other half having between 30 and 60 minutiae captured. Prints from the little finger typically had fewer minutiae as compared with the other fingers.
Figure 197 Iasi - TC1 NFIQ scores per finger at the first attempt with contact scanner

Figure 198 Iasi - TC1 minutiae amount per finger at the first attempt with contact scanner

Figure 199 Iasi - TC2 NFIQ scores per finger at the first attempt with contact scanner

Figure 200 Iasi - TC2 minutiae amount per finger at the first attempt with contact scanner

Duration

The points of measurement for duration of TC1, TC2 and TC3 were set as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the first two fingerprints.</td>
<td>2. Successful capture with a maximum of 3 attempts.</td>
</tr>
</tbody>
</table>

The duration of fingerprint enrolment was provided by the vendor's software.

Note that enrolment durations in Iasi were calculated from the time that the border guard activated the enrolment attempt by mouse click through to the complete enrolment of the required number of fingers.

The graph below shows the distribution of enrolment durations of the one attempt that was recorded in the logs.

Important remark: the duration of TC1 below seems to have been influenced by the application and does not show only the time taken to capture the prints. It includes also guidance to the traveller. This is visible in the difference between TC1 and TC2 where the capture of the 8 fingers is not double of the TC1 duration. Given this specific characteristic for these tests it can be derived that the actual capturing of the fingerprints has a shorter duration than what is displayed in the graphs.
All the test cases for TC1 took more than 15 seconds. An almost similar percentage of cases were recorded for enrolments taking between 15 and 30 seconds (47%) and enrolments between 30 and 60 seconds (48%). The average duration of enrolling 4 fingerprints was about 34 seconds.

For TC2, the enrolment of the right and left hand took more than 30 seconds in overall and 90% of the cases were recorded with duration between 30 and 60 seconds.

5.2.2.2. Facial Image (TC4, TC6, TC7)

The purpose of the facial image tests is to perform local automated bearer verification at the border based on the facial image biometric identifier.

Regarding facial image the following test cases were performed:

- Retrieval of the facial image from the eMRTD chip (TC6);
- Enrolment of a live facial image (TC4);
- Comparison, verification of the two above (TC7).

Tc4, TC6 and TC7 are highly interrelated. As a result, this section will analyse the results from a joint perspective, pointing at specific aspects of individual test case when relevant.

Success / failure

In Iasi, the success condition was if the verification score was above the set threshold and the image could be accessed and retrieved from the eMRTD without errors. A threshold pertaining to a FAR of 0.1% was used in the calculation.
The graph below illustrates the success/failure for the verification of the live facial image against the facial image retrieved from the chip of the eMRTD.

![Graph showing success and failure rates.]

**Figure 203** Iasi - FI related test cases success and failure rate

We can observe from the results that using the vendor specified threshold, a quite significant success rate is obtained which amounts to 90%.

Note that due to modalities with the device used in Iasi the chip image verification score was not recorded. The errors encountered during chip image capture were also not recorded.

**Quality**

The quality of the chip facial image was evaluated based on the specific vendor quality index\textsuperscript{23}. As for the live facial image, the quality was determined both by ICAO and vendor specific index.

However due to modalities with the device used in Iasi, data was neither logged for the chip image quality nor for the live image quality.

**Duration**

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader;</td>
<td>1. To the result of the eMRTD FI acquisition (success or failure), including the time to perform the passive authentication;</td>
</tr>
<tr>
<td>2. From the start of the live image enrolment;</td>
<td>2. To the successful enrolment of live image or timeout (if relevant);</td>
</tr>
<tr>
<td>3. From the start of the facial image verification.</td>
<td>3. To the outcome of the facial image verification.</td>
</tr>
</tbody>
</table>

---

\textsuperscript{23} Specific vendor scores will not be analysed, and they are presented only for the purpose to allow comparison of the quality scores between the live and chip facial image. Absolute values of the scores will not be assessed.
The following observations can be made:

- The overall duration of the three steps was in average 35 seconds;
- In the majority of the cases (98%), the extraction of the facial image from the chip took above 8 seconds;
- For the enrolment of the live facial image, 54% of the total sample took between 15 and 30 seconds to enrol while 43% took between 5 and 15 seconds. It should be noted that this includes that the border guard started this test step by pressing a button on the screen of the device;
- The verification of the chip facial image against live facial image was made in less than 6 seconds in most cases.

The following figures show the distribution of durations obtained for each of the above steps:

**Figure 204** lasi - TC6 facial image from the chip retrieval duration for eMRTD holders (in seconds)

**Figure 205** lasi - TC4 live facial image enrolment duration for eMRTD holders (in seconds)

**Figure 206** lasi - TC7 facial image verification duration for eMRTD holders (in seconds)

During the tests performed in lasi, the device used did not record the duration of the passive authentication.

**Security**

Passive authentication is recommended as a means to guard against document modification and to verify appropriate document issuance. Please refer to the "Reading chips in e-passport" desk research chapter in the main report (Volume 1- Chapter 3.6, section 3.6.4) for a more detailed overview of passive authentication and for further details on other security measures associated with eMRTDs.

During the tests performed in lasi, the device used did not record the passive authentication.

5.2.2.3. Iris (TC5)

**Success / failure**

In most cases, 1 attempt only was required to enrol the right iris pattern (88%) and left iris pattern (87.4%). A maximum of 5 attempts had to be made to enrol the right iris and the left iris pattern in the extreme cases.

In 99% of the cases in lasi, a successful enrolment of the iris pattern was recorded.
Figure 207 lasi - TC5 iris pattern enrolment success and failure rate

Quality

During testing, it was not possible to represent the quality of iris images enrolled using any sort of numerical measure. However, the device accepted the enrolment if the acquisition met the vendor’s quality threshold.

Duration

The points of measurement for duration of the test case were set as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the iris pattern.</td>
<td>1. The successful capture of the iris pattern.</td>
</tr>
</tbody>
</table>

The following observations can be made:

- The overall duration of the step was in average 26 seconds;
- In the majority of the cases (73%), the capturing of the iris pattern to less than 30 seconds;
- It should be noted that in the time recorded for the duration it is also included some interaction between the border guards and the device used.

![Duration distribution](image)

Figure 208 lasi - TC5 right and left iris enrolment process duration (in seconds)

5.2.2.4. Duration impact on the end to end process

In lasi, there was no baseline measurement done since the test process is not comparable to any current process and it was performed fully standalone.
5.2.3. Users’ perception

5.2.3.1. Travellers’ feedback

The travellers’ feedback was performed via an application integrated in the device used for the tests. The survey was made at the end of the tests. In total, 381 entries (corresponding to around 88% of participating travellers) were recorded for TC1 and TC2 (4 fingerprint and 8 fingerprint enrolment). 206 entries (corresponding to around 10% of participating travellers) were recorded for TC5 (iris pattern enrolment) and 271 entries (corresponding to around 45% of participating travellers) for TC4, 6, 7 (facial image).

For TC1 and TC2 it can be observed that only a minority of the respondents (46%) were satisfied with regards to their participation. These tests were the first to be executed and in particular enrolling 8 FP was not seen as positive by the respondents, according to feedback from border guards.

The enrolling of iris (TC5) received more positive feedback from the respondents with 72 % satisfied or very satisfied. The most positive feedback is related to the last test phase, where TC4, 6 and 7, were performed. For these tests 86% of the respondents were satisfied or very satisfied.

It is possible that a number of factors, such as the learning curve for using the device, the very hot weather in the first test phases and that capturing iris and face can be made without any contact, played a role in the feedback received. To balance this result it should be noted that the willingness of travellers to participate was high throughout the whole test campaign.

<table>
<thead>
<tr>
<th>lasi - TC1, TC2</th>
<th>lasi - TC5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very unsatisfied</td>
<td>Unsatisfied</td>
</tr>
<tr>
<td>6%</td>
<td>1%</td>
</tr>
<tr>
<td>Neutral</td>
<td>48%</td>
</tr>
<tr>
<td>Very satisfied</td>
<td>Satisfied</td>
</tr>
<tr>
<td>46%</td>
<td>72%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>lasi - TC4, TC6, TC7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very unsatisfied</td>
</tr>
<tr>
<td>Neutral</td>
</tr>
<tr>
<td>Very satisfied</td>
</tr>
</tbody>
</table>

*Figure 209 lasi - results of the travellers’ survey*
5.2.3.2. Border guards’ feedback

In total, responses from 10 border guards were collected at Iasi for the fingerprints. The results of the feedback is summarised in the tables below, one table per type of biometrics. The border guards from Iasi made a combined feedback, including the view of all the 10 border guards in one questionnaire.

Fingerprints

Table 37 Iasi - TC1, TC2 border guards’ feedback

<table>
<thead>
<tr>
<th>Process added value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Feedback</strong></td>
<td>Border guards were positive to perform the test. In general it was seen as feasible to enroll 4 FP.</td>
<td>Overall the device worked well, besides what is reported as impediments.</td>
</tr>
<tr>
<td><strong>Impediments</strong></td>
<td>8 FP was not seen as feasible to enrol. It was difficult to find a good method for enrolling the fingerprints inside the train compartment, due to limited space. The border guards had to sit down next to the traveller, when possible, to make a good enrolment.</td>
<td>The weather was very hot and this made the device to sometimes stop working (when temperature was over 35 deg.). Enrolling FP in a moving train was sometimes difficult. Enrolling 8 FP with a reader that handles 2FP makes for many steps in the process. Some travellers had problems to put the fingers on the plate due to physiological (osteoarthritis) constraints.</td>
</tr>
<tr>
<td><strong>Improvements</strong></td>
<td>When determining the future use of the biometrics also other changes to the border control process should be looked at, to get the full picture.</td>
<td>The device could be more ergonomic, in certain aspects, for instance as regards how to swipe the passport in an easy way, where the handle to the device was in the way.</td>
</tr>
</tbody>
</table>
### Facial Image

**Table 38: lasi - TC4, TC6, and TC7 border guards’ feedback**

<table>
<thead>
<tr>
<th>Process added value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Feedback</strong></td>
<td>Border guards were positive to perform the test. The capturing of live photo and facial verification worked in general quite well.</td>
<td>Overall the device worked well, besides what is reported as impediments.</td>
</tr>
<tr>
<td><strong>Impediments</strong></td>
<td>The volumes decreased at the end of the summer making it more difficult to reach the target for the samples. As for TC 1, 2 the limited space made it difficult to find a good method for performing the tests.</td>
<td>The device could not read the majority (95%) of the Moldavian passports (called “blue passports”). Difficult to take a live photo in certain light conditions:  - Backlight of the windows in the compartment;  - Reflection for the device lights on the windows and mirror.</td>
</tr>
<tr>
<td><strong>Improvements</strong></td>
<td>Easier to take a photo when the traveller sat down and also when the backlight or reflections from the window could be avoided.</td>
<td>The device could be more ergonomic, in certain aspects, for instance as regards how to swipe the passport in an easy way, where the handle of the device was in the way.</td>
</tr>
</tbody>
</table>

### Iris Pattern

**Table 39: lasi - TC5 border guards’ feedback**

<table>
<thead>
<tr>
<th>Process added value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Feedback</strong></td>
<td>Border guards stressed that it was extremely difficult to perform this test in moving train. They tried several approach recommended by the vendor but none of them were fully satisfying. When the test continued the duration gradually decreased and there were fewer problems, indicating that many problems are related to</td>
<td>The device could be more ergonomic, in certain aspects. Difficult to enrol the iris in a moving train.</td>
</tr>
</tbody>
</table>
a learning curve.

<table>
<thead>
<tr>
<th>Impediments</th>
<th>N/A</th>
<th>N/A</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>There were problems with travellers that could not open their eyes enough.</td>
<td>20 cm for being able to capture the iris seems too close to the travellers face when the train is moving. The blinking light of the device, facing the travellers, made the traveller closing their eyes as a reflex.</td>
<td>Device too close to the traveller, which was found as a bit intrusive by some travellers.</td>
<td></td>
</tr>
</tbody>
</table>

In general, according to the border guards, the travellers were less positive to 8 FP, iris and facial verification than to enrolling 4 FP.

5.2.4. Constraints

5.2.4.1. Environmental conditions

The tests in lasi were performed in indoor conditions. The tests were however negatively impacted in very hot temperatures, in bad light conditions (too sunny, low light in the train during the night) and when the testing was made in a moving train.

An environmental measurement device was deployed to monitor temperature, humidity and light throughout the entire testing period. The device was placed inside of the train. Border guards reported about equipment failures in extreme weather conditions (e.g. hot temperatures). As can be seen in the table below, during the entire testing period, temperatures ranged from 12.8° to 39.5° C. A correlation could be found between equipment failures and the specific days in July and August where the temperatures where above 34° C.

The light conditions had an influence during the tests especially on the backlight when the capture was done in front of the windows

Table 40 lasi - maximum, minimum and average of temperature, humidity and light

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Humidity (RH%)</th>
<th>Light (Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>12.8°</td>
<td>22.1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(dry day)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(night)</td>
</tr>
<tr>
<td>Max</td>
<td>39.5°</td>
<td>89.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Humid)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>88716</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(direct sun light)</td>
</tr>
<tr>
<td>Average</td>
<td>26.2 °</td>
<td>52.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5436</td>
</tr>
<tr>
<td>Observations</td>
<td>7 days &gt; 34° in July</td>
<td>from 8h to 20h00, it was between 1000 and 30000</td>
</tr>
<tr>
<td></td>
<td>10 days &gt; 34° in August</td>
<td></td>
</tr>
</tbody>
</table>

5.2.5. Main observations

Fingerprints

- The enrolment was difficult because of limited space and sometimes quite full trains;
- 4 FP was considered as feasible to enrol with an acceptable duration;
- 8 FP was considered not feasible to enrol due to the long duration and the complicated situation of enrolling in a very limited space.

**Facial Image**
- The enrolment was difficult because of limited space and sometimes quite full trains;
- In general, when the capture of the live photo worked well, then the success rate of the verification was 90%;
- The problems to read the chips in 95% of the Moldavian passports made it difficult to reach the sample size;
- Low or too strong lighting sometimes brought problems to take a live photo;
- The best results were reached when the traveller was sitting down while taking the live photo;
- Capturing live FI in a moving train was not tested in Iasi but given the problems encountered when trying to capture the iris when the train moved; it can be assumed that capturing FI could cause some difficulties.

**Iris**
- It was difficult to find a good method for enrolment because of limited space and sometimes quite full trains;
- Once the capturing could be performed it worked rather well. The iris success rate is very high (99%) but this success rate does not take the quality of the captured iris pattern into account. The high success rate can therefore not be fully taken into account in the observations;
- Enrolling iris in a moving train was very difficult;
- It could be observed that while there were difficulties to enrol iris at the start of this phase, these problems decreased as the tests continued;
- Some persons (e.g. old persons) could not keep their eyes open enough to capture the iris.
5.3. Kipoi – Fingerprints and iris

5.3.1. Test description

In this chapter, the tests undertaken at the border-crossing point of Kipoi Evrou in Greece are described in detail. The BCP is a road border between Greece and Turkey. It is a busy land border-crossing point, one of the largest on the eastern frontier of the Schengen Area. Peak flows are seen over the Christmas, New Year and summer holiday periods.

Within the Smart Borders pilot, tests were undertaken from April to August 2015 on the entry (i.e. entering Greece from Turkey) side of the BCP. In general, the goals of the tests run were to test the feasibility of both fingerprint and iris enrolment at such a land border-crossing point, the time required to enrol different biometrics, the quality obtained and the extent to which users accepted the biometric enrolment process and the device utilised. Tests associated with fingerprint and iris biometrics were run in parallel throughout, enrolling 4 fingerprints plus iris (TC1+TC5), 8 fingerprints and iris (TC2+TC5) and finally 10 fingerprints and iris (TC3+TC5).

Tests were run in outdoor conditions using a mobile fingerprint and iris enrolment device. Enrolments were made both under the roof of the border-crossing point and uncovered in the daylight and sunlight.

5.3.1.1. Set-up and configuration

The main characteristics of pilot tests at Kipoi are summarised in the table below:

Table 41 Kipoi - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Land: Road - Land border located in Greece at the border with Turkey.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>In outdoor conditions, evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td>Test location</td>
<td>Area around BCP at entry</td>
</tr>
<tr>
<td><strong>Staff involved</strong></td>
<td><strong>6 in total</strong></td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>- 4 border guards (2 per shift) for the 4 TCs</td>
</tr>
<tr>
<td></td>
<td>- 1 supervisor</td>
</tr>
<tr>
<td></td>
<td>- 1 commander</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Total duration</strong></th>
<th><strong>18 weeks in total</strong></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Timetable</strong></th>
<th><strong>TC1 + TC5: from 17.04.2015 to 09.05.2015 (3 weeks)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>TC2 + TC5: from 10.05.2015 to 14.06.2015 (5 weeks)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>TC3 + TC5: from 15.06.2015 to 19.08.2015 (9 weeks)</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Sample size</strong></th>
<th><strong>Fingerprints</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>(target / actual)</td>
<td><strong>TC1: 600 / 638</strong></td>
</tr>
<tr>
<td></td>
<td><strong>TC2: 1000 / 990</strong></td>
</tr>
<tr>
<td></td>
<td><strong>TC3: 1550 / 893</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Iris</strong></td>
</tr>
<tr>
<td></td>
<td><strong>TC5: 1550 / 1729</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Process layout</strong></th>
<th><strong>Combined process</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>TC1: 4 FPs + TC5: iris</strong></td>
</tr>
<tr>
<td></td>
<td><strong>TC2: 8 FPs + TC5: iris</strong></td>
</tr>
<tr>
<td></td>
<td><strong>TC3: 10 FPs + TC5: iris</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Integration within the regular border-crossing process</strong></th>
<th><strong>Not Integrated</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>No dedicated lane; testing executed in the area around the BCP at entry only; travellers (in cars or buses or otherwise lorry drivers who had disembarked their vehicle) were approached while they queued or waited around the BCP.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Technical integration</strong></th>
<th><strong>Standalone</strong></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Type of device</strong></th>
<th>Multimodal mobile device including:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Light Emitting Sensor (LES) FBI Appendix F certified FAP 45 (i.e. two finger) contact scanner for FPs</td>
</tr>
<tr>
<td></td>
<td>- Stand-off SAP 40 simultaneous dual eye iris capture camera</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Quality thresholds</strong></th>
<th><strong>TC1-2-3: vendor-specific (including NFIQ)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>TC5: vendor-specific</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Environmental device</strong></th>
<th><strong>Available</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monitoring temperature and humidity conditions. Deployed under the outdoor roof of the BCP.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Travellers’ feedback</strong></th>
<th>Survey integrated into the mobile device used for the tests - displayed at the end of tests</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Data protection</strong></th>
<th><strong>Verbal consent requested</strong></th>
</tr>
</thead>
</table>

72 Tests on TC3 were organized for 9 weeks, notably longer than for other tests. However, it was nonetheless not possible to reach the requested sample size of 1550 travellers. This was related to the relatively higher sample request and the longer duration of testing with 10 fingerprints, meaning fewer travellers processed per day. Additionally, travellers were less inclined to participate with 10-finger enrolment. The smaller sample size implies a margin of error of approximately 1 second in tests on duration rather than 0.75 seconds as initially planned at a confidence interval of 95%.

73 A 'soft' NFIQ-based threshold of NFIQ>4, for all fingers was used at Kipoi. The main threshold was based on device auto-capture functionalities as explained in the text.
5.3.1.2. Workflow

At Kipoi Evrou land border, four lanes are normally available at entry:

- 2 lanes dedicated to cars;
- 1 lane dedicated to trucks;
- 1 lane for buses at entry and exit.

The border guards participating in the tests approached travellers according to availability and their perceived likelihood of participation based on experiences, approaching drivers and travellers in cars, trucks and busses. In discussions following testing, it was estimated that around 50% of test results correspond to enrolments from truck drivers, 30% from travellers of buses and 20% car drivers or travellers. Truck drivers and bus travellers submitted to testing outside vehicles in order to best fit the processes used, while car drivers and travellers participated without exiting the vehicle. No dedicated lane was set up.

In all cases, the required number of fingerprints was first enrolled, followed by the two iris images.

Fingerprints

1. **TC1: Enrolment of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).**

   Fingerprints for the index, middle, ring and little fingers of the right hand of volunteering TCNs were captured using a 2-finger slap scanner. The index and middle fingers were taken first and then the ring and little fingers were captured.

2. **TC2: Enrolment of 8 fingerprints (index, middle, ring and little fingers for both hands)**

   Fingerprints for the index, middle, ring and little fingers of the right hand of volunteering TCNs were captured first using a 2-finger slap scanner, followed by those of the left hand (2-2-2-2 method).

3. **TC3: Enrolment of 10 fingerprints (thumbs, index, middle, ring and little fingers for both hands)**

   Fingerprints for the index, middle, ring and little fingers of the right hand of volunteering TCNs were captured first using a 2-finger slap scanner, followed by those of the left hand. Thumbprints were enrolled simultaneously as a final step (2-2-2-2 method).

The fingerprinting device used had auto-capture functionality, such that as fingers were pressed on the sensor, the best print based on metrics including image contrast, print dimensions and image clarity was selected and accepted. NFIQ values were calculated as a second step with notification being provided in the software in case that the NFIQ values were 4 or 5 - NFIQ values were thus a ‘soft’ threshold.
Iris

TC5: Capture of the iris pattern

The mobile device used in testing at Kipoj Evrou included a stand-off simultaneous dual iris capture camera. Attempts were always made to enrol two iris images after travellers had provided their fingerprints. Thus, the iris-focussed tests were always run alongside but subsequent to the fingerprint enrolment tests.

In order to enrol both iris images, the mobile device needed to be held in front of the traveller’s eyes at an approximate distance of 15 to 25 cm. Visual real-time feedback was provided to the operator showing the iris image within the intended camera capture area, allowing for small adjustments to be made to ensure that the device was at an appropriate height and distance from the traveller.

As for fingerprints, auto-capture functionalities were implemented. Thus, the iris images were captured simultaneously from the continuous live stream of the camera once appropriate images of sufficient quality were detected in the camera field of view. Simultaneous iris capture ensured alignment of both irises along the same axis at capture. Although specific measures of quality were not provided, the supplying vendor indicated that the iris images thus enrolled have been demonstrated to be sufficient for use in the Aadhaar (Unique Identification -UID) project in India.24

5.3.1.3. Participation and sample characteristics

Compared to other test locations, few female travellers submitted to pilot testing. In fact, just 15% of participants were female. 54% of participating travellers were aged between 31 and 50.

The majority (64%) of participants were Turkish.

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24 This project aims to enroll multi-biometrics from 1.2 billion people. In large-scale studies on the use of iris for authentication within this project in India, the irises enrolled were sufficient in quality to produce a FRR of 0.12% at a FAR of 0.01% for authentication/verification. Using these iris images with 10 fingerprints in 1:n searching gave false negative identification rates (FNIR) of 0.03% at a false positive identification rate (FPIR) of 0.037% in a database of 84 million people. See, for example, Alan Gelb and Julia Clark. 2013. “Performance Lessons from India’s Universal Identification Program.” CGD Policy Paper 020. Washington DC: Center for Global Development. http://www.cgdev.org/publication/performance-lessons
It is interesting to note that the vast majority (~70%) of those enrolling fingerprints in testing at Kipoi Evrou were visa holders. In a future Smart Borders system that would use fingerprints as a biometric, it is anticipated that these travellers would already have enrolled fingerprints during the visa application process. Thus, a larger proportion of travellers were targeted as potential test participants compared to the proportion of those who would need to enrol fingerprints at the border in the future.

5.3.2. Test cases operational and technical results

5.3.2.1. Fingerprints (TC1, TC2, TC3)

Success / failure

For procedural reasons, no second or third attempts were typically performed (in 99.4% of cases, one attempt only was made) even when the enrolment at first attempt did not result in enrolment of all fingerprints with NFIQ values between 1 and 3. As noted above, the device made use of auto-capture functionalities with this NFIQ-based threshold being applied at a second stage and once all fingers had been enrolled. Thus, the re-enrolment procedure would have been complicated and time-consuming according to the procedure implemented at Kipoi Evrou and was generally not possible in the time available.

Across all test cases, the right hand was enrolled successfully in 82% of instances, the left hand in 85% of cases and the thumbs in 96% of all tests undertaken in which their enrolment was sought. Looking at test cases individually, 73% of the enrolments were successful for all fingers in TC1, 81% in TC2 and 65% in TC3.26

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25 The country codes used in the graph are the three-letter country codes defined in ISO 3166-1:
http://www.nationsonline.org/oneworld/country_code_list.htm
26 Success rates according to the threshold: NFIQ<4 for all fingers.
Quality

The quality of enrolled fingerprints was assessed using the NFIQ quality metric as well as through enumeration of the number of detected minutiae per print. The main outcomes of quality assessment using both metrics were as follows:

NFIQ results

- Enrolment of fingerprints from the little finger caused most difficulties; even when successfully enrolled, the little finger had relatively poor quality scores compared to the other fingers;
- The quality of ring finger enrolment was somewhat worse than for middle and index fingers and the thumbs.

Minutiae results

- Prints from the little fingers were poorest in quality, with 76% of such prints having between 30 and 60 minutiae in the case of TC1. Similar quality results were seen throughout testing;
- Thumbs and index fingers had the highest number of minutiae on average, followed by the middle fingers.

As expected, the correlation between the two quality indicators output during testing was negative: a higher number of minutiae in a fingerprint image corresponded to a lower, i.e. better NFIQ score for that image.
The relatively high rates of successful enrolment can be attributed at least partly to the less stringent enrolment thresholds applied at Kipoi Evrou. Nevertheless, the prints were of good quality. The use of a two-finger scanner which in some cases was said to be easier to use from an ergonomic viewpoint than a four-finger scanner for single 4-finger enrolment may have contributed in this regard. Also note that the high-quality results were obtained in outdoor conditions; the use of a Light Emitting Sensor (LES)-based scanner within the mobile device certainly helped in this regard, as such scanners are typically not affected by extraneous light and were seen to be very suitable for use outdoors and in strong sunlight. Finally, note that the device gave real-time feedback to travellers enrolling their
prints (the prints were shown in real-time on screen during enrolment, making it easier for travellers to modify the placement of their fingers as well as the pressure that they applied in order to achieve good quality results.

**Duration**

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the first two fingerprints.</td>
<td>1. The successful capture with a maximum of 3 attempts.</td>
</tr>
<tr>
<td>(Note that no second or third attempts were typically performed in Kipoi)</td>
<td></td>
</tr>
</tbody>
</table>

Typically, the enrolment of 8 fingerprints took between 30 seconds and one minute. 22% of 8-fingerprint enrolments and 34% of all 10-fingerprint enrolments took more than 1 minute. Enrolment of 8 and 10 fingers was possible in about 30 seconds in the best cases.

It should be noted that the time for enrolment of fingerprints included the time required to start-up and close the fingerprinting module within the device. Based on tests estimates comparing the results against monitoring using a manual clock, it appeared that the time in which the fingerprint enrolment actually took place was approximately 16 seconds less than that recorded in the output dataset and shown in the graphs herein.

Note that direct estimates of the enrolment time for 4 fingers were not obtained. Based on results obtained elsewhere, it may be suggested that enrolment of 4 fingers should have taken approximately 34 seconds.\(^2\)

![Figure 227 Kipoi - TC2 duration with contact scanner](in seconds)

![Figure 228 Kipoi - TC3 duration with contact scanner (in seconds)]

5.3.2.2. **Iris (TC5)**

**Success / failure**

The enrolment of the iris pattern was considered successful in Kipoi if the enrolment data could be logged according to the quality thresholds described earlier.

In 98% of the cases, a successful enrolment of the iris pattern was recorded. In most cases, only 1 attempt was required to enrol the right iris pattern (95%) and left iris pattern (94%). Successful enrolment required a maximum of 4 attempts.

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\(^2\)This is the average time recorded for enrolment of 4 fingers at Iasi BCP where an device identical to that used at Kipoi Evrou was deployed.
Quality

Individual measures of iris quality were not measured at Kipoi Eroyou. The good quality of the enrolments made is inferred based on the applied thresholds used for iris enrolment, used also for enrolment of iris templates to a large-scale database in India.

Duration

The measurement points for the duration of the test case were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the iris pattern.</td>
<td>1. The successful capture of the iris pattern.</td>
</tr>
</tbody>
</table>

Figure 22 shows the distribution of durations for successful capture of iris patterns using the dual iris camera deployed at the Kipoi Evroyou border-crossing point.

Note that:

- In about 5% of cases, successful enrolment of the pair of iris patterns took less than 5 seconds;
- In 65% of cases, the capture process took less than 20 seconds;
- 74% of enrolment attempts were successful in less than 30 seconds.
These durations include several process-related steps. The handheld device had to be positioned at the right distance and height, requiring the standing traveller to be cooperative and fully open his/her eyes, sometimes despite the presence of bright background sunlight (outdoor conditions).

5.3.3. Users’ perception

5.3.3.1. Travellers’ feedback

Attempts to enrol 4, 8 and 10 fingerprints were executed alongside those for iris enrolment at Kipoi Evrou. 626 entries (corresponding to around 37% of participating travellers) were recorded for TC1/TC5, 952 entries (corresponding to around 55% of participating travellers) for TC2/TC5 and 786 entries (corresponding to around 46% of participating travellers) for TC3/TC5.

Respondents generally expressed satisfaction subsequent to their participation in the pilot. Throughout testing, just 4% of the traveller population expressed themselves as dissatisfied. As shown in Figure 22 below, fewer respondents were satisfied as more fingerprints were enrolled - 74% with enrolment of 10 fingerprints compared to 91% for 4 and 8 prints.

![Kipoi - results of the travellers’ survey](image)

Border guards indicated that tests were well accepted by travellers and that those who participated generally expressed satisfaction. However, in some cases travellers refused to participate either because they did not understand what the tests were about or because they considered fingerprinting and enrolment of iris images as more typical law enforcement activities.
5.3.3.2. Border guards’ feedback

Replies from the four participating border guards provided during and subsequent to testing, are aggregated in the table below.

Table 42 Kipoi - TC1, TC2, TC3 and TC5 border guards’ feedback

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Feedback</strong></td>
<td>57% of replies indicated that they did not see any added-value with the process as tested; the remaining 43% indicated that the additional biometric step made no significant difference.</td>
<td>57% highlighted the delays introduced by fingerprinting.</td>
</tr>
<tr>
<td><strong>Impediments</strong></td>
<td>50% indicated that an inability to instruct travellers due to having no common language caused problems.</td>
<td>17% indicated that they found the equipment difficult to use.</td>
</tr>
<tr>
<td><strong>Improvements</strong></td>
<td>Border guards generally noted that the duration of enrolment of even 4 fingerprints plus iris was too lengthy and should be somehow reduced.</td>
<td>63% indicated that the equipment used could be more ergonomic.</td>
</tr>
</tbody>
</table>

The above information was discussed with the participating border guards during end-of-testing interviews. Based on the composite written and oral feedback provided, the following observations are highlighted as particularly noteworthy:

- Cultural and social traditions impact traveller acceptance and were highlighted in the testing:
  - Very few female travellers enrolled: some male travellers rejected involvement of their wives or daughters, particularly when the involved border guards were male;
  - Truck drivers were often very willing to participate, at least in part because they had to wait at the BCP for long periods of time for customs clearance. This largely explains why the majority of participants were aged between 31 and 70;
  - Older people were reportedly more reluctant to participate in the tests.

- Communication is crucial for process success:
  - Travellers often refused to participate because they could not understand the reasons for testing or provide their consent without fully understanding the test to be undertaken - thus, language barriers were high. Many

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78 Percentages are calculated per question and are based on the number of replies given. In some cases, BGs have given more than one reply to one question.

79 It should be borne in mind that fingerprints were being enrolled from travellers who often, as visa holders (e.g. Turkish travellers), also had to verify fingerprints for VIS in another step. Thus, there was notable duplication of efforts because of testing arrangements. Added value could be better assessed if the process had been integrated into the border control process.

80 According to the qualitative feedback received, the process of performing tests on the top of the normal border crossing procedures (stand-alone) was too lengthy and too burdensome. However, the device was said to be efficient and intuitive.

81 It should be noted that this is not aligned with scores from the travellers’ survey, in which 82.3% indicated that they were satisfied or very satisfied.
TCNs (in this case mainly Turkish travellers) spoke neither English nor Greek;

- Usability of equipment
  - The staff noted that the new equipment (multimodal - mobile device) was “efficient” and “intuitive” (easy to use from the start) and compared favourably with their existing optical FP scanner (used to verify against the VIS using two fingerprints). They did not see any significant added value in taking four fingerprints given that the process was lengthy and burdensome\(^5\), however. They did identify a possibility to use this device in designated queues for the processing of travellers from a fast-lane. At this specific BCP, cars frequently pass in which the majority are EU citizens but due to the presence of a single non-EU citizen, must join the longer car queue for TCNs; border guards suggested that such vehicles could be directed to such a fast-lane and the single traveller processed using the mobile device. The device would hence be used as a process accelerator during peak periods (summer - i.e. from June to September and at weekends).

### 5.3.4. Constraints

#### 5.3.4.1. Environmental conditions

**Fingerprints**

- There was no notable impact on the device according to border guards. Border guards assessed the device as reliable and indicated that it worked equally well in the shade and in the sun, as well as at night;
- Drastic changes in humidity and temperature did not have a significant impact on the performance or battery life of the device.

**Iris**

- Border guards did not report any difficulties associated with the lighting or other environmental conditions. Enrolment was possible at night time.

In Kipoi, an environmental measurement device was deployed to monitor temperature, humidity throughout the entire testing period. It was placed outside, under the roof of the border-crossing point (i.e. remained in the shade). Border guards did not report about any difficulty with the device that would be linked with environmental conditions. As can be seen in the table below, during the entire testing period, the temperature ranged from a minimum of 8.3\(^\circ\) to 31.7\(^\circ\) C.

**Table 43** Kipoi - maximum, minimum and average of temperature and humidity

<table>
<thead>
<tr>
<th>Temperature ((^{\circ})C)</th>
<th>Humidity (RH%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>8.3(^\circ)</td>
</tr>
<tr>
<td>Max</td>
<td>31.7(^\circ)</td>
</tr>
<tr>
<td>Average</td>
<td>23.53(^\circ)</td>
</tr>
<tr>
<td>Observations</td>
<td>Vast majority between 20(^\circ) and 31(^\circ)</td>
</tr>
</tbody>
</table>

#### 5.3.4.2. Others

Iris enrolment was sometimes difficult due to operational arrangements and the overall process set-up. In particular, difficulties were observed with:

- Asian travellers;

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\(^5\) Tests were run as an addition to normal border control procedures.
Non-cooperative travellers (e.g. closing eyes, moving); Tall travellers for whom the border guard sometimes found it difficult to position the camera in front of the eyes.

Overall, border guards indicated that they preferred fingerprint to iris enrolment as a process, with the latter being less convenient and less straightforward.

5.3.5. Main observations

Fingerprints

- A mobile device can be deployed at a land border and achieve relatively high rates of successful fingerprint enrolment. The FAP45 sensor integrated in the mobile device used at Kipoi Evrou can be used to enrol 4, 8 or 10 fingers with good success (75%-85% success at the implemented quality threshold, somewhat less stringent than at other testing locations) and with durations for enrolment ranging from 30 seconds to 2-3 minutes;
- The device used was not affected significantly by environmental influences. Enrolment of fingerprints was possible in strong sunlight and at diverse temperatures. Use of such a device both outdoors and indoors is feasible. This was not the case for other devices used outdoors at other test locations;
- Enrolment of higher numbers of fingerprints with a two-finger scanner increased the time needed quite noticeably (in 34% of the cases, 10-finger enrolment took more than one minute). This meant that the originally planned sample size for TC3, enrolment of 10-fingerprints, was not reached. The number of travellers tested for TC3 was less than for TC2 despite the former being tested for several more weeks than the latter;
- Success in fingerprint enrolment would appear to have benefitted from the good ergonomics of the device (only two fingers were enrolled at a time which was convenient for easy placement of the fingers, while being mobile, the device could be held at the correct height for travellers of different stature) and the instantaneous feedback of the fingerprinting device;
- Some issues were noted with the enrolment of fingerprints from travellers with worn hands.

Iris

- Both images of the iris could be enrolled at the demanded level of quality in the majority (98%) of cases. Border guards indicated that they had some problems enrolling the iris images from Asian travellers. Enrolment also required the cooperation of the traveller to stand still and open their eyes which was sometimes difficult and led to failure of longer enrolment durations;
- Enrolment of the iris images was relatively quick, with three quarters of enrolments completed within 30 seconds;
- The enrolment of iris images was apparently not affected by extraneous light or variations in temperature. The device used was well suited to use in an outdoor environment;
- Although the equipment was generally found to work well and its usability was rated as being good by the majority of participating border guards, it was sometimes difficult to appropriately lift the device and hold it steady at the height required for iris capture. This was particularly the case when travellers were very tall and were outside their vehicle. It was possible nevertheless to enrol the iris from travellers seated in their vehicles.

Other

- Border guards found the equipment quite easy to use. Feedback was most negative on the duration of processes and the lack of added value, but it must be borne in mind that the tests were run in a standalone manner in addition to normal border control procedures. Thus, there was no benefit for them in terms of gains on subsequent checks. Sometimes, language barriers also made process control difficult. They preferred enrolment of fingerprints to iris images;
- Cultural and social traditions significantly impacted participation rates at Kipoi Evrou BCP; in particular, enrolment of biometrics from female travellers was considered undesirable or inappropriate, particularly when the border guard was male. This is highlighted by the low percentage of female travellers in the final dataset;

Note that the travellers were standing up.
The use of a mobile device allowed border guards to move around the BCP, moving along a queue of vehicles and entering buses to capture biometrics.
5.4. Narva – ABC gates

5.4.1. Test description

Narva is a city in the east of Estonia, located next to the Russian border. The city is separated from the Russian town of Ivangorod by a short river bridge that marks the external border of the European Union. It is thus a busy land border-crossing point accommodating pedestrian as well as vehicular traffic because of the afore-mentioned urban location. In 2014, almost 22.4 million third country nationals crossed the border in both directions alongside almost 500000 EU citizens. As well as 400,000 cars and 75000 trucks, almost 25000 buses passed through the BCP, typically at thirty-minute intervals throughout the day and on a daily basis.

In the Smart Borders pilot project, authorities at Narva deployed two new automated border control (ABC) gates for the processing of travellers transiting as pedestrians or on buses. Specifically, the goal was to test the feasibility of using such e-gates in the terminal building of a busy land BCP such as Narva, assessing the time required for typical transit through the gate, the security and efficiency of such crossings and the users’ acceptance of the technology.

Two ABC gates were deployed, one each at entry and exit. Travellers who held Estonian alien passports were targeted for testing. Although TCNs, their passports do not need to be stamped during the border-crossing and thorough questioning is not necessary, meaning that they can legally cross the border without a physical interaction with border guards, using entirely the same process as EU citizens passing through these gates. Thus, the process examined at Narva was the one that might apply following introduction of an EES and/or RTP system and that would remove the need for document stamping and questioning some travellers at least. During testing, the gates were also open to EU citizens.

5.4.1.1. Set-up and configuration

The main characteristics of pilot tests at Narva are summarised in the points below:

Table 44 Narva - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Land: Road - Narva BCP is located in Estonia at the border with Russia.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td></td>
<td>• TC9: Using ABC gates for border checks of TCNs</td>
</tr>
</tbody>
</table>
### Test location

Entry: Border checks of travellers arriving by bus
Exit: Travellers arriving on foot

### Staff involved

4 in total

Shifts of 2 to 3 border guards plus 1 hostess

### Total duration

9 weeks in total

### Timetable

From 16.07.2015 to 22.09.2015 (9 weeks)

### Sample size (target / actual)

- ABC gates
- TC9: 1000 / 1476

### Process layout

Lane type: ABC gate for travellers arriving by bus or on foot

### Integration within the regular border-crossing process

Integrated

### Technical integration

New and Integrated

### Type of device

2 ABC gates

### Quality thresholds

Facial image quality was assessed based on the results of verification. The verification threshold applied at Narva corresponded to a typical FAR of approximately 0.2% according to the supporting vendor.

### Environmental device

N/A

### Travellers’ feedback

After test completion: Self-service tablet

### Data protection

Verbal consent requested

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5.4.1.2. **Workflow**

The gates used in Narva were one-step "man-trap" gates.\(^8^a\) All 4 steps noted below thus took place at the same location as a single composite process as follows:

1. Passport inspection (including Passive Authentication\(^8^b\));
2. Capture of the facial image from the eMRTD chip;
3. Capture of the live facial image (photo) from the TCN;
4. Verification of the facial image captured from the eMRTD against the live facial image captured from the TCN.

---

\(^8^a\) As described in the Frontex Best Practice Technical Guidelines for ABC Systems, Frontex 2012.

\(^8^b\) Passive Authentication (PA) is used to check if the data on the RF chip of the electronic ID document is authentic and not forged. Further details are available in the chapter on chip reading.
Both male and female travellers participated in reasonably equal numbers. A majority (66%) of the persons participating were under 50 years old.

5.4.2. Test cases operational and technical results

5.4.2.1. ABC gates (TC9)

Success / failure

As evident from the workflow described above, ABC gates perform automated document bearer verification based on the facial image biometric identifier by comparing the facial image retrieved from the passport chip with the live facial image captured. Success of the process is therefore equivalent to successful verification of the facial image and requires successful completion of the following steps:

a) Facial image retrieval from the eMRTD chip without errors.
   Note that passive authentication (PA), discussed further below, is an important means of verifying the document’s authenticity and veracity but in the implementation used at Narva (and indeed elsewhere), successful PA was not a pre-requisite for process completion as the facial image could nonetheless be obtained.

b) Live facial image enrolment.
   The facial image was enrolled using a continuous capture camera with successive images compared to the reference from the chip until success or cancellation of the process by the monitoring border guard.

c) Image comparison.
   The score for the comparison between the live facial image and the photograph extracted from the chip of the
eMRTD had to be above the set threshold. This threshold was based on an algorithm provided by the supporting vendor and was chosen to result in a performance of approximately 0.2% FAR.

When assessing success and failure rates in Narva, the following assumption was made:

- In some instances, the nationality of the traveller was not recorded. This was assumed to result from errors in reading the travel document, specifically the MRZ. As both EU nationals and TCNs passed through the gate in testing, it was impossible to know which type of traveller had been using the gate at the time of error. In order to obtain representative error rates for MRZ reading failure, the number of failures was scaled using the proportion of TCNs in the overall sample. 50 samples from 1476 were removed.

![Figure 236 Narva - TC9 success and failure rate for the entire bearer verification process based on the facial image modality at a FAR of 0.2%](image)

In 63% of cases the traveller successfully transited the ABC gate and thus completed the entire border control process. Failures were mostly (in 24% of cases overall) related to problems with reading the chip of the eMRTD. The remaining 13% of instances relate to travellers for whom border guards executed a manual process override due to a failure to verify the facial image in an acceptable time. Note that there was no automatic time-out applied at Narva.

At some other locations, a more stringent verification threshold corresponding to a FAR of 0.1% was applied. In order to attempt comparison with such results, the figure below shows an estimate of the success-failure rates that would result when a threshold of 0.1% would be applied to the sample. Note that these estimates are biased by the actual threshold used - images obtained at the applied thresholds will have been accepted that would not be of suitable quality to match the reference at the more stringent threshold and that therefore would have resulted in re-capture to attempt attainment of better quality images. The success rate shown is thus an underestimation.

![Figure 237 Narva - TC9 success and failure rate for the entire bearer verification process based on the facial image modality at a FAR of 0.1%](image)
The graph below breaks down the basis of eMRTD reading errors (occurring in 24% of cases overall). In 10% of cases overall, the MRZ could not be read while in 14% of cases the electronic reading itself failed. Errors in basic access control (BAC) were responsible for a very small proportion of errors.

![Graph showing eMRTD reading errors breakdown]

**Figure 238 Narva - TC9 chip reading outcome**

**Quality**

Quality assessment of the live and chip facial images captured and extracted from the document were assessed using a vendor-provided algorithm. Thus, the quality of the images from both sources can be compared, as in the figure below.

![Quality score comparison between live and chip facial images]

**Figure 239 Narva - TC9 quality score comparison between live and chip facial image based on vendor’s algorithm**

In the majority of cases (84%) the chip image had a better quality than the live image. It was noted that the quality of chip image in Narva was high, likely related to the very homogenous sample of passports (all were alien passports issued by Estonia), influencing this ratio notably. The live facial images, meanwhile, were obtained in less controlled conditions in a newly-deployed gate in which the environment had not been tailored fully for testing, hence the difference depicted.

**Duration**

The typical duration of traveller checks at a manual booth in Narva was compared to that for checks at automated border control gates in testing. The durations were obtained using a manual clock on the wall methodology and using system logs respectively according to the time-points noted in the table below.

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The moment the eMRTD is placed on the reader (causing the rear doors of the mantrap to close).</td>
<td>2. The moment that the front gate opens allowing the traveller to leave the ABC gate.</td>
</tr>
</tbody>
</table>

In the vast majority (96%) of cases, the entire process was completed within 30 seconds. No travellers took more than 60 seconds to pass through the gates.

---

The cases where the whole process in the ABC gates was performed but the verification failed are included in the duration measured. Errors associated with document reading were removed from the analysis.
Comparisons with durations at the manual booth are made in section 2.2 below.

Security

Passive authentication is recommended as a means to guard against document modification and to verify appropriate document issuance. Please refer to section [link to PA explanation in final report] for a more detailed overview of passive authentication and for further details on other security measures associated with eMRTDs.

At Narva, execution of PA typically took about 6.8 seconds. For the majority of the processes in which the average end-to-end duration was under 30 seconds as above, execution of PA consumed around 25% of the total time (although it should be noted that at least some of this time overlaps with the time required for reading of the document and extraction of the facial image from the chip, an important step fundamental for the whole process.

5.4.2.2. Duration impact on the end to end process

The purpose of this section is to compare how the introduction of the biometric enrolment and verification steps analysed might affect the duration of the border check process. We describe herein both:

- A baseline measurement: the average duration of the current border check process (at a manual booth);
- Average times for the crossing of ABC gates.
Values are provided in the following table:

Table 45 Narva - impact on the end to end process

<table>
<thead>
<tr>
<th>Aspect under measurement</th>
<th>Average duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline\textsuperscript{b7}</td>
<td>16-22 seconds</td>
</tr>
<tr>
<td>ABC gate crossing</td>
<td>21 seconds</td>
</tr>
</tbody>
</table>

The average time provided for passage through the ABC gate is a composite of results for both entry and exit (the processes, being identical, have very similar distributions for end-to-end durations). For the baseline figure at manual booths, the average time of 16 seconds corresponds to exit and that of 22 seconds to the entry process - border guards clearly spend a little more time on entry checks. Note that all figures are for Estonian alien passport holders only. The relatively quick manual border-crossing times for such travellers result from the fact that the checks applied to these travellers are very similar to the minimal checks applied to the majority of EU citizens.

The average times for complete border checks of alien passport holders at manual booths and at ABC gates are similar. Use of ABC gates would permit a single border guard to supervise several travellers passing through the BCP at once, but any deployment would require an analysis of the business case for such based on factors including traveller flows and the availability of space.

5.4.3. Users’ perception

In order to assess the acceptance and perception of the new steps, both travellers and border guards have been consulted.

5.4.3.1. Travellers’ feedback

In total, 1204 entries (corresponding to around 82% of the participating travellers) were recorded.

Travellers’ feedback was collected after the passing of the gate positioned at exit. Overall the respondents expressed satisfaction (98%) with regards to the test case executed in Narva.

Narva - TC9

<table>
<thead>
<tr>
<th>Very unsatisfied</th>
<th>Unsatisfied</th>
<th>Neutral</th>
<th>Very satisfied</th>
<th>Satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>98%</td>
</tr>
</tbody>
</table>

Figure 242 Narva - results of travellers’ survey

\textsuperscript{b7} The average baseline duration was based on measurements made by border guards
5.4.3.2. Border guards’ feedback

Border guard feedback at Narva was collected from discussions during field visits, during the end-of-testing visit as well as through weekly reports submitted during testing.

Table 46 Narva - TC9 border guard’s feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Border guards indicated that their testing of ABC gates had been a positive experience and that the gates were something that they would like to have in the future.</td>
<td>The gates worked, after initial problems, rather well. Video instructions helped travellers to use them correctly.</td>
<td>Travellers were very positive when participating and also seemed content with the function.</td>
</tr>
<tr>
<td>Impediments</td>
<td>2 control rooms were needed with the present set-up, requiring infrastructural rearrangement. Manual intervention from the border guards was frequently required, leading to increased duration of the process overall.</td>
<td>The ABC gates needed to be restarted frequently, especially early in testing, and there were a number of other technical issues that required vendor support.</td>
</tr>
<tr>
<td>Improvements</td>
<td>It was suggested that only one control should be needed in a future set-up (for all gates). One possible option proposed was use of a mobile device (e.g. mobile phone) when needed to intervene.</td>
<td>It was suggested that the gate could be smaller to better fit into the available space. Within the gate, most also felt that a camera that is straight in front of the traveller would improve the process and workflow.</td>
</tr>
</tbody>
</table>

5.4.4. Constraints

5.4.4.1. Environmental conditions

As the gates were newly-deployed, some negative environmental influences were noted. Some TV screens affected the tailgating checks in the gate, for example, while the camera in use had to be adjusted to avoid detection of travellers waiting behind the gate. However, adjustments were made to adapt to these aspects that were specific to the Narva deployment.

5.4.4.2. Others

Because of the layout of the new terminal building at Narva BCP, the gate at entry was only accessible to travellers arriving from buses and that at exit to pedestrian travellers. In the former case, therefore, flows were rather intermittent and the gate had frequent downtime. An altered configuration of gates in the terminal would likely have led to increased use of the gates.
5.4.5. **Main observations**

Aside from the technical problems enumerated above, testing at the ABC gates in Narva was quite successful, with travellers being checked quickly and generally being very willing to participate.

The following observations can be made:

- The duration of traveller checks at ABCs was typically less than 30 seconds and the process worked well;
- The overall duration of passage through an ABC gate was very similar to that for the same category of traveller passing through manual booths;
- The majority of problems related to document reading, most frequently the reading of the electronic chip. Because of the homogenous nature of passports used in testing at the gates in Narva, it is suggested that the errors were likely more related with travellers inappropriately placing their document onto the reader or removing it too quickly;
- Border guards felt that improved provision of information to travellers in advance of their use of the gate as well as better instructions in the gate would lead to improvements. They also suggested that surveillance of the gates could be optimised, using fewer staff in a better-placed control room/manual booth;
- The overall test set-up at Narva BCP involved testing with alien passport holders who did have to submit to questioning or have their documents stamped allowed for testing of a process that might be envisaged for at least some TCNs following deployment of Smart Borders systems. Thus, the general success of testing at this location showed promise;
- ABC gates can be deployed in indoor terminal buildings at land border-crossing points and are particularly useful for processing of pedestrians and travellers on buses.
5.5. Sculeni – Facial image and iris

5.5.1. Test description

This chapter describes the tests executed at Sculeni, in the eastern part of Romania. This road border crossing point is between Moldova and Romania outside the town of Iasi, one of the largest cities of the area, where the Border police County Inspectorate, responsible for these BCPs, have their headquarters. A river bridge marks the external border of the European Union.

The BCP has 6 lanes for entry checks. 1 lane is dedicated to busses and CD vehicles, 3 lanes for cars and 2 lanes for trucks. The traffic coming from Moldova comes over a bridge crossing the river of Prut, with the border check on the Moldovan side around 200 meters away. The waiting area on the entry side is quite limited in space. All pilot tests are have been carried out in the lane dedicated for buses and .There is normally not many buses or CD vehicles passing this lane, which makes it useful as a “priority lane”.

Statistics show around 500 000 crossings per year. Many of the persons crossing this border have local border traffic permits (LBT), which allows them to move up to 30 kilometres into Romanian territory. These persons do not have their passports stamped and they are obliged to carry their permit for the LBT (in the form of an id card) with them.

The border checks are carried out in close cooperation with the customs, where the custom control is directly following the border check, and the vehicle is not allowed to leave a dedicated zone until both types of controls have been performed. The impacts of the custom check have been excluded from the end to end end-to-end duration in the pilot.

The tests focused on the use of automated facial recognition and iris enrolment at manual border controls in an outdoor environment.

5.5.1.1. Set-up and configuration

The main characteristics of pilot tests at Sculeni are summarised in the points below:

Table 47 Sculeni - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Land: Road - Sculeni BCP is located in Romania and is the border-crossing with Moldova.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>In outdoor conditions, evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
</tbody>
</table>
5.5.1.2. **Workflow**

TC4, TC6, TC7 (facial image) and TC5 (iris) in Sculeni were executed as a combined process for each volunteering TCN traveller who gave their consent in written form. The enrolment of the facial image (TC4) and the iris (TC5) was performed simultaneously. The process starts by the border guard putting the eMRTD on the passport reader and it stops when the verification is made.
TC4, TC6 and TC7 correspond to the use of **facial image** in border checks and TC5 has been considered for the **iris** biometric modality. The order of the process was undertaken in four steps as follows:

1. TC6 - Capture of the facial image from the eMRTD including Passive Authentication ;
2. TC4 - Enrolment of the live facial image (photo);
3. TC5 - Enrolment of the iris pattern (after the eyes have been located in TC4 live facial image capture);
4. TC7 - Verification of the facial image captured from the eMRTD against the live facial image.

![Figure 243 Sculeni - facial image (TC4, 6 and 7) and iris (TC5) steps](image)

### 5.5.13. Participation and sample characteristics

There were slightly more female participating travellers with a share of 53% and 47% for male participants. The highest percentage of the participating travellers was aged between 18 and 30 years of age (46%). No participants were above 70 years. The test in Sculeni did not accept enrolment of children (below 13 years). Participating travellers of Moldavian nationality constituted the absolute majority with a share of above 99%.

![Figure 244 Sculeni - sample distribution by gender](image)  
![Figure 245 Sculeni - sample distribution by age](image)
5.5.2. Test cases operational and technical results

5.5.2.1. Facial Image (TC4, TC6, TC7)

The purpose of the facial image tests is to perform local automated bearer verification at the border based on the facial image biometric identifier. The following test cases were performed:

- Retrieval of the facial image from the eMRTD chip (TC6);
- Enrolment of a live facial image (TC4);
- Comparison, verification of the two above (TC7).

As all three test cases were highly related to each other, this section will analyse the results from a joint perspective and specific aspects of individual test case are presented when relevant.

Success / failure

TC4, TC6 and TC7 were considered successful if the verification score was above the set threshold and the image could be accessed and retrieved from the eMRTD without errors. The vendor threshold used for this graph represents a FAR of 1%.

The graph below presents the overall success rate for overall facial image related test cases at Sculeni.

![Figure 246 Sculeni - sample distribution by nationality](image)

The graph shows the distribution of test cases by nationality.

5.5.2.2. Facial Image - Success / Failure rate

The success rate for the verification of the image (matching) was around 65%. The camera is optimised for capturing Iris and not FL, which could influence the success rate achieved.

It should be noted that out of ~2530 participants filed, ~710 were MRTD-holders and were excluded from the chip error analysis and these samples are also excluded for the success rate of TC7 (facial verification). Out of the remaining ~1810 samples, only 4 errors were recorded for chip reading. This negligible chip error rate could be explained with the fact that the Moldavian passports (issued after 2012) were new and hence the chip worked well.

---

*The country codes used in the graph are the three-letter country codes defined in ISO 3166-1: [link](http://www.nationsonline.org/oneworld/country_code_list.htm)*
Quality

For Sculeni, the quality measurement of TC4 and TC7 was based on a vendor’s quality index.\textsuperscript{89} The graphs below illustrate the distribution of the quality score in Sculeni for the test cases related to facial image.

\begin{center}
\begin{tabular}{|c|c|}
\hline
\textbf{Low} & \textbf{High} \\
\hline
\end{tabular}
\end{center}

\textit{Figure 248 Sculeni - TC4 and TC6 quality score comparison between live and chip facial image based on vendor’s algorithm}

The following can be observed:

- The distribution of quality scores was higher for the image retrieved from the chip than for the live facial image, meaning the scores for the live image was stable;
- The higher quality can partly be explained by the more controlled environment in which pictures used for passports issuance are taken, compared to the variable and less optimal environment at the border;
- The distribution of quality scores is more concentrated for the chip facial images, which suggests that the quality of the pictures on the passport is more homogenous compared to live facial image scores.

Duration

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader;</td>
<td>1. To the result of the eMRTD FI acquisition (success or failure), including the time to perform the passive authentication;</td>
</tr>
<tr>
<td>2. From the start of the live image enrolment;</td>
<td>2. To the successful enrolment of live image or timeout (if relevant);</td>
</tr>
<tr>
<td>3. From the start of the facial image verification.</td>
<td>3. To the outcome of the facial image verification.</td>
</tr>
</tbody>
</table>

\textsuperscript{89} Specific vendor scores will not be analysed, and they are presented only for the purpose to allow comparison of the quality scores between the live and chip facial image. Absolute values of the scores will not be assessed. Here we have presented only the distribution of the score. Note that the vendor quality measurement was also complemented with a set of additional elements from ICAO.
The overall duration of the facial image related test cases can be analysed by estimating the duration of each individual step. In the vast majority of the cases the total duration of the three steps was under 10 seconds and in many cases even under 5 seconds, also confirmed by the border guards’ observations during the tests. The combination of the individual time of these steps will depend on the specific process workflow:

1. Extract facial image from the eMRTD;
2. Perform Passive Authentication of the chip;
3. Enrolment of the live facial image;
4. Verification of live and chip facial image.

The following figures show the distribution of durations obtained for each of the above steps:

![Figure 249 Sculeni - TC6 facial image from the chip retrieval duration for eMRTD holders (in seconds)](image)

![Figure 250 Sculeni - TC4 live facial image enrolment duration for eMRTD holders (in seconds)](image)

![Figure 251 Sculeni - TC7 facial image verification duration for eMRTD holders (in seconds)](image)

It can be observed that in 100% of the cases the live FI enrolment took less than 5 seconds. The vendor noted that this fast time could be an effect of the limited quality of the majority of the eMRTD photos (i.e. small size). In the majority of cases the chip image retrieval took between 2 and 4 seconds with an average of 2.7 seconds. The verification of the chip image and live image took less than 2 seconds with an average of 0.1 seconds. All these measurements correspond to what was observed by the border guards at Sculeni.

**Security**

Passive authentication is recommended as a means to guard against document modification and to verify appropriate document issuance. Please refer to the “Reading chips in e-passport” chapter in the main report (chapter 3.6, section 3.6.4) for a more detailed overview of passive authentication and for further details on other security measures associated with eMRTDs.

In Sculeni, passive authentication was complete in less than 2 seconds in 64% of cases.
With regards to passive authentication error, the rate could be negligible since only one case was recorded.

5.5.2.2. Iris (TC5)

In Sculeni, the iris pattern could be acquired within 1 attempt only in 80% of the total cases. 7% of the cases required up to 3 attempts to acquire the iris pattern.

Success / failure

The enrolment of the iris was considered successful if the threshold set by the vendor with regards to the quality of the iris was met.

We observe the left iris and right iris has the same success rate. In overall, a success rate of 91% was observed for the iris pattern enrolment in Sculeni.

Quality

The quality of the iris pattern captured live is evaluated based on one of two criteria depending on the data received from the MS:

- NISTIR 7820 (extract);
- Vendor quality index.

The indicator retained for Sculeni is the Vendor quality index.

The graph below presents the quality score results of the iris patterns obtained in Sculeni.
With the gaze of the traveller not completely facing the camera (i.e. with more modification of the BCP the

The measurement points for the duration of the test case were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the iris pattern.</td>
<td>1. The successful capture of the iris pattern.</td>
</tr>
</tbody>
</table>

In 90% of the cases the duration capturing the iris pattern was made in less than 5 seconds with an average of 1.8
seconds. Capturing the live image (see figure 7), as requested by the ToR, was made in parallel and do not add to the
average time. This can be considered as a very fast process for capturing both the iris and the live photo, a result that is also confirmed by the border guards’ observations during the tests.

![Bar chart showing facial image enrolment and verification times](image)

*Figure 255 Sculeni - TC5 right and left iris enrolment process duration (in seconds)*

These durations include several process-related steps. The handheld device had to be positioned at the right distance and height, requiring the standing traveller to be cooperative and fully open his/her eyes, sometimes despite the presence of bright background sunlight (outdoor conditions).

5.5.2.3. **Duration impact on the end to end process**

It is worth analysing, from a time perspective, how the introduction of the new biometric steps would influence the global duration of the current border check process - where no biometric identifier is involved. For this aim, the estimated duration of the tests cases described above is compared\textsuperscript{99} to the:

a. baseline measurement: duration of the current border check process;

b. global end to end time for the border check modified by the testing, which includes both facial image and iris.

The following table summarises the average times:

*Table 48 Sculeni - duration impact on the end to end process*  

<table>
<thead>
<tr>
<th>Aspect under measurement</th>
<th>Average duration per person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline\textsuperscript{98}</td>
<td>84 seconds</td>
</tr>
<tr>
<td>Pilot measured end to end</td>
<td>End to end border check process under testing</td>
</tr>
<tr>
<td></td>
<td>Facial image enrolment and verification</td>
</tr>
<tr>
<td></td>
<td>Retrieval of the FI from the chip</td>
</tr>
<tr>
<td></td>
<td>Iris</td>
</tr>
</tbody>
</table>

From the values in the table above, it can be observed:

\textsuperscript{98} Different methodologies were used for measuring the baseline (COTW) and the end to end (logs), which limits the reliability of the comparison.

\textsuperscript{99} The baseline measurement was made by means of a COTW on a sample of 290 visa holders and 285 visa exempt travellers. It was measured as the time when the person arrives at the booth until the border guard disengages (i.e. gives back the passports).
• No measurement was made for the end-to-end process in the pilot lane;
• It should be noted that the extra time added for the traveller to come out of the vehicle is an additional activity compared to the procedure of the existing checks at the BCP. The time for this extra step is not measured but need to be considered in the total added duration;
• Taking the above into account it can be noted the actual test steps add only 7-8 seconds to the process. The instructions to the traveller and the time to get out of the car would make for additional duration but this cannot be quantified due to lack of measurements.

The border guards participating in the tests also confirmed the duration measured.

5.5.3. Users’ perception

5.5.3.1. Travellers’ feedback

In total, 1753 entries (corresponding to around 70% of the participating travellers) were recorded. The vast majority of respondents (92%) gave very positive feedback related to participating in the tests at Sculeni. The factors that most likely contributed to this were that the tests were very fast and that participating meant using a dedicated lane with less queues.

![Figure 256 Sculeni - results of the travellers’ survey](image)

5.5.3.2. Border guards’ feedback

In total, responses from 6 border guards were collected for the survey at Sculeni. The results of the feedbacks are summarised in the table below.
Facial Image

Table 49 Sculeni - TC4, TC6, and TC7 border guards’ feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive: 6 out of 6</td>
<td>The border guards found it very quick and easy to use the device. The facial image verification could bring added security to the border check.</td>
<td>Positive: 6 out of 6</td>
<td>Positive: 6 out of 6</td>
</tr>
<tr>
<td>Impediments</td>
<td>It is important that the total process time is not extended compared to today’s process time. In this experimentation the real end-to -end process has not been measured. The process set-up was adapted for the test and do not correspond necessarily to an operational one.</td>
<td>Not many problems were reported, in general. There were problems sometimes to read the blue Moldavian passports.</td>
<td>No specific problems recorded related to travellers’ participation.</td>
</tr>
<tr>
<td>Improvements</td>
<td>No improvements proposed in the context of the experimentation. However the process need to be improved but at this stage the BG consider that it is difficult to define what needs to be done.</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Iris Pattern

TC5 was performed in combination with TC4, 6 and 7 and the border guards did not have any observations related specifically to capturing the iris other than what is presented in table 1 above.

5.5.4. Constraints

5.5.4.1. Environmental conditions

Besides that shifting light sometimes, related to the time of day and weather, brought problems to capture a live FI there were no environmental problems reported. The device was kept in a manual booth with conditions similar to indoor conditions.

5.5.5. Main observations

The tests in Sculeni were made with TC4, 5, 6 and 7 in a combined manner due to that the device used was set up in this manner. The duration of performing this combined test was very fast and the main added duration to the entire border check process was related to the fact that the traveller had to leave the vehicle to participate in the test. The positioning of the traveller in front of the device had a big influence on the duration and quality of the capture (face
and iris). This was identified before the test started. Footprints placed on the ground helped considerably in making the capture stable all along the pilot tests.

**Facial Image**

- The process to perform all the steps (i.e. reading the passport, live photo and verification) was very fast, with a majority having a total under 10 sec and many even under 5 seconds for all three steps. The performance of the three steps did therefore not add any significant time to the total end-to-end process;
- The success rate of 37% is considered as quite low, possibly related to that the camera used, according to the vendor, was not optimised for enrolling of live facial images;
- The quality of the live facial was seemingly more stable than for the chip image. However image retrieved form the eMRTD (chip) had higher quality scoring than the live facial image;
- The quality of the capture seems not to have been influenced by any environmental conditions;
- The border guards appreciated the high speed of the process and the ease to perform the tests;
- The same reactions were observed from the travellers who were willing to participate and appreciated the speed of the tests.

**Iris**

- The process to perform the two steps, virtually parallel, (i.e. capturing the iris and taking a live photo) was very fast, with a majority having a total of less than 5 sec and a total average duration of around 2 seconds. The performance of the three steps did therefore not add any significant time to the total end-to-end process;
- The success rate was very high (93%), using the threshold provided by the vendor;
- The border guards and travellers feedback as regards iris is the same as for facial image (see above).
5.6. Sillamäe - Kiosks

5.6.1. Test description

Sillamäe is a city in eastern Estonia close to the border with Russia. A busy commercial port is located in the area while it is also the site of a waiting area for drivers of heavy goods vehicles (HGVs, i.e. trucks) who wish to exit the EU at the Estonian-Russian border at Narva. Estonia devised the system of waiting areas to obviate problems with long vehicular queues clogging up border areas in locations such as Narva city. Those wishing to cross the border book transit times and must wait at these waiting areas until their slot becomes available for border-crossing. They can also complete customs paperwork while waiting. In order to examine the possibility to exploit this waiting time to allow enrolment of biometric samples and biographic data, a self-service kiosk was deployed at the waiting area at Sillamäe during the Smart Borders pilot. In this chapter, the feasibility of using a self-service kiosk at such a location was assessed, taking into account the quality of data obtained at the kiosk, the time required for sample enrolment and the users’ acceptance of the set-up and process. The kiosk was located in an indoor environment.

The kiosk used was able to enrol a live facial image and fingerprints and to perform document bearer verification by comparing the live image enrolled against the image extracted from the traveller’s electronic document.

5.6.1.1. Set-up and configuration

The main characteristics of pilot tests at Iasi are summarised in the points below:

**Table 50 Sillamäe - set-up and configuration**

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Land: Road waiting area - Sillamäe is the location of the waiting area for truck drivers wishing to exit Estonia at Narva BCP</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TC11: Using a self-service kiosk at a waiting area</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test location</th>
<th>In the building of the waiting area for exit: Travellers arriving on foot from the adjacent parking area</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Staff involved</th>
<th>2 in total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 person administrating issues related to the port was asked to support the use of the kiosk during office hours</td>
</tr>
<tr>
<td></td>
<td>1 person was employed as a host specifically for the tests for the final 10 days of testing</td>
</tr>
</tbody>
</table>
Total duration: **13 weeks in total**

<table>
<thead>
<tr>
<th>Table</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timetable</strong></td>
<td>From 07.07.2015 to 05.10.2015 (13 weeks)</td>
</tr>
</tbody>
</table>
| **Sample size (target / actual)** | Facial image  
- TC1: 1000/45 (72)  
72 samples were collected but following a filtering of outliers (typically durations well outside the time required for normal use, likely erroneous values based on travellers failing to complete the process so that the 'clock' was stopped) the number of valid samples for analysis was 45. |
| **Process layout** | Check performed inside trains - with compartments for 6 travellers |
| **Integration within the regular border-crossing process** | Not Integrated |
| **Technical integration** | New and not integrated |
| **Type of device** | Self-service biometric enrolment and verification kiosk with:  
- A 4-finger fingerprint scanner, FBI Appendix F certified (FAP 45)  
- A standard facial image enrolment camera with autofocus capabilities and external lighting to aid image capture  
- A flatbed document scanner  
- A controlled white background to support quality facial image enrolment |
| **Quality thresholds** | TC1: NFIQ92  
TC2: NFIQ  
TC6: ICAO  
TC4, TC5, TC7: ICAO93, Vendor-specific |
| **Environmental device** | N/A |
| **Travellers’ feedback** | After test completion: Self-service tablet |
| **Data protection** | Verbal consent requested |

### 5.6.1.2. Workflow

Travellers were informed about the availability of the kiosk and the purposes of testing through the provision of leaflets in the waiting area building and through posters mounted in the area. Use of the kiosk was taken to imply consent to participate in the tests and no written procedure was required for these purposes. A dedicated host was employed for the final 10 days of testing. Otherwise, a port staff member on site was available to provide support during office hours but only upon request.

The process proceeded as follows:

1. Language selection (both Russian and English were available);
2. Passport inspection (including Passive Authentication94);

---

92 NFIQ version 1.
93 ICAO 9303 was used to evaluate the quality of both facial images on the chip and that captured live.
3. Capture of the facial image from the eMRTD;
4. Enrolment of the live facial image (photo);
5. Enrolment of 8 fingerprints.

Figure 257 Sillamäe - TC11 workflow

5.6.1.3. Constraints in performing the tests
The waiting area at Sillamäe was the only site available for testing the use of a kiosk at a waiting area in the pilot. When setting up the tests, it was observed that the circumstances at the waiting area would make it hard to reach the desired sample size, however. Based on statistics from 2014, some 200-400 trucks pass through the waiting area on the way to Narva BCP per month, implying a low number of travellers available for participation in tests (certainly when considering that some of these will also be EU nationals and therefore were ineligible). For those eligible travellers present, it was impossible to provide any incentive to participate beyond provision of small token gifts. In contrast to other locations, the lack of border guard presence at the site meant that there was typically nobody present to direct travellers to the test in person as well as to provide any assistance. A host was deployed on-site for the final 10 days of testing to assist in the latter regard but this resulted in little improvement in participant numbers. Thus, just 45 samples were available for analysis of results following test completion. It should be noted that this small sample size might not be sufficiently representative to make conclusions in some instances. For example, the margin of error for duration measurements, given the values assumed when calculating sample size (described in the methodology chapter), would be 5.5 seconds with a sample of 45 compared to 0.5 seconds for the target sample size of 1000.

5.6.1.4. Participation and sample characteristics
The majority of the participating travellers were Russian. Approximately 25% were Estonian alien passport holders.

5.6.2. Test cases operational and technical results

5.6.2.1. Kiosk (TC11)
Statistical measures of performance have a larger margin of error in Sillamäe than for results from other locations due to the low sample size and this must be borne in mind when making any conclusions. The most relevant results are included here.

Success / failure
It was observed that just 25% of the participants completed the full process including valid document reading and enrolment of 8 fingerprints and a live facial image, as depicted in figure 2 below. The majority of failures were associated with document reading; indeed more than 50% of failures were associated with a failure to read the document MRZ. When considering this result, it should be borne in mind that the kiosk was unattended. Thus, no support was provided to travellers having difficulty with the process. Furthermore, as no benefit derived from their

---

Passive Authentication (PA) is used to check if the data on the RF chip of the electronic ID document is authentic and unaltered from that present at time of issuance. It is described more fully elsewhere in this report.
use of the kiosk, there was little issues.

![Graph](image_url)

Figure 258 Sillamäe - TC11 success and failure rate for travellers using the kiosk

Quality Fingerprint

The quality of enrolled fingerprints was assessed using the NFIQ quality metric as well as through enumeration of the number of detected minutiae per print. The main outcomes of quality assessment using both metrics were as follows:

**NFIQ results**

- The majority of fingerprints were enrolled were of NFIQ levels 1, 2 and 3, identified as highest quality in the NIST report on the development of the NFIQ metric;
- The quality of fingers enrolled from the right hand was superior to that of the left. The quality of the left index finger was surprisingly poor relative to the right.

Approximately 50% of attempts would pass the NFIQ threshold of 2 for the index, middle and ring fingers and 3 for the little finger.

![Graph](image_url)

Figure 259 Sillamäe - TC11 NFIQ score per finger enrolled at the kiosk (enrolment of 8 fingerprints)

**Minutiae results**

- Many enrolled prints had more than 60 minutiae and few less than 30;
- There was good correlation with quality assessed by NFIQ scores, with the left index finger again having poor quality prints.

The little fingers generally had more than 30 minutiae; in up to 40% of cases, they had more than 60 minutiae, indicating very good quality.
**Facial image**

The kiosk used was an adapted version of a station often used for the enrolment of facial images for document issuance. Notwithstanding the small sample size for analysis of results, it was clear that it was capable of enrolling high quality facial images that were very suitable for facial image-based document bearer verification. In 100% of cases, the live facial image enrolled was either of equal quality or superior in quality to the image on the passport based on the vendor-provided metric. As a result, 92% of verification attempts were successful at a threshold that would typically imply false acceptance rates (FAR) below 0.01%.

Examination of the ICAO quality metrics provided for the live photo highlighted some of the reasons for the high performance observed. Up to 200 pixels were noted to be present between the eyes in the facial images captured, indicating the high resolution of the camera used in the kiosk. Roll angles on the nose axis were always zero, indicating a likely post-processing of the image in this regard. In every case, the images conformed to the photo requirements of ISO/IEC 19794-5 in terms of the vertical position of the face (0.3 ≤ VPF ≤ 0.5), the width of the head (0.5 ≤ CC ≤ 0.75) and the length of the head (0.6 ≤ DD ≤ 0.9), indicating that the guidance provided to the traveller in terms of his/her position during capture was appropriately constrained to ensure quality capture from the outset.

**Duration**

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The moment the traveller initiates the transaction at the kiosk (e.g. by selecting the language or by placing the document on the reader).</td>
<td>1. The completion of the workflow at the kiosks.</td>
</tr>
</tbody>
</table>

When travellers completed the process, the average end-to-end duration of the process was approximately 200 seconds, as shown below. 27% of travellers spent more than 2 minutes at the kiosk, however. When including those who failed to complete the process (data not shown), the average duration increased to approximately 4 minutes, highlighting the fact that some travellers spent significant amounts of time attempting to follow the process but ultimately failing.
The bulk of the time spent at the kiosk was associated with the fingerprint enrolment process. As shown in figure 4, the average time required to enrol 8 fingerprints successfully was 70 seconds. In 50% of cases for each of the left and right hands, travellers attempted to enrol 3 times, somewhat explaining the rather long enrolment durations.

Live facial image enrolment took on average 23 seconds, with 82% of travellers successfully enrolling the facial image within 30 seconds. Re-attempts were never necessary.
5.6.3. Users’ perception

5.6.3.1. Travellers’ feedback

In total, 50 entries (corresponding to around 112% of the participating travellers) were recorded.

Travellers had the possibility to provide anonymous feedback on their experience by indicating the extent of their satisfaction on a touch-screen pad placed adjacent to the kiosk itself. Thus, it should be noted that all travellers had the opportunity to provide feedback, including those who failed to complete the process. Nevertheless, a majority of respondents (72%) expressed themselves to be satisfied or very satisfied.

![Sillamäe - TC11](image)

*Figure 264 Sillamäe - results of the travellers’ survey*

5.6.3.2. Border guards’ feedback

No border guards were involved in performing the tests at Sillamäe. During the end of the test visit, feedback was obtained from representatives of the authorities involved in accommodating and executing the tests and is reported in the table below.

*Table 51 Sillamäe - border guards’ feedback*

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travellers participating were generally happy with the process for biometric enrolment. However, given the lack of real benefit, there was little added value, hence the low participation rates observed.</td>
<td>The kiosk generally seemed to work well. On some occasions, technical faults were encountered that required system restart.</td>
<td>Many travellers did not want to participate because they saw no added value.</td>
</tr>
<tr>
<td>Impediments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It was suggested that all travellers who participated needed some guidance. Directions were only available in English and Russian and were difficult to follow for some.</td>
<td>Initial problems were encountered with reading the chip of Russian passports but the supporting vendor quickly resolved these issues. The fingerprint sensor needed to be cleaned frequently in order to allow enrolment.</td>
<td>Some Russian citizens were against giving their biometrics.</td>
</tr>
</tbody>
</table>
5.6.4. **Constraints**

No particular constraints were observed. Lighting conditions were not cited as an issue for facial recognition (in any case, the kiosk had its own lighting in built for facial image capture) or for fingerprinting (the kiosk was located away from windows of other direct external light sources).

5.6.5. **Main observations**

The low sample size casts into doubt the potential of self-service enrolment kiosks at waiting areas in the context of Smart Borders. One of the most striking outcomes of the test at Sillamäe was the low sample size reached. This was related to the lack of added value for travellers participating but also the low number of travellers passing through the terminal building at the Sillamäe waiting area during testing. Improvements in the efficiency and effectiveness of the online booking system used by the Estonian authorities for reserving border-crossing slots made in the period between the Smart Borders technical study and the pilot have resulted in few travellers spending any significant time in the area. Often, LGV drivers do not enter the building before departing once more. Deployment of kiosks for biometric enrolment in the waiting area would thus not typically take advantage of traveller down-time; use of kiosks would rather have to be compulsory if they were to be exploited.

The majority of travellers were not able to complete the process independently. This may have been a consequence of the fact that the use of the kiosk at Sillamäe was not supervised and no guidance was typically offered to travellers,

1. Of those that completed the live enrolment of a facial image to allow subsequent verification against the document image, 92% were successfully verified at a threshold equivalent to an FAR below 0.01%. The use of a kiosk with its own in-built lighting, with strong guidance to constrain the positioning of the traveller relative to the camera and with a controlled white background seemed to bring benefits. In fact, the live image captured was rated to be of the same or higher quality than the chip image in 100% of cases;
2. All travellers who completed the process spent at least one minute at the kiosk, with the average duration for the complete process being approximately 100 seconds for enrolment of the live facial image and 8 fingerprints along with successful document scanning. Fingerprint enrolment was the most significant contributor to the overall time required.
5.7. Udvar - Fingerprints

5.7.1. Test description

This road border-crossing point is located in the south of Hungary in a little village called Udvar at the border with Croatia within European Union. Hungarian and Croatian border guards perform joined controls.

The BCP operates 24/7 and the tests have been executed almost non-stop, except during peak hours, i.e. during the weekends and summer time.

For the pilot tests, three lanes have been made available that are currently used for all types of passports for cars, busses and trucks. All of those 3 lanes were already equipped with fingerprints scanners, able to scan 4, 8 and 10 fingerprints. The national application was modified to fully integrate the pilot checks within the normal control. As such the pilot tests were integrated.

The lanes for EU/EEA and CH citizens have been used for the baseline measurement.

Most of the crossing TCNs are Bosnians (17,935), Serbians (2,900) and other (3,924), incl. Chinese and Russians. There is approx. 20% increase in travellers flow per year. TCN VH represent a very marginal share of all travellers.

The tests were conducted mainly during the summer period, which was reported as particularly busy. The border guards have reported that 162,001 travellers have crossed this border during the pilot.

The tests focussed on fingerprints enrolment at first line border check in an outdoor environment.

5.7.1.1. Set-up and configuration

The execution and organisation of the test cases at Udvar were set up and configured based on characteristics listed in the table below.

Table 52 Udvar - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Land: Road - Udvar is a land border-crossing to Croatia. It is a joined control with Croatian border guards.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td></td>
<td>• TC1: Enrolling 4 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC2: Enrolling 8 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC3: Enrolling 10 fingerprints</td>
</tr>
<tr>
<td><strong>Test location</strong></td>
<td>Land border-crossing point in Udvar</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td><strong>Staff involved</strong></td>
<td><strong>8 in total</strong></td>
</tr>
<tr>
<td></td>
<td>- 8 border guards at the BCP were trained and participated in the tests</td>
</tr>
<tr>
<td></td>
<td>- Border guards also acted as hosts</td>
</tr>
<tr>
<td><strong>Total duration</strong></td>
<td><strong>18 weeks in total</strong> (with a four-week break)</td>
</tr>
<tr>
<td><strong>Timetable</strong></td>
<td>TC1: From 23.04.2015 to 07.05.2015 and 16.09.2015 to 24.09.2015 (<strong>3 weeks</strong>)</td>
</tr>
<tr>
<td></td>
<td>TC2: From 25.07.2015 to 29.08.2015 (<strong>5 weeks</strong>)</td>
</tr>
<tr>
<td></td>
<td>TC3: From 26.05.2015 to 15.07.2015 (<strong>7 weeks</strong>)</td>
</tr>
<tr>
<td><strong>Sample size</strong></td>
<td><strong>(target / actual)</strong></td>
</tr>
<tr>
<td>(target/actual)</td>
<td>Fingerprints</td>
</tr>
<tr>
<td></td>
<td>- TC1: 600 / ~102\textsuperscript{96}</td>
</tr>
<tr>
<td></td>
<td>- TC2: 1000 / 1003</td>
</tr>
<tr>
<td></td>
<td>- TC3: 1550 / 1740</td>
</tr>
<tr>
<td><strong>Process layout</strong></td>
<td>2 lanes dedicated for the pilot tests, for all TCs.</td>
</tr>
<tr>
<td></td>
<td>- One lane used for cars and the other for trucks. The same type of device and the same process used in both lanes.</td>
</tr>
<tr>
<td></td>
<td>- Both lanes were used for getting the traveller feedback with the eu-LISA tablet</td>
</tr>
<tr>
<td><strong>Integration within the regular border-crossing process</strong></td>
<td><strong>Integrated</strong></td>
</tr>
<tr>
<td></td>
<td>Process steps were integrated in the normal border-crossing process (in a first phase not integrated but these tests were repeated later)</td>
</tr>
<tr>
<td></td>
<td>The check included also the access to national and EU databases, which is reflected in the end to end process duration.</td>
</tr>
<tr>
<td><strong>Technical integration</strong></td>
<td><strong>Integrated</strong> (in a first phase not integrated but these tests were repeated later in integrated mode)</td>
</tr>
<tr>
<td><strong>Type of device</strong></td>
<td><strong>Existing 4 FP slap, contact scanner</strong></td>
</tr>
<tr>
<td><strong>Quality thresholds</strong></td>
<td>Fingerprints</td>
</tr>
<tr>
<td></td>
<td>- TC1: vendor-specific</td>
</tr>
<tr>
<td></td>
<td>- TC2: vendor-specific</td>
</tr>
<tr>
<td></td>
<td>- TC3: vendor-specific</td>
</tr>
<tr>
<td></td>
<td>NFIQ measured but not used as threshold.</td>
</tr>
<tr>
<td><strong>Environmental device</strong></td>
<td><strong>Available</strong></td>
</tr>
<tr>
<td></td>
<td>Monitoring light, humidity and temperature conditions</td>
</tr>
<tr>
<td><strong>Travellers’ feedback</strong></td>
<td>After test completion: Self-service tablet</td>
</tr>
<tr>
<td><strong>Data protection</strong></td>
<td>Verbal consent requested</td>
</tr>
</tbody>
</table>

**5.7.1.2. Workflow**

**Fingerprints enrolment**

\textsuperscript{96} 710 samples were logged during the tests. For the first 600 samples a demo application was used, with the consequence that logs were not fully usable for the analysis of the tests.
1. **TC1: Enrolment of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).**

   Fingerprints for the index, middle, ring and little fingers for the right hand of volunteering TCNs were captured first using an existing 4 FP scanner.

2. **TC2: Enrolment of 8 fingerprints (index, middle, ring and little fingers for both hands)**

   Fingerprints for the index, middle, ring and little fingers for the right hand of volunteering TCNs were captured first using an existing 4 FP scanner, and then the same was done for the left hand (4-4 method).

3. **TC3: Enrolment of 10 fingerprints (index, middle, ring, little fingers and thumbs for both hands)**

   Fingerprints for the index, middle, ring and little fingers for the right hand of volunteering TCNs were captured all at once first using an existing 4 FP scanner (identical scanner type used for TC2), followed by the same process for the left hand. The thumbs for both hands were then captured both at once.

   At the BCP in Udvar, 2 lanes were used for the pilot tests, one for cars and the other for trucks. The existing 4FP-reader devices were used for the tests and fully integrated to the border management system, which also produced the data to the test result logs. For performing the enrolment the travellers had to step out of the vehicle, which is a different method than in the existing process where they can stay in the vehicle.

   Note that in Udvar, the test cases were executed separately in the order TC1, TC3 and TC2. TC1 was decided to repeat at the end, after TC2.

   5.7.1.3. **Participation and sample characteristics**

   The below graphs show the main characteristics of the sample, consisting of approximately 2800\(^{96}\) travellers:

---

\(^{96}\) Sample size after data cleaning process
5.7.2. Test cases operational and technical results

5.7.2.1. Fingerprints (TC1, TC2, TC3)

Success / failure

The enrolment of the fingerprints was considered successful, during the execution of the tests, if the vendor threshold was reached, for TC1, TC2 and TC3. The device had lights that turned green for each finger when the fingerprints were properly enrolled. The target was to reach this threshold within the three allowed attempts. This method was rarely applied as in most cases no second or third attempt was made. The main reason being the high flow of travellers, which made border guards not making any re-attempt, when queues were building up.

The graphs below demonstrate the success/failure rate for TC1, TC2 and TC3. In the graphs presented below the vendor threshold is not used but instead the success rate is based on using NFIQ 2-2-2-3.

---

The country codes used in the graph are the three-letter country codes defined in ISO 3166-1: http://www.nationonline.org/oneworld/country_code_list.htm
Figure 273 Udvar - success and failure rate by hand with contact device at NFIQ 2-2-2-3 threshold within the 3 allowed attempts

Across all test cases, the right hand was enrolled successfully in 39% of instances, the left hand in 36% of cases and the thumbs in 60% of all tests undertaken in which their enrolment was sought. Looking at test cases individually, 31% of the enrolments were successful for all fingers in TC1, 28% in TC2 and 16% in TC3.98

TC 1 was first run with insufficient data gathered in the logs and then re-run at the end of the test period. This made for a very low number of samples and the success rate of 31% cannot be seen as fully representative.

For TC2, as mentioned the high flow of travellers seems to have impacted the willingness to make re-attempts and since 8 FP takes more time to enrol than 4 FP this could have impacted the success rate (28%).

The above mentioned high flow of travellers, leading to that border guards did not make re-attempts, have most likely impacted the success rate. To enrol 10 fingerprints (TC3), all fingers must reach the threshold and even the added time to achieve this during the first attempt could have impacted the success rate (16%).

Quality

Quality measurement of individual fingerprints in Udvar was based on NFIQ and number of minutiae.

NFIQ results

• Unlike the results in many other BCP the little finger was not the one that made the most problems in capturing a high quality fingerprint. However when looking at the score for NFIQ 1-2 combined it is true that the little finger has the lowest score. It should be noted that the quality analysed is based on only 102 samples;

• The same observation for the little finger, as for TC1, is valid for TC2;

• For TC3, The observation for the problems to capture a good quality for the little finger corresponds with the results of TC 1 and TC2.

Minutiae results

• Prints from the little fingers were poorest in quality, with 58% of such prints having between 30 and 60 minutiae in the case of TC1. Similar quality results were seen throughout testing;

• Unlike the results from other BCPs, the ring fingers rather than the thumbs had the highest number of minutiae on average.

98 Success rates according to the threshold: NFIQ 2-2-2-2-3 (thumbs - index - middle - ring - little fingers).
Figure 274 Udvar - TC1 NFIQ scores per finger at the first attempt with contact scanner

Figure 275 Udvar - TC1 minutiae amount per finger at the first attempt with contact scanner

Figure 276 Udvar - TC2 NFIQ scores per finger at the first attempt with contact scanner

Figure 277 Udvar - TC2 minutiae amount per finger at the first attempt with contact scanner

Figure 278 Udvar - TC3 NFIQ scores per finger at the first attempt with contact scanner
Duration

The duration of fingerprint enrolment is measured in order to assess the added duration compared to the current situation where no biometric identifier is enrolled and to measure the difference between enrolling 4, 8 or 10 fingerprints. Time-stamped log files, produced by the Hungarian entry-exit system, were used for duration measurement.

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the FP;</td>
<td>1. The successful capture with a maximum of 3 attempts or the end of the third attempt;</td>
</tr>
<tr>
<td>2. The start of the successful capture.</td>
<td>2. The successful capture with a maximum of 3 attempts or the end of the third attempt.</td>
</tr>
</tbody>
</table>

It was found that there is a linear increase from 4 to 8 to 10 FP (TC 1 - 100% under 15 sec, TC2 - 88 % under 30 sec, TC3 - 94% under 60 sec but only 5 % under 30 sec. The added 4 FP for TC2 and the added thumbs for TC3 clearly added time to the process of enrolment.
The majority (65%) of the total end-to-end duration for TC 1 was between 30-60 seconds and a vast majority was under 120 seconds. For TC 2 the average end-to-end duration is slightly higher with around 52% below 30-60 and the
majority under 120 sec. For TC3 this increase continues with only 7% between 30-60 seconds and 51% had end-to-end duration occurring between 60-90 seconds. It is clear that the end-to-end duration increases when the number of fingers enrolled increases. The proportion of the increase is less remarkable between Tc1 and Tc2 than for TC3. It can just be concluded that taking the thumb has a big influence on the duration of the capture and hence on the end-to-end process.

The baseline was measured before the pilot started at three occasions, using the logs of the national entry-exit system.

It can be observed that the baseline end-to-end process is not significantly shorter than the pilot end-to-end process, in particular for the enrolment of 4 FP (12 seconds). The difference increases when introducing the enrolment of 8 FP (26 seconds) and even further increases with the enrolment of 10 FP (41 seconds).

The values are summarised in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Avg.</th>
<th>Med.</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC1</td>
<td>55.47</td>
<td>52.00</td>
<td>21.53</td>
</tr>
<tr>
<td>TC2</td>
<td>64.04</td>
<td>59.00</td>
<td>21.84</td>
</tr>
<tr>
<td>TC3</td>
<td>90.95</td>
<td>84.00</td>
<td>30.47</td>
</tr>
</tbody>
</table>
Table 53 Udvar - duration impact on the end to end process

<table>
<thead>
<tr>
<th>Aspect under measurement</th>
<th>Average duration (low threshold</th>
<th>high threshold)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline\textsuperscript{99}</td>
<td>43 seconds</td>
<td></td>
</tr>
<tr>
<td>Pilot measured end to end</td>
<td>4 fingerprint enrolment with 4FP scanner</td>
<td>55 seconds</td>
</tr>
<tr>
<td></td>
<td>8 fingerprint enrolment with 4FP scanner</td>
<td>64 seconds</td>
</tr>
<tr>
<td></td>
<td>10 fingerprint enrolment with 4FP scanner</td>
<td>91 seconds</td>
</tr>
<tr>
<td>Contact</td>
<td>4 fingerprint enrolment with 4FP scanner</td>
<td>12 seconds</td>
</tr>
<tr>
<td></td>
<td>8 fingerprint enrolment with 4FP scanner</td>
<td>26 seconds</td>
</tr>
<tr>
<td></td>
<td>10 fingerprint enrolment with 4FP scanner</td>
<td>42 seconds</td>
</tr>
</tbody>
</table>

From the values in the table above, it can be observed that in the case of the testing set-up at Udvar:

- Fingerprints have a noticeable impact on the border-crossing procedure, in particular when taking eight or ten fingerprints. The total border control procedure with fingerprint enrolment increased by 28% for TC1, 49% for TC2 and 111% for TC3.

5.7.3. Users’ perception

5.7.3.1. Travellers’ feedback

In total, 279 entries (corresponding to around 39% of the participating travellers) were recorded for TC1, 379 entries (corresponding to around 38% of the participating travellers) for TC2 (8 fingerprints) and 543 entries (corresponding to around 32% of the participating travellers) for TC3 (10 fingerprints).

Overall, respondents expressed satisfaction subsequent to their participation in the pilot. A subset remained neutral while only 18% of respondents provided negative feedback for TC1, 21% for TC2 and 29% for TC3. More details about the feedback are provided in the figures below.

<table>
<thead>
<tr>
<th>Udvar - TC1</th>
<th>Udvar - TC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very unsatisfied</td>
<td>Unsatisfied</td>
</tr>
<tr>
<td>18%</td>
<td>21%</td>
</tr>
<tr>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>13%</td>
<td>26%</td>
</tr>
<tr>
<td>Very satisfied</td>
<td>Satisfied</td>
</tr>
<tr>
<td>69%</td>
<td>53%</td>
</tr>
</tbody>
</table>

\textsuperscript{99} The average baseline duration was calculated from a sample of 154 travellers, and recorded manually by the border guard using a clock on the wall. Data points for the pilot end to end were extracted centrally using the border guard’s software log files. (from the time the travellers passport was put onto the reader until the border guard disengaged (i.e. gave back the passport).
5.7.3.2. Border guards' feedback

In total, responses from 8 border guards were collected for the survey in Udvar. The feedbacks results are summarised in the table below.
### Table 54 Udvar - TC 1, TC2 and TC3 border guards’ feedback

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td>The tests worked well and are interesting for enhanced security but measures need to be found not to add more duration to the total process time.</td>
<td>Using the scanner with the new application (connected to the national entry/exit system) was easy. Overall it was considered to work well to get travellers volunteering (if the border guard was able to speak English/Croatian).</td>
</tr>
<tr>
<td>Impediments</td>
<td>Travellers have to leave the vehicle for making the enrolment, which added time to the total duration even though not part of the actual enrolment time. Due to the touristic season and the number of travellers there is less possibility for re-attempts. Capturing the two thumbs in the TC3 was requested more guidance thus increasing the duration of the control. Currently a border check shall be below 2 minutes and 40 seconds per car. Here it has to be stressed that not all steps of the end to end have been measured (e.g. the time it takes for the traveller to leave the car). For the future decision all the additional time, related to any changes, has to be factored in. Of course depending on the solution that will be put in place.</td>
<td>In some cases the participants had rough or dry skin, which made the capturing of FP slower. In very few cases it was difficult to capture large hands because only 3 fingers could match easily the surface of the device sensor. Language was seen as a barrier. The border guards were trained in phrases to use for guiding the travellers.</td>
</tr>
<tr>
<td>Improvements</td>
<td>Border guard stressed that it is important to look at the entire process and also the impact of other changes that are brought to it, such as the need for leaving the car and abolition of the current stamping.</td>
<td>N/A</td>
</tr>
</tbody>
</table>
5.7.4. **Constraints**

5.7.4.1. **Environmental conditions**

No specific problems related to environmental conditions were reported. The fingerprint scanner was placed inside a manual booth. An environmental measurement device was placed over the manual booth to monitor temperature, humidity and light throughout the entire testing period. As can be seen in the table below, during the entire testing period, temperatures ranged from 6° to 37.4° Celsius.

**Table 55** lasi - maximum, minimum and average of temperature, humidity and light

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Humidity (RH%)</th>
<th>Light (Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>6°</td>
<td>18.1%</td>
</tr>
<tr>
<td>Max</td>
<td>37.4°</td>
<td>95.7%</td>
</tr>
<tr>
<td>Average</td>
<td>22.56°</td>
<td>60.18%</td>
</tr>
<tr>
<td>Remark</td>
<td>Vast majority between 15 and 29°</td>
<td>Vast majority between 30% and 99%</td>
</tr>
</tbody>
</table>

5.7.5. **Main observations**

In general the tests went well and with a quite limited added duration to the end-to-end process. Enrolling FP has a specific impact at land borders, due to the fact that travellers need to leave their cars and this adds duration to the process. This method is normally not used in the existing checks at land borders, expect for when verifications of FP are made to the VIS.

In the case of Udvar the national entry-exit system was fully integrated with the test equipment. This made it possible to make clear observations on the added duration. The added duration to the process clearly increased in relation to the number of fingers enrolled. 100% of the tests for 4 FP was below 15 seconds, for 8 FP the majority (88%) were enrolled within 30 seconds. When enrolling 10 FP the added duration increased further with the majority (94%) under 60 sec but only 5% under 30 sec.

Language was seen as an important factor to successfully instruct travellers when making the FP enrollment.

Enrolling 4 FP was seen as the most feasible option by the border guards. The quite low success rate could be related to that the flow of travellers at the BCP was very high. If the queue became very long, or according to the wish of the traveller, there was no 2nd or 3rd attempt made by the border guard. The lower success rate for TC 3 could also be seen as a consequence of this, having the longest added duration to the process.
5.8. Vaalimaa - Fingerprint and facial image

5.8.1. Test description
In this chapter, the tests undertaken at the border-crossing point of Vaalimaa in Finland are described in detail. The BCP is a road border between Finland and Russia.

Operational tests in the frame of the Smart Border pilot ran from April to August 2015. Tests were run in parallel on both entry and exit sides of the BCP using a standalone device acquired for the purposes of the tests. In general, the goals were to test the feasibility of both fingerprint and facial image enrolment at a large land border crossing point as well as the possibility or using enrolled live facial images to perform automated document bearer verification by comparing the photo to that on the eMRTD chip. Metrics recorded included the time required to enrol both biometrics and to execute the photo comparison, the quality of biometrics obtained and the extent to which users accepted the biometric enrolment process and the device utilised.

Tests were run out of modern border control booths with travellers exiting their vehicles to provide their biometric samples using the devices through the booth window. Fingerprints and facial images were always enrolled in a single encounter, with processes for 4-, 8- and 10-fingerprint enrolment being examined successively. Among the aspects of most interest in tests at Vaalimaa were the influences of cold, humidity and light in such an outdoor environment and the perspectives of the many travellers who cross this border very frequently. The same device set-up was used on the moving cruise ship at Piraeus and in the terminal building of Helsinki port, allowing direct comparisons to be made with the results obtained under the different environmental influences apparent at these locations.

5.8.1.1. Set-up and configuration
The execution and organisation of the test cases at Vaalimaa were set up and configured based on characteristics listed in the table below.

Table 56 Vaalimaa - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Land: Road - Vaalimaa is one of the main road BCPs between Finland and Russia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>In outdoor conditions, evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td></td>
<td>• TC1: Enrolling 4 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC2: Enrolling 8 fingerprints</td>
</tr>
<tr>
<td>Test location</td>
<td>Vaalimaa road BCP, at entry and exit</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Staff involved</td>
<td>13 in total</td>
</tr>
<tr>
<td>Total duration</td>
<td>17 weeks in total</td>
</tr>
</tbody>
</table>
| Timetable     | TC1: From 14.04.2015 to 26.05.2015 (2 weeks)  
TC2: From 27.04.2015 to 06.06.2015 (6 weeks)  
TC3: From 06.06.2015 to 09.08.2015 (9 weeks)  
TC6, TC4, TC7: From 14.04.2015 to 09.08.2015 (17 weeks) |
| Sample size (target / actual) | Fingerprint:  
TC1: ~600  
TC2: ~1000  
TC3: ~1550  
Facial image:  
TC6: ~1550 (2D)  
TC7: ~2300 (2D) |
| Process layout | One existing manual booth on both entry and exit sides of the BCP; (Dedicated lane; Testing at the regular border guard booth) |
| Integration within the regular border-crossing process | Integrated  
Process steps were integrated in the normal border-crossing process, i.e. made during (in this case immediately after) the regular border check procedure |
| Technical integration | Standalone  
The equipment was standalone and did not interact in any way with the standard border check equipment. |
| Type of device | TC1, TC2, TC3: New 4FP fixed contact fingerprint scanner - optical  
TC4: New standard single-shot web-camera  
TC6: New flatbed eMRTD reader  
TC7: Matching software from the vendor |
| Quality thresholds | Fingerprint:  
TC1: NFIQ 2-2-2-3  
TC2: NFIQ 2-2-2-3  
TC3: NFIQ 2-2-2-2-3  
Facial image:  
TC6: N/A  
TC4: No specific threshold applied, verification success guided re-enrolment attempts  
TC7: 0.1% FAR |
| Environmental device | Available  
To measure the light, humidity and temperature conditions |
| Travellers’ feedback | After test completion: Self-service tablet |
5.8.1.2. Workflow

Fingerprints enrolment

1. TC1: Enrolment of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).

The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were captured using a standard optical livescan device.

2. TC2: Enrolment of 8 fingerprints (index, middle, ring and little fingers for both hands)

The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were firstly captured followed by those of the left hand. (4-4 method).

3. TC3: Enrolment of 10 fingerprints (index, middle, ring, little fingers and thumbs for both hands)

The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were captured in the first step, followed by those of the left hand. The thumbs of both hands were captured in the final step of fingerprint enrolment.

The participating border guards activated 4, 8 or 10 finger enrolment by mouse click at the beginning of each enrolment process. The device itself had small LED indicators to indicate successful enrolment of each finger to the required thresholds indicated in the table above. Re-enrolment of fingerprints (for the whole slap) was requested manually if the prints fell below these thresholds, with a limitation of 3 re-enrolment attempts hard-coded within the software. Within the border guard’s software, tiered thresholds were applied; thus, if the fingerprints had more than 60 minutiae, they were highlighted in green, if they had between 15 and 60 minutiae they were highlighted in orange, and otherwise they were marked in red. Re-enrolment was encouraged whenever any finger due to be enrolled failed to be marked as green.

Facial image

The test cases were executed sequentially and as a combined process according to the following sequence of three steps:

1. TC6 - Passport inspection (including Passive Authentication) and retrieval of the facial image from the eMRTD (this step was in fact carried out as the first step of the process, followed by fingerprint capture. Steps 2 and 3 below followed subsequently);

2. TC4 - Enrolment of the live facial image (photo) from the TCN;

3. TC7 - Verification of the facial image captured from the eMRTD chip against the live facial image enrolled from the TCNs.
A standard web-camera was used for live facial image enrolment. Auto-focus functionalities were implemented. The software automatically zoomed and cropped the obtained image in order to enforce ICAO-type results. Facial image matching proceeded automatically and the comparison score displayed with an indication as to whether the threshold was exceeded. Re-enrolment of the facial image was suggested by the software up to 3 times in case of matching failure. The facial image from the chip was obtained using a flatbed (i.e. full page) document scanner.

5.8.1.3. Participation and sample characteristics

The proportion of male to female travellers was balanced, with slightly more male travellers participating in the tests in Vaalimaa. The majority of participants were aged between 31 and 50, with 1% of the total travellers over 70 participating. The vast majority of travellers were Russian.

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The country codes used in the graph are the three-letter country codes defined in ISO 3166-1:
http://www.nationsonline.org/oneworld/country_code_list.htm
5.8.2. **Test cases operational and technical results**

5.8.2.1. **Fingerprints (TC1, TC2, TC3)**

**Success / failure**

Fingerprint enrolment was considered successful if the NFIQ threshold (values of 1 or 2 for the thumb, index, middle and ring fingers and 1,2or 3 for the little finger) was reached at the first attempt. Second attempts were done in 28% of cases, and third attempts in 14% of cases. Because of operational pressures, border guards felt unable to force re-enrolment attempts in all cases despite the thresholds not being reached - this was noted to have been the case in approximately 40% of cases in which the first enrolment had at least one finger below threshold. Thus, it may be assumed that the overall success rates shown below might be improved if 3 enrolment attempts were always made.

The figure below shows the success/failure rate per hand, and for the two thumbs combined across the test cases 1, 2 and 3. No significant differences were seen per hand between test cases.

**Figure 294 Vaalimaa - TC1 success and failure rate with contact device at NFIQ 2-2-2-3 threshold**

**Figure 295 Vaalimaa - TC2 success and failure rate with contact device at NFIQ 2-2-2-3 threshold**

**Figure 296 Vaalimaa - TC3 success and failure rate with contact device at NFIQ 2-2-2-2-3 threshold**

**Figure 297 Vaalimaa - success and failure rate by hand with contact device at NFIQ 2-2-2-3 threshold**

With the applied thresholds, only one third of first attempts were successful for the left and the right hand. Thumbs show a better success rate, with more than half of the first attempts being successful. Higher success rates were seen with enrolment of the thumbs, with 52% of thumb enrolment first attempts being successful. Overall, it can be seen that at best around one third of the first attempts to enrol the ten fingerprints could be successful based on the NFIQ threshold.
The cases marked as having no value recorded in the above graph are those for which at least one finger failed to reach the quality threshold applied to be considered a valid scan - the lowest threshold of 15 reliable minutiae.

Quality

The quality of fingerprints enrolled was assessed using both NFIQ version 1 scores and the number of reliable minutiae in each print.

As mentioned, it was the case that some fingerprint enrolment attempts presented at least one finger that failed to be enrolled - this occurred in approximately 25% to 30% of first enrolment attempts (of either the right hand, or the left hand, or the two thumbs). The results presented do not take into account such fingerprints. Thus, the overall results will be slightly worse than those displayed in the graphs below.

NFIQ results

- TC1: NFIQ scores between 1 and 3 were most frequently obtained. As elsewhere, that fingerprints from the little finger were of lowest quality; those for the index, middle and ring fingers were of similar quality overall. Approximately one in two fingerprints captured could be considered to be of good quality (NFIQ 1 or 2) and one in three of average quality (NFIQ 3). Only one in ten fingerprints were of poor quality (NFIQ 4 or 5);
- TC2: Generally, the quality of prints from the left hand was less than with the right hand. The quality distribution across fingers obtained was comparable to TC1, except for the right index - 10% more prints had an NFIQ of 1 than in results from four fingerprint enrolment;
- TC3: As for TC2, the quality of prints from the left hand was lower than those from the right (except for the thumb and the little finger). The thumbs gave prints of higher quality than other fingers, with more than three out of five being rated as being of good quality (NFIQ 1 and 2). The quality distribution across fingers was comparable to TC1.

Minutiae results

- TC1: The number of minutiae identified was relatively low with approximately 50% of fingerprint images having less than 30 minutiae and less than one in ten having more than 60 detectable minutiae. Prints from the little finger typically had very few minutiae, with only one in six fingerprints presenting more than 30 minutiae;
- The number of minutiae in the prints obtained in TC2 testing was low as for TC1. Significant differences between the left and right hands were not noted except in the case of the index finger, which had better quality in case of right hand enrolment, as was also noted with the NFIQ values.
- As for TCs 1 and 2, overall fingerprint quality assessed by number of minutiae was relatively low. However, the thumb-prints were something of an exception, with four out of five thumb-prints having more than 30 minutiae. Prints from the little finger of the right hand were better than for the left, but otherwise few notable differences were seen between prints from the right and left hands. This correlates well with results based on NFIQ scores.
TC1

Figure 298 Vaalimaa - TC1 NFIQ scores per finger at the first attempt with contact scanner

Figure 299 Vaalimaa - TC1 minutiae amount per finger at the first attempt with contact scanner

TC2

Figure 300 Vaalimaa - TC2 NFIQ scores per finger at the first attempt with contact scanner

Figure 301 Vaalimaa - TC2 minutiae amount per finger at the first attempt with contact scanner
### TC3

**Figure 302 Vaalimaa - TC3 NFIQ scores per finger at the first attempt with contact scanner**

**Figure 303 Vaalimaa - TC3 minutiae amount per finger at the first attempt with contact scanner**

### Duration

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The time that the border guard activated the enrolment attempt by mouse click.</td>
<td>1. The complete enrolment of the required number of fingers.</td>
</tr>
</tbody>
</table>

The duration of fingerprint enrolment was provided by the vendor’s software.
Note that enrolment durations in Vaalimaa were calculated per attempt, from the time that the border guard activated the enrolment attempt by mouse click through to the complete enrolment of the required number of fingers.

In order to provide estimations for the total duration of the fingerprint enrolment process per attempt, the average durations for each TC are combined.

The graph below shows the distribution of enrolment duration for TC1 for one attempt.

![Graph showing distribution of enrolment duration for TC1](image)

*Figure 304 Vaalimaa - TC1 duration with contact scanner (in seconds)*

One third of attempts at capturing four fingerprints were completed in less than 15 seconds, and four out of five in less than 30 seconds. The average duration of one attempt to capture four fingerprints was 22 seconds.

Regarding TC2, because of the modular set-up of the device in Vaalimaa, enrolment times provided in the frame of TC2 testing were for those of the left hand only. The recorded attempt was the last one to be done.

![Graph showing enrolment duration per attempt for TC2 left hand](image)

*Figure 305 Vaalimaa - TC2 left hand enrolment duration per attempt (in seconds)*

In order to allow better comparison with results presented elsewhere in this report the average value for enrolment of the right hand (coming from TC1) was added to the obtained data in order to estimate the average duration of 8-fingerprint enrolment from both the left and right hands.

![Graph showing estimated enrolment duration per attempt for TC2](image)

*Figure 306 Vaalimaa - TC2 (8 FPs enrolment) estimated duration per attempt (in seconds)*

It may be noted that enrolment of the 4 fingerprints of the left hand was faster than for TC1 (3 seconds less average and median values), potentially because of the experience obtained through right hand enrolment immediately beforehand and the reduced demand for explanation from the border guard for this second step.
Based on the estimation for total duration of eight fingerprint enrolment, the capture of eight fingerprints would take 39 seconds on average.

As for TC3, due to the modular set-up of the device in Vaalimaa, enrolment times provided in the frame of TC3 testing were for those of the thumbs only.

In order to allow better comparison with results presented elsewhere in this report the average value for enrolment of the right hand and left hand (coming from TC1 and TC2) was added to the obtained data in order to estimate the average duration of 10-fingerprint enrolment from both the left and right hands.

**Figure 307** Vaalimaa - TC3 thumbs enrolment duration per attempt (in seconds)

Enrolment of the thumbs was seen to take 16 seconds on average, with more than half of the attempts taking less than 15 seconds.

Based on the estimation for total duration of ten fingerprint enrolment, the capture of all of the ten fingerprints would take 55 seconds on average.

**5.8.2.2. Facial Image Results (TC4, TC6, TC7)**

Regarding facial image the following test cases were performed:

- Retrieval of the facial image from the eMRTD chip (TC6);
- Enrolment of a live facial image (TC4);
- Comparison of the two images (TC7).

As the different tests were undertaken together during tests, this section will analyse the results obtained in combination although analysis of specific aspects related to individual test cases is performed when relevant.

**Success / failure**

The vendor threshold set at Vaalimaa corresponded to 0.1% FAR.

**Figure 309** Vaalimaa - FI related test cases success and failure rate

The success rate at this threshold was 22%, with the majority of attempts below threshold.
Quality

In Vaalimaa, there was no particular quality threshold for enrolment of the live facial image. Rather, images were enrolled following manual activation of the camera by the border guard. He/she could re-enrol if the captured photo displayed on screen appeared to be of low quality visually, but no numerical score was provided. Re-enrolment was suggested, however, if verification failed according to the implemented thresholds. Nevertheless, the quality of the facial image was assessed within the software based on a quality index provided by the supporting vendor and provided in the output dataset for post-analysis.

The graph below shows the distribution of the facial image captured live with the one captured from the chip.

![Graph showing the distribution of facial image quality](image)

**Figure 310 Vaalimaa - Quality of the enrolled live image versus quality of chip image captured**

It can be observed that the quality of the document images was typically higher than that of images taken live at the border. This is almost certainly related to the more controlled environment in which passport photos are taken relative to the outdoor environment in which testing was undertaken at Vaalimaa BCP.

Duration

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader;</td>
<td>1. To the result of the eMRTD FI acquisition (success or failure), including the time to perform the passive authentication;</td>
</tr>
<tr>
<td>2. From the start of the live image enrolment;</td>
<td>2. To the successful enrolment of live image or timeout (if relevant);</td>
</tr>
<tr>
<td>3. From the start of the facial image verification.</td>
<td>3. To the outcome of the facial image verification.</td>
</tr>
</tbody>
</table>

The duration of live facial image enrolment and facial image verification are described in this section.

The distributions were as follows:
With the facial image enrolment and verification equipment used at Vaalimaa, the following observations can be made:

- In 83% of cases, the live facial image enrolment took less than 15 seconds and in 97% of cases less than 30 seconds;
- Software-based image comparison never took more than two seconds, averaging 0.51 seconds.

Other durations, like chip image reading time and passive authentication, were not recorded. However these operations are usually run in parallel and are therefore not expected to impact the duration of the test case.

5.8.2.3. **Duration impact on the end to end process**

At the time of testing, biometrics were not enrolled at Vaalimaa BCP in almost all cases, and thus it was considered worthwhile to compare how the introduction of the biometric enrolment and verification steps analysed might affect the duration of the border check process. In the analysis below, the recorded and estimated averages for each test duration are used. We describe both:

- A baseline measurement: the average duration of the current border check process for TCN visa holder travellers (Russian travellers were not submitting to biometric-based VIS checks at the time of testing);
- Average times for the individual biometric enrolment and verification steps calculated based on the operational tests undertaken as well as estimated end to end times for the border check with the facial image and fingerprint-based processes.

Values are provided in the following table:
Table 57 Vaalimaa - duration impact on the end to end process

<table>
<thead>
<tr>
<th>Aspect under measurement</th>
<th>Average duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>21 seconds</td>
</tr>
<tr>
<td>Live facial image enrolment and verification</td>
<td>10 seconds</td>
</tr>
<tr>
<td>Contact</td>
<td></td>
</tr>
<tr>
<td>4 fingerprint enrolment with 4FP scanner</td>
<td>21 seconds</td>
</tr>
<tr>
<td>8 fingerprint enrolment with 4FP scanner</td>
<td>39 seconds</td>
</tr>
<tr>
<td>10 fingerprint enrolment with 4FP scanner</td>
<td>55 seconds</td>
</tr>
</tbody>
</table>

From the values in the table above, it can be observed that in the case of the testing set-up at Vaalimaa:

- The time required for live facial image enrolment and verification is almost half the time required for the enrolment of four fingers, one fourth of the time required for eight, and one sixth of the time required for ten;
- The time required for facial image enrolment and verification is never more than one fifth of the estimated end-to-end time when fingerprinting is included in the process and overall its impact on the global time could be considered limited;
- The estimated end-to-end times with facial image and fingerprints are between 247% and 410% higher than the baseline depending on the number of fingerprints captured.

5.8.3 Users’ perception

5.8.3.1 Travellers’ feedback

In total, 86 entries (corresponding to around 15% of the participating travellers) were recorded for TC1, 242 entries (corresponding to around 31% of the participating travellers) for TC2, 858 entries (corresponding to around 86% of the participating travellers) for TC3 and 1186 (corresponding to around 52% of the participating travellers) for TC4, 6 and 7.

Respondents generally expressed satisfaction subsequent to their participation in the pilot. Throughout testing, only 5% of the total respondents expressed themselves as dissatisfied.

---

101 The average baseline duration was calculated from a sample of 599 travellers, with each datapoint recorded manually by the border guard using a clock on the wall. It was measured from the time at which the traveller arrived at the booth until the border guard disengaged (i.e. gave back the passport).
Vaalimaa - TC1

Very unsatisfied | Unsatisfied 8%
Neutral 2%
Very satisfied | Satisfied 90%

Vaalimaa - TC2

Very unsatisfied | Unsatisfied 3%
Neutral 5%
Very satisfied | Satisfied 92%

Vaalimaa - TC3

Very unsatisfied | Unsatisfied 4%
Neutral 5%
Very satisfied | Satisfied 90%

Vaalimaa - TC4, TC6, TC7

Very unsatisfied | Unsatisfied 4%
Neutral 5%
Very satisfied | Satisfied 91%

Figure 313 Vaalimaa - results of the travellers’ survey

5.8.3.2. Border guards’ feedback

In Vaalimaa, 4 border guards participated and replied to the questionnaire for TC1, 2 border guards for TC2 and 4 for TC3. All surveys included reflection on the processes for TCs 4, 6 and 7 run in parallel.

The results of the feedbacks are summarised in the tables below.

Table 58 Vaalimaa - TC1, TC4, TC6 and TC7 border guards’ feedback

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Feedback</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive: 2 out of 4 Neutral: 2 out of 4</td>
<td>Positive: 2 out of 4 Neutral: 1 out of 4 Negative: 1 out of 4</td>
<td>Positive: 3 out of 4 No reply: 1 out of 4</td>
</tr>
<tr>
<td><strong>Impediments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Language: some had issues explaining steps to the participants. The extra time required to execute tests meant that they were abandoned when queues were long.</td>
<td>Hardware problems were experienced on occasions. Difficulty to use the equipment correctly.</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Improvements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fingerprint device could be made faster.</td>
<td>Set-ups should be more user friendly and set-ups more ergonomic.</td>
<td>More guidance should be provided to travellers in advance in case of future deployments.</td>
</tr>
</tbody>
</table>
Table 59 Vaalimaa - TC2, TC4, TC6 and TC7 border guards’ feedback

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral: 1 out of 2</td>
<td>Negative: 2 out of 2</td>
<td>Positive: 2 out of 2</td>
</tr>
<tr>
<td>Negative: 1 out of 2</td>
<td>Instability of FP reader was highlighted</td>
<td>Acceptance by the traveller was rated as good</td>
</tr>
<tr>
<td>Impediments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long enrolment time and use of camera in parallel.</td>
<td>Disturbance to FP reader caused by sidelight. Environmental issues.</td>
<td>N/A</td>
</tr>
<tr>
<td>Improvements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>More guidance to travellers is needed.</td>
</tr>
</tbody>
</table>

Table 60 Vaalimaa - TC3, 4, 6 and 7 border guards’ feedback

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive: 2 out of 4</td>
<td>As for TC2</td>
<td>As for TC2</td>
</tr>
<tr>
<td>Neutral: 2 out of 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impediments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>As for TC2</td>
<td>As for TC2</td>
<td>As for TC2</td>
</tr>
<tr>
<td>Improvements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>As for TC2</td>
<td>As for TC2</td>
<td>As for TC2</td>
</tr>
</tbody>
</table>

The responses provided in written form were dissected and discussed further during interactions with the border guards during the end-of-testing debrief session. The border guards highlighted in particular the difficulties in communicating with travellers in order to instruct their behaviour, with some guards unable to speak Russian, the dominant language of participants. A sheet of commonly-used phrases was prepared and used and reported to bring some improvement in this regard. More positive comments were provided regarding the document reader which was reported to have worked extremely well and the camera that provided good facial images despite being a relatively cheap and standard device.

Border guards also expressed doubt regarding the full validity of the traveller feedback results, as they had been present during feedback provision; they felt that this could skew the feedback towards more positive responses. Nevertheless, few had refused to participate (one border guard estimated that only about 10 travellers had refused throughout testing) and those that had typically cited the fact that they had already participated, that they were in a hurry or that they would rather not exit the vehicle to perform the tests. The latter would likely become more problematic in winter. Most negative feedback was because of the long duration of the testing process, they suggested.

When asked to consider the tests undertaken together, border guards were unanimous in their opinion that fingerprint enrolment is difficult and the number of fingers to be enrolled should be minimised in any future process, particularly at peak times or from a significant number of travellers at any time. Enrolment of four fingers was considered fast and put forward as a reasonable solution. They suggested that such enrolment processes should be done at second line in order to reduce queuing time at booths and to reduce costs for more expensive equipment.

They noted that facial image enrolment worked better at Vaalimaa BCP and benefitted from the fact that a biometric sample was available from the travel document and therefore any initial enrolment was not necessary. Nevertheless, most felt that any future Smart Borders solutions should still somehow include fingerprints in order to ensure
homogeneity with VIS processes (most test participants, being Russian, were visa holders) and enhance future system security.

5.8.4. Constraints

5.8.4.1. Environmental conditions

In Vaalimaa, an environmental measurement device was deployed to monitor temperature, humidity and light throughout the entire testing period. It was placed in indoor conditions (on the boat). As can be seen in the table below, during the entire testing period, the temperature ranged from a minimum of 14.3° to 29.9° Celsius.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Humidity (RH%)</th>
<th>Light (Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>14.3°</td>
<td>67.6%</td>
</tr>
<tr>
<td>Max</td>
<td>29.9°</td>
<td>79.5%</td>
</tr>
<tr>
<td>Average</td>
<td>21.1°</td>
<td>44.1%</td>
</tr>
<tr>
<td>Observations</td>
<td>Vast majority between 16° and 25°</td>
<td>Vast majority between 20% and 59%</td>
</tr>
</tbody>
</table>

The set-up was moved from one side of the booth on the entry side to the other in between TCs 2 and 3 because of a perceived negative effect of morning sunlight on both the camera and the optical fingerprint sensor. The border guards reported issues with both moist and dry hands on the fingerprint reader.

5.8.5. Main observations

At the thresholds applied, the enrolment of 4 fingerprints at once was seen to be difficult in outdoor conditions at the land border-crossing point when a standard optical 4-finger scanner was used;

The fingerprinting device had been negatively affected by light and by cold weather. In fact, the platen had frozen during early morning testing in April and fingerprints were typically not registered in such conditions. Regarding light, the border guards had moved the whole set-up from one side of the booth to the other during testing in order to avoid the morning sunlight that was seen to cause great problems for both fingerprinting and facial image capture. The fingerprinting device was often too high for shorter travellers, particularly for enrolling thumbs. However, the configuration of the booth didn’t allow for alteration of this height;

Some travellers simply could not enrol fingerprints due to their fingers being excessively moist or dry. One traveller could not enrol because her fingernails were too long;

The camera for facial recognition was deemed to have worked better than the fingerprinting sensor, although automation of the process was cited as being desirable. The camera had worked well even in night conditions, with light from surrounding buildings being sufficient to allow good image capture;

Border guards found the results of automated face recognition to be useful as a support in decision making but emphasised that the final decision regarding matching success should be based on their own manual processes;

An ability to communicate with travellers in order to provide instructions on fingerprint and facial image enrolment was important. Those border guards who could not speak Russian had more difficulties. Although instruction leaflets had been prepared for travellers, they were not found to be useful and oral interaction was seen to be crucial.
6. Sea borders BCP results

6.1. Cherbourg – Facial image and iris

6.1.1. Test description

The port of Cherbourg in northern France is a busy harbour accommodating ferry and cruise ship traffic. Ports for commercial goods and military purposes are located in areas adjacent to the passenger terminal.

Almost 600,000 passengers passed through the passenger terminal at Cherbourg in 2014, the vast majority on ferry vessels travelling from the UK.

One of the test set-ups described in this chapter was carried out at a dedicated fast track lane set up at one of the available booths for checking vehicular traffic on exit that was previously reserved for police and customs, with some of the travellers in the approximately 2000 cars passing through per day in the summer period volunteering to participate.

The scope of the tests was the enrolment of live facial image (TC4) and enrolment of iris (TC5). The main focus was on the capture of iris, but as the tracking of the facial image was needed for the capture of the iris, the tests were expanded to also enrol the facial image and thus assess the feasibility of capturing both biometric modalities at once.

It is important to note that because of the focus on iris enrolment, a quality threshold was only implemented for iris and not for facial image. Therefore the re-attempt policy (of up to three captures) was based on the success to enrol iris at the required level of quality. During the capture of the iris, successive facial image captures were attempted, and the best quality facial image which it was possible to capture during the capture of the iris was also enrolled. The failure to enrol facial image of a sufficient quality, or at all, did not prompt re-attempts.

In the initial planning for the testing at Cherbourg seaport, the enrolment of four fingerprints (TC1) was also included. During the testing, difficulties with the correct operation of the equipment led to data loss which resulted in a very small number of test data records (approximately 50 records) being available. This was deemed too small a sample for analysis, and thus this test case is not included in the report. As TC1 was also executed in other locations, it has been assessed that this decision has no overall impact neither on the outcome of the pilot nor on the conclusions presented in this report.

6.1.1.1. Set-up and configuration

The execution and organisation of the test case at Cherbourg seaport are set up as follows.
### Table 62 Cherbourg - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Sea: Cherbourg BCP is located in the northwest of France and is a sea Schengen border used both by ferries and cruise ships.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• TC4: Enrolling a live facial image</td>
</tr>
<tr>
<td></td>
<td>• TC5: Enrolling iris pattern</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test location</th>
<th>At exit in ferry harbour</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Staff involved</th>
<th>Shifts of 1-2 border guards (out of three trained) plus 1-2 hosts</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Total duration</th>
<th><strong>13 weeks in total</strong></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Timetable</th>
<th>TC4 &amp; TC5: From 03.07.2015 to 01.10.2015 (<strong>13 weeks</strong>)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sample size (target / actual)</th>
<th>Facial image</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• TC4: 1550 / ~3400</td>
</tr>
<tr>
<td></td>
<td>• TC5: 1550 / ~3400</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process layout</th>
<th>Dedicated lane for vehicles at existing manual booth.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Integration within the regular border-crossing process</th>
<th><strong>Standalone</strong> (before the regular border-crossing process).</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Technical integration</th>
<th><strong>Standalone</strong></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type of device</th>
<th>Two <strong>new fixed devices</strong> capable of capturing iris and facial image at a distance placed one metre apart on the right-hand side of the car, aimed at both the traveller of the front and back seat. Verification software in a separate computer placed inside the booth.</th>
</tr>
</thead>
</table>

| Quality thresholds | Facial image |
6.1.1.2. Workflow

TC4 (facial image enrolment) and TC5 (iris enrolment) in Cherbourg was a standalone step included in the regular border control process and performed on volunteering TCN travellers in vehicles, who remained inside their vehicle while their iris pattern and facial image was captured at a distance. The participants gave their consent in written form and then used the dedicated vehicle lane. As the vehicle approached the manual booth, the vehicle had to align, to stop in an appropriate position enabling the device to capture images from the travellers sitting in the front right- and/or rear right-hand side of the car. The car window(s) had to be open.

In more detail, the sequence was the following:

1. Car stops before the booth with some guidance provided by the border guard to align the car position to the optimal position for having the proper alignment of the sensor (parallel to the lane) with the car travellers;
2. Border guard manually triggers biometric capture on the dedicated workstation;
3. The travellers are requested to turn their head (approximately 90 degrees) and to look at the device which has guidance presented on a screen; where applicable the traveller is requested to remove his glasses;
4. TC4 - Enrolment of the live facial image (photo), at the same time;
5. TC5 - Enrolment of the iris pattern (after the eyes have been located in TC4 live facial image capture). Capture stops when quality threshold is reached (vendor specific). Capture stops if images do not have sufficient quality after 10 seconds;
6. If failed capture or quality threshold is not reached for the iris patterns, re-attempt is performed up to 3 times;
7. Border guard performs regular border-crossing check and authorizes exit.

![Figure 314 Cherbourg - facial image (TC4) and iris (TC5) enrolment set-up](image)

6.1.1.3. Participation and sample characteristics

No data related to gender, age or nationality was collected for Cherbourg, as the tests did not include the reading of the passport.
6.1.2. Test cases operational and technical results

6.1.2.1. Facial image enrolment (TC4)

Success / failure

TC4 was considered successful if the quality of the captured facial image was above the set threshold, which was proposed by the vendor as being in the "sufficient for enrolment" range, on the basis of their proprietary information.

The graph below presents the success rate for facial image enrolment at Cherbourg based on this threshold.

![Graph showing success rates for facial image enrolment](image)

*Figure 315 Cherbourg - TC4 success and failure rate of facial image enrolment based on vendor specific quality threshold*

Enrolment was considered successful, meaning that the recorded image was above the threshold, in 69% of cases. The relatively low percentage of enrolments below the threshold (8%) demonstrates that whenever an enrolment was possible, it was very likely to be above the threshold. Failure to enrol occurred in 23% of cases, however it should be noted that this was not the main objective of this test and, should reattempts for the capture of the facial image have been made based on the FI quality, the results for successful enrolment could be higher, though probably at the cost of a longer durations.

The results presented have been obtained in an experimental environment, with only limited tailoring of the solution to the challenges presented at the given BCP. Therefore the results should be understood with reservations. At Cherbourg, the technical set-up was changed during the test period, whereby the devices were lowered to the level of the travellers’ head. When considering the last two weeks of testing, it could be observed that the modified set-up where the devices had been lowered to the traveller’s face improved the results: failure to enrol went down to 5%, and success rate increased to 84%.

Quality

Quality was measured based on a vendor specific algorithm as described in the previous section. Cherbourg, unlike other locations, did not perform verification of the image against the image contained in the eMRTD chip of the participating traveller. Thus, assessing the quality of the captured image in terms of being adequate for verification against the chip image, was not done.

Duration

The measurement points for the duration of the test case were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the start of the live image enrolment.</td>
<td>1. To the successful enrolment of live image or timeout (if relevant).</td>
</tr>
</tbody>
</table>
The duration for facial image enrolment at Cherbourg is presented below.

![Bar chart showing percentage of enrolments within different time intervals.](image)

**Figure 316 Cherbourg - TC4 duration for the live facial image enrolment (in seconds)**

We can see that in 100% of cases the duration of an enrolment was below 5 seconds.

On average, an enrolment took around 0.3 seconds across all attempts. All enrolments took between 0.2 and 0.5 seconds. The standard deviation was of 0.03 which demonstrates that all enrolments were close to the 0.3 rather than 5s.

However, it should be noted in this case, that the facial image capture was integrated to take place at the same time as the iris and thus a stream of facial images were captured simultaneously, and the above timing is for the marginal time of capturing the final facial image when the irises have been captured. Thus this time does not signify the time it would capture the image, if the process only included the capture of a facial image.

### 6.1.2.2. Iris (TC5)

In most cases, only one attempt was required to enrol the right and left iris pattern (79%), while 16% had to go to a second attempt to successfully get their iris patterns enrolled. The maximum number of retries that was made in Cherbourg was three (5% of the cases had to go through a 3rd attempt).

**Success / failure**

In Cherbourg, the iris enrolment was considered successful if the threshold set by the vendor with regards to the quality of the iris was met within three attempts.
Figure 317 Cherbourg - TC5 iris pattern enrolment success and failure rate

We can observe that the left iris and right iris had almost the same success rate. Overall, a success rate of 81% was observed for the iris pattern enrolment in Cherbourg. Failure to enrol occurred in 14% of cases.

When considering the last two weeks of testing, it could be observed that the modified set-up, where the devices had been lowered to the traveller’s face, improved the results: failure to enrol went down to 5%, and success rate increased to 90%.

Quality

ISO-standard and vendor-specific algorithms were used to determine the quality of the iris pattern enrolled in Cherbourg.

Figure 318 Cherbourg - TC5 quality distribution of right and left iris patterns

We can observe that for both the left and the right iris pattern, a quality deemed sufficient for verification and identification purposes (based on vendor’s assessment) was obtained in more than 95% of the cases where the enrolment was possible.

Following consultation with the vendor who provided equipment for the tests, it was possible to estimate the expected performances of the iris matcher on the basis of the quality scores obtained at Cherbourg.

The estimation was based on the following assumptions:

- Performance is indicated for 1:n searching in a database size of 100 million records (there is an inverse relation between the database size and the accuracy of the ABIS);
- Identification would be performed using the two iris patterns;
- The threshold for identification would be set such that the false positive identification rate (FPIR) would be 0.01%.

By using a database with data having similar quality scores to those obtained in the tests, a false negative identification rate (FNIR) of 23% could be estimated by this vendor.

This false negative rate needs to be put into perspective as it was obtained

- With a process focussed on duration instead of quality (less than 5 second acquisitions in 66% of the cases);
- With eye obstructions in some cases (e.g. glasses or car frame);
- With the gaze of the traveller not completely facing the camera (i.e. because of the position of the camera relative to the car);
- In outdoor conditions with direct lighting impacting the captors and the traveller’s faces;

Specific vendor scores will not be analysed, and they are presented only for the purpose to allow comparison of the quality scores between the live and chip facial image. Absolute values of the scores will not be assessed.
Without any specific optimisation of the ergonomics of the set-up.

It was estimated that with better lighting control, user ergonomics and removal of obstructions (i.e. asking the traveller to remove glasses), the expected FNIR could be decreased to 2.5%. In the same conditions, but by using a short-range capture device (in contact with the face, but not with the eye), it was suggested that an FNIR of 2.5% could also be obtained.

**Duration**

The measurement points for the duration of the test case were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the iris pattern.</td>
<td>1. The successful capture of the iris pattern.</td>
</tr>
</tbody>
</table>

The graph below shows the required time for the successful capture of the iris patterns (right and left) deployed in Cherbourg Port.

![Figure 319 Cherbourg - TC5 right and left iris enrolment process duration (in seconds)](image)

It can be observed that:

- In most cases (66%), successful enrolment of the pair of iris took less than 5 seconds;
- In 99% of the cases, the capture took less than 15 seconds;
- No successful enrolments took more than 30 seconds;
- The average duration for enrolment of the iris pattern was 3.9 seconds.

### 6.1.3. Users’ perception

#### 6.1.3.1. Travellers’ feedback

In total, 162 entries (corresponding to around 5% of participating travellers) were recorded for TC4 (Facial Image enrolment) and TC5 (Iris enrolment). Travellers’ feedback was not recorded individually for the different test cases but rather reflects traveller responses to the process incorporating both of the two test cases performed in one combined process at Cherbourg Port.

Overall, respondents were very satisfied with the process of capturing their facial image and iris pattern at Cherbourg. Only 3% of respondents expressed dissatisfaction with the process.

---

Rounding
Cherbourg - TC4, TC5

Very unsatisfied | Unsatisfied | 3%
Neutral | 6%
Very satisfied | Satisfied | 91%

Figure 320 Cherbourg - results of the travellers’ survey

6.1.3.2. Border guards’ feedback

In Cherbourg, 3 border guards in total provided their feedback for TC4 (Facial image enrolment) and TC5 (Iris pattern enrolment).

The results are summarised in the table below.

Table 63 Cherbourg - TC4 and TC5 border guards’ feedback

<table>
<thead>
<tr>
<th></th>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td>Positive: 2 out of 3</td>
<td>Positive: 2 out of 3</td>
<td>Positive: 2 out of 3</td>
</tr>
<tr>
<td></td>
<td>Neutral: 1 out of 3</td>
<td>Negative: 1 out of 3</td>
<td>Neutral: 1 out of 3</td>
</tr>
<tr>
<td>Impediments</td>
<td>Need for the border guards to guide each car to position for the alignment of the 2 cameras with the travellers inside the car. Difficulty to see how a traveller sitting in the middle can get his iris captured.</td>
<td>Narrow field of acquisition of the camera. Glare from the sun/lighting condition impacting the possibility to capture the facial image and iris.</td>
<td>Difficulties encountered by old or large-bodied travellers to turn 90 degrees towards the camera while being seated in the vehicle.</td>
</tr>
<tr>
<td>Improvements</td>
<td>Better guidance to border guards on how to execute the process.</td>
<td>N/A</td>
<td>More guidance to travellers.</td>
</tr>
</tbody>
</table>

6.1.4. Constraints

6.1.4.1. Environmental conditions

In Cherbourg, modification of the BCP environment was done to improve the results obtained with the device. The device was made for indoor use, so a metal protection was built around it to protect it from weather hazards. A roof was built on top of the booth to protect from rain and direct lighting.

Therefore the conditions found at the BCP are not fully representative of purely outdoor conditions; the decision to modify the BCP environment suggests that the equipment is sensitive to humidity and lighting.
An environmental measurement device was deployed to monitor temperature, humidity and light throughout the entire testing period. It was placed in outdoor conditions. Border guards did not report about any difficulty with the device that would be linked with environmental conditions. As can be seen in the table below, during the entire testing period, the temperature ranged from a minimum of 12.9° to 32.6° Celsius.

**Table 64 Cherbourg - maximum, minimum and average of temperature, humidity and light**

<table>
<thead>
<tr>
<th></th>
<th>Temperature (°C)</th>
<th>Humidity (RH%)</th>
<th>Light (Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>12.9°</td>
<td>28.9%</td>
<td>6.59</td>
</tr>
<tr>
<td>Max</td>
<td>32.6°</td>
<td>93.4%</td>
<td>22806.14</td>
</tr>
<tr>
<td>Average</td>
<td>24.18°</td>
<td>51.3%</td>
<td>22806.14</td>
</tr>
<tr>
<td>Observations</td>
<td>Vast majority between 16° and 29°</td>
<td>Vast majority between 40% and 89%</td>
<td>Vast majority between 300 and 10299</td>
</tr>
</tbody>
</table>

6.1.4.2. **Others**

The positioning of the car was observed to have noticeable impact on the capacity to acquire facial image and iris at the booth. Too little or too much distance from the car to the device meant that the person was not in the range of acquisition of the device, which resulted in lower success rates.

The fact that the device was placed at a 90-degree angle compared to the traveller’s gaze direction made it also difficult for travellers to face the device. Placing the device at a 45-degree angle could potentially have improved the results.

The window frame was also an issue in some settings as faces should be aligned with the cameras without any obstacle. Spectacles were also in some case preventing the successful capture.

Another issue was the sheer size of the device, which needed therefore to be placed before the booth. Drivers were normally used to going to the level of the booth to hand over passports, and therefore they often had to reverse back to reach the device, despite it being set close to the booth. Positioning the devices before the booth also made it difficult for the border guard to properly judge where the car should stop.

Several modifications were made to improve the positioning of the car, namely guiding rails on the ground as well as a mark for the border guard to better assess when a car was positioned correctly.

The last improvement consisting of lowering the devices to the height of the travellers’ head helped reach 95% successful enrolment. Some more improvement could even be sought from physical guides for tyres, or, reversely, horizontally self-guiding iris devices.

6.1.5. **Main observations**

**Facial Image**

From the tests it can be seen that capturing the facial image with a given level of quality, in a set-up combined with iris, and inside a vehicle, worked in 83% of the cases. The acquisition was very fast (always less than 5 seconds, average of 0.3 seconds), and it could possibly be parallelized with other activities (e.g. reading the passport) - though this was not tested.

The border guards were mostly positive about the process and the use of the equipment, while remarking that the process needed to be adapted for outside use, in particular with travellers in a car.

**Iris**
Capturing the iris pattern worked well, with results above threshold in 81% of cases. The right iris was of a slightly better quality than the left one. This slight discrepancy could be explained by the angle at which the traveller looked at the camera, as he/she had to turn his head 90° towards the right from the seated car position, towards the open window of the car.

 Improvement in the results could be observed following the enhancements done to the set-up at the BCP in terms of aids to the correct positioning of the cars.

 The border guards were mostly positive about the process and the use of the equipment, and enthusiastic about the potential of the technology, while remarking that the process needed to be adapted for outside use, in particular with travellers in a car.

 The tests overall demonstrated that capturing iris and facial image at the same time is feasible, in a manner transparent to the traveller, with one device that is developed with the same distance range for the capturing of iris and facial image.
6.2. Genoa – Fingerprint and facial image

6.2.1. Test description

Genoa is the capital of Liguria and the sixth largest city in Italy with a population of almost 600,000. The sea port is one of the biggest in Europe, with a lot of ferries coming from the Maghreb area (mostly Tangier and Tunisia), and also cruises. The amount of travellers per year is around 3.4 million, out of which around 2.7 million are TCN. In summer the travellers’ flow is around 6000 passengers coming in each ferry, with daily peaks up to 30,000 PAX and a total of 1.4 Million of TCNs only in July and August. Of these travellers transiting through Genoa, a high percentage has a resident permit either from Italy or France.

This chapter describes the tests executed at Genoa sea port, Italy, within the Smart Borders pilot.

The tests focussed on the use of automated facial recognition and fingerprints enrolment at manual border controls in a port environment.

6.2.1.1. Set-up and configuration

The execution and organisation of the test cases at Genoa sea port are set up as follows.

Table 65 Genoa - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Sea: Genoa BCP is located in the southwest of France and is a sea Schengen border used both by ferries and cruise ships.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td></td>
<td>• TC1: Enrolling 4 fingerprints</td>
</tr>
<tr>
<td></td>
<td>o With new equipment</td>
</tr>
<tr>
<td></td>
<td>o With existing equipment</td>
</tr>
<tr>
<td></td>
<td>• TC4: Enrolling live facial image</td>
</tr>
<tr>
<td></td>
<td>• TC6: Capturing the facial image from an eMRTD</td>
</tr>
<tr>
<td></td>
<td>• TC7: Verifying the facial image captured from the eMRTD against the enrolled live facial image</td>
</tr>
<tr>
<td>Test location</td>
<td>TC1, TC4, TC6, TC7: Ponte Caracciolo - entry area (pedestrian + vehicle lane)</td>
</tr>
<tr>
<td>Staff involved</td>
<td>8 border guards were trained and participated in the tests to varying degrees depending on their work schedules.</td>
</tr>
<tr>
<td>Total duration</td>
<td>Assistance leading the volunteering cars to the dedicated lane</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td><strong>10 weeks in total</strong></td>
</tr>
</tbody>
</table>
| Timetable      | • TC1 new equipment, TC4, TC6, TC7: From 15.07.2015 to 11.09.2015 (9 weeks)  
|                | • TC1 existing equipment, TC4, TC6, TC7: From 14.09.2015 to 21.09.2015 (1 week) |
| Sample size    | **Fingerprints**  
| (target / actual) | • TC1: New equipment 600 / ~1670  
|                | • TC1: Existing equipment 600 / ~189 *  
|                | **Facial image**  
|                | • TC4: 1550 / ~1600  
|                | • TC6: 1550 / ~1600  
|                | • TC7: 1600 / ~1600  
| Process layout | TC1, TC4, TC6, TC7: Existing manual booth with two stations, one for pedestrians and one for cars (Dedicated lane; Done at the regular border guard booth) |
| Integration within the regular border-crossing process | **Integrated**: Process steps are integrated in the normal border-crossing process |
| Technical integration | TC1, TC4, TC6, TC7: **Integrated** with the standard border check |
| Type of device | **TC1**:  
| | • New 4FP fixed contact fingerprint scanner  
| | • Existing 1FP scanner  
| | **TC4**: New web camera (single-shot) placed on top of the computer (no integrated lighting system)  
| | **TC6**: Existing eMRTD reader, Fixed, Full-page  
| | **TC7**: New local facial image matching system |
| Quality thresholds | **Fingerprints**  
| | • TC1: NFIQ 2-2-2-3  
| | **Facial Image**  
| | • TC7: The live facial image quality is assessed based on specific vendor’s quality algorithm. It is considered successfully captured when it is verified against the FI contained in the passport’s chip. A threshold for the verification algorithm was agreed together with the integrator. |
| Environmental device | Available  
| | One environmental measurement device was located inside each of the dedicated booths, to measure light, humidity and temperature. |
| Travellers’ feedback | After test completion: Self-service tablet |
| Data protection | Verbal consent requested |

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*109 Due to technical constraints related to the necessary software development, only a reduced number of participants, below the target sample size of 600 travellers, could be involved in the tests within the Pilot timeline.*
Workflow

At a given time, volunteering TCNs over 18 years old, could participate in one of the following test cases:

- TC1 with new equipment, TC4, TC6 and TC7 - i.e. four fingerprints enrolment and facial image capture and verification between live and photo extracted from eMRTD;
- TC1 with existing equipment i.e. four fingerprints enrolment with each finger captured individually.

eMRTD holders participate in all tests, while non eMRTD holders participate only in TC1 (fingerprints).

The workflow is described in details hereafter.

Fingerprints enrolment

1. TC1: New 4FP scanner to enrol of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).

   Fingerprints for the index, middle, ring and little fingers for the right hand of volunteering TCNs are captured using a fixed 4FP contact scanner.

   The software configuration enforces the retry in case the quality of any of the fingers is below a defined threshold level - up to three times. Only those fingers which did not reach the quality level are recaptured.

   Detailed real time feedback during the capturing process is provided to the border guard in the user interface, as well as to the traveller by means of green lights on the scanner. In addition, the scanner incorporates its own quality control (based on vendor specific algorithm) during the capturing process (auto capture). The border guards have the possibility to force the capture if the auto capture takes too long.

2. TC1: Existing 1FP scanner to enrol 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).

   Fingerprints for the index, middle, ring and little fingers for the right hand of volunteering TCNs are captured using a fixed 1FP contact scanner, capturing one finger at a time starting by the index finger.

   For each individual finger, the software configuration enforces the retry in case the defined threshold quality level has not been reached. In that case, a new attempt to capture that individual finger is made up to three times. In case a finger cannot be successfully enrolled after a third attempt, the capture of the next fingers is aborted.

   Detailed real time feedback during the capturing process is provided to the border guard in the user interface, as well as to the traveller by means of green lights on the scanner. In addition, the scanner incorporates its own quality control (based on NFIQ) during the capturing
Facial image related test cases

- **eMRTD reading and extraction of the FI**
  The eMRTD is placed in a document reader, which performs the following operations:
  - Extract the alphanumeric information from the document to consult all relevant databases;
  - Perform Passive Authentication of the chip to verify the certificate;
  - Retrieve the picture / facial image from the chip;
  - Measure the quality of that picture according to the vendor specific algorithm.

- **FI enrolment**
  The live capture of a traveller’s facial image is done by means of a webcam, used by the border guard to take individual pictures of the traveller. The camera is attached to the monitor of the border guard work station and cannot therefore be easily adjusted. The camera does not incorporate an integrated light system.

- **Verify FI captured from eMRTD against live facial image**
  The border guard manually selects the option to perform a comparison between the facial image just captured and the one retrieved from the eMRTD. The verification result is based on vendor’s specific algorithm, with a threshold corresponding to a FAR of 0.02%. If the verification score is below a given threshold, then the comparison is retried by capturing a different live facial image up to three times.

- **FI enrolment and verification of FI captured from eMRTD against live facial image (combined process)**

  ![Figure 323: Genoa - facial image test cases (TC4, 6 and 7) and fingerprint enrolment steps](image)

6.2.1.2. Participation and sample characteristics

The below graphs show the main characteristics of the sample, consisting of approximately 2500 travellers.

As can be seen the proportion of men is much higher than women, which is related to the cultural background of the travellers. The vast majority was aged between 31 and 50 years old.

Regarding the nationality of the participants, almost all of them were North-Africans, mainly from Morocco (eMRTD holders) or Tunisia (non eMRTD holders). Most of them had an EU resident permit, which was checked during the border control process.
6.2.2. Test cases operational and technical results

6.2.2.1. Fingerprints (TC1 with new and existing equipment)

Success / failure

Thresholds based on NFIQ values (NFIQ ≤ 2 for index, middle and ring finger; NFIQ ≤ 3 for the little finger) have been implemented in the operational tests, with enforced re-attempts (up to three captures) in case the required quality is not achieved for all fingers.

For the 4FP scanner, for each attempt, the system would retain only fingerprint images with a better quality score than the previous attempt; for this reason second and third attempts would become successful as soon as the finger(s) which previously failed to reach the threshold, reaches it.

The following charts illustrate the proportion of travellers for whom it was possible to enrol four fingerprints with the required level of quality at the last attempt, depending on the equipment used.

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Figure 324 Genoa - sample distribution by gender

Figure 325 Genoa - sample distribution by age

Figure 326 Genoa - sample distribution by nationality

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The country codes used in the graph are the three-letter country codes defined in ISO 3166-1: http://www.nationsonline.org/oneworld/country_code_list.htm
As can be observed:

- The global success rate for the whole hand, (i.e. above the threshold) is higher using the new equipment (4FP scanner) compared to the existing equipment (1FP scanner): Using the new equipment, 84% of the participants could successfully enrol all four fingers of the right hand with the required level of quality. When the existing equipment was used instead, 70% of the enrolments were successful;
- For the 1FP scanner, given that the enrolment is attempted up to three times per finger in order to reach the required quality level, for 22% of the participants the process was aborted at some point and not all fingers were captured;
- If we analyse individual finger’s success rate, the new equipment shows as well better results than the new equipment. This is especially the case for the right index, for which the failure rate with the 1FP scanner almost duplicated the 4FP scanner failure rate. Around 87% of individual fingers were successfully enrolled with the 4FP scanner.

**Figure 327 Genoa - TC1 success and failure rate with contact device at NFIQ 2.2.2.3 threshold**

*Quality*

*Quality measurement of individual fingerprints in Genoa is based on NFIQ and number of minutia.*
The distribution of NFIQ values for each individual finger obtained with a single attempt with each of the equipment is shown below:

\[1\text{FP SCANNER} \quad 4\text{FP SCANNER}\]

\[\text{Figure 328 Genoa - TC1 NFIQ score}\] \(\text{per finger captured at the first attempt}\)

In order to complement the indication provided by NFIQ, the figures below illustrates the distribution of minutiae for each individual finger for TC1 with new and existing equipment.

\[1\text{FP SCANNER} \quad 4\text{FP SCANNER}\]

\[\text{Figure 329 Genoa - TC1 minutiae amount per finger at the first attempt}\]

The following observations can be made:

- New scanner (4FP) presents better results for all fingers both in terms of quality scores and amount of minutia;
- Both scanners present similar distribution for all fingers, both in terms of quality scores and minutiae. The ring and middle finger obtain slightly higher values than the index and little finger - the worst values correspond to the little finger and the best, to the ring finger in all cases;
- For both scanners, the quality registered is very good. The vast majority of fingers present a quality score that

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\(^{106}\) Only valid NFIQ scores (1-5) are considered.
corresponds to NFIQ 1 or 2, and almost all fingers have NFIQ values below 4, regardless of the FP scanner used for the capture. This may be influenced by the auto capture feature implemented, which performs a live assessment of the quality of the FP and stops the capture when the fingerprints reach a sufficient quality\textsuperscript{107}. The real time feedback provided both to the border guards and the travellers is also likely to have a positive impact on the quality of the FP captured.

**Duration**

The duration of fingerprint enrolment is measured in order to assess the added duration compared to the current situation where no biometric identifier is enrolled. Time-stamped log files, produced by FP scanners, were used to measure the duration of this step.

The points of measurement for duration of TC1 are set as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The start of FP capture either by placing the slap in the 4FP scanner or an individual finger for the existing equipment.</td>
<td>1. The capture of all four fingers or failure after three attempts.</td>
</tr>
</tbody>
</table>

The distribution of the process step duration for capturing all four fingers is shown below, for both devices used:

- **1FP SCANNER**
- **4FP SCANNER**

![Figure 330 Genoa - TC1 duration with contact scanner (in seconds)](image)

The following observations can be made:

- It takes in general half the time to enrol 4 fingerprints with a 4FP scanner than capturing one finger at a time. The median time is around 15 seconds for the 4FP scanner, and 30 seconds for the 1FP scanner;
- Capturing one finger at a time, the enrolment of four fingers takes between 15 and 30 seconds for half of the travellers, and between 30-60 seconds for the majority of the rest of travellers. This means that for 90% of the participants, the process took less than one minute;
- The vast majority of participants (76%) can capture the four fingerprints using a 4FP scanner in less than 30 seconds, and almost half of all participants could do it in less than 15 seconds.

**Impact of the reattempts on success, quality and duration**

\textsuperscript{107} Auto capture quality thresholds are configured within the device by the vendor.
In the case of using the new equipment (4FP scanner), it is worth analysing how each of the attempts influence this global duration\(^{108}\). Analysing the results for Genoa considering the participants whose FP were captured using the 4FP scanner:

- 76% of the cases required only one FP capture attempt;
- 12% of the cases required two FP capture attempts;
- 12% of the cases required three FP capture attempts.

The duration of the process depending on the amount of attempts performed is shown in the figures below.

![Figure 331 Genoa - TC4 FP capture duration with 4FP scanner depending on the amount of attempts (in seconds)](image)

As can be observed, for the 4FP scanner, each further retry added around 17 seconds to the process looking at the median, which is slightly over the duration of a single attempt. When only one attempt was done, 62% of the cases took less than 15 seconds; the proportion decreased to 46% when two attempts took place and only 1% when three reattempts were needed.

With regards to the effect of re-attempt policy on the success of the enrolment, it was observed that subsequent captures provided decreasing benefits to the overall success/failure rate. The figure below shows the success rate for each attempt. The second attempt improved the overall success failure rate in approximately 11% and the third attempt improved it a further 6%.

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\(^{108}\) In the case of the 1FP scanner, it is not possible to show the breakdown per attempts.
6.2.2. Facial Image Results (TC4, TC6, TC7)

Regarding facial image, the following test cases were performed:
• Retrieval of the facial image from the eMRTD chip (TC6);
• Enrolment of a live facial image (TC4);
• Comparison, verification of the two above (TC7).

As all three test cases are highly related to each other, this section will analyse the results from a joint perspective and specific aspects of individual test cases are presented when relevant.

Success / failure

The purpose of the facial image tests are to perform local automated bearer verification at the border based on the facial image biometric identifier, by comparing the facial image captured from the passport chip (TC6) and the live facial image captured (TC4). Therefore, the success condition for all three test cases jointly is the successful verification of the facial image:

- a. The facial image can be accessed and retrieved from the eMRTD without errors
- b. The enrolment of the live facial image is successful
- c. The verification score is above the set threshold, which was proposed by the vendor together with the integrator based on their experience in similar systems, corresponding to a stringent FAR of 0.01%. In case the threshold is not reached, a new facial image will be captured live and the matching will be reattempted - until three times. \(^{109}\)

The graph below presents the overall success rate for overall facial image related test cases at Genoa sea port.

\(^{109}\) For the FI matching, all data presented in this analysis considers all attempts made up to three.
The following observations can be made regarding the figure presented above:

- For the vast majority of cases the FI verification was successful (87%);
- Errors with the passport chip were negligible. Therefore, those cases with failure are only related to a failure of the verification itself;
- During the tests performed in Genoa the occurrences with Passive Authentication error was negligible. This result is influenced by the characteristics of the sample for eMRTD which was composed almost solely of Moroccan passports.

**Quality**

The quality of the facial image was evaluated based on the specific vendor quality index\(^{110}\). The graph below presents the quality score results, both for the facial images retrieved from the eMRTDs and the live facial image captured at the manual booth.

![Figure 334](image)

*Figure 334* Genoa - TC4 and TC6 quality score comparison between live and chip facial image based on vendor’s algorithm

It can be observed that both the live FI and FI from the chip are considered as having sufficient quality to perform a verification in almost all cases. Live facial image scored just slightly worse. This can be explained by the fact that up to three attempts were made for its capture.

**Duration**

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader;</td>
<td>1. To the result of the eMRTD FI acquisition (success or failure), including the time to perform the passive authentication.</td>
</tr>
<tr>
<td>2. From the start of the live image enrolment;</td>
<td>2. To the successful enrolment of live image or timeout (if relevant);</td>
</tr>
<tr>
<td>3. From the start of the facial image verification.</td>
<td>3. To the outcome of the facial image verification.</td>
</tr>
</tbody>
</table>

\(^{110}\) Specific vendor scores will not be analysed, and they are presented only for the purpose to allow comparison of the quality scores between the live and chip facial image. Absolute values of the scores will not be assessed.
The overall duration of the facial image related test cases can be analysed by estimating the duration of each individual step. The combination of the individual time of these steps will depend on the specific process workflow:

1. Extract facial image form the eMRTD;
2. Perform Passive Authentication of the chip;
3. Enrolment of the live facial image (up to three attempts);
4. Verification of live and chip facial image.

The following figures show the distribution of durations obtained for each of the above steps:

**Figure 335** Genoa - TC6 facial image from the chip retrieval duration for eMRTD holders (in seconds)

**Figure 336** Genoa - TC4 live facial image enrolment duration for eMRTD holders (in seconds)

**Figure 337** Genoa - TC6 facial image verification duration for eMRTD holders (in seconds)

**Figure 338** Genoa - TC7 facial image verification duration for eMRTD holders (in seconds)

The following observations can be made:

- The atomic durations for retrieval, passive authentication and verification are all below 2 seconds (with average values below the seconds);
- The duration of the verification process is in general negligible, given that it takes in average 0.06 seconds;
- The main contribution for the duration of the FI related test cases corresponds to the capture of the live facial image, which usually takes around 4 seconds. In 66% of the cases, it takes less than 5 seconds, and for almost all participants, it takes less than 15 seconds.
Duration impact on the end to end process

It is worth analysing, from a time perspective, how the introduction of the new biometric steps would influence the global duration of the current border check process - where no biometric identifier is involved. For this aim, the estimated duration of the tests cases described above is compared to:

a. The baseline measurement: duration of the current border check process;
b. The global end to end time for the border check modified by the testing, which includes depending on the case:
   i. Facial image related test cases;
   ii. 4 FP enrolment with new or existing equipment;
   iii. 4 FP enrolment with new equipment and facial image related test cases.

The actual testing took longer as there was a significant idle time: the travellers had to step out of the car and enter the manual booth to provide the biometrics. This time was very variable but could be estimated to amount to an average of additional 10 seconds. In the standard current process the border check takes place inside the car, as the car stops by the booth window.

This idle time is not considered in this section, as it depends on the specific layout, which can be optimized in order to minimise the overhead (such optimisation could not be implemented within the scope of the pilot as they would entail infrastructural changes).

The following table summarises the average times resulted from the testing, looking only at the technical logs analysed:

Table 66 Genoa - duration impact on the end to end process

<table>
<thead>
<tr>
<th>Aspect under measurement</th>
<th>Median duration (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline(^{111})</td>
<td>32</td>
</tr>
<tr>
<td>End to end border check process including the test cases execution:</td>
<td></td>
</tr>
<tr>
<td>- 4 FP enrolment with new scanner (4FP) and FI related test cases</td>
<td>62</td>
</tr>
<tr>
<td>- 4 FP enrolment with new equipment (4FP)</td>
<td>40</td>
</tr>
<tr>
<td>- 4 FP enrolment with existing equipment (1FP)</td>
<td>45</td>
</tr>
<tr>
<td>- Facial image related test cases</td>
<td>41</td>
</tr>
<tr>
<td>Retrieval of the FI from the chip(^{112})</td>
<td>0.8</td>
</tr>
<tr>
<td>Facial image enrolment and verification</td>
<td>4</td>
</tr>
<tr>
<td>4 fingerprint enrolment with 4FP scanner</td>
<td>15.4</td>
</tr>
<tr>
<td>4 fingerprint enrolment with 1FP scanner</td>
<td>29.6</td>
</tr>
</tbody>
</table>

\(^{111}\) The baseline measurement was made by means of a system logs a sample of 500 travellers. It was measured as the time when the border guard starts places the passport in the passport reader until the technical steps are completed for the traveller. It does therefore not include the time it takes to approach the booth or stamp the passport, and is thus analogue to the manner the rest of durations of the table were calculated.

\(^{112}\) Usually done in parallel with the other steps.
From the values in the table above, it can be observed:

- The time required for the 4FP enrolment depends on the equipment used and it represents a meaningful part of the end to end time:
  - With the new equipment (4FP):
    - 25% of overhead to the baseline;
    - 38.5% of the border check process when only fingerprints are enrolled;
    - 25% of the border check process including FI related test cases and 4 FP enrolment.
  - With the existing equipment (1FP):
    - 40% of overhead to the baseline;
    - 66% of the border check process when only 4 fingerprints are enrolled.

- The time required for the facial image enrolment and verification alone represents around:
  - 28% of overhead to the baseline;
  - 10% of the end-to-end process when it includes only FI related test cases;
  - 6.5% of the end-to-end time including the 4FP enrolment with a 4FP scanner as well.

- The end-to-end time shows that including these further steps increase the baseline time of the current process by:
  - 25% when 4 fingerprints are enrolled with the existing equipment (1FP);
  - 40% when 4 fingerprints are enrolled with the new equipment (4FP);
  - 93% when 4 fingerprints are enrolled with the new equipment (4FP) and the live FI is enrolled and verified.

The inclusion of FI related test cases compared to the process where 4FP are enrolled with the new equipment increases the end to end duration by 50% and vice versa.

### 6.2.3. Users’ perception

#### 6.2.3.1. Travellers’ survey

In total, 1593 entries (corresponding to around 96% of the participating travellers) were recorded.

Travellers’ feedback was recorded for the test cases taking place at a given time, and not individually for the different test cases. The results collected in Genoa are summarised in the chart below, and corresponds to 1700 answers - 68% of the participating travellers:

![Genoa TC1, TC4, TC6, TC7](Image)

*Figure 339 Genoa - results of the travellers’ survey*
The following observations can be made:

- Respondents are in general satisfied or very satisfied with the new biometric related steps;
- 20% of the respondents expressed dissatisfaction. This could be related to the fact that the new process implied stepping out of the vehicle and going inside the manual booth, which is different to the standard process where the check is done inside the car by approaching the booth window, and also resulted in longer idle time.

### 6.2.3.2. Border guards’ feedback

2 border guards participated and replied to the survey from Genoa sea port for fingerprint enrolment and facial image related test cases. Regarding fingerprint enrolment, different feedback has been gathered depending on the specific equipment used: new equipment (4FP scanner with slap technology); and existing equipment (one finger scanner).

The following dashboard presents a summary of replies.

**Table 67 Genoa - TC1, TC4, TC6 and TC7 border guards’ feedback**

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Feedback</strong></td>
<td>The experience is similar for the new and existing equipment. In both cases the enrolment process goes smoothly in general. In some cases with the 4FP scanner travellers require more assistance.</td>
<td>Some travellers complained of the additional time spent waiting in queue.</td>
</tr>
<tr>
<td><strong>Impediments</strong></td>
<td>Problems with direct light, especially affecting the FP scanner. Some people with big hands have issues using the 4FP scanner. Scanner needs to be cleaned often. Humidity layer on the scanner due to the temperature difference. FI matching problems when the photograph in the passport is very old.</td>
<td>Guidance and assistance to the traveller is needed and can be improved or increased. Cultural difficulties to assist women; a female border guard was required.</td>
</tr>
</tbody>
</table>
Based on the qualitative replies, the following observations and conclusions should be highlighted:

- The aim of the pilot was welcomed;
- The equipment and technical solution do not bring difficulties;
- The set-up played an important role;
- The booths are not intended to accommodate travellers inside;
- Travellers had to get out the car, which was more complicated in case of families;
- Environmental conditions and ergonomics shall be taken into consideration;
- To make the process more performant and smoother;
- To improve the experience of the travellers.

### 6.2.4. Constraints

#### 6.2.4.1. Environmental conditions

The set-up of the testing was constrained by the limited space and infrastructure conditions of the location. Some small variations were made for the purpose of the pilot, which did not always prevent direct sunlight, which affected the performance of the biometric capture.

In addition, the temperature difference between the outside and inside the booth created occasional humidity problems which required cleaning and dry the FP scanner surface.

No other issue was identified regarding the environmental conditions. Even if the environmental measurement device shows different temperature, humidity and light values under which the tests were performed, this does not seem to affect the tests results.

In Genoa, environmental measurement devices were deployed to monitor temperature, humidity and light throughout the entire testing period. It was placed at the inside of the manual booth, which is outdoors. Border guards reported about difficulties with the device that would be linked with environmental conditions (e.g. light and humidity). As can be seen in the table below, during the entire testing period, the temperature ranged from a minimum of 13.5° to 35.3° Celsius.

**Table 68 Genoa - maximum, minimum and average of temperature, humidity and light**

<table>
<thead>
<tr>
<th></th>
<th>Temperature (°C)</th>
<th>Humidity (RH%)</th>
<th>Light (Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>17.8°</td>
<td>32.7%</td>
<td>3.16</td>
</tr>
<tr>
<td>Max</td>
<td>31°</td>
<td>91%</td>
<td>33698.42</td>
</tr>
<tr>
<td>Average</td>
<td>24.60°</td>
<td>58.26%</td>
<td>951.33</td>
</tr>
</tbody>
</table>

**Observations**

Vast majority between 21° and 29°
Vast majority between 40% and 79%
Vast majority between 300 and 5299
6.2.4.2. Others

Physical limitations of the existing infrastructure

The existing infrastructure and physical limitations at Genoa sea port created some challenges to perform the test, as fixed equipment was used for the biometric capture. The only option found for the execution of the testing consisted of asking the travellers to leave the car and enter the booth, which is also very small. This implies a change in the current process and has also a big impact on the border check throughput.

Manual workers FP

The typology of travellers transiting through Genoa includes a significant portion of manual workers whose fingerprints.

6.2.5. Main observations

In general, tests worked well and were performed without creating big impacts during the ferry disembark. The tests have proven that it is possible to incorporate biometrics in the existing process, and that it would be feasible to use the existing equipment as well.

It is also clear that the existing infrastructure is not optimized for this purpose, as it creates new logistic problems that should be addressed properly to make the border check quicker and easier to the traveller. The main challenge comes from having the travellers coming out of the cars, especially in the case of families, which introduces a significant delay and difficulties compared to the current process.

Fingerprints

During the test, fingerprints could be enrolled with good quality already at the first attempt; this is likely to be a result of the auto capture feature. Additional attempts increase significantly the time required. The positive contribution of the re-attempts to the overall success failure rate decreases from the second to the third attempt, improving the overall success rate by approximately 15-16%.

The existing equipment captured almost as good quality fingerprints as the new scanner, but it took much longer. Therefore, from an operational perspective the use of the new scanner seems more efficient.

The feedback provided by the border guards concludes that ergonomics could be improved, and the environmental conditions (especially light) should be better controlled as they heavily influence the possibility to capture FP.

Facial Image

The facial image solution at Genoa is very quick and able to perform the bearer verification in an automated and efficient. Light conditions would require the addition of covers to shield the booth against the sunlight, which are currently in place.
6.3. Helsinki – Fingerprints, facial image, ABC gates and kiosks

6.3.1. Test description

Helsinki West terminal receives frequent intra- and extra-Schengen ferry and cruise vessels. In the Smart Borders pilot, tests undertaken with travellers arriving from cruise vessels that had departed St. Petersburg in Russia are described. Specifically, the port receives up to 6 arrivals from St. Petersburg per week, each with 2000-3000 travellers on board on typical days, with peaks during the Christmas holidays. In 2014, 330,000 travellers transited through the arrivals terminal.

Operational tests ran from April to September. A number of test cases were executed throughout this period in the terminal building of the harbour, involving both manual and automated controls. At manual controls at both entry and exit, the feasibility of processes for both fingerprint and live facial image enrolment and comparison of the live image against the facial image of the eMRTD were assessed. The use of automated biometric enrolment kiosks at entry and Automated Border Control (ABC) gates at exit was also examined. Aspects of particular interest at Helsinki port included examination of the viability of using semi-automated kiosks to enrol biometrics and carry out visa checking in the terminal building of a busy port, the use of ABC gates in a harbour environment for the processing of foot travellers and the comparison of the results of manual biometric enrolment with that at other locations - the same set-up was used on the moving cruise ship at Piraeus and at the land border of Vaalimaa.

6.3.1.1. Set-up and configuration

The test cases at Helsinki were set up and configured based on characteristics listed in the table below.

Table 69 Helsinki - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Sea - Helsinki Port is the main port in Finland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td></td>
<td>• TC1: Enrolling 4 fingerprints;</td>
</tr>
<tr>
<td></td>
<td>• TC2: Enrolling 8 fingerprints;</td>
</tr>
<tr>
<td></td>
<td>• TC3: Enrolling 10 fingerprints;</td>
</tr>
<tr>
<td></td>
<td>• TC6: Capturing the Facial image from an eMRTD;</td>
</tr>
<tr>
<td></td>
<td>• TC4: Enrolling a live facial image;</td>
</tr>
</tbody>
</table>
### Test location
- TC1, TC2, TC3: Helsinki West Harbour, terminal building, entry and exit
- TC9: Helsinki West Harbour, terminal building, exit
- TC10: Helsinki West Harbour, terminal building, entry

### Staff involved
- 2 full time translators/assistants (Russian) for all tests.
- 4 Border Guards, 1 supervisor

### Total duration
- **19.5 weeks in total**

### Timetable
- **TC1:** From 15.04.2015 to 08.05.2015 (*3.5 weeks*)
- **TC2:** From 09.05.2015 to 01.08.2015 (*12 weeks*)
- **TC3:** From 03.08.2015 to 02.09.2015 (*4 weeks*)
- **TC4, TC6 and TC7:** From 15.04.2015 to 02.09.2015 (*19.5 weeks*)
- **TC9:** From 23.05.2015 to 03.09.2015 (*14 weeks*)
- **TC10:** From 18.06.2015 to 03.09.2015 (*11 weeks*)

### Sample size (target / actual)

<table>
<thead>
<tr>
<th>Device</th>
<th>Target</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fingerprints</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC1:</td>
<td>600 / 605 (272 at entry and 323 at exit)</td>
<td></td>
</tr>
<tr>
<td>TC2:</td>
<td>1000 / 1059 (618 at entry and 441 at exit)</td>
<td></td>
</tr>
<tr>
<td>TC3:</td>
<td>1000 / 402 (318 at entry and 84 at exit)</td>
<td></td>
</tr>
<tr>
<td><strong>Facial Image</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC4:</td>
<td>1550 / 2050 (1208 at entry and 848 at exit)</td>
<td></td>
</tr>
<tr>
<td>TC6:</td>
<td>1550 / 2050 (1208 at entry and 848 at exit)</td>
<td></td>
</tr>
<tr>
<td>TC7:</td>
<td>1600 / 2050 (1208 at entry and 848 at exit)</td>
<td></td>
</tr>
<tr>
<td><strong>ABC gates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC9:</td>
<td>1000 / 1390</td>
<td></td>
</tr>
<tr>
<td><strong>Kiosk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC10:</td>
<td>1000 / 2260</td>
<td></td>
</tr>
</tbody>
</table>

### Process layout
- TC1, TC2, TC3, TC4, TC6, TC7: 1 lane at exit and 1 lane at entry, both dedicated to pilot testing.
- TC9: Existing ABC gates (two-step integrated): 3 lanes at exit used for normal EU traveller processing and testing with TCNs in parallel
- TC10: Self-Service kiosk. Two enrolment kiosks plus one verification kiosk in front of a manual booth

### Integration within the regular border-crossing process
- **Integrated:** Process steps were integrated in the normal border-crossing process

### Technical integration
- TC4, TC2, TC3, TC6 and TC7: **Standalone** development for the purposes of testing
- TC9: **Fully integrated** with Finnish Border Guard National System
- TC10: **Standalone** development for the purposes of testing

### Type of device
- TC3: **New 4FP fixed contact fingerprint scanner - optical**
- TC4: **Standard web-camera (single-shot)**
- TC6: **New flatbed eMRTD reader**

### TC7: Verifying the facial image captured from the eMRTD against the enrolled live facial image;

### TC9: Executing Automated Exit Checks for TCNs;

### TC10: Using Self-service Kiosks for biometric enrolment and/or traveller processing.
### Quality threshold

**TC7:** Matching software from the vendor  
**TC9:** Existing two-step integrated ABC gates, adapted to accommodate TCNs  
**TC10:** New biometric enrolment kiosks (two enrolment kiosks each with an optical 4 fingerprint scanner, flatbed document reader and standard webcam with automated height adjustment integrated) and a new verification kiosk with a high-resolution camera with automated height adjustment.

### Environmental device

<table>
<thead>
<tr>
<th>Environmental device</th>
<th>N/A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Traveller’s survey</th>
<th>After test completion: Self-service tablet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data protection</td>
<td>Verbal consent requested</td>
</tr>
</tbody>
</table>

### 6.3.1.2. Workflow

**Fingerprints enrolment**

1. **TC1:** Enrolment of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).
   
   a. The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were captured using a standard optical live-scan device.

   ![Figure 340 Helsinki - TC1 (4 FPs enrolment) steps using contact scanner](image1)

2. **TC2:** Enrolment of 8 fingerprints (index, middle, ring and little fingers for both hands)
   
   a. The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were firstly captured followed by those of the left hand. (4-4 method).

   ![Figure 341 Helsinki - TC2 (8 FPs enrolment) steps using contact scanner](image2)
3. TC3: Enrolment of 10 fingerprints (index, middle, ring, little fingers and thumbs for both hands)

   a. The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were captured in the first step, followed by those of the left hand. The thumbs of both hands were captured in the final step of fingerprint enrolment.

   The fingerprinting process proceeded as follows:

   1. The border guard chose 4-, 8- or 10-fingerprints enrolment through mouse click;
   2. The traveller, given instructions, placed his/her fingers onto the sensor. LEDs indicated suitable positioning and pressure of the fingers. If unsuccessful according to set thresholds, re-enrolment for the whole slap could be attempted to a maximum of three attempts per 4-fingerprints (or 2-thumb prints) set. Re-enrolment was activated manually;
   3. Within the border guard’s software, tiered thresholds were applied; thus, if the fingerprints reached a designated upper threshold, they were highlighted in green; with intermediate quality they were highlighted in orange; otherwise they were marked in red. Re-enrolment was encouraged whenever any finger due to be enrolled failed to be marked as green.

Facial image

The test cases were executed sequentially and as a combined process according to the following sequence of three steps:

   1. TC6 - Passport inspection (including Passive Authentication) and retrieval of the facial image from the eMRTD (this step was in fact carried out as the first step of the process, followed by fingerprint capture. Steps 2 and 3 below followed subsequently);
   2. TC4 - Enrolment of the live facial image (photo) from the TCN;
   3. TC7 - Verification of the facial image captured from the eMRTD chip against the live facial image enrolled from the TCNs.

   A standard web-camera was used for live facial image enrolment. Auto-focus functionalities were implemented. The software automatically zoomed and cropped the obtained image in order to enforce ICAO-type results. Facial image matching proceeded automatically and the comparison score displayed with an indication as to whether the suggested score was exceeded. Re-enrolment of the facial image was suggested by the software up to 3 times in case of matching failure. The facial image from the chip was obtained using a flatbed (i.e. full page) document scanner.
ABC gates

The process for passage through the ABC gates encompassed the following steps:

1. Reading of the MRZ and eMRTD of the passport, visual and electronic passport authentication and formatting of data for use by the system and interrogation of national and European databases;

2. Capture of the facial image from the eMRTD’s chip (accomplished within step one but considered herein as a separate process to aid analyses below);

3. Enrolment of a live facial image;

4. Verification of the facial image from the eMRTD’s chip against the live facial image. If the verification failed (i.e. a result below threshold was obtained), steps 3 and 4 were repeated;

5. Stamping of the document to record the border-crossing at a manual booth after crossing the ABC gate.

The ABC gates at Helsinki airport were typical integrated two-step gates with man-trap.

![Figure 344 Helsinki - ABC gates test case (TC9) set-up (two-step process with man-trap)](image)

Steps 1 and 2 above were accomplished at the first step undertaken outside the mantrap. If successful, the traveller moved to a second stage where biometric verification (including the verification of the live Fl against the image retrieved from the eMRTD chip) was carried out. Any checks of national or European databases or other parallel processes were run in parallel throughout the whole process.

Self-Service Kiosk

The self-service kiosk provided for a semi-automated border check procedure. The traveller first presented himself/herself at one of two biometric enrolment kiosks. At these kiosks, the following steps were implemented:

1. The traveller selected his/her preferred language (Russian or English);

2. The traveller placed his/her document onto the document reader for reading of the MRZ and eMRTD and visual/electronic document verification;

3. Subsequently and if necessary, the traveller proceeded to place their visa onto the document reader device for query of the VIS (the majority of travellers were Russian as above, and hence visa scanning was needed, although as VIS had not rolled out with biometrics in Russia at the time of testing, biometric checks were not necessary for the purposes of border control);

4. He/she proceeded to answer a series of questions probing one’s purpose of stay in the country and his/her financial resources;

5. He/she chose whether to enrol four fingers from either the right or left hand using the touch screen interface and then proceeded to enrol the fingers; in case that the prints enrolled below the implemented threshold of NFIQ≤4, up to 2 re-enrolment attempts were made;

---

113 The five steps have been defined to permit judgement to be made on whether to allow the traveller to pass without manual intervention and are applicable to all BCPs.

114 As defined in the Frontex Best Practice Operational Guidelines for Automated Border Control (ABC) Systems, Frontex, 2012.

115 Ibid.
6. Enrolment of the live facial image proceeded automatically as a final step in the process.

At the second stage of the process, the traveller presented him-/herself at a verification kiosk equipped with a high quality camera. At this station, a second live facial image was enrolled (the camera had automatic height adjustment and autofocus capabilities) for the purposes of 1:n searching through the database of facial images enrolled on that day (all images were deleted at the end of each day, the maximum number of images in the database at any time was approximately 50 images). Based on the result of the identification process, the data for the presenting traveller was brought onto the border guards’ screen for completion of the process at the manual booth. The coordinating border guard stamped the passport as well as verifying any information brought forward on the screen.

6.3.1.3. Sample characteristics

The majority of travellers participating in the tests in Helsinki were women, with a 60% share of total participants. The majority of participants were aged between 31 and 50, with few travellers over 70 participating. The vast majority of travellers were Russian.

*Figure 345* Helsinki - sample distribution by gender

*Figure 346* Helsinki - sample distribution by age

*Figure 347* Helsinki - sample distribution by nationality
6.3.2. Test cases operational and technical results

6.3.2.1. Fingerprints (TC1, TC2, TC3)
Tests for the enrolment of 4, 8 and 10 fingerprints were executed at a manual booth alongside tests on facial image enrolment and verification.

Success / failure
Fingerprint enrolment was considered successful if the vendor’s threshold was reached at the first attempt. A second enrolment attempt was made in 26% of cases and a third attempt in 5% of cases. Because of operational pressures, border guards felt unable to force re-enrolment attempts in all cases despite the thresholds not being reached - this was noted to have been the case in approximately 60% of cases in which the first enrolment had at least one finger below threshold. Thus, it may be assumed that the overall success rates shown below might be improved if 3 enrolment attempts were always made.

For the purposes of assessment, an analysis has been carried out on the basis of the standard advised NFIQ thresholds within the pilot, namely values of 1 or 2 for the thumb, index, middle and ring fingers and 1, 2 or 3 for the little finger. Noting that the vendor threshold included assessment of NFIQ scores, this approach is considered applicable and sensible. The figure below shows the success/failure rate for TC1, TC2 and TC3 following application of the NFIQ-based threshold.

![Figure 348](image)

**Figure 348 Helsinki - TC1 success and failure rates with contact devices at NFIQ 2-2-2-3 threshold after all attempts**
As can be seen in the above figure, the success rate for TC1 was 35%. Around 1 in 5 attempts resulted in an error or acquisition failure.

![Figure 349](image)

**Figure 349 Helsinki - TC2 success and failure rates with contact devices at NFIQ 2-2-2-3 threshold after all attempts**
For TC2, the overall success rate was 16%. 50% of attempts resulted in an error or acquisition failure. The results for the right hand and left hand were similar. Comparing the success rate of the right hand with the results of TC1 (35%), we can observe a lower success rate in this case (27%).
The overall success rate for TC3 was 14% with the majority of attempts resulting in an error or acquisition failure. The results for the right hand and left hand were similar. The success rates for the right hand and left hand were identical to those in TC2 at 27% and 26% respectively.

**Quality - NFIQ**

The quality of fingerprints enrolled was assessed using both NFIQ version 1 scores and the number of reliable minutiae in each print.

As mentioned, it was the case that some fingerprint enrolment attempts presented at least one finger that failed to be enrolled - this occurred in approximately 30% to 40% of first enrolment attempts (of either the right hand, or the left hand, or the two thumbs). The results presented do not take into account such fingerprints. Thus, the overall results will be slightly worse than those displayed in the graphs below.

**TC1**

NFIQ scores between 1 and 3 were obtained in the majority of cases. Fingerprints from the little finger were of lowest quality; those for the index, middle and ring fingers were of similar quality overall.

Approximately one in two fingerprints captured could be considered to be of good quality (NFIQ 1 or 2) and one in three of average quality (NFIQ 3).
**TC2**

![Figure 352](image) Helsinki - TC2 NFIQ scores per finger at the first attempt with contact scanner

Generally, the quality of prints from the left hand was less than with the right hand. This may be related to the fact that the fingerprinting device was mounted on the right hand side of the booth from the beginning (as TC1 was executed at Helsinki port in the first few weeks). This positioning meant that enrolment of the left hand was difficult and therefore the device was moved to a more central position after some time.

**TC3**

![Figure 353](image) Helsinki - TC3 NFIQ scores per finger at the first attempt with contact scanner

As for TC2, the percentage of good quality fingerprints (NFIQ 1 or 2) lower for the left hand than for the right. As the fingerprinting device had been moved to a more central location prior to testing 10-finger enrolment, this result is less easily explained than for TC2. One might suggest that travellers are better able to enrol higher quality fingerprints from the dominant right hand at least with the set-up used at Helsinki port. The thumbs gave prints of higher quality than other fingers, with approximately three in five being rated good quality (NFIQ 1 and 2). The quality distribution across fingers was comparable to TC1.
6.3.2.2. Quality - Minutiae

The presence of a reasonable number of reliable minutiae is important for fingerprint comparison, therefore the number of minutiae detectable in each fingerprint image was also recorded as a measure of print quality. The graphs below illustrate the distribution of minutiae per finger for TC1, TC2 and TC3.

TC1

![Minutiae distribution chart for TC1](image)

**Figure 354 Helsinki - TC1 minutiae amount per finger at the first attempt with contact scanner**

The number of minutiae identified was relatively low with approximately 50% of fingerprint images having less than 30 minutiae and less than one in ten having more than 60 detectable minutiae. Prints from the little finger typically had very few minutiae, with only one in six fingerprints presenting more than 30 minutiae.

TC2

![Minutiae distribution chart for TC2](image)

**Figure 355 Helsinki - TC2 minutiae amount per finger at the first attempt with contact scanner**

The number of minutiae in the prints obtained in TC2 testing was low as for TC1. Contrary to NFIQ values, the prints from the left hand seemed to be of higher quality than those from the right hand in terms of the number of minutiae. Further assessment would be required to examine which of the quality metrics measured is most relevant and this would likely depend on the AFIS used to compare data and the nature of the data that it worked with.

TC3
As for TCs 1 and 2, overall fingerprint quality assessed by number of minutiae was relatively low. However, the thumbprints were something of an exception, with four out of five thumbprints having more than 30 minutiae. This correlates with results based on NFIQ scores described above.

Duration

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The first attempt to capture the FP;</td>
<td>1. The successful capture with a maximum of 3 attempts or the end of the third attempt;</td>
</tr>
<tr>
<td>2. The start of the successful capture.</td>
<td>2. The successful capture with a maximum of 3 attempts or the end of the third attempt.</td>
</tr>
</tbody>
</table>

The duration of fingerprint enrolment was extracted from system logs.

Note that for TC1 and TC2, enrolment durations were calculated per single attempt (i.e. per enrolment from one set of fingers placed onto the sensor) from the time that the border guard activated the enrolment attempt by mouse click through to the complete enrolment of the required number of fingers.

**TC1 - duration of one enrolment attempt**

The graph below shows the distribution of enrolment durations for one attempt.

![Figure 357 Helsinki - TC1 duration per attempt with contact scanner (in seconds)](image)
Three quarters of attempts at capturing four fingerprints were completed in less than 15 seconds, and 94% in less than 30 seconds. The average duration of one attempt to capture four fingerprints was 14 seconds.

**TC2 - duration of one enrolment attempt**

Because of the modular set-up of the device in Helsinki, enrolment times provided in the frame of TC2 testing were for those of the left hand only. The recorded attempt was the last one executed.

![Helsinki - TC2 left hand enrolment duration per attempt (in seconds)](#)

In order to allow better comparison with results presented elsewhere in this report the average value for enrolment of the right hand (coming from TC1, 13.6 seconds) was added to the obtained data in order to estimate the average and median durations of 8-fingerprint enrolment from both the left and right hands.

![Helsinki - TC2 (8 FPs enrolment) estimated duration per attempt (in seconds)](#)

It may be noted that enrolment of the 4 fingerprints of the left hand was slightly slower than for TC1. Still, around 95% of attempts were made in less than 30 seconds.

It is estimated that the capture of eight fingerprints (assuming one attempt per hand) would take 28 seconds on average.

**TC3 - duration of 10-fingerprint enrolment**

A software update was deployed during the testing phase to allow output of the entire enrolment duration. The graphs presented below show data gathered from this date onwards (90% of the total data gathered).

![Helsinki - TC3 duration per attempt with contact scanner (in seconds)](#)

36 samples were excluded from a total of 402 samples.
One tenth of attempts at capturing ten fingerprints were completed in less than 30 seconds, and 78% in less than 60 seconds. The average duration of ten-fingerprint enrolment was 49 seconds, almost double the previous estimation of capture of eight fingerprints. This highlights a likely underestimation in the figure above, perhaps related to the fact that it only includes time in which the fingers were in contact with the scanner and not the lag time in between attempts with left and right hands for 8-finger enrolment. Additionally, these figures include any re-enrolment attempts undertaken, unlike those above for TCs 1 and 2.

6.3.2.3. Facial image related test cases

Regarding facial image the following test cases were performed:

- Retrieval of the facial image from the eMRTD chip (TC6);
- Enrolment of a live facial image (TC4);
- Comparison of the two images (TC7).

As the different tests were undertaken together during tests, this section will analyse the results obtained in combination although analysis of specific aspects related to individual test cases is performed when relevant.

Success / failure

In the context of the facial image tests executed at Helsinki port, success is taken to mean successful verification of the live facial image against that obtained from the eMRTD according to the implemented verification threshold. The vendor advised a threshold corresponding to a FAR of 0.1% on large-scale tests that they had undertaken. The graph below highlights the ratio of success to failure according to this measure.

![Graph showing success and failure rate](image)

*Figure 361. Helsinki - TC7 FI related test cases success and failure rate*

It is seen that less than 50% of verifications were successful according to the applied threshold. Frontex advises the application of a threshold corresponding to a FAR of 0.1% in the frame of ABC gate operation. However, it should be borne in mind that conditions in these tests were less controlled than in typical e-gates. Furthermore, a border guard will verify the facial match in person at such a manual booth. Therefore, in future it may be considered that less stringent thresholds might be suitable that would imply a higher success rate.

Document reading errors were not recorded for this test case and, as such, are not presented here.

Retrieved and live FI quality

In Helsinki, enrolment of the live facial image was guided by the display of 20 ICAO-type measures of image quality. If 15 of these 20 measures were enrolled above implemented thresholds, the border guard received an indication that the image was of reasonable quality and could be used for image comparison. He/she could re-enrol if this soft threshold was not reached or if the captured photo displayed on screen appeared to be of low quality visually. A different, composite measure of quality was nevertheless calculated and output in the final dataset although not displayed to the border guard. This quality measure allows comparison of live and chip images.

The graph below compares the facial image captured live with the one captured from the chip according to a threshold provided by the vendor as an indication of good quality.
It can be observed that the quality of the document images was typically higher than that of images taken live at the border. This is almost certainly related to the more controlled environment in which passport photos are taken relative to the terminal environment in which testing was undertaken at Helsinki BCP.

**FI related tests duration**

At Helsinki, the software output information on the durations of live facial image enrolment and facial image verification.

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader;</td>
<td>1. To the result of the eMRTD FI acquisition (success or failure), including the time to perform the passive authentication;</td>
</tr>
<tr>
<td>2. From the start of the live image enrolment;</td>
<td>2. To the successful enrolment of live image or timeout (if relevant);</td>
</tr>
<tr>
<td>3. From the start of the facial image verification.</td>
<td>3. To the outcome of the facial image verification.</td>
</tr>
</tbody>
</table>

The following figures show the distribution of durations:

**Figure 362** Helsinki - TC4 and TC6 quality score comparison between live and chip facial image based on vendor’s algorithm

**Figure 363** Helsinki - TC4 live facial image enrolment duration for eMRTD holders (in seconds)

**Figure 364** Helsinki - TC4 facial image verification duration for eMRTD holders (in seconds)
With the facial image enrolment and verification equipment used at Helsinki, the following observations can be made:

- In 97% of cases, live facial image enrolment took less than 15 seconds and in 100% of cases less than 30 seconds;
- Software-based image comparison never took more than two seconds, averaging 0.48 seconds;
- Other durations like chip image reading time and the time required for passive authentication were not recorded.

6.3.2.4. **ABC gates (TC9)**

As noted in Table 1 above, three e-gates were available for semi-automated border checks of third country nationals at Helsinki port during the pilot tests. Following passage through the two-step integrated gates, the document was stamped and any questions asked at a separate manual booth. All information in this section, particularly related to duration of processes, is for those within the e-gate only. Thus, end-to-end lane times are for the process through the e-gate, not including any time spent at the manual booth.

**Success / failure**

Success within the ABC gate tests at Helsinki port implied successful completion of steps 1-4 enumerated in the workflow section above without human intervention. Thus, a successful crossing included document reading and facial image extraction (note that passive authentication, although executed, was not considered necessary for successful process completion; similarly, warnings were provided in case of a concern with optical document checks but the process continued) and enrolment of a live image of sufficient quality to give comparison scores above a particular verification threshold.

At Helsinki, a threshold was applied that corresponded to false acceptance rates of 1% in large-scale tests. Figure 22 below shows the ratio of success to failure with application of this threshold.

![Figure 365](image)

**Figure 365** Helsinki - TC9 success and failure rate for the entire bearer verification process based on the facial image modality at an FAR of 1%

In 37% of cases, errors in preceding steps of the process (for example, document reading or live image enrolment) or manual override of the process by the supervising border guard meant that verification was not completed. However, once verification of live against chip facial images completed, it was successful in 89% of cases. At various locations, a more stringent verification threshold corresponding to a FAR of 0.1% was applied. In order to allow comparison with such results, the figure below demonstrates success-failure at such a threshold. It should be noted that these figures are solely estimates - if such a threshold was applied in reality, live facial images could have been re-enrolled in case of verification failure. Thus, the proportion of successful verifications is doubtless an underestimation of the proportion that would be seen in reality.

![Figure 366](image)

**Figure 366** Helsinki - TC9 success and failure rate for the entire bearer verification process based on the facial image modality at an FAR of 0.1%
As shown below, 10% of attempts at passage failed because of errors in reading the travel document, i.e. 27% of failures overall were associated with document reading.

![Figure 367 Helsinki - TC9 chip reading outcome](image)

The majority of reading errors were associated with the electronic reading of the chip’s contents.

**Duration**

The measurement points for the duration of the test case were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader.</td>
<td>1. To the opening of the doors.</td>
</tr>
</tbody>
</table>

The duration of the end-to-end process was analysed for those instances in which a traveller had entered the e-gate. Thus, cases in which initial document reading had failed were excluded from the analysis. Instances in which failures occurred during live image enrolment or verification and that thus necessitated manual override were included.

![Figure 368 Helsinki - TC9 ABC gate process duration (in seconds)](image)

As per the figure above, 84% of travellers passed through the e-gate within one minute and 96% within 90 seconds.

**Security**

As described in detail elsewhere, passive authentication (PA) helps to verify the authenticity and integrity of the travel document presented and can be seen as crucial to ensure full security of automated border control. In Helsinki, PA was successful in the majority of cases. Data obtained indicated that approximately 5% of attempts at PA failed in some manner.
Execution of PA, including associated chip reading and checking of the various data group hashes, took some 11 seconds on average.

6.3.2.5. **Self-service Kiosk**

As described above, enrolment kiosks were deployed at Helsinki port for the enrolment of 4 fingerprints and a live facial image as well as for the extraction of data from the biographical page of the eMRTD, the electronic chip of such documents and the machine-readable visas contained in these documents when necessary. Data related to all of these aspects is reported in this section. A verification kiosk was deployed as a process accelerator in order to automatically bring the border guard’s attention to the enrolment details for the traveller presenting at the booth for final check. Results from this station are also briefly noted.

**Success / failure**

Success in testing using the self-service kiosks deployed at Helsinki port implied successful enrolment of both 4 fingerprints and a live facial image to the required quality levels, successful presentation of the document and visa (if necessary) to the kiosk to allow for facial image extraction from the eMRTD and facial image comparison as well as navigation through the various screens in order to complete the process.

The figure below highlights that 44% of participating travellers were unable to complete the process, i.e. they interacted with the kiosk but were unable to proceed to the final step of facial image verification, failing at some step along the way. The basis of such failures is analysed further in the breakdown on the right of the figure. The majority (77%) are flagged as having errors with both facial recognition and fingerprinting, but it is important to note that the process involved enrolment of fingerprints at an earlier stage than enrolment of the facial image. Thus, failure to enrol fingerprints implied a break in the process and in most cases abandonment of subsequent steps - in such cases, no attempts were made to enrol facial images and thus an error was also indicated for the facial image enrolment and verification steps.

Amongst the 56% of instances in which the enrolment and verification steps were completed, success-failure can be further analysed on the basis of quality thresholds in order to examine whether the biometrics enrolled were of the quality demanded generally in testing throughout the pilot. In 40% of the instances (including, if appropriate, re-enrolment), the enrolled fingerprints were below the general NFIQ thresholds (scores of maximum 2 for the index, middle and ring fingers and maximum 3 for the little finger). Facial image enrolment and verification was more successful. 88% of facial image verifications executed provided matches above a threshold that corresponded to an FAR of 0.1% according to large-scale tests executed by the supporting vendor. In this regard, it is important to note that the actual threshold applied on site was a little less stringent. It may be suggested that with actual application of the threshold corresponding to an FAR of 0.1%, re-enrolment of samples in case of failed verification would have been possible and likely would have provided a higher rate of success.
Overall, it may be noted that just 22% of travellers were able to complete the enrolment process at the self-service kiosk and enrol both fingerprints and a facial image sample to the quality levels requested in testing in this project.

**Figure 370 Helsinki - a) Rates of process completion at the enrolment kiosk, b) sources of error in case of process abandonment, c) rates of success and failure for those who complete the enrolment process according to the set thresholds for fingerprint enrolment and facial image verification**

The success-failure rates for fingerprint and facial image verification as separate processes are highlighted below. It is clear that fingerprint enrolment at the kiosk was difficult, with 39% of participant enrolment sessions ending in error and just 28% of enrolment above threshold for all four fingers. Facial image verification was more successful, with 50% of instances resulting in verification success.
Quality

Fingerprints

It is reminded that participating travellers selected to enrol either the left or right hands when using the kiosks. The results in this section are based on the combined results for all travellers no matter which hand they chose to enrol. Any single traveller enrolled just 4 fingers.

The quality of enrolled fingerprints was assessed using both NFIQ version 1 scores and also by examining the number of minutiae per print across the prints enrolled.

The majority of fingerprints enrolled had NFIQ values of 1, 2 or 3. For the index, middle and ring fingers, at least 85% of prints were rated in this range. In fact, more than 60% of prints from each of these fingers had NFIQ values of either 1 or 2 and could thus be described as being of good quality. The little fingers of both hands were of lower quality, with 17-18% of little finger prints being rated as NFIQ quality 4 or 5 and 43-44% as NFIQ values 1 or 2. Generally, there was no noticeable difference in terms of quality achieved for fingers of one hand compared to those of the other.

For all fingers except the little fingers of both hands, at least 30 minutiae were detected in the prints as shown in Figure 31. Typically, 65%-75% of prints from the index, middle and ring fingers had somewhere between 30 and 60 minutiae. The middle and ring fingers of the left hand had a median of 41 and 42 minutiae respectively; the same fingers on the right hand had median 38 and 39. The little fingers had fewer minutiae as might be anticipated - 56% of prints from the little finger of the left hand had less than 30 minutiae (median 28) and 60% of those from the little finger of the right hand (median 27). The prints obtained from the left hand were somewhat higher in quality than those from the right hand based on the number of minutiae detected. This could, perhaps, be related to increased damage to the fingers of the right hand due to its more dominant use amongst the general population.

![Figure 31](image1.png)

**Figure 31** Helsinki - success and failure rate for a) fingerprint enrolment at the kiosk when applying NFIQ thresholds of maximum 2 for the index, middle and ring fingers and maximum 3 for the little fingers, and for b) verification of the live image against the eMRTD image at a comparison threshold corresponding to an FAR of 0.1%

**Figure 32** Helsinki - TC10 NFIQ scores per finger enrolled at the kiosk
Facial image

There was no enrolment threshold for the live facial image during testing at the self-service kiosk at Helsinki port. Rather, assessment of quality was based on the success of verification, with re-enrolment attempted automatically in case of failed verification (as for most ABC gates, including those discussed in the previous section). Nevertheless, indications of the quality of the live image compared to the images obtained from the eMRTDs were provided using a vendor quality score. It is very evident that the live facial images enrolled at the kiosk were of poorer quality than those obtained from the travel documents. This is doubtless related to the less controlled environment in which the facial images were enrolled at the port terminal and the lack of refinement of aspects such as lighting, background in this test deployment.
Duration
The measurement points for the duration of the test case were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The moment the traveller initiates the transaction at the kiosk (e.g. by selecting the language or by placing the document on the reader).</td>
<td>1. The completion of the workflow at the kiosks.</td>
</tr>
</tbody>
</table>

Durations provided in this section relate only to successful enrolment and verification processes. In instances of failure at an enrolment kiosk, the traveller will typically have to proceed to an alternative manual control booth. For the purposes of testing, therefore, it was considered that the time required to be processed should only be reported when the process was completed and not including instances in which the process might have been abandoned at a mid-way point.

As described above, the end-to-end time involved processing at two separate kiosks, one for enrolment and one for verification separated by a space of some few metres. The figure below indicates how long it took for travellers to complete the process with both kiosks, including the time spent walking from one terminal to the other (estimated to take about 5-10 seconds per traveller.) The end-to-end times shown do not include time required for the final interaction with the border guard including stamping of the travel document.

![Figure 375](image)

**Figure 375** Helsinki - TC10 end-to-end duration across both enrolment and verification kiosks

24% of travellers were able to complete the process successfully within one minute and 90% within two minutes. The median time of transit was 75 seconds.

The steps of which the above durations are comprised include the times for fingerprint and live facial image enrolment. Enrolment of 4 fingerprints took longer than live facial image enrolment with a median time of 16 seconds compared to 12 seconds.
Figure 376 Helsinki - TC10 duration per attempt of 4-fingerprint enrolment at the self-service enrolment kiosk

<table>
<thead>
<tr>
<th>Attempts</th>
<th>Sample count</th>
<th>Avg.</th>
<th>Med.</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>693</td>
<td>29.4</td>
<td>24.0</td>
<td>17.2</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>63.8</td>
<td>55.5</td>
<td>29.7</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>94.3</td>
<td>84.5</td>
<td>25.5</td>
</tr>
</tbody>
</table>

All successful live image enrolments took less than 30 seconds (including the time for height adjustment of the camera ahead of image capture) while 58% of fingerprint captures were completed in this time. The breakdown in duration based on number of fingerprint enrolment attempts highlights the fact that many of the fingerprint enrolment processes of longer duration were associated with two or three attempts. Furthermore, the duration varied with number of attempts in a non-linear manner. I.e. second and third attempts appeared to take longer than the first. This may be related to the fact that those re-enrolling may have had inherent difficulties in enrolling their prints compared to the majority who have enrolled successfully at the first attempt.
As shown above, steps for chip image retrieval and facial image verification added little to the overall process. Thus, a significant portion of the overall process time should be attributed to steps not probed in the charts above - notably, the navigation through the kiosk screens to provide answers to questions regarding the border crossing and step through the enrolment steps, scanning of the visa page, walking between enrolment and verification kiosks and verification at the second stage (which typically took only a few seconds).

6.3.2.6. Duration impact on the end to end process

At the time of testing, biometrics were not enrolled at Helsinki BCP in almost all cases, and thus it was considered worthwhile to compare how the introduction of the biometric enrolment and verification steps analysed might affect the duration of the border check process. We describe herein both:

A baseline measurement: the average duration of the current border check process for TCN visa holder travellers (Russian travellers were not submitting to biometric-based VIS checks at the time of testing)

Average times for the individual biometric enrolment and verification steps calculated based on the operational tests undertaken as well as end to end times for the border check with the facial image and fingerprint-based processes (note that these end-to-end times do not typically include time for questioning, document stamping or any other processes that might be undertaken in normal border control but were not undertaken within the time period associated with the test. The extent to which these steps could be incorporated into the process as tested would require further study).

Values are provided in the following table:
Table 70 Helsinki - duration impact on the end to end process

<table>
<thead>
<tr>
<th>Aspect under measurement</th>
<th>Average duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline&lt;sup&gt;117&lt;/sup&gt;</td>
<td>36 seconds</td>
</tr>
<tr>
<td>Live facial image enrolment and verification&lt;sup&gt;118&lt;/sup&gt;</td>
<td>6 seconds</td>
</tr>
<tr>
<td>Contact</td>
<td></td>
</tr>
<tr>
<td>4 fingerprint enrolment with 4FP scanner</td>
<td>14 seconds</td>
</tr>
<tr>
<td>8 fingerprint enrolment with 4FP scanner</td>
<td>28 seconds</td>
</tr>
<tr>
<td>10 fingerprint enrolment with 4FP scanner</td>
<td>49 seconds</td>
</tr>
</tbody>
</table>

From the values in the table above, it can be observed that in the case of the testing set-up at Helsinki:

- The time required for live facial image enrolment and verification at the manual booth is less than half the time required for the enrolment of four fingers, one fifth of the time required for enrolment of eight, and one eighth of the time required for enrolment of ten;
- The enrolment of fingerprints at the manual booth takes longer than the enrolment and verification of the facial image. Enrolment of 8 fingerprints could lead to an approximate doubling of the time required for a border check if no parallelisation of the enrolment process with other process steps is possible; enrolment of 10 fingerprints would extend the process even more significantly (precisely, the process would be 2.4 times longer);
- Passage through ABC gates was very possible in times analogous to the overall time required for passage through a manual booth according to current processes. The processes are not entirely analogous - the ABC transit times recorded in testing do not include questioning, stamping and checking of the stamps to ensure compliance with terms of stay. Nevertheless, given the possibilities for parallelisation of traveller processing through several gates monitored by a single border guard and discussions on taking away the need for questioning and stamping for at least some travellers in Smart Borders, ABC gates appear to have potential for use in an environment such as Helsinki port;
- Successful enrolment of biometrics at the self-service kiosk typically took twice as long as standard border control at manual booths (without any biometric enrolment). As self-service enrolment takes place independently of the border guard and the time to interact with the guard subsequent to kiosk enrolment should be significantly reduced compared to the status quo, use of kiosks may still be warranted. However, the need for those who fail to complete enrolment at the kiosks to go forward to manual control for a standard border check should be borne in mind.

6.3.3. Users’ perception

6.3.3.1. Travellers’ survey

In total, 455 entries (corresponding to around 23% of the participating travellers) were recorded for TC1, 2 and 3, 384 entries (corresponding to around 17% of the participating travellers) for TC10, and 384 entries (corresponding to around 25% of the participating travellers) for TC9.

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<sup>117</sup> The average baseline duration was calculated from a sample of 135 travellers, with each data-point recorded manually by the border guard using a clock on the wall. It was measured from the time at which the traveller arrived at the booth until the border guard disengaged (i.e. gave back the passport).

<sup>118</sup> Note that this does not include the time for extraction of the facial image from the eMRTD, a pre-requisite for the verification step. Typical times for obtaining the chip image are noted in other BCP chapters and also in the chapter on chip reading.
At Helsinki, participating travellers provided their feedback after going through all the test cases (fingerprints, facial image, ABC gates and kiosks). Feedback was provided via a tablet at each test case set-up.

**Helsinki TC1-2-3-4-6-7**
- Very unsatisfied | Unsatisfied: 9%
- Neutral: 8%
- Very satisfied | Satisfied: 83%

**Helsinki TC9**
- Very unsatisfied | Unsatisfied: 7%
- Neutral: 7%
- Very satisfied | Satisfied: 86%

**Helsinki TC10**
- Very unsatisfied | Unsatisfied: 8%
- Neutral: 5%
- Very satisfied | Satisfied: 87%

*Figure 380 Helsinki -results of the travellers’ survey*

The feedback was positive with around 82%-83% of respondents expressing their satisfaction for TC1, 2 and 3.

6.3.3.2. **Border guards’ feedback**

Feedback forms from border guards and assisting personnel were gathered into two composite reports in which they assessed the fingerprint and facial recognition tests undertaken in Helsinki. The tables below present the different results.
Fingerprints and Facial Image

Table 71 Helsinki - TC1, TC2, TC3, TC4, TC6 and TC7 border guards' feedback

<table>
<thead>
<tr>
<th>Overall Feedback</th>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive: 1 out of 2</td>
<td>Negative: 2 out of 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No reply: 1 out of 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Impediments | Language: some had issues explaining steps understandably. |
|             | Notable problems included frequent inappropriate placement of the fingers on the reading device. |
|             | 1 group suggested that the device's reading area was not large enough for large hands. |
|             | Issues were noted for travellers with larger hands/elderly travellers. |

| Improvements | 1 BG indicated that the placement could be accurately illustrated on the reading area for clearer guidance. |
|             | 1 group claimed that the equipment could be more ergonomic. |
|             | N/A |

Further information was gleaned from post-testing discussions with the participating border guards and assistants. Border Guards stated that during the pilot, some of the travellers were suspicious and thought that the collected information about their fingerprints could be misused.

Language issues were commonly cited in post-test discussions. Most border guards felt that the tests would have failed without the Russian-speaking assistant being present as explanation of steps and behavioural guidance was crucial. For example, many travellers did not understand that they should keep their fingers together when they were placed on the reading area of the 4FP contact scanner and suggested that visual guidance should have been provided to help in this regard. Sometimes, travellers took their hands away from the device too early because of the lack of visual feedback. In fact, it was noted that turning the border guard screen so that the traveller could observe his/her prints during enrolment provided benefit. Also, travellers with larger hands had some trouble placing all fingers within the reading area. Dry fingers had sometimes presented problems.

An interesting topic was the difficulty noted in positioning the fingerprint device. The device had initially been placed on the right side of the booth for testing in TC1, but this position was found to be inappropriate once two hands had to be enrolled in TC2. This needed movement of the device to a central position which was non-optimal for both hands.

Most difficulties related to facial image enrolment pertained to correct positioning of the camera. Often, travellers were not at the correct distance from the camera and therefore images obtained were frequently distorted. Similarly, the camera was fixed to the booth meaning that it couldn't be moved easily to deal with smaller or taller travellers. There was also some concern regarding lighting, with light coming through the terminal windows to the side of the traveller causing issues in an estimated 20-30% of cases. Some border guards also felt that the other-race effect had a negative impact on results.
ABC gates

Table 72 Helsinki - TC9 border guards’ feedback

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impediments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive: 1 out of 2</td>
<td>Positive: 2 out of 2</td>
<td>Positive: 2 out of 2</td>
</tr>
<tr>
<td>No reply: 1 out of 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some travellers found it difficult to follow the process. Guidance from on-site assistants was sometimes required.</td>
<td>The gates sometimes broke down, requiring equipment restart.</td>
<td>N/A</td>
</tr>
<tr>
<td>Improvements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>Better guidance was needed for travellers. Better flow control within the gate.</td>
<td>N/A</td>
</tr>
</tbody>
</table>

In discussions following testing, border guards and assisting personnel elaborated further on the above. The breakdown of the ABC gates had often been caused by liveness detection processes running in the gate but technical improvements implemented mid-test had addressed most of these issues. Thus, the gates generally worked well. Facial recognition within the gates worked very well because of the controlled background and lighting (and hence was better than for the self-service kiosks used at the same location). Border guards felt that the gates should be open for use by low risk travellers, including TCNs, suggesting that all travellers could use the gates at exit and some form of trusted traveller at entry.

Note that Finland had run their own ABC-based tests at the same time and some brief points from such tests were noted. In particular, the border guards noted that their tests had looked at fingerprint capture within the ABC gate (a process that was found to cause problems, particularly when enrolling four fingers) and the reading of the visa as required on entry (which had caused problems as travellers often couldn’t find and place their visa and stamps on the visa often caused reading problems).

Self-Service Kiosk

Table 73 Helsinki - TC10 border guards’ feedback

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impediments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The travellers had issues with navigating the kiosk interface without guidance. Many did not recognize how to move between steps on screen. In general, it was felt that there were too many steps involved. It was suggested that the</td>
<td>The fingerprinting device was found to cause particular problems. Re-enrolment was almost always necessary. The equipment frequently broke down, requiring full system restarts. The photo comparison was</td>
<td>Many elderly travellers could not utilize the interface properly and furthermore had problems enrolling their fingerprints. Many found the text used in the questioning difficult to understand.</td>
</tr>
<tr>
<td>No reply: 2 out of 2</td>
<td>Positive: 1 out of 2 Mixed: 1 out of 2</td>
<td>Positive: 1 out of 2 Mixed: 1 out of 2</td>
</tr>
<tr>
<td>Improvements</td>
<td>The interface should be better configured in terms of language and process. More languages should be offered. The workflow needed to be better considered (e.g. sometimes travellers who didn’t require visas were asked to provide a visa, inappropriate questions were asked re. residence permits)</td>
<td>It was suggested that automatic capture once travellers presented at the verification kiosk would be useful. More feedback needed to be provided to travellers during fingerprint enrolment. The reading area for the fingerprint reader could be made larger to accommodate those with large hands.</td>
</tr>
</tbody>
</table>

In discussions, border guards and assisting personnel expressed their views that tests demonstrated the potential of self-service kiosks for to enhance the efficiency of border checks at Helsinki port but emphasised that such kiosks would have to be adapted if intended to be deployed more widely.

The main issues noted were with the language used and the overall process flows through the enrolment kiosks that could be improved with more extensive study of the interface usability ahead of any deployment. Other common problems related to placement of the document and visa onto the document reader and the enrolment of fingerprints. The implemented workflow allowed travellers to choose enrolment of either the left or the right hand and this caused confusion. Furthermore, the lack of feedback during enrolment was cited as a problem that could be easily remedied.

The process of live facial image enrolment worked much more smoothly. Some issues had been observed with light coming from windows in the area affecting the facial capture process. In fact, the verification kiosk had been turned following initial deployment in order to minimise the effects of this extraneous light. Some wondered whether the use of an in-built flash might have obviated some of these lighting issues. Nevertheless, in almost all cases, the correct traveller had been identified at the verification kiosk.

Given the potential demonstrated, border guards agreed that a more-evolved version of such kiosks could be utilised at the port. They felt that in order to improve efficiency, more enrolment kiosks would be needed to feed a single verification kiosk as the enrolment kiosk was the main bottleneck in the process. As there is little queuing space at the port, it was suggested that kiosks could be placed on the walkways from the cruise ship to the terminal or even on the cruise ship itself. In the latter case and if unsupervised, they indicated a mechanism to ensure use only by one traveller at a time would be needed (for example, the kiosk could be placed into a closed booth). Otherwise, a full risk analysis would be needed before deployment. The verification kiosk could be integrated into the booth in future deployments.

6.3.4. Constraints

6.3.4.1. Impact of environmental conditions

Variable lighting within the terminal building throughout the day impacted negatively on tests dealing with facial recognition. In tests at the manual booths, border guards reported that light shining directly onto the camera or causing shadows on the traveller’s face led to difficulties enrolling and verifying the live image. The verification kiosk
deployed as part of TC10, meanwhile, had to be rotated 180° subsequent to initial deployment to obviate the negative influences of morning sun coming through the terminal windows. It may be noted that ABC gate tests were not affected by lighting in similar ways. The gates were already in place ahead of testing and shade and lighting had been appropriately configured. This highlights the fact that remedial actions can typically be taken to address issues of lighting, at least in indoor locations.

6.3.4.2. Others

Although tests at Helsinki port were carried out in an indoor environment, the flows of travellers differ from those seen at an airport. Most notably, travellers typically exit a large cruise ship in large numbers within a short space of time, leading to significant congestion for short periods. Some interesting results of testing in such an environment could be briefly considered. In tests on self-service kiosks, it was noted that there was insufficient space to install many more such kiosks and have queuing space around them, thereby reducing their viability in the current situation. The congestion also meant that monitoring of kiosk users was more difficult. Passage of travellers from the enrolment kiosk to the verification kiosk and onwards to the manual booth was also slow as directions were unclear. Border guards suggested that guidance to travellers when moving from one station to another needed to be improved.

6.3.5. Main observations

Fingerprint enrolment (TC 1/2/3)

Enrolment of fingerprints to the quality thresholds implemented at Helsinki port was difficult. Frequent re-enrolment attempts were necessary. Problems noted included dryness of hands and inappropriate placement of the fingers onto the sensor of the device, a problem exacerbated by the difficulty that some border guards had to communicate instructions to the travellers.

A need for better visual feedback to travellers on enrolment was communicated. Improvement in enrolment success were noted when the border guard screen was turned in the direction of the travellers to allow them to observe their enrolment.

During testing, the fingerprint device was moved from a right-sided placement on the booth to a central position once 8-fingerprints were enrolled rather than 4. The latter position was deemed to be non-optimal for both hands.

The fingerprinting device was somewhat higher than desired due to the configuration of the booth. This made enrolment more difficult for some travellers, particularly smaller travellers.

Some travellers wondered about misuse of fingerprint data, particularly early in testing.

Facial Image (TC 4/6/7)

At a verification threshold corresponding to an FAR of 0.1%, only 43% of attempts were successful.

Live facial image enrolment and verification against the photo was nevertheless quick relative to fingerprint enrolment.

The camera was fixed to the booth and could not be raised and lowered easily, leading to some problems with taller or shorter travellers. Horizontal capture of the image appeared to be important, and hence border guards suggested that any future deployment have automatic height adjustment of the camera.

Negative effects of lighting were quite noticeable at Helsinki port.

High quality images were obtained from the document chips in most cases. Border guards reported that very few issues were noted with document reading and extraction of the relevant data including the stored facial image.

All border guards felt that automatic facial image verification could be useful as a support to decision-making going forward.
ABC gates

ABC gates worked well and processing of third country nationals through these gates at exit was seen to be quite feasible. The majority of travellers passed through the gate in less than 60 seconds.

Border guards were generally positive regarding the processing of such travellers through these gates in the future. Travellers were also deemed to have been positive about their use of the e-gates.

Self-Service Kiosk

Successful completion of the enrolment process at the self-service kiosks took some 1-2 minutes, with a 75 seconds recorded median duration of successful enrolment. However, only 22% of travellers were able to complete the process and enrol both 4 fingerprints and a facial image to the quality necessary within the pilot.

Many travellers were not able to navigate the workflow implemented without support. An assistant was employed full-time to support use of the kiosks at Helsinki port. The border guards suggested that the process could not be implemented in a completely self-service manner without some support being provided by trained personnel who could speak the necessary languages to deal with the most frequently encountered travellers.

The enrolment of the facial image was seen to be more intuitive than that of fingerprints. Many problems were noted with fingerprint enrolment and most travellers had to attempt to submit fingerprints three times in line with the re-enrolment policy. Even then, only 26% of travellers enrolled fingerprints successfully at the required NFIQ thresholds.

Extraneous light coming from terminal windows at Helsinki port negatively affected live facial image enrolment. The verification kiosk needed to be turned to address this issue.

Participating border guards felt that the use of kiosks for enrolment of face and fingerprints showed promise for increasing the efficiency of border checks in the future while emphasising that the technologies and workflow needed improvement.
6.4. Piraeus – Fingerprints and facial image

6.4.1. Test description

This chapter describes the tests executed in Piraeus (Greece), within the Smart Borders pilot. The tests focused on the enrolment of fingerprints and the use of automated facial recognition in a moving cruise vessel.

6.4.1.1. Set-up and configuration

The execution and organisation of the test cases at Piraeus were set up and configured based on characteristics listed in the table below.

Table 74 Piraeus - set-up and configuration

<table>
<thead>
<tr>
<th>BCP type</th>
<th>Sea: Moving cruise vessel from Piraeus to Mykonos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Evaluate the feasibility, user-acceptance, duration and the delivered quality of:</td>
</tr>
<tr>
<td></td>
<td>• TC1: Enrolling 4 fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC4: Enrolling a live facial image</td>
</tr>
<tr>
<td></td>
<td>• TC6: Capturing the facial image from an eMRTD</td>
</tr>
<tr>
<td></td>
<td>• TC7: Verifying the facial image captured from the eMRTD against the enrolled live facial image</td>
</tr>
<tr>
<td>Test location</td>
<td>Open area on a cruise vessel</td>
</tr>
<tr>
<td>Staff involved</td>
<td>6-7 in total</td>
</tr>
<tr>
<td></td>
<td>• 1 border guard per shift</td>
</tr>
<tr>
<td></td>
<td>• 2 cruise ship staff members to invite the travellers to participate in the pilot</td>
</tr>
<tr>
<td>Total duration</td>
<td>15 weeks in total</td>
</tr>
<tr>
<td>Timetable</td>
<td>TC1, TC4, TC6 and TC7: From 04.05.2015 to 15.08.2015 (15 weeks)</td>
</tr>
<tr>
<td>Sample size (target / actual)</td>
<td>Fingerprints</td>
</tr>
<tr>
<td></td>
<td>• TC1: 600 / -1950</td>
</tr>
<tr>
<td></td>
<td>Facial image</td>
</tr>
</tbody>
</table>
6.4.1.2. Workflow

Fingerprints enrolment

1. **TC1**: Enrolment of 4 fingerprints (index, middle, ring and little finger for the right hand unless not present).

   The fingerprints of the index, middle, ring and little fingers of the right hand of volunteering TCNs were captured using a standard optical livescan device. Reattempts were not enforced in case the quality didn’t exceed the set threshold, and was left at the discretion of the border guard.

   ![Image of hand with palm up](image.png)

   *Figure 381 Piraeus - TC1 (4FPs enrolment) steps*

Facial image

The test cases were executed sequentially and as a combined process according to the following sequence of three steps:

1. **TC6** - Passport inspection (including Passive Authentication) and retrieval of the facial image from the eMRTD (this step was in fact carried out as the first step of the process, followed by fingerprint capture. Steps 2 and 3 below followed subsequently);

2. **TC4** - Enrolment of the live facial image (photos) from the TCN;

3. **TC7** - Verification of the facial image captured from the eMRTD chip against the live facial image enrolled from the TCNs.
Figure 382 Piraeus - facial image test cases (TC4, 6 and 7) steps

A standard web-camera was used for live facial image enrolment. Auto-focus functionalities were implemented. The software automatically zoomed and cropped the obtained image in order to enforce ICAO-type results. Facial image matching proceeded automatically and the comparison score displayed with an indication as to whether the suggested score was exceeded. Re-enrolment of the facial image was suggested by the software up to 3 times in case of matching failure. The facial image from the chip was obtained using a flatbed (i.e. full page) document scanner.

6.4.1.3. Participation and sample characteristics

The majority of travellers participating in the tests in Piraeus were women, with a 60% share of total participants. Travellers’ nationalities were very diverse, which provided good conditions to test different types of passports. The main nationalities represented were the USA and Turkey. 40% of participating travellers were between 51 and 70 years old, and age groups from 13 to 70 were represented.

Figure 383 Piraeus - sample distribution by gender

Figure 384 Piraeus - sample distribution by age
6.4.2. Test cases operational and technical results

6.4.2.1. Fingerprints (TC1)

Success / failure

Fingerprint enrolment was considered successful if the NFIQ threshold (values of 1 or 2 for the thumb, index, middle and ring fingers and 1, 2 or 3 for the little finger) was reached at the first attempt. Because of operational pressures, border guards felt unable to force re-enrolment attempts in all cases despite the thresholds not being reached - this was noted to have been the case in approximately 68% of cases in which the first enrolment had at least one finger below threshold.

The graphs below show the overall success/failure rate for the right hand.

![Graph showing success/failure rate](image)

*Figure 386 Piraeus - TC1 success and failure rate with contact device at vendor threshold*

Quality

The quality of fingerprints enrolled was assessed using both NFIQ version 1 scores and the number of reliable minutiae in each print.

As mentioned, it was the case that some fingerprint enrolment attempts presented at least one finger that failed to be enrolled - this occurred in approximately 40% of first enrolment attempts. The results presented do not take into account such fingerprints. Thus, the overall results will be slightly worse than those displayed in the graphs below.

![Graph showing NFIQ scores by finger](image)

*Figure 387 Piraeus - TC1 NFIQ scores per finger at the first attempt with contact scanner*

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159 The country codes used in the graph are the three-letter country codes defined in ISO 3166-1: http://www.nationonline.org/oneworld/country_code_list.htm
NFIQ scores between 1 and 3 were most frequently obtained. Fingerprints from the little finger were of lowest quality; those for the index, middle and ring fingers were of similar quality overall.

Approximately one in two fingerprints captured could be considered to be of good quality (NFIQ 1 or 2) and one in three of average quality (NFIQ 3). Only 8% to 14% were of poor quality (NFIQ 4 or 5).

The number of minutiae detectable in each fingerprint image was also recorded as a measure of print quality. The graph below illustrates the distribution of minutiae per finger for TC1.

![Figure 388 Piraeus - TC1 minutiae amount per finger at the first attempt](image)

The number of minutiae identified was relatively low with approximately 50% of fingerprint images having less than 30 minutiae and less than one in twenty having more than 60 detectable minutiae. Prints from the little finger typically had very few minutiae, with only one in six fingerprints presenting more than 30 minutiae.

Duration

![Figure 389 Piraeus - TC1 duration with contact scanner per attempt (in seconds)](image)

Half of attempts were completed in less than 15 seconds, and 91% in less than 30 seconds. The average duration of one attempt to capture 4 fingerprints was 17 seconds.
6.4.2.2. **Facial Image Results (TC4, TC6, TC7)**

**Success / failure**

The graph below presents the success/failure for image verification:

![Graph showing success/failure rates](image1)

*Figure 390 Piraeus - Fl related test cases success and failure rate*

The success rate for the verification of the image (matching) was 30%.

Due to the modalities of the device, document reading errors were not collected at Piraeus and, as such, are not presented here.

**Quality**

In Piraeus, the quality of the facial image was evaluated based on a quality index provided by the supporting vendor. It should be noted that these values were not provided to the border guards running the tests and therefore were not used as a basis for any re-enrolment during testing.

The graph below compares the facial image captured live with the one captured from the chip according to a threshold provided by the vendor as an indication of good quality (1 indicating vendor’s threshold reached, while 0 indicating vendor’s threshold not reached).

![Graph showing quality score comparison](image2)

*Figure 391 Piraeus - TC4 and TC6 quality score comparison between live and chip facial image based on vendor’s algorithm*

It can be observed that the quality of the document images was similar between the ones taken live at the border and the ones captured from the chip.
### Duration

The duration of live facial image enrolment and facial image verification are described in this section.

The measurement points for the duration of the test cases were as follows:

<table>
<thead>
<tr>
<th>From ...</th>
<th>To ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. From the moment the passport is placed in the eMRTD reader;</td>
<td>1. To the result of the eMRTD FI acquisition (success or failure), including the time to perform the passive authentication;</td>
</tr>
<tr>
<td>2. From the start of the live image enrolment;</td>
<td>2. To the successful enrolment of live image or timeout (if relevant);</td>
</tr>
<tr>
<td>3. From the start of the facial image verification.</td>
<td>3. To the outcome of the facial image verification.</td>
</tr>
</tbody>
</table>

The distributions were as follows:

![Image](image.png)

With the facial image enrolment and verification equipment used at Piraeus, the following observations can be made:

- In 91% of cases, the live facial image enrolment took less than 15 seconds and in 99% of cases less than 30 seconds;
- Software-based image comparison never took more than two seconds, averaging 0.98 seconds.

#### 6.4.3. Users’ perception

6.4.3.1. **Travellers’ feedback**

In total, 1048 entries (corresponding to around 54% of the participating travellers) were recorded.

The travellers’ survey reflects test cases related to both fingerprints and facial image (TC1, TC4, TC6 and TC7).

Overall, respondents were very satisfied/satisfied (90%) with regards to the test cases with only about 4% of them expressing dissatisfaction. More details are presented in the diagram below.
Piraeus - TC1, TC4, TC6, TC7

Very unsatisfied | Unsatisfied | 4%
Neutral | 6%
Very satisfied | Satisfied | 90%

Figure 394 Piraeus - results of the traveller’s survey

6.4.3.2. Border guards’ feedback

In Piraeus, 4 border guards participated and replied to the questionnaire for TC1, TC4, TC6 and TC7 together.

The results of the feedbacks are summarised in the tables below.

Table 2 Piraeus - TC1, TC4, TC6 and TC7 border guards’ feedback

<table>
<thead>
<tr>
<th>Process added-value</th>
<th>Equipment</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive: 4 out of 4</td>
<td>Negative: 4 out of 4</td>
<td>Negative: 4 out of 4</td>
</tr>
<tr>
<td>Device seen as heavy, slow and too large.</td>
<td>Device unresponsive and had to be restarted.</td>
<td>Travellers are reluctant and suspicious of fingerprints capture.</td>
</tr>
<tr>
<td>Impediments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The extra time required to execute tests meant that they were abandoned when queues were long.</td>
<td>The device was not stable due to the boat’s movement.</td>
<td>Physical constraints: Elders, Parkinson and other diseases. Culture. Language: some had issues explaining steps to the participants.</td>
</tr>
<tr>
<td>Improvements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>It was suggested that the set-ups should be more user friendly and set-ups more ergonomic.</td>
<td>N/A</td>
</tr>
</tbody>
</table>

6.4.4. Constraints

6.4.4.1. Environmental conditions

In Piraeus, an environmental measurement device was deployed to monitor temperature, humidity, light and movement throughout the entire testing period. It was placed into the suitcase device and therefore was located at the point of testing in all cases. Testing was always carried out indoors on the cruise vessel. As can be seen in the table below, during the entire testing period, the temperature ranged from a minimum of 16.7° to 31.4° Celsius. Movement on the vessel was consistent but limited in terms of acceleration in any given direction at any time. Border guards did not report any difficulties that they associated with the monitored environment and no particular correlations could be observed that would indicate that temperature, humidity, light or movement had any significant effects.
Table 75: Piraeus - maximum, minimum and average of temperature, humidity and light

<table>
<thead>
<tr>
<th></th>
<th>Temperature (°C)</th>
<th>Humidity (RH%)</th>
<th>Light (Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>16.7°</td>
<td>36.15%</td>
<td>67.4</td>
</tr>
<tr>
<td>Max</td>
<td>31.4°</td>
<td>60.1%</td>
<td>2621.2</td>
</tr>
<tr>
<td>Average</td>
<td>22.85°</td>
<td>49.35%</td>
<td>23.56</td>
</tr>
<tr>
<td>Observations</td>
<td>Vast majority between 20° and 25°</td>
<td>Vast majority between 30% and 59%</td>
<td>Vast majority between 300 and 2299</td>
</tr>
</tbody>
</table>

Traveller flows to testing were intermittent because of the organisation of activities on the vessel. Passengers were typically grouped according to the languages spoken and undertook all activities, including eating, entertainment, safety briefings etc. together. Thus, they were informed about testing in the group and often arrived as such, putting great pressure on the border guard executing testing for a short period of time. Otherwise, he/she was often idle. Border guards suggested that self-service kiosks could be considered as an approach to allow enrolment without the drain on resources apparent in the case of the pilot tests. As there was a large amount of space available for deployment of facilities around the vessel, this approach appeared reasonable.

6.4.4.2. Others

One issue noted was the fact that travellers typically gave up their passport upon check-in according to current cruise ship procedures. As the document was needed for testing, cruise ship personnel were needed at all times to support the tests. These procedures would need to be re-examined if enrolment involving document scan was to be fully implemented as a normal procedure on the vessel.

6.4.5. Main observations

Fingerprint enrolment (TC1)

The success rates for enrolment and overall fingerprint qualities obtained were similar to those obtained at other test locations where the same devices were used. This suggested that the movement of the cruise ship did not significantly influence the enrolment process.

Nevertheless, only 1 in 3 enrolment attempts were successful at the set thresholds. It is suggested that a lower threshold would have to be applied to reduce the failure to enrol rates obtained, with possible implications for the accuracy of results obtained in subsequent transactions with the enrolled prints. The majority of prints had NFIQ levels better than 3. Otherwise, alternative enrolment strategies with re-attempts might be worth testing.

Enrolment of four fingerprints was generally quick, with 90% of enrolment attempts complete within 30 seconds.

Enrolment was always undertaken indoors, away from direct sunlight in an area subject to little temperature or humidity fluctuations. The environment appeared to play little role in affecting the quality of enrolled sample or the duration of the enrolment.

Some travellers were suspicious of the testing of fingerprint capture and preferred not to participate as a result. Sometimes, elderly passengers or those with some physical conditions found the process difficult, noting that it had not been adapted to be ergonomically comfortable. In fact, the devices, being portable, were removed between cruises and set-up upon departure each time; thus, the set-up could not be optimised easily.
Facial image (TCs 4/6/7)

Live facial images could be enrolled on the moving vessel, with the movement not affecting the capture process significantly. 96% of attempts resulted in successful image capture.

The quality obtained was reasonable given the unconstrained environment in which capture was undertaken. Verification results were similar to those obtained with the same equipment in an indoor environment and better than achieved outdoors using the same set-up. Quality measures indicated that the live images obtained were generally as good as those obtained from documents.

Live image enrolment was quick, complete in less than 5 seconds in 45% of cases and less than 15 seconds in 91% of instances. In fact, the whole facial image capture and comparison process typically took only a few seconds.

Border guards generally preferred the facial image capture process to the capture process for fingerprints.
7. Fundamental Rights Agency Survey results

FRA survey in the framework of the eu-LISA pilot on smart borders – travellers’ views on and experiences of smart borders

Main findings

This Annex presents the views of travellers on a number of fundamental rights aspects related to the use of biometrics in the context of border control. The results are based on a small-scale survey conducted with 1,234 randomly selected third-country nationals. The interviews for the survey were conducted between July and October 2015 at seven different border crossing points among those selected for the Smart Borders Pilot entrusted to eu-LISA by the European Commission.

The results show that most respondents are comfortable with providing biometrics when crossing borders, with the exception of iris-scan. Most respondents do not feel that biometrics compromises their right to dignity. Except for iris-scan, there is a tendency among respondents to perceive biometric data provision as not being intrusive on their privacy. Trust in the reliability of biometric technologies is also high; however, up to one third of the respondents were less positive.

A key result is what happens when something goes wrong and the system does not function as expected. Here, more than half of the respondents believe that they would not be able or do not know if they will be able to cross the border in case the technology does not work properly. Similar concerns emerged in relation to the right to correct wrong data. Half of the respondents believe that in case of an error in their personal data, the latter could not be easily corrected.

This finding resonates with the concerns expressed by the European Data Protection Supervisor (EDPS) and other organisations on the negative consequences that mistakes in the system and in the automated processing of personal data can have on an individual. For example, when the system fails to recognize an individual or if the extension of a visa is not included in the database, a person might be denied entry into an EU Member State or, in the worst case, run the risk of being apprehended and detained. The person affected may face difficulties to prove that he/she really is the person he/she claims to be. In the case of third-country nationals travelling to the EU, this vulnerability might be compounded by language problems.

Many problems could occur, for example data errors, but also fraud and forgery of biometric data and incorrect or not up to date personal data included in the IT system. The most likely implication of incorrect data in the Entry Exit system concern the risks of persons mistakenly flagged as over-stayers and the use that police, immigration or other officials may make of such information.

The results of the survey show that third-country national travellers take data protection seriously and more than 80% consider it important to be informed on the purpose of collecting and processing their personal data.

There is a widely held view that automated systems could cause less discrimination – for example on the basis of race or ethnicity – compared to checks carried out in person by border guards. This might be based on the assumption that machines entail a lower risk of discriminatory profiling compared to checks by border guards. However, it should be noted that automated systems could be programmed to identify individuals using sensitive data, such as race, ethnicity or health. Measures to avoid discriminatory profiling are, therefore, required.

Most respondents believe that only adults (i.e. 18 years of age onwards) should be allowed to go through biometric checks. Hence, there is a difference between the views of the respondents and the current age limits
for fingerprinting set in the EES proposal, according to which fingerprints should be provided from 12 years onwards.

Finally, respondents were asked whether they are afraid that the technology to collect their biometrics might be harmful to their health. The survey result show that more than half of the respondents either believe that biometric technologies could harm their health or show uncertainty on this issue. Travellers would benefit from receiving objective and scientific information on the health consequences of the use of biometric data.

7.1. Background

In the context of the Smart Borders second phase of the ‘Proof of Concept’ also referred as “Pilot” which was entrusted to eu-LISA by the European Commission, the European Union Agency for Fundamental Rights (FRA) complemented eu-LISA’s tests by conducting a survey of travellers on fundamental rights-related issues linked to the use of biometrics during border checks.

Biometric identifiers can be biological properties, physiological characteristics, living traits or repeatable actions that are both unique to that individual and are measurable\textsuperscript{120} such as fingerprints, iris-scan (referred to ‘iris pattern’ in the report) and facial image.

Modern identification and verification technologies entail both risks and benefits for fundamental rights that have not yet been fully explored. In the context of the Smart Borders proposal, the European Data Protection Supervisor, the Article 29 Working Party and representatives of civil society have expressed concerns over the necessity and proportionality of the Commission proposal to create a new large-scale centralised system for processing fingerprints

and personal information of third-country nationals crossing the Schengen borders. Data protection and privacy related issues have so far been at the forefront of discussion in this field. Other fundamental rights, such as the right to dignity and non-discrimination, may also be at stake. In parallel to FRA’s survey in the context of the eu-LISA Pilot on Smart Borders, FRA is currently conducting a project on “Biometric data in large EU IT-systems in the areas of borders, visa and asylum – fundamental rights implications”. The project will identify the positive as well as negative fundamental rights implications of processing biometric data in the following already existing large-scale IT-systems: Eurodac\footnote{European Commission, Identification of asylum applicants, http://ec.europa.eu/dgs/home-affairs/what-we-do/policies/asylum/identification-of-applicants/index_en.htm}, the Schengen Information System (SIS II)\footnote{European Commission, Schengen information system, http://ec.europa.eu/dgs/home-affairs/what-we-do/policies/borders-and-visas/schengen-information-system/index_en.htm} and the Visa Information System (VIS).\footnote{European Commission, Visa information system, http://ec.europa.eu/dgs/home-affairs/what-we-do/policies/borders-and-visas/visa-information-system/index_en.htm}

The objective of FRA’s small-scale survey is to explore third-country national travellers’ attitudes about the use of biometrics at border crossing points (BCPs) in relation to selected fundamental rights issues. The results intend to provide information to policy makers about the attitudes they can expect to encounter from travellers when introducing Smart Borders technologies.

Travellers’ attitudes are an important element when assessing how new measures will be received. They can help authorities to forecast possible reactions and address existing fears or concerns. At the same time, travellers’ perceptions are only one element to take into account when assessing fundamental rights compliance of certain measures. Violations of fundamental rights may occur regardless of whether the individual consents or not to a certain treatment, particularly in light of limited rights awareness.

### 7.2. Methodology and sample

#### 7.2.1. Scope

The survey was conducted in seven border crossing points in six Schengen Member States, all covered by the eu-LISA Pilot and aimed at interviewing a similar number of travellers in each BCP. The seven BCPs were selected to cover a variety of different types of borders (road, train, seaports and airports) and to allow for a balanced geographical distribution between Member States and travellers. As illustrated in Figure 1 interviews were conducted in the following BCPs:

- three airports: Charles de Gaulle (Paris), Frankfurt (Germany) and Madrid (Spain)
- one harbour: Helsinki (Finland)
- three land border crossing points: the road BCP in Sculeni (Romania); the road BCP in Narva (Estonia) and the train BCP in Iaşi (Romania)
Figure 1: Overview of border crossing points covered by the FRA survey within the eu-LISA Pilot on smart borders\textsuperscript{124}

7.2.2. Target group

The target group included non-EU citizens (i.e. third-country nationals and stateless persons) crossing an external border of the Schengen Area.\textsuperscript{125} This was the same target group of the eu-LISA Pilot, except for Narva, where the eu-LISA pilot targeted only people holding an alien’s passport issued by Estonia (stateless persons residing permanently in Estonia). As few people belonging to this group were travelling in Narva when the survey was conducted, it was decided to include all third-country nationals, in line with the eligible population of the other BCPs surveyed. All respondents were aged 18 years or older.

\textsuperscript{124} The background of the maps presented in Figure 1 and Figure 2 are based on shapefiles made available through Eurostat, © EuroGeographics for the administrative boundaries, available at: http://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units.

\textsuperscript{125} Citizens of a country that is a member of the European Free Trade Association (EFTA) have not been included in the sample.
7.2.3. **Sample selection**

The sampling approach aimed to deliver a representative sample of the target group in the BCPs covered. The following strategies were followed to randomly select travellers, screen for their eligibility and conduct the interview at airports, ports and land BCPs, respectively.

At airports interviews were conducted at the departure area, at boarding gates of flights travelling outside the EU. Boarding gates were considered the best place to approach respondents because travellers reach boarding gates some 30-60 minutes before flight departure and, having completed all departure procedures, have time and are more likely to be willing to take part in the survey.

A two stage sampling was carried out at gates. Boarding gates with departing flights to destinations outside the EU were selected randomly. At each gate, passengers were approached through systematic sampling, with every third traveller selected. No more than 30 persons were interviewed at each gate in order to guarantee heterogeneity of the sample in terms of destinations and nationality of travellers.

Only at Frankfurt airport, where access to boarding gates was not possible due to the airport’s security measures, interviews were conducted at the check-in area and in the waiting hall prior to security. Travellers checking in for flights departing to destinations outside the EU were selected and approached in a systematic way (i.e. every third traveller resting in sitting areas next to check-in counters) and only eligible travellers were interviewed.

The fieldwork took place at Madrid airport between 14 and 16 July 2015; at Paris airport between 7 and 9 August 2015 and at Frankfurt airport between 25 and 27 August 2015 and from 21 to 22 October 2015.

At Helsinki sea port (Finland), interviews were conducted with people travelling on ferries arriving from or travelling to St. Petersburg (Russia) between 18 and 20 July 2015. Two ferries a day were surveyed (disembarking in the morning, boarding in the afternoon). Travellers arriving were approached in the waiting area, just before border check procedures and on the ferry itself. Travellers departing were approached after border check procedures. As in airports, every third traveller was selected.

At land borders the sampling units included pedestrians, cars and buses, as relevant. Systematic sampling was applied by selecting every third pedestrian and every third car. Within each car, one person was selected, unless there were four or five people travelling in the car, in which case two questionnaires could be completed for the same vehicle (provided the selected persons were eligible). All buses where approached and every third person within each bus was selected.

Interviews were conducted in different areas. In Narva (Estonia), the sampling units included pedestrians, buses and cars. Cars were selected in two different locations: close to the BCP, where cars are queueing for border checks and in the car waiting area 3 km away from the BCP. Interviews with people travelling by bus were conducted in a special waiting area for bus passengers while the bus was being inspected by customs officers. Pedestrians entering as well as leaving the Schengen Area were approached and interviewed. Border guards advised the interviewers not to approach trucks due to low flows and because the average waiting time for trucks at the waiting area was too short to complete the questionnaire.

In Sculeni (Romania), the sampling units were cars, which were systematically selected in the same way as in Narva. Pedestrians were very few; trucks were also very few and difficult to approach.

In Iaşi (Romania), interviews were conducted on trains connecting Romania and Moldova in both directions, including local trains connecting Iași-Ungheni (in both directions) and trains connecting Chisinau and Bucharest.

The fieldwork was conducted in Narva between 11 and 13 August 2015 and in Iaşi and Sculeni between 20 and 24 August 2015.

7.2.4. **Questionnaire**

The questionnaire was designed by FRA and covers attitudes towards potential fundamental rights issues related to collecting, storing and processing biometric data in the context of border crossing. Besides the general attitudes
towards the provision of biometric data for border crossing, the questions reflect issues related to the following Articles of the Charter of Fundamental Rights of the European Union:

- Dignity (Article 1): interviewees were asked whether they thought it was humiliating to give their biometrics, have their passport checked by a border guard (with no biometrics involved) or any kind of border check in general
- Respect for private and family life (Article 7): interviewees were asked if they believe that giving their biometrics when crossing the border is intrusive or not to their privacy
- Right to protection of personal data (Article 8), including
  - the right to information on the purpose for collecting the data and on its processing: interviewees were asked whether they believe it is important to be informed on why their biometric identifiers are collected and used;
  - the right to access and rectify the data: interviewees were asked whether they believe that their personal data could be easily corrected in case of mistakes; interviewees were also asked if they trust that only legally authorised people access the data and if they have problems with the police accessing their data.
- Non-discrimination (Article 21): interviewees were asked whether they believed that automated systems would cause more or less discrimination compared to checks done by border guards.

Additional questions on previous experience with providing biometrics and information on general attitudes to technology were asked to help contextualise and interpret the results.

Comments on the questionnaire were provided by eu-LISA.

The English questionnaire was translated into seven languages, including four languages of EU Member States where the survey was conducted (Spanish, French, Romanian and German) plus a selection of languages widely spoken by third-country nationals travelling through the BCPs surveyed (Russian, Chinese and Arabic).

Fieldwork

The fieldwork was carried out by Eticas Research & Consulting from July 14 2015 until 22 October 2015. A team of four interviewers was deployed to carry out the fieldwork. In addition to English, each interviewer was fluent in at least two languages among the following: Spanish, French, Chinese, Russian and Arabic. The interviewers were trained prior to fieldwork in a one day training attended by FRA and eu-LISA.

Interviews were conducted with interviewees completing the questionnaire themselves, using both tablet devices and on paper. Interviews were self-administered. Interviewers were always available for questions and clarifications.

7.2.5. Descriptive statistics of the sample

In total 1,234 interviews were conducted\(^\text{126}\) ranging from 72 at Iași BCP up to 249 in Frankfurt, with an average of 176 interviews per BCP. In all BCPs, but one, at least 150 interviews were carried out. In Iași only 72 were conducted due to the small number of eligible respondents at the time of the survey.\(^\text{127}\)

The respondents are citizens from over 80 different countries. The distribution of countries of citizenship of respondents is shown in Figure 2. The majority of respondents are citizens of a European country\(^\text{128}\) (42.1% of the sample), followed by Asia (22.9 percent), Latin America or the Caribbean (13.2 percent), Africa (9.8 percent), Northern America (9.6 percent) and Oceania (0.9 percent). 1.5 percent of respondents where either 'stateless'...

\(^{126}\) Initially a minimum of 150 interviews per BCP was planned. This requirement could not be reached due to lower traffic and very low response rates at the BCP in Iași, where only 72 interviews were conducted. In order to reach a bigger overall sample, an additional fieldwork phase was carried out at Frankfurt airport.

\(^{127}\) Most of the travellers on the trains surveyed where either Moldovan residents with double nationality, Moldovan and Romanian (and thus non-eligible) or did not want to take part to the survey.

\(^{128}\) "Europe" does not include citizens of any EU or EFTA country. Russia is counted as a European country according the regional composition defined by the United Nations.
persons in Estonia or the exact citizenship could not be established. Most respondents were Russian citizens (282 respondents or 22.9% of the sample) followed by Moldovans (223 or 18.1%), Chinese (114 or 9.2%) and US citizens (91 or 7.4%).

Figure 2: Distribution of countries of citizenship of respondents in the survey\textsuperscript{129}, average of the seven BCPs surveyed

Source: FRA survey on smart borders, 2015

The citizenship of travellers differs across BCPs. Table 1 provides an overview of the citizenship of travellers interviewed per BCP. In Sculeni and Iași almost all travellers were Moldovan citizens and in Narva almost all were Russian citizens. Travellers in Helsinki, arriving by ferry, were mainly Russians and Chinese. In Frankfurt airport 51.8 percent of the sample were citizens from an Asian country (mainly China and India). In Madrid airport the majority of respondents originated from Latin America and the Caribbean (most travellers from Mexico, Colombia, Cuba and Peru, but also from other countries). At Charles de Gaulle the majority came from Asia (36.2%), but also from Africa (26.0%) and Northern America (22.4%).

Table 1: Percentage distribution of region of citizenship of respondents per border crossing point\textsuperscript{130}

<table>
<thead>
<tr>
<th>BCP</th>
<th>Charles de Gaulle</th>
<th>Frankfurt</th>
<th>Helsinki</th>
<th>Iași</th>
<th>Madrid</th>
<th>Narva</th>
<th>Sculeni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>26.0</td>
<td>13.7</td>
<td>0.0</td>
<td>0.0</td>
<td>18.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Asia</td>
<td>36.2</td>
<td>51.8</td>
<td>37.7</td>
<td>2.8</td>
<td>9.9</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Europe*</td>
<td>3.1</td>
<td>2.8</td>
<td>53.7</td>
<td>91.7</td>
<td>7.3</td>
<td>88.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>11.7</td>
<td>17.7</td>
<td>4.3</td>
<td>0.0</td>
<td>45.3</td>
<td>1.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

\textsuperscript{129} Background of the map is based on shapefiles made available through Eurostat, © EuroGeographics for the administrative boundaries, available at: http://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units.

\textsuperscript{130} The allocation of countries to regions is based on composition by the United Nations, available here: http://unstats.un.org/unsd/methods/m49/m49gecin.htm (last revision: October 2013).
The gender distribution of the sample is balanced with 47.2 percent women and 47.4 percent men. Six respondents (0.5%) chose ‘other’ gender and for the remaining 4.9 percent the information could not be collected (because the respondent did not fill in the field). For 4.1 percent of the sample the gender of the respondent was guessed by the interviewer. At the BCP for Charles de Gaulle, Frankfurt and Sculeni more men were interviewed and at Helsinki and Iași considerably more women were interviewed.

Figure 3: Gender distribution across BCPs in the sample (%)
7.3. Results

7.3.1. Acceptability of technology

Acceptability of technology refers to the general agreement by the public with the use of biological characteristics for biometric systems.\(^{31}\)

Respondents were asked whether they feel comfortable with the use of the following biometric identifiers when crossing the border: fingerprints, iris-scan and facial image. Generally, third-country nationals travelling to the EU tend to feel comfortable with providing biometric data when crossing the border. For all three types of biometric identifiers (fingerprints, iris-scan and facial image) most respondents feel very comfortable. However, there are important differences: people feel more comfortable with providing fingerprints or facial image when crossing the border compared to having their iris scanned, a tendency which remains true across all BCPs, across all regions of citizenship of travellers, gender and age groups.\(^{32}\) Figure 5 presents an overview of how comfortable respondents are with the provision each of the three biometric identifiers when crossing the border.

Approximately 1 in 10 travellers feels very uncomfortable with providing fingerprints or facial image (12.8 and 12.1 percent) when crossing the border, while 38.2 and 38.4 percent respectively feel ‘very comfortable’. The percentage of travellers feeling very uncomfortable is considerably higher for iris-scan: 21.7 percent chose this answer. With 26.9 percent there is also a lower percentage of travellers feeling very comfortable with having their iris scanned when crossing the border.

\(^{31}\) E. Kindt (2013), Privacy and Data Protection Issues of Biometric Applications, p.33.

\(^{32}\) Further analysis per BCPs, per region of citizenship of travellers, gender and age groups is not reported and can be made available, upon request.
Figure 5: How comfortable are travellers with providing biometrics (fingerprints, iris-scan and facial image, respectively) when crossing the border, average of the seven BCPs surveyed (%) The dashed vertical line gives the average/mean of the values chosen on the 1-5 scale.

Source: FRA survey on smart borders, 2015. Question: How comfortable are you with the use of the following biometric identifiers when crossing the border? Fingerprints, iris-scan, facial image. N: 1,233, 1,228 and 1,227, respectively.

Having previously provided biometrics has an influence on how comfortable people are with this technology being used in the context of border control. 65.5 percent of respondents have provided their fingerprints previously. Compared to fingerprints, fewer travellers had a previous experience of iris-scan (22.5 percent) or facial image (50.4 percent). Figure 6 presents respondents’ previous experience with providing biometric details by citizenship of respondents (four main countries of citizenship considered). Wider differences among respondents of different nationality can be observed in relation to past experience with provision of fingerprints, compared to iris-scan and facial image. As an illustration, 76 percent of US citizens had previously provided their fingerprints compared to only 42 percent of Russians. However, a similar share of US citizens and Russians have let their iris be scanned and provided their facial image.

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According to the VIS regulation, visa applicants are under the obligation to provide fingerprints when applying for a visa at consulates and embassies of EU Member States.
Figure 6. Past experience with providing biometric details by citizenship, average of the seven BCPs surveyed (in %)

Source: FRA survey on smart borders, 2015. Question: have you ever given your biometric details in the past? Fingerprints, iris-scan, facial image. N = 1,148, 1,101 and 1,113, respectively.

For each of the three biometric identifiers, previous experience leads to higher acceptability. As an illustration, while 40.7 percent of travellers who had given their fingerprints in the past feel very comfortable, only 33.9 percent of travellers without any experiences feel very comfortable.

In addition, persons who tend to be more in favour of the use of new technologies in general, also feel more comfortable with providing their biometrics when crossing the border. Most travellers interviewed indicated to be in favour of new technologies in general. On a five-point scale, where 1 means ‘in favour of new technologies’ and 5 ‘against new technologies’, 42.4 percent selected the value 1 and 19.5 percent the value 2. Only 5.5 percent selected the value 5, meaning that only a small group of travellers is against new technologies.

Looking at fingerprints specifically, how comfortable people feel with this biometric identifier when crossing the border depends on several factors. The difference can be explained to some extent by the citizenship and gender of travellers. Russian citizens feel on average slightly more comfortable than other nationalities with providing fingerprints when crossing the border (average value of 3.9 compared to the overall average of 3.7). Comparing the mean score by gender, we find that women feel slightly more comfortable than men. Persons aged 51 or older tend to select more often that they feel very comfortable with providing fingerprints. However, no clear patterns were found with respect to age of respondents and how comfortable they feel with the provision of fingerprints when crossing the border.

Table 3 summarises the results of a logistic regression analysis that estimates the influence of each of several factors on the likelihood of travellers feeling comfortable with the provision of fingerprints when crossing the border (feeling comfortable means having selected either 4 or 5 on the 5-point-scale, where 1 means very uncomfortable). The estimates in the tables provide an estimate to what extent the likelihood changes. Although the estimates cannot be directly interpreted, as a general rule, a positive estimate means that this factor increases the likelihood of feeling comfortable and a negative estimate decreases the likelihood. The results confirm some of the above reported

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In a logistic regression model the likelihood needs to be transformed for an efficient estimation.
differences in a multivariate context. Having provided fingerprints previously increases the likelihood of feeling comfortable with the provision of fingerprints in the context of border control, even when controlling for other factors such as citizenship, gender, age and views on technologies. Compared to the group of Russian citizens, all other groups of citizens are less likely to feel comfortable with providing fingerprints, holding other factors constant. This lower likelihood is not statistically significant for the group of US citizens and has a very low level of significance for Chinese and ‘other’ citizens (as compared to Russians). Being less in favour of new technologies decreases the likelihood of feeling comfortable with fingerprints considerably. The results show that for a Russian male citizen aged 18 to 30, who has already given fingerprints and is in favour of new technologies, there is an estimated likelihood of 78 percent that he feels comfortable with giving fingerprints when crossing the border. For a person with the same characteristics but who has never given fingerprints, the estimated likelihood decreases to 70 percent. If the latter person would be against the use of new technologies, the estimated likelihood decreases to 31 percent.

Table 3: Logistic regression on the likelihood of reporting that the person feels comfortable with the provision of fingerprints when crossing the border (i.e. has selected either 4 or 5 on the five points scale compared to all other results)

<table>
<thead>
<tr>
<th>Citizenship</th>
<th>Estimate (standard error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>Reference</td>
</tr>
<tr>
<td>China</td>
<td>-0.54 (0.28)*</td>
</tr>
<tr>
<td>Moldova</td>
<td>-0.61 (0.22)**</td>
</tr>
<tr>
<td>Other</td>
<td>-0.46 (0.19)*</td>
</tr>
<tr>
<td>USA</td>
<td>-0.41 (0.28)</td>
</tr>
<tr>
<td>Gender</td>
<td>Reference</td>
</tr>
<tr>
<td>Man</td>
<td></td>
</tr>
<tr>
<td>Woman</td>
<td>0.22 (0.14)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>18-30</td>
<td>Reference</td>
</tr>
<tr>
<td>31-40</td>
<td>-0.20 (0.18)</td>
</tr>
<tr>
<td>41-50</td>
<td>0.05 (0.19)</td>
</tr>
<tr>
<td>51 or older</td>
<td>0.19 (0.18)</td>
</tr>
<tr>
<td>In favour of or against new technologies (measured on a five-point scale 1 = in favour and 5 = against new technologies)</td>
<td>-0.41 (0.06)**</td>
</tr>
</tbody>
</table>

Source: FRA survey on smart borders, 2015. Notes: Number of observations = 1,004. Significance levels: ***, < 0.001, ** < 0.01, * < 0.05. A logistic regression model estimates the influence of a number of independent variables on the likelihood of an event occurring. For this the likelihood of the event is transformed to create a linear relationship (into the ‘logit’). The ‘estimates’ provide the average value by which the dependent variable changes if the independent variable changes by 1. Since the dependent variable is transformed into the logit, the estimates are not straightforwardly interpreted. Generally, the detailed influence on the likelihoods can be determined, when transforming the estimated coefficients, which has been done in the text for some examples. A statistically significant positive value of the estimates means that the observed group has a higher likelihood compared to the reference group. A negative value of the estimates indicates a lower likelihood.
In sum, there is the tendency to feel comfortable with providing biometrics when crossing the border among third-country nationals travelling at the selected BCPs. This tendency is lower for iris-scan and this remains true across all BCPs, across all regions of citizenship of travellers, gender and age groups.

7.3.2. **Private (and family) life**

Case law by the European Court of Human Rights (ECTHR) and the Court of Justice of the EU (CJEU) recalls that the mere storing of data relating to the private life of an individual amounts to an interference within the meaning of Article 8 of the European Convention on Human Rights (ECHR). The routine storage of data on individuals relating to their entry to and exit from the territory of European Union Member States may affect directly the traveller and indirectly the family. For example, family life could be affected in the context of family reunification process where a member of the family is refused entry because of a previous record in the system indicating that the person has overstayed his/her visa. Article 7 of the Charter of Fundamental Rights and Article 8 of the ECHR protect the right to respect for private and family life. Such rights can be limited but restrictions must be in conformity with the general requirements of Article 52 (1) of the Charter of Fundamental Rights. This means that limitations must be provided for by law, must meet genuine objectives of general interest recognized by the Union or the need to protect the rights and freedoms of others, respect the essence of the right, and be proportionate. The European Data Protection Supervisor listed several aspects to be taken into account to assess the degree of interference, such as, the nature of the data, the scale of data collection, the further use and possible change of purpose as well as transfer of data to third countries.

Respondents were asked whether they believe that giving their biometrics when crossing the border is intrusive or not to their private life. The results are presented in Figure 7. 46.6% and 42.3%, believe that providing fingerprints and facial image respectively is not intrusive to their privacy (i.e. selected options 1 or 2 on the five points scale). Still, there is a relevant share of persons - approximately 30 percent, depending on the biometric identifier - who think that the provision of the respective information is intrusive or very intrusive (i.e. selected options 4 or 5 on the five points scale). Attitudes towards iris-scan are different, with a higher percentage (36.4%) believing that having their iris scanned is intrusive or very intrusive to their privacy (i.e. selected options 4 or 5 on the five points scale). In general, having previously provided fingerprints and being more in favour of new technologies is correlated with the perception that providing biometric data is not intrusive to one’s privacy (no considerable differences could be found according to age and gender of respondents).

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135 See, for example, ECHR, Leander v. Sweden, No. 9248/81, 26 March 1987, para. 48; Amann v. Switzerland (GC), No. 27798/95, 16 February 2000, para. 65; CJEU, Joined Cases C-92/09 and C-93/09, Volker und Markus Schecke GbR and Hartmut Eiffert v. Land Hessen and Bundesanstalt für Landwirtschaft und Ernährung, 9 November 2010, paras. 52 and 59.

136 EDPS, Opinion on the Proposals for a Regulation establishing an Entry/Exit System (EES) and a Regulation establishing a Registered Traveller Programme (RTP), 18 July 2013.
Figure 7: Perception of intrusiveness of collection of providing biometric data (in %)

In sum, with the exception of iris-scan, there is a tendency among respondents to perceive the provision of biometric data to be not intrusive on their privacy. However, a large share, approximately 30 percent, perceived providing fingerprints and facial pattern as intrusive or very intrusive. As with any other limitation to a right enshrined in the Charter of Fundamental Rights, the collection and processing of biometric data has to respect the requirements of Article 52(1) of the Charter, else it would not be justified.

7.3.2.1. Dignity

The concept of dignity forms a cornerstone in the EU Charter of Fundamental Rights. The first five articles fall under the title ‘Dignity’, bringing together various rights that are especially closely related to dignity, for instance the right to integrity of the person (Article 4(1)). Article 6 of the Schengen Borders Code as amended in 2013 requires that “border guards shall, in the performance of their duties, fully respect human dignity, in particular in cases involving vulnerable persons”. This raises the question on how far Member States can go in enforcing the collection of biometric data when – due for example to medical reasons (an injured hand), or damaged fingerprints due to manual work – factual difficulties emerge, an issue which needs to be addressed in a manner which does not interfere disproportionately with the right to physical and mental integrity of the person.

In the questionnaire, violation of human dignity has been operationalised as ‘humiliating behaviour’. In human rights law there is an intimate connection between the notion of human dignity and the notion of humiliation, and humiliation can be explained in terms of (violation of) human dignity. For example, when assessing if a certain action constitutes degrading treatment, the ECtHR examines whether the treatment suffered humiliates or debases an individual, showing a lack of respect for, or diminishing, his or her human dignity, or arouses feelings of fear, anguish or inferiority capable of breaking an individual’s moral and physical resistance.

Respondents were asked whether they believed that the following situations might be humiliating: to give their biometrics (fingerprints, iris-scan and facial image, respectively), to have their passport checked by a border guard (with no biometrics involved) or any kind of border check in general. The results are presented in Figure 8. The

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138 See, for example, ECtHR, M.S.S. v. Belgium and Greece, No. 30656/09, 21 January 2011. para. 220, and Pretty v. the United Kingdom, no. 2346/02, 29 April 2002, para. 52.
majority of respondents find these situations not humiliating. Almost one third (32.2%) believe that letting their iris be scanned might be humiliating, one in four (26.2%) finds that that providing facial image might be humiliating and slightly more than a fifth (22.6%) that providing fingerprints might be humiliating. Again, iris-scan is the biometric identifier which is more negatively perceived among the three considered. The least humiliating situation is having a 'passport checked by a border guard with no biometrics involved' (only 15.1% find it humiliating). Thus, more respondents think that providing biometrics might be humiliating compared with those who think that a check conducted by a border guard might be humiliating.

Figure 8: Assessment on situations that might be humiliating, average of the seven BCPs surveyed (in %)

Source: FRA survey on smart borders, 2015. Question: Please tell us which of the following situations might be humiliating or not. N = 1,141 fingerprints, 1,134 iris-scan, 1,131 facial image, 1,140 border guard, 1,127 any border check.

There are differences in the extent to which persons find border checks humiliating by region of citizenship of the travellers. Figure 9 reports the percentage of travellers who perceive the following situations to be humiliating: the provision of any biometric identifier (i.e. respondents who reported the provision of at least one of the three biometric identifiers as humiliating), a border check conducted by a border guard or any kind of border check. Overall, 45.5 percent of respondents consider at least one of the three ways of providing biometric data potentially humiliating. This percentage is much higher for citizens of an African country, where 59 percent find at least one way of providing biometric data potentially humiliating. Among citizens of an Asian country there is also a slightly higher percentage seeing the provision of biometric data as humiliating. On the other end, North Americans are less likely to see any of the ways of providing biometric data as humiliating (30.5%). There is also a higher percentage of Africans who think that having their passport checked by a border guard without biometrics involved (23.5%) or 'any kind of border check in general' (21.9%) might be humiliating.

This result could be interpreted as a higher perception among African people of being discriminated against at border checks, which is confirmed by the findings of FRA's EU-MIDIS survey where African people report higher rates of perceived discrimination compared with most other groups of immigrants in the EU.339

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In sum, although the majority of all respondents do not feel that providing biometrics in the context of border control might be humiliating, more respondents find providing biometrics more humiliating compared to a check conducted by a border guard. More research would be needed to understand the reasons for this finding. The EU legislator might consider addressing travellers concerns by increasing the fundamental rights safeguards related to the protection of dignity in the EES proposal, including the handling of situations where there are objective obstacles for travellers to provide biometrics.

7.3.3. **Accuracy of the data**

The accuracy of the biometric data depends on the quality of fingerprints – both when taking fingerprints and reading these for comparison – and on the accuracy of other personal data included in the database. The quality of fingerprints and the accuracy of information in the databases may impact on the fundamental rights of the person. Human and technical factors influence fingerprints’ quality. For example, when the system fails to recognise an individual (also called ‘false negative’), the person may risk to be denied entry into an EU Member State. The person affected may face difficulties to prove that he/she really is the person he/she claims to be. In the case of third-country nationals travelling to the EU, this vulnerability might be compounded by language problems.

Biometric and other personal data included in the database should be correct and up to date. If the data stored is outdated this may lead the authorities to take a wrong decision affecting the person concerned. For example, if the extension of a visa is not included in the EES database, a person may be wrongfully considered as having overstayed the visa, which in turn could lead to apprehension, detention or denial of entry into an EU Member State. No evidence is available on the prevalence of incorrect data included in any of the three EU IT-systems currently in use in the areas of borders, visa and asylum (i.e. VIS, Eurodac and SIS II).\textsuperscript{140}

\textsuperscript{140} This issue is addressed in FRA ongoing project “Biometric data in large EU IT-systems in the areas of borders, visa and asylum – fundamental rights implications”.

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**Figure 9:** Travellers who think that the provision of at least one of the three biometric identifiers or other border checks might be humiliating by region of citizenship, average of the seven BCPs surveyed (%)
The European Data Protection Supervisor (EDPS) has underlined the importance of accuracy of the data in light of the risk of severe negative consequences for the person concerned. For example, Article 9 of the EES proposal in particular deserves specific attention as it provides that, in order to facilitate the calculation of stay, the system will automatically calculate which entry records do not have exit data immediately following the date of expiry of the authorised length of stay and inform competent authorities. This raises questions about how to avoid mistakes caused by an automated decision which could fail to register exits due to various reasons (e.g., a third-country national - e.g. a non-EU national - may have a European Union and a non-European Union nationality using different passports when crossing the border, extended stay due to force majeure or humanitarian reasons, or technical problems with the system). There is a need to find solutions which would not make it excessively difficult for a traveler to provide evidence that he/she did not overstay without justified grounds.

Travellers were asked whether they trust biometric technologies to always properly identify who they are. The results are presented in Figure 10.

More respondents (46.6%) have trust (i.e. selected options 1 and 2 of the five points scale) that biometric technologies will always properly identify who they are, compared to those who tend to have no trust (20.8% selected options 4 and 5 of the five points scale). 12 percent do not know what to answer and 20.1 percent chose the middle value, which could be interpreted as lack of knowledge on the reliability of the data. There is higher trust among those who previously provided biometric data. Russians show the highest level of trust as compared to other groups of citizenship. There are no marked differences according to gender and age with respect to the level of trust in the reliability of biometric technologies.

**Figure 10: Trust in reliability of biometric technologies, average of the seven BCPs surveyed (%)**

![Bar chart showing trust levels](image)

Source: FRA survey on smart borders, 2015. Question: Do you trust biometric technologies to always properly identify who you are? N = 1,203

In sum, although close to half of the respondents trust that biometric technologies will always properly identify who they are, there is a great amount of uncertainty about how well biometric systems work to properly identify people. In order to increase trust in biometric technologies, objective information on the reliability and accuracy of biometric

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systems could be provided to third-country nationals travelling to the EU and communicated through adequate means.

Respondents were also asked what they think would happen in case the technology does not work properly. The results are presented in Figure 11. Respondents had to indicate to what extent they believe they would be able to cross the border in those cases. Most respondents (24.8%), almost one in four, declare not to know if they would be able to cross the border. One fifth (20.3%) believe they might not be able to cross the border and 17.6% believe they could easily cross the border if the technology does not work properly. There are more people (32.7%) who believe they might not be able to cross the border in case of problems with technology (options 4 and 5 of the five points scale), compared to those (25.6%) who believe they will be able to cross the border (options 1 and 2 of the five points scale).

Figure 11: Ability to cross the border if technology does not work properly, average of the seven BCPs surveyed (%)

Source: FRA survey on smart borders, 2015. Question: In case the technology does not work properly, to what extent do you believe you would be able to cross the border? N = 1,205

The fact that most respondents either believe that they will not be able (i.e. selected options 4 or 5 of the five points scale) or do not know if they will be able to cross the border in case the technology does not work properly is an important finding. It resonates with the concerns expressed by the EDPS on the negative consequences that mistakes in the system and in the automated processing of personal data can have on the individual.

An important implication of potential incorrect data in EES concern the risks of persons mistakenly flagged as overstayers and the use that police, immigration or other officials may make of such information. Specific measures could, therefore, be introduced in the EES to deal with situations where the data stored in the system are – for various reasons – not up to date without negative consequences for the travellers. In addition, police or immigration officers should have a clear duty to verify the accuracy of the lists of over-stayers produced by the IT-system before they take action, initiating for example, a return procedure.

7.3.4. Data protection

The use of biometric technologies and of IT systems in the context of border control affect the right to data protection. The right to data protection is guaranteed in Article 8 of the Charter of Fundamental Rights. It forms part of the rights protected under Article 8 of the ECHR. According to the Charter, a person’s data can only be processed fairly, for specified purposes, on the basis of the consent of the person concerned or some other legitimate basis laid down by law, and everyone has the right to access to data which have been collected concerning him or her, and has the right to have it rectified. The right to correct wrong data relates directly to the right to an effective remedy, which
is enshrined in Article 47 of the EU Charter of Fundamental Rights. The possibility to correct the data is particularly crucial. If data connected to the biometric identifier is inaccurate or outdated, this may lead the authorities to take a wrong decision affecting this and other fundamental rights of the person concerned. Secondary EU law, such as the Data Protection Directive 95/46/EC, the forthcoming data protection reform package or the EES proposal further specify the right to the protection of personal data. Further, general security measures aimed at protecting the biometric information need to be taken to protect the right to data protection.

Respondents were asked a number of questions relating to data protection, including questions on access to data by authorised persons and by law enforcement authorities and on the rights of the individuals, such as on the provision of information on the purpose of collecting biometrics and on the right to access and rectify one’s own personal data.

7.3.4.1. Right to information

Article 33 of the EES proposal clarifies the information that should be provided by Member States to persons whose data are recorded in the EES. The information to be provided include, inter alia, the identity of the controller of the data, the purposes for which the data will be processed, the categories of recipients of the data; the data retention period and the existence of the right of access to one’s own data, the right to rectify inaccurate or unlawfully processed data including information on the procedures for exercising those rights and contact details of supervisory data protection authorities. This information should be provided in writing.

The EDPS suggested to include an obligation to provide additional information to the travellers, especially in relation to overstay, for example, information on the fact that overstay will lead to the publication of the individual’s personal data on a list of over-stayers which will be sent to recipients of this list.

Respondents were asked whether they considered it important to be informed about why their biometric identifiers are collected and used. The results are presented in Figure 12. 83.9 percent of the respondents strongly agree, or agree, that it is important to be informed on why their biometric identifiers are collected and used. This shows a wide consensus.

Figure 12: Agreement to the importance of being informed on why biometric identifiers are collected and used, average of the seven BCPs surveyed (%)

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143 EDPS Opinion, p.13
Source: FRA survey on smart borders, 2015. Question: Please say to what extent you agree or disagree with each of the following statements. It is important that I am informed on why my biometric identifiers are collected and used. N = 1,153

The legal obligation to provide information on the data recorded in the EES is further underlined by a strong interest of respondents to receive information on the purpose of collecting and processing their personal data. As recommended by the EDPS, the EES proposal could specify that such information be provided “in an intelligible form, using clear and plain language, adapted to the data subject” as it is foreseen in Article 11.1 of the proposed Data Protection Regulation. Translations of this information should be available for third-country nationals not understanding the language of the responsible Member State.344

7.3.4.2. Right to access and rectify the data

According to Article 8 of the Charter of Fundamental Rights “everyone has the right of access to data which has been collected concerning him or her, and the right to have it rectified”. This is reflected in Article 34 of the EES345 proposal which provides a framework for the rights of information, access and rectification of third-country nationals’ personal data. According to article 34 (2) any person may request that data relating to him or her which is inaccurate be corrected and that data recorded unlawfully should be deleted. The correction and deletion shall be carried out without delay by the Member State that is responsible, in accordance with its laws, regulations and procedures.

Respondents were asked whether – in case of an error in their personal data when crossing the border – they believe that their personal data could be easily corrected. The results are presented in Figure 13. Half of the respondents (50.6%) believe that their data could not be easily corrected (options 4 and 5 of the 5 points scale). Only 17.4 percent believe that the data could be easily corrected (options 1 and 2 of the 5 points scale). One in five respondents does not know what to answer (20.1%).

Figure 13: Opinions on possibility to correct the data in case of an error in the personal data, average of the seven BCPs surveyed (%)

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344 Ibid., p. 34
345 Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing an Entry/Exit System (EES) to register entry and exit data of third-country nationals crossing the external borders of the Member States of the European Union, COM(2013) 95 final, Article 34.
Source: FRA survey on smart borders, 2015. Question: In case there is an error in your personal data when crossing the border, for example your biometrics do not match with your name, do you think that your personal data could be easily corrected? N = 1,196

As reported by the EDPS, the rights of the data subject are key to data protection. Ensuring the effectiveness of the rights of the data subject is particularly important in the area of freedom, security and justice, where, on the one hand, the exceptions and limitations imposed by law have a larger scope of application, and, on the other hand, the erroneous processing of personal data may have serious direct consequences on the data subject.146

Most respondents are concerned that their right to have wrong personal data corrected would not be easily safeguarded. This could be based on travellers’ unfamiliarity with their rights and access to remedies, as well as a lack of trust in the effectiveness of these mechanisms. Third-country nationals travelling to an EU Member State need to be better informed about the right to access and to rectify personal data and the existence of remedies and available support in case of difficulties.

7.3.4.3. Access to data by authorised persons

Unauthorised access to personal data constitutes a violation of the right to protection of personal data and as the case may be the right to private life. Technical security measures including logging practices can limit the risk that people who are not authorised to access the database do so or that authorised persons access the data for a non-authorised purpose, such as a private one.

According to Article 7 of the EES proposal, each Member State must designate the competent authorities, including border, visa and immigration authorities, the duly authorised staff of which has access to enter, amend, delete or consult data in the EES. According to Article 40, the authorised staff of Member States, of eu-LISA and of Frontex has access to the specific personal data listed in Article 40, for the purposes of reporting and statistics without allowing individual identification.

Respondents were asked whether they trust that only legally authorised people will access their data. The majority of travellers trust that only legally authorised people can access biometric data. As shown in Figure 14, approximately three quarters of respondents strongly agree or agree with this statement and only 7.9 percent disagree or strongly disagree.

Figure 14: Views on access to data, average of the seven BCPs surveyed (%)
In order to make sure that only authorised persons access personal data included in the EES database, adequate security measures should be in place. The number of persons having authorised access could also be limited to what is absolutely necessary for the purpose to be attained. For example the data controller (eu-LISA or the respective authority at national level) may only produce anonymised statistics for relevant stakeholder instead of giving those who need the statistics direct access to the personal data.

7.3.4.4. Access to data for law enforcement purposes

According to the EES proposal, after two years of its functioning an evaluation of the system should take place. The European Commission should also evaluate the possible access to the system for law enforcement purposes. On the basis of this evaluation, as well as the evaluation of the experience of access for such purposes into the VIS, the Regulation could be amended to define the conditions for access by law enforcement authorities.\footnote{Proposal for a Regulation of the European Parliament and of the Council establishing an EntryExit System (EES) to register entry and exit data of third-country nationals crossing the external borders of the Member States of the European Union, COM(2013) 95 final 2013/0057 (COD), p.6}

Access by law enforcement authorities to the EES would fit in the general trend to grant law enforcement authorities access to several large-scale information and identification systems.

A number of Member States have, however, expressed their preference for including the access by law enforcement authorities directly into the proposal, particularly for the purpose of combating cross-border crime and terrorism, as an ancillary objective from the very start of operation of the EES.\footnote{Council of the European Union, Access for law enforcement purposes to the EES, Brussels, 16 July 2015, available at http://data.consilium.europa.eu/doc/document/ST-10732-2015-INIT/en/pdf.}

This initiated a discussion on the legal challenges of such extension of the purpose of the instrument – as well as on additional fundamental rights issues – particularly bearing in mind the principles of necessity and proportionality which shall be observed; the CJEU emphasised in the Digital Rights Ireland judgment that a measure of indiscriminate, blanket nature violates the Charter.\footnote{CJEU, Joined cases C-293/12 and C-594/12, Digital Rights Ireland and Seitlinger and Others, 8 April 2014.} Other potential issues relate to discrimination, presumption of innocence and potential stigmatisation of third-country nationals given that the availability of their data for law
enforcement purposes would necessarily affect the detection rate and statistics of criminal activity compared to EU nationals.

Respondents to FRA’s survey were asked whether they have no problems with the police accessing their personal data. The results are reported in Figure 14. More than half of the respondents do not have any problems with the police accessing their biometric data (54.8 percent agree or strongly agree with this statement). However, access by law enforcement authorities to EES is an issue for a relevant part of the population, with approximately one in five (20.1%) who either disagree or strongly disagree with the statement.

While the majority of the respondents express no concerns over the measure, it needs to be taken into account that the question could only be phrased very generally and could not refer to the actual extent of, and fundamental rights safeguards relating to, possible law enforcement access. Regardless of the indicative information provided by this survey, it will be the obligation of the EU legislator to ensure full compliance with fundamental rights and take into account standards set by relevant CJEU and ECtHR judgements, as well as experience with systems where law enforcement access is currently permitted.150

7.3.5. Automated border control systems

Border controls are changing and there is increasing reliance on automated border controls (ABC) including relevant technologies. Increasingly in the EU, biometric data are being used in conjunction with ABC. The ABC gate compares the biometric data (in most cases, facial image) from the passenger’s travel document with the real-life equivalent. It also verifies the validity and reliability of the travel document. If the scoring is high enough, the passenger is let through the gate.151 In addition, an ABC gate could also carry out checks against the authorities’ databases. These systems are considered to match the high security in verification of a traveller’s identity with increased efficiency and speed in conducting border control. Respondents were asked if they were to choose, whether they would go to a machine or a border guard. Results are presented in Figure 15. Approximately one third of the respondents reported they would go to a machine and another third reported they would go to a border guard. For one in every four respondents, it makes no difference.

Figure 15: Travellers’ preference between machine or border guard, average of the seven BCPs surveyed (%)

150 ECtHR, Rotaru v. Romania [GC], No. 28341/95, 4 May 2000; ECtHR, M.K. v. France, No. 19522/09, 18 April 2013; ECtHR, Liberty and Others v. the United Kingdom, No. 58243/00, 1 July 2008; ECtHR, S. and Marper v. the United Kingdom, Nos. 39562/04 and 39566/04, 4 December 2008; CJEU, Joined cases C-293/12 and C-594/12, Digital Rights Ireland and Seitlinger and Others, 8 April 2014.
151 See project ABC4EU.
Source: FRA survey on smart borders, 2015. Question: Border controls are changing and there is increasing reliance on automated systems (with no border guards involved). If you could choose, would you go to a machine or to a border guard to have your documents checked at the border? N = 1,195

There are no marked differences in the results by age or gender, where men tend to prefer machines slightly more often than women. However, there are clear differences with respect to region of citizenship. Citizens of an African country, Latin America, the Caribbean and North America prefer border guards over machines. While citizens of Asian countries do not have specific preferences, travellers who are European citizens prefer machines over border guards. The latter is mainly due to Moldovan citizens strong preference for machines over board guards, since Russian citizens appear to be indifferent in their choice regarding machine or border guard.

7.3.6. Discrimination

Article 6 of the Schengen Borders Code requires that “border check controls have to be carried out in a way which does not discriminate against a person on grounds of sex, racial or ethnic origin, religion or belief, disability, age or sexual orientation”\(^{155}\). This provision must be read in light of Article 21 of the Charter of Fundamental Rights which extends the prohibition of discrimination to other grounds.

It could be argued that automated systems cause less discrimination than border guards because of the absence of human judgement selecting passengers for further checks.

The results of the survey confirm this view. Respondents were asked whether they believe that automated systems could cause more or less discrimination compared to checks done by border guards. The results are presented in Figure 16. The majority believe that automated system could cause less discrimination. Overall, 60.4% believe it could cause less discrimination (options 1 and 2 of the 5 points scale) and only one in ten (10.6%) believe that an automated system could cause more discrimination (options 4 and 5 of the 5 points scale). 13.6% do not know what to answer.

Particularly, citizens of a European country, most notably Moldovans, think that the use of machines would lead to less discrimination.

Figure 16: Travellers opinion on the extent to which automated system cause more or less discrimination, average of the seven BCPs surveyed (%)

Source: FRA survey on smart borders, 2015. Figure: Do you think that automated systems could cause more or less discrimination compared to checks done by border guards? By discrimination we mean when somebody is treated unfavourably compared to others because of their skin colour, age, sex, sexual orientation, disability, ethnic origin, religion or religious beliefs. N = 1,176

There is a widely held view that automated systems could cause less discrimination compared to checks carried out in person by border guards. This might be based on the assumption that machines entail a lower risk of discriminatory profiling compared to checks by border guards. However, it should be noted that automated systems could be programmed to identify individuals using sensitive data, such as race, ethnicity or health. Measures to avoid discriminatory profiling are, therefore, required.

7.3.7. Children

The EES proposal envisages the processing of fingerprints of children from the age of 12. In the survey, FRA asked from what age respondents think that children should be allowed to go through biometric checks. The results are presented in Figure 17. Most respondents (29.4%) think that only adults (from 18 years onward) should go through biometric checks, followed by those who think that biometric checks should be done at any age (16.5%) and those who would recommend them from 16 years onwards (15.1%).

Figure 17: age at which biometric checks of children should be allowed, average of the seven BCPs surveyed (%)

Source: FRA survey on smart borders, 2015. Question: In some countries children already go through biometric checks. From what age do you think they should be allowed? N = 1,172

In sum, although most respondents believe fingerprints should be taken from 18 years of age onwards, there are different views on at which age children should be allowed to provide biometric checks. Less than one third of the respondents believe children should be allowed to provide fingerprints from 12 year onwards (i.e. selected the option ‘from any age’ or ‘from 12 onwards’), the current age limits for fingerprinting set in the EES proposal. Based on these results and on the previously discussed negative fundamental rights implications on the individual in case of mistakes in the data, more reference to the specific situation of children (but also of other vulnerable groups such as older people and persons with disability) could be made in the EES proposal. Not only the methods for collecting fingerprints, but also those for providing information about fingerprinting should be carried out in an age-appropriate manner. Moreover, long data retention periods, even if allowed by law, may cause a particular hardship to children. The child had most likely no role in the decision to travel. Therefore, retaining a child’s data in EES may disproportionately impact on any future decisions by the state concerning the child in question.
It should be noted that including children in the EES dataset might also have positive fundamental rights implications. If SIS II was to be optimised for tracing missing children, for instance by including all missing children in the database on a routine basis, an alert could appear in EES when a missing child is checked against the database.

7.3.8. Other issues

Finally, respondents were asked whether they are afraid that the technology to collect their biometrics might be harmful to their health. The results are reported in Figure 18. 39.9 percent of the respondents either disagree or strongly disagree with this statement. 22.1 percent believe biometric technologies could harm their health (agree or strongly agree). A large share of travellers, almost one in five, does not know if technologies to collect biometric data would be harmful to their health (18.8 percent). 18.4 percent neither agree nor disagree with the statement.

In sum, despite the tendency to feel safe, more than half of the respondents either believe that biometric technologies could harm their health or show uncertainty on this issue. Objective and scientific information should be provided to travellers on the health consequences of the use of biometric data.

Respondents were also asked if the collection of biometric data is important to secure borders, one of the objectives mentioned for the establishment of an entry/exit system (EES). The majority agree with the statement (67%). Only 8.7 percent believe that the use of biometric technologies is not important to secure EU borders (i.e. either disagrees or strongly disagree with the statement).

One of the aims of the Smart Border proposal is to speed up border crossing. Respondents were finally asked whether they believe that providing biometric data makes the border procedure quicker. Two thirds of the respondents either strongly agree or agree with the statement. 8.5 percent disagree or strongly disagree. About one quarter of respondents said either that they neither agree nor disagree or that they do not know whether or not to believe the collection of biometric data at the border increases the speed of border checks.

Figure 18: Opinions on biometric data regarding speed, security and health (in %)

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54 See eu-LISA, Smart Borders Roadmap of the Testing Phase, Version 5.0, 28 February 2015.
The collection of biometric data is important to secure borders

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Do not know</th>
<th>Do not want to answer</th>
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<td>26.7%</td>
<td>40.3%</td>
<td>14.6%</td>
<td>5.8%</td>
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Providing biometric data makes border procedures quicker

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Do not know</th>
<th>Do not want to answer</th>
</tr>
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<tbody>
<tr>
<td>27.9%</td>
<td>37.9%</td>
<td>14.9%</td>
<td>6.4%</td>
<td>2.1%</td>
<td>10.3%</td>
<td>0.5%</td>
</tr>
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Source: FRA survey on smart borders, 2015. N = 1,164, 1,168 and 1,165, respectively.
7.4. Conclusions

There are a number of fundamental rights implications related to modern identification and verification technologies in the context of border control. Third-country national travellers’ views on these implications can inform the legislator and policy makers on specific areas of concern and how the population targeted by these measures will perceive the Entry Exit System, once in place. At the same time, travellers’ perceptions are only one element that needs to be taken into account when assessing fundamental rights compliance with certain measures. Violations of fundamental rights may occur regardless of whether the individual consents or not to a certain treatment, particularly in light of limited rights awareness.

The results show that most respondents are comfortable with providing biometrics when crossing borders, with the exception of iris-scan. Most respondents do not feel that biometrics compromises their right to dignity. Except for iris-scan, there is a tendency among respondents to perceive biometric data provision as not being intrusive on their privacy. However, about 30% believe that biometrics represent an interference with their private life and between 22% and 32%, depending on the biometric identifier, feel that the provision of biometric data is potentially humiliating. In addition, more respondents think that providing biometrics might be humiliating compared to those who think that a check conducted by a border guard might be humiliating. Travellers’ concerns could be addressed by increasing the fundamental rights safeguards related to the protection of dignity in the EES proposal, for instance by complementing specific provisions with an obligation to act in full respect of the human dignity of the third-country national.

The results of the survey show that trust in the reliability of biometric technologies is quite high. This reflects the consensus among experts that identifies biometrics as the most accurate means to determine a person’s identity.

A key finding of the survey relates to what happens when something goes wrong and the system does not function as expected. Here, more than half of the respondents believe that they will not be able (or do not know if they will be able) to cross the border in case the technology does not work properly. Similar concerns emerged in relation to the right to rectify the data, a key to data protection. Half of the respondents believe that in case of a mistake in the data, it would be difficult to correct this.

This finding resonates with the concerns expressed by the EDPS and other organisations on the negative consequences that mistakes in the system and in the automated processing of personal data can have on an individual. For example, when the system fails to recognise an authentic individual (also called ‘false negative’), the person might be denied entry into an EU Member State or, in the worst case, run the risk of being apprehended and detained. The person affected may face difficulties to prove that he/she really is the person he/she claims to be. In the case of third-country nationals travelling to the EU, this vulnerability might be compounded by language problems.

There are many ways mistakes could occur, for example errors such as false negatives, but also fraud and forgery of biometric data and incorrect or not up to date personal data included in the database. The most likely implication of incorrect data in EES concern the risks of persons mistakenly flagged as over-stayers and the use that police, immigration or other officials may make with such information. Specific measures could be, therefore, introduced in the EES to deal with situations where the data stored in the system are – for various reasons – not up to date without negative consequences for the travellers. In addition, police or immigration officers should have a clear duty to verify the accuracy of the lists of over-stayers produced by the IT-system before they take action, initiating for example, a return procedure.

The results of the survey show that third-country national travellers take data protection seriously and more than 80% consider it important to be informed on the purpose of collecting and processing their personal data. The legal duty to provide information on the data recorded in the EES could be further strengthened by specifying in the proposal that information should be provided in a way that takes into account the needs of specific groups (for example, child-friendly language for children and ‘easy to read’ for persons with disabilities). Translations of this
information should be made available for third-country nationals not understanding the language of the responsible Member State.

There is a widely held view that automated systems could cause less discrimination – for example on the basis of race or ethnicity – compared to checks carried out in person by border guards. This might be based on the assumption that machines entail a lower risk of discriminatory profiling compared to checks by border guards. However, it should be noted that automated systems could be programmed to identify individuals using sensitive data, such as race, ethnicity or health. Measures to avoid discriminatory profiling are, therefore, required.

Less than one third of the respondents agree with the current age limits for fingerprinting set in the EES proposal, according to which fingerprints should be provided from 12 years onwards. Most respondents would exclude children (i.e. minors) from the obligation to provide fingerprints. Based on these results and on the serious negative fundamental rights implications on the individual in case of mistakes in the data, more efforts should be made to protect the fundamental rights of children.

Finally, respondents were asked whether they are afraid that the technology to collect their biometrics might be harmful to their health. The survey result show that despite the tendency to feel their health is not at risk, two thirds of respondents either believe that biometric technologies could harm their health or show great uncertainty on this issue. Objective and scientific information should be provided to travellers on the health consequences of the use of biometric data.
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