

Technology Foresight on Biometrics for the Future of Travel

BORDER SECURITY OBSERVATORY
RESEARCH AND INNOVATION UNIT

FRONTEX

CERIS SSRI EVENT: "FORESIGHT AND KEY
ENABLING TECHNOLOGIES"

BRUSSELS – 5 MARCH 2024

FRONTEX

 **EUROPEAN BORDER AND
COAST GUARD AGENCY**

Project Overview

Project Overview

1. Analysis of Research Context
2. Insight Hunt
3. Filtering Results
4. Deep Analysis
5. Mapping Capabilities



Project Overview

Research Team

Steinbeis 2i
Germany



4CF
Poland



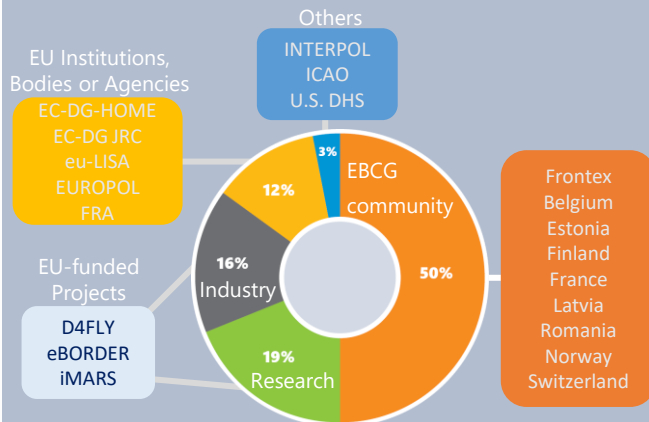
Erre Quadro
Italy



Institute of Optoelectronics
Military University of Technology
Poland



>40 Stakeholders actively involved
(strong focus on EU and EBCG)



2021



Objectives

Research study

Research study on the future

opportunities that biometric technologies could provide to the European Border and Coast Guard (EBCG) community



Identify specific research and innovation activities

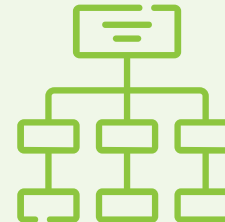


Knowledge on how to maximize future benefits of biometric technologies

Desired outputs



TF Methodology and Supporting Tools

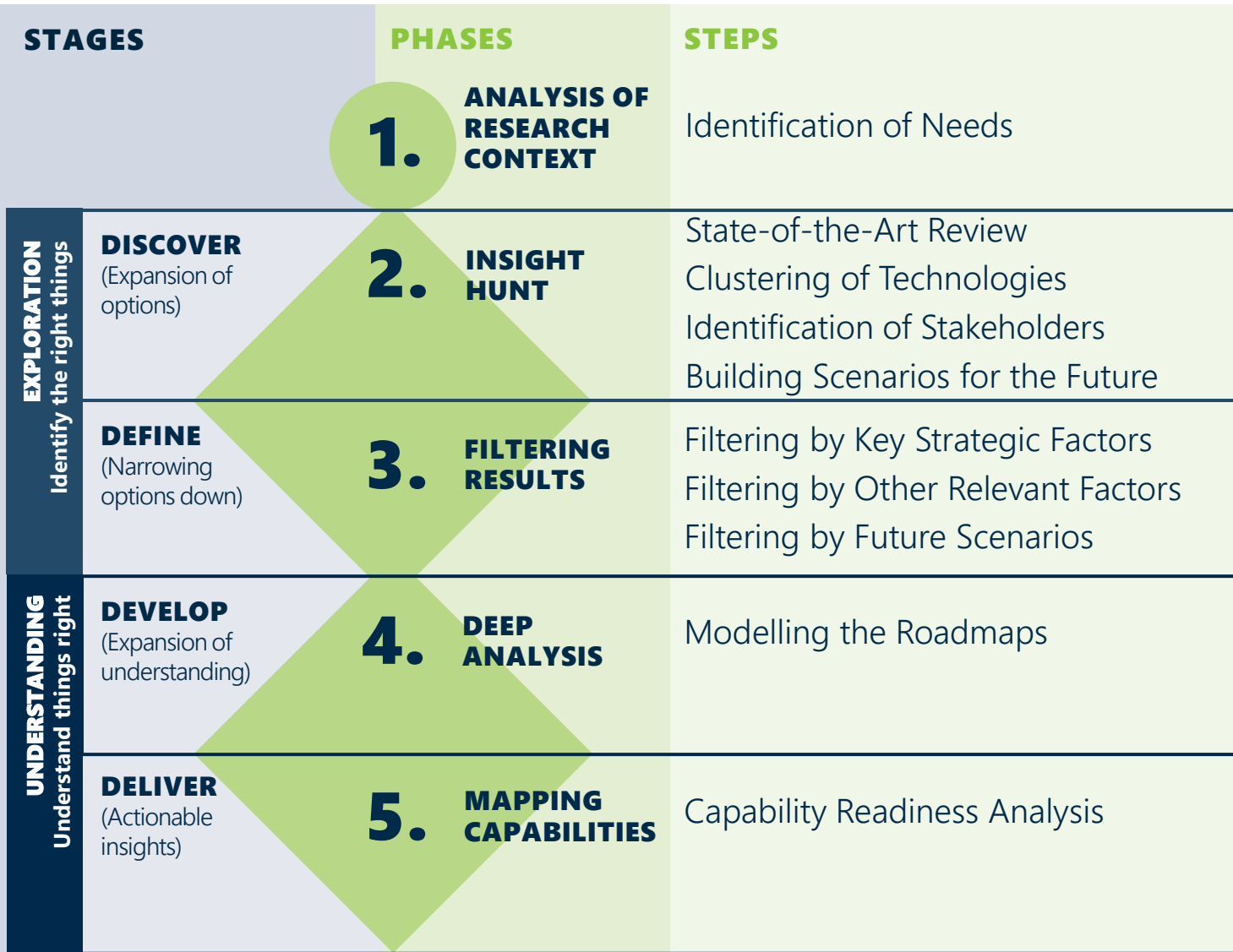


Taxonomy of biometric technologies



Research Study

Methodological Framework



METHODS

Matrixes of needs & functional requirements
Desk research

Patentometric & bibliometric analyses
Delphi Survey
4CF Matrix

Rip Van Winkle Method
Futures Wheel
Forecasting/Backcasting
Scenario Analysis

Weighted Criteria Matrix
Workshops

TOOLS

4CF HalnyX	Smart Ranker
Miro Board	Weighted Clusterer
Domain Terminology Extractor	

1. Analysis of Research Context

Project Overview

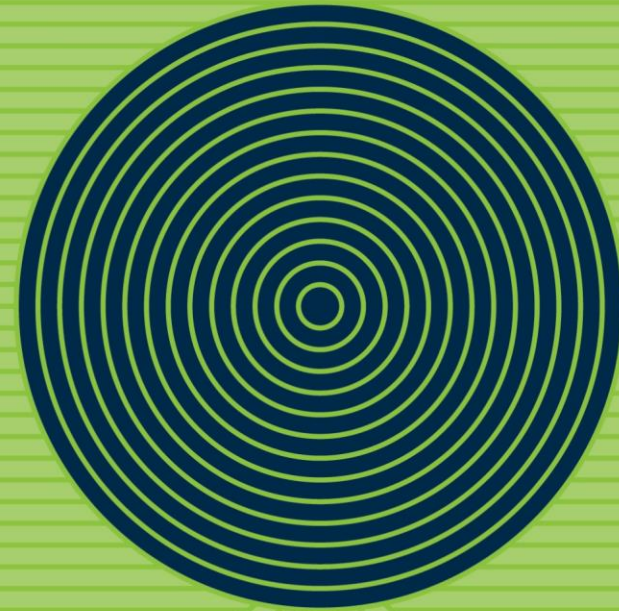
1. Analysis of Research Context

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Identification of Needs

Analysis of Frontex needs for key functions of biometric technologies



Aim

- Needs analysis to specify the field and scope of the research and to set the goals for the study
- Tailor the Technology Foresight Methodology to Frontex needs



4 “must-haves” for biometric technologies identified for reference in later phases of the project

- Seamlessness
- Compliancy with fundamental EU values and regulations
- Applicability within pandemic-specific restrictions
- Low vulnerability to adversary attacks

2. Insight Hunt

Project Overview

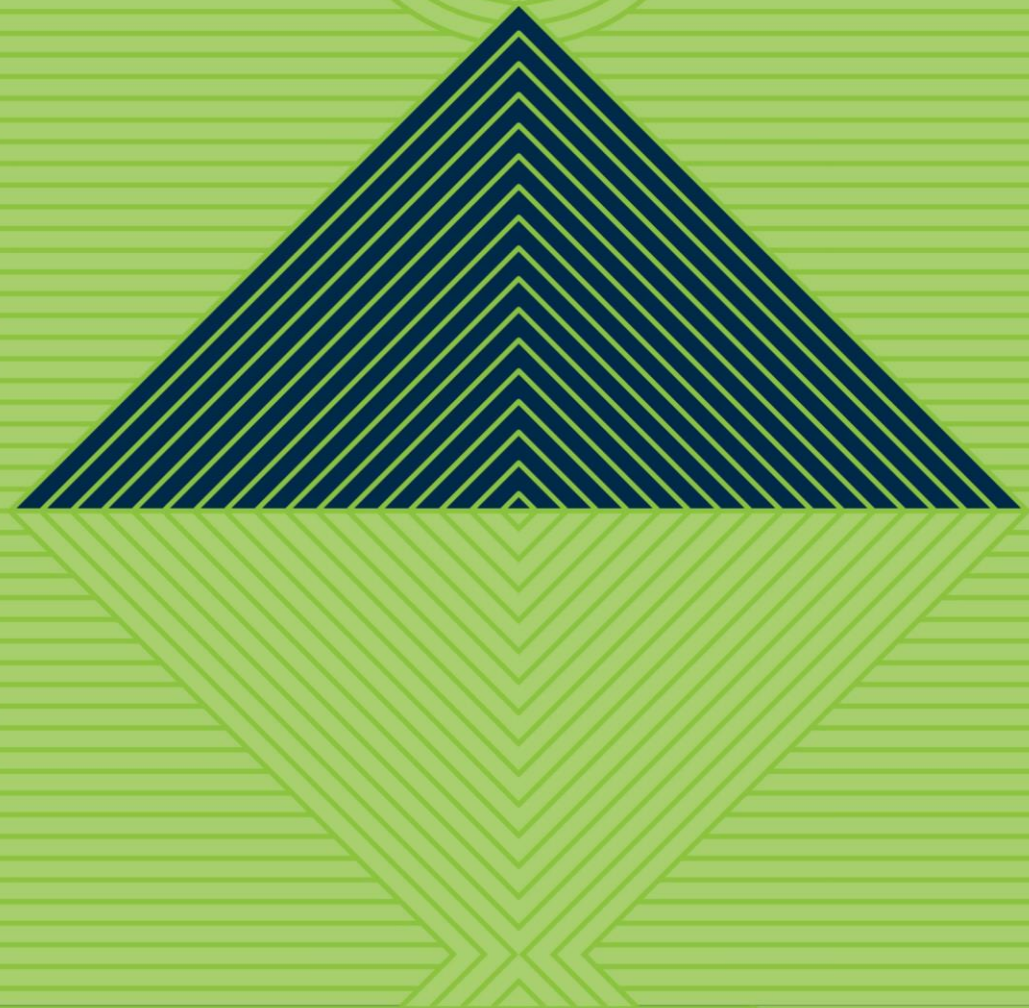
1. Analysis of Research Context

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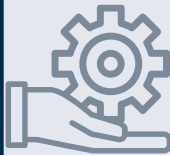
State-of-the art Review

Taxonomies



Aim

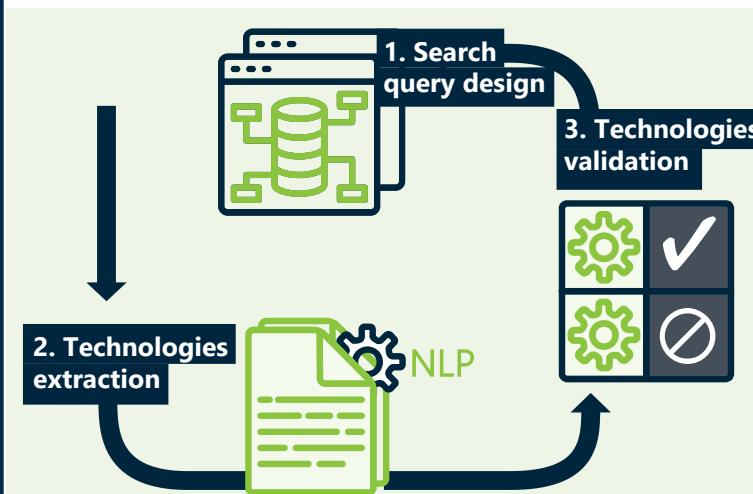
- Establish a common systematic understanding of the biometrics domain
- Create reference documents which could enable future R&I activities



Output

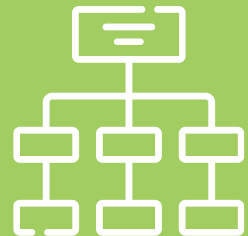
- Taxonomy of biometric technologies
- Taxonomy of biometrics-enabled technological systems

- **Highly iterative** process based on the extraction of terminology from patents and scientific literature
- **Automatic tools** (embedding NLP) for analysis of massive technical and scientific documentation



Three-level Taxonomy of Biometric Technologies

- 57 biometric technologies
 - 5 biomolecular
 - 39 morphological
 - 13 behavioural
























Two-level Taxonomy of Biometrics-Enabled Technological Systems



State-of-the art Review

Taxonomies

- 1 **BIOMOLECULAR BIOMETRICS** 
- 2 **MORPHOLOGICAL BIOMETRICS** 
- 3 **BEHAVIOURAL BIOMETRICS** 

BIOMETRICS TECHNOLOGIES	1.1 DNA biometrics 	1.2. Other biomolecular biometrics 	2.1. Face recognition 	2.2. Friction ridge recognition 	2.3. Iris recognition 	2.4. Vascular pattern recognition 	2.5. Physiological signals biometrics 
	2.6. Hand geometry recognition 	2.7. Other minor morphological biometrics 	3.1. Keystroke recognition 	3.2. Gait recognition 	3.3. Handwriting recognition 	3.4. Speaker recognition 	3.5. Other minor behavioural biometrics 
	1. Self-service systems 	2. Identity document readers and verification sub-systems 	3. Full-body scanning systems 	4. Systems based on personal devices 	5. Movable systems 	6. Large-scale IT systems 	7. Virtual traveller identity schemes 

Clustering of Technologies

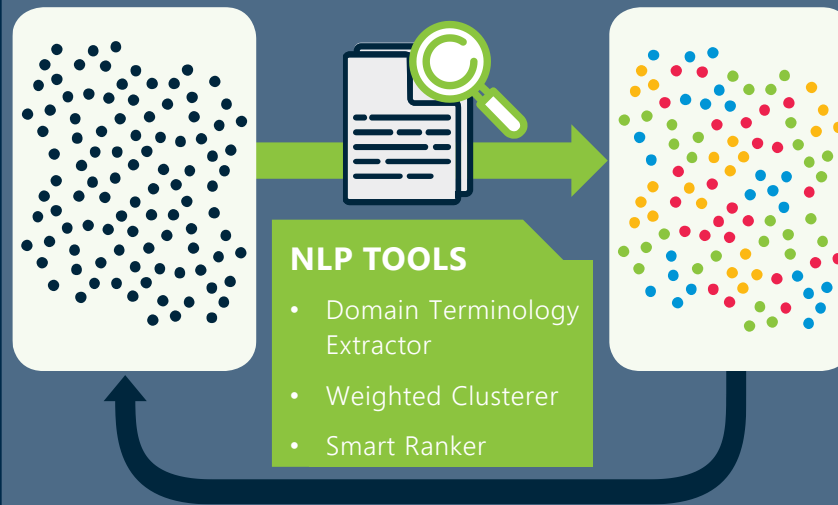
Identification of Technological Clusters



Aim

- Group the large set of biometric technologies into **clusters** to assure the usability of the taxonomy in the different phases of the Tech Foresight
- Create homogeneous datasets of patents and scientific publications suitable to conduct patentometric and bibliometric analyses

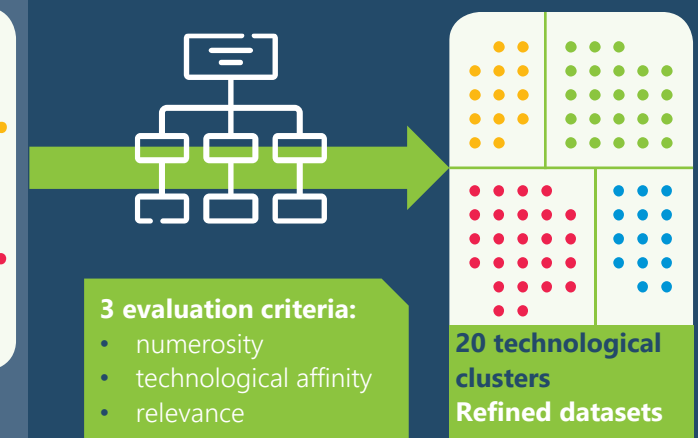
PRELIMINARY AUTOMATIC STEP



NLP TOOLS

- Domain Terminology Extractor
- Weighted Clusterer
- Smart Ranker

CONTROL STEP























3 evaluation criteria:

- numerosity
- technological affinity
- relevance

20 technological clusters
Refined datasets

Clustering of Technologies

Identification of Technological Clusters

1.  DNA biometrics	6.  3D friction ridge recognition	11.  Iris recognition at a distance	16.  Periocular recognition
2.  Infrared face recognition	7.  Contactless friction ridge recognition	12.  Eye vein recognition	17.  Keystroke recognition
3.  2D face recognition in the visible spectrum	8.  Contact-based friction ridge recognition	13.  Hand vein recognition	18.  Gait recognition
4.  3D face recognition	9.  Iris recognition in the NIR spectrum	14.  Heart signal recognition	19.  Handwriting recognition
5.  Infrared friction ridge recognition	10.  Iris recognition in the visible spectrum	15.  Hand geometry recognition	20.  Speaker recognition

Clustering of Technologies

Patentometric and bibliometric analyses of Clusters



Aim

- **Analyse the lifecycle** of 20 Biometric Technological Clusters to gather information about their evolution
- **Theory of Technology Lifecycle applied**
- Datasets of patent families and scientific publications were used to **study technological evolution**



Technological
life-cycle
assessment



Proprietary patent database
(based on EPO's Database)



OpenAIRE database
(scientific publications)



CORDIS database
of EU-funded projects

DATA ANALYSIS



Geographical
distribution
of R&D,
manufacturing
and commercial
activities

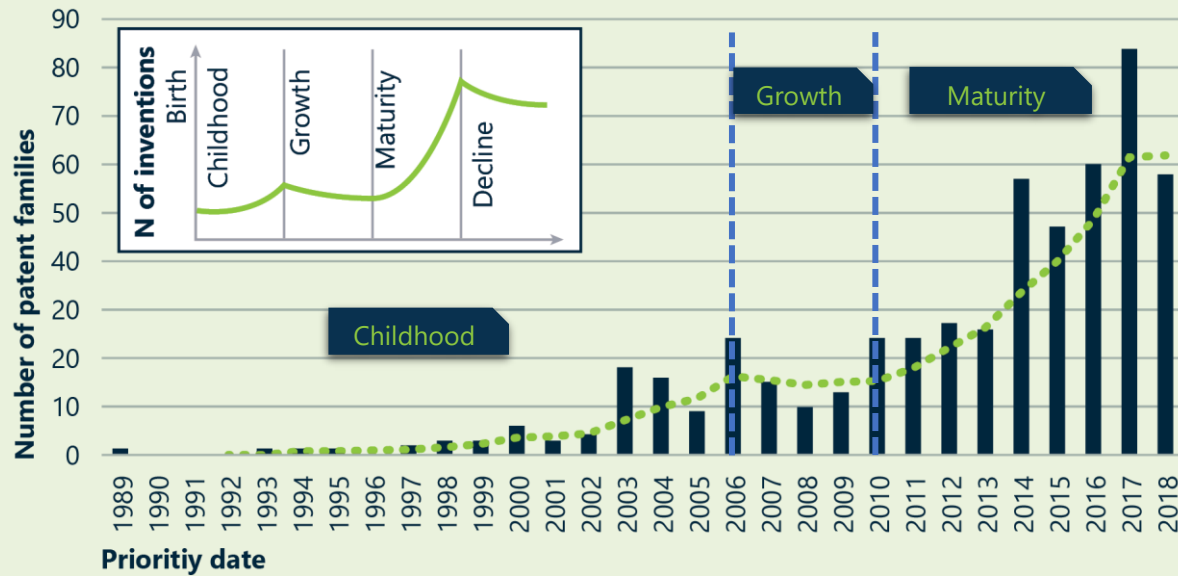


Most prolific
R&D entities

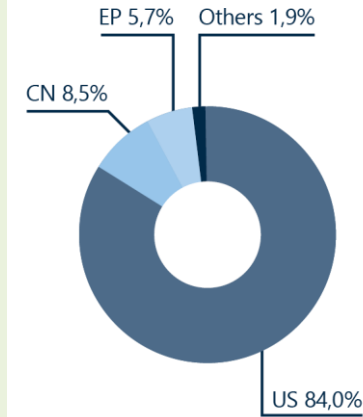
Clustering of Technologies

Patentometric and bibliometric analyses on Clusters

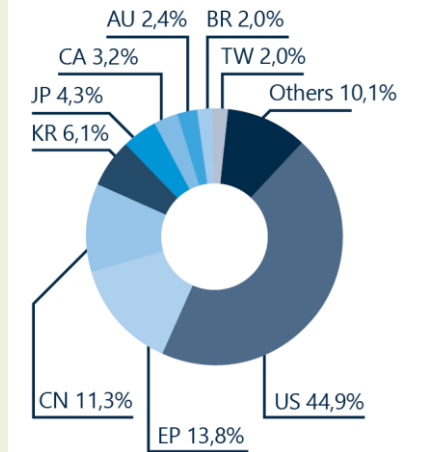
3D face recognition



Geographic distribution of priority patents



Geographic distribution of all patents



Assignee	Number of patent families	% of the total
Microsoft	21	3.8
Amazon Technologies	19	3.4
Google	18	3.2
Apple	13	2.3

Publisher	Number of scientific publications	% of the total
IEEE	87	32.3
Springer	34	12.6
Elsevier	25	9.3

Building Scenarios for the Future

Scenarios for the future of travel, border checks and biometrics in 2040



Aim

- Reframing visions of the future in order to challenge them
- Assessing how alternative futures might influence the evolution of biometrics.



Choice of scenarios

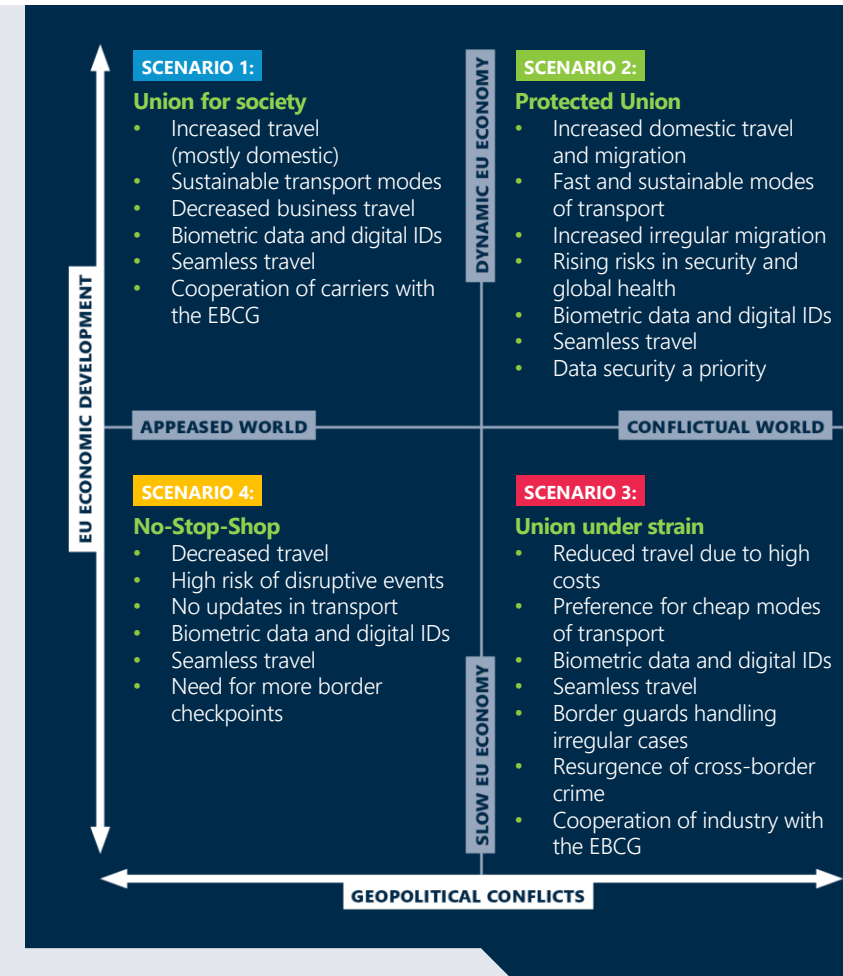
- Based on JRC's study "*The Future of Customs in the EU 2040: A foresight project for EU policy*"^[1]
- Adapted to incorporate aspects relevant to the travel and border check context



Use of scenarios

- Roadmapping
- Mapping capabilities

[1] Ghiran A., Hakami A., Bontoux L., Scapolo, F. *The Future of Customs in the EU 2040: A foresight project for EU policy*, EUR 30463 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-26299-2, doi:10.2760/29195, JRC121859.



3. Filtering Results

Project Overview

1. Analysis of Research Context

2. Insight Hunt

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Filtering by Key Strategic Factors

Prioritisation of biometric technologies – The Delphi Survey



Aim

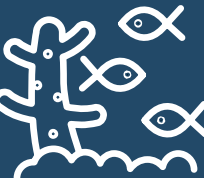
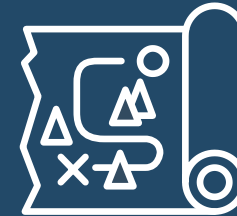
- Select the Key biometric Technological Clusters – KTCs
- Quantitative assessment of the 20 Technological Clusters using 2 metrics: **Relative Advantage** and **Earliest Time to Mainstream** by a **real-time Delphi**
 - Exploit collective intelligence, not only statistical distribution of answers
 - Stimulate consensus-oriented structured discussions
 - Collect experts' opinions

Relative Advantage

Squalls



Pirate Treasure



Coral Reef



Sirens

Earliest Time to Mainstream (ETM)






Filtering by Other Relevant Factors

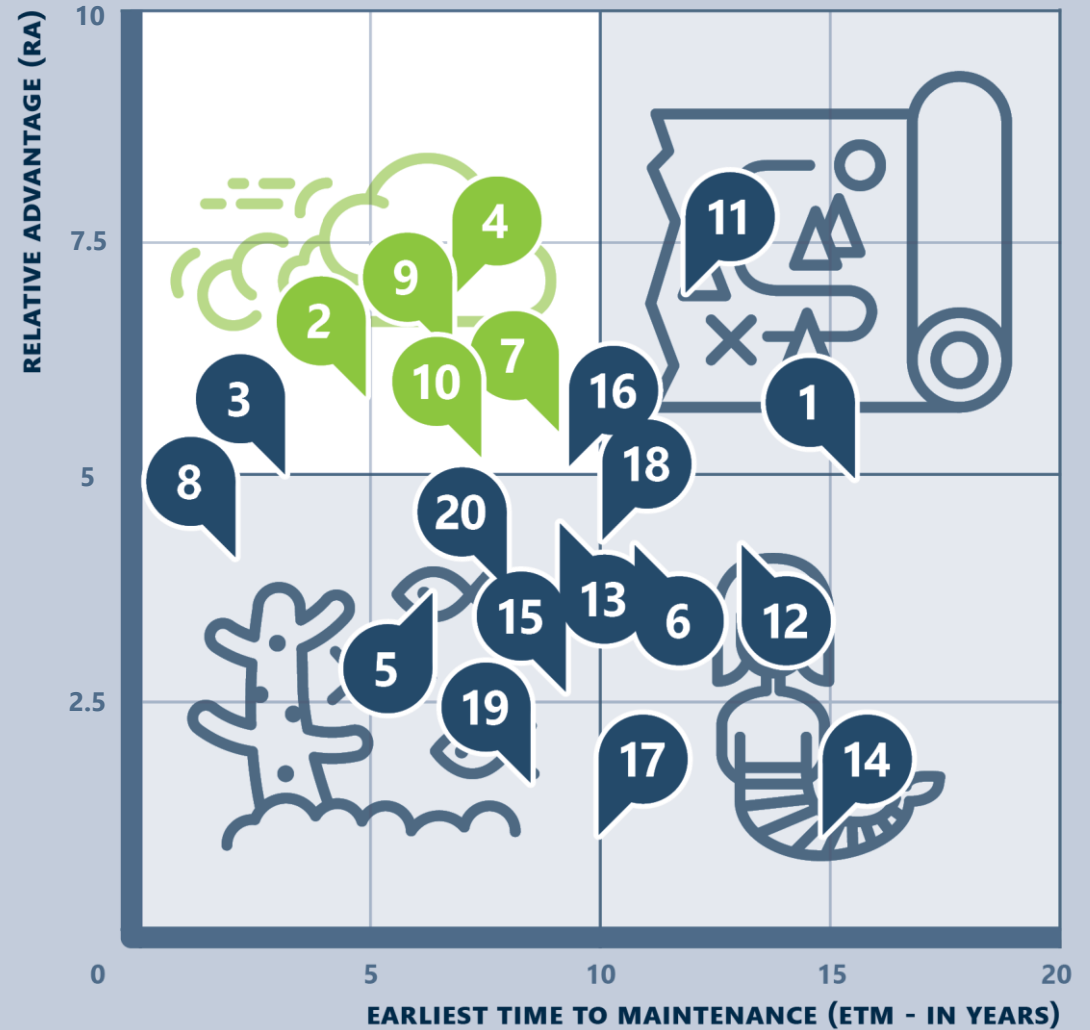


ADDITIONAL CHECKS FOR

- ✓ redundancy
- ✓ vulnerability to adversary attacks
- ✓ "must-haves" from the needs analysis

FINAL SELECTION OF 5 KTC

2.  Infrared face recognition
4.  3D face recognition
7.  Contactless friction ridge recognition
9.  Iris recognition in the NIR spectrum
10.  Iris recognition in the visible spectrum



4. Deep Analysis

Project Overview

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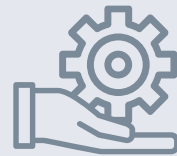


Roadmaps of key biometric technological clusters



Aim

- In-depth analysis of the key technological clusters
- Envisage potential future developments in terms of:
 - Applications
 - Functions
 - Products and systems



Outcomes (for each KTC)

- Visual technology roadmap chart
- List of expected key opportunities and challenges in the today-2040 timeframe
- Comparative analysis to study how the hypothetical scenarios might influence the developments envisaged in the roadmaps

Roadmaps of key biometric technological clusters

Visual technology roadmap charts – 3D face recognition

EXAMPLE DEVELOPMENTS

2028 – 2040

Seamless border checks using 2D and 3D face recognition (after check-in, biometric data is acquired and stored; it is removed after the passenger leaves the airport/BCP)

2026 – 2040

Short-distance 3D face recognition on-the-move for seamless border crossing

2032 – 2040

Long-distance 3D face recognition on-the-move for seamless border crossing

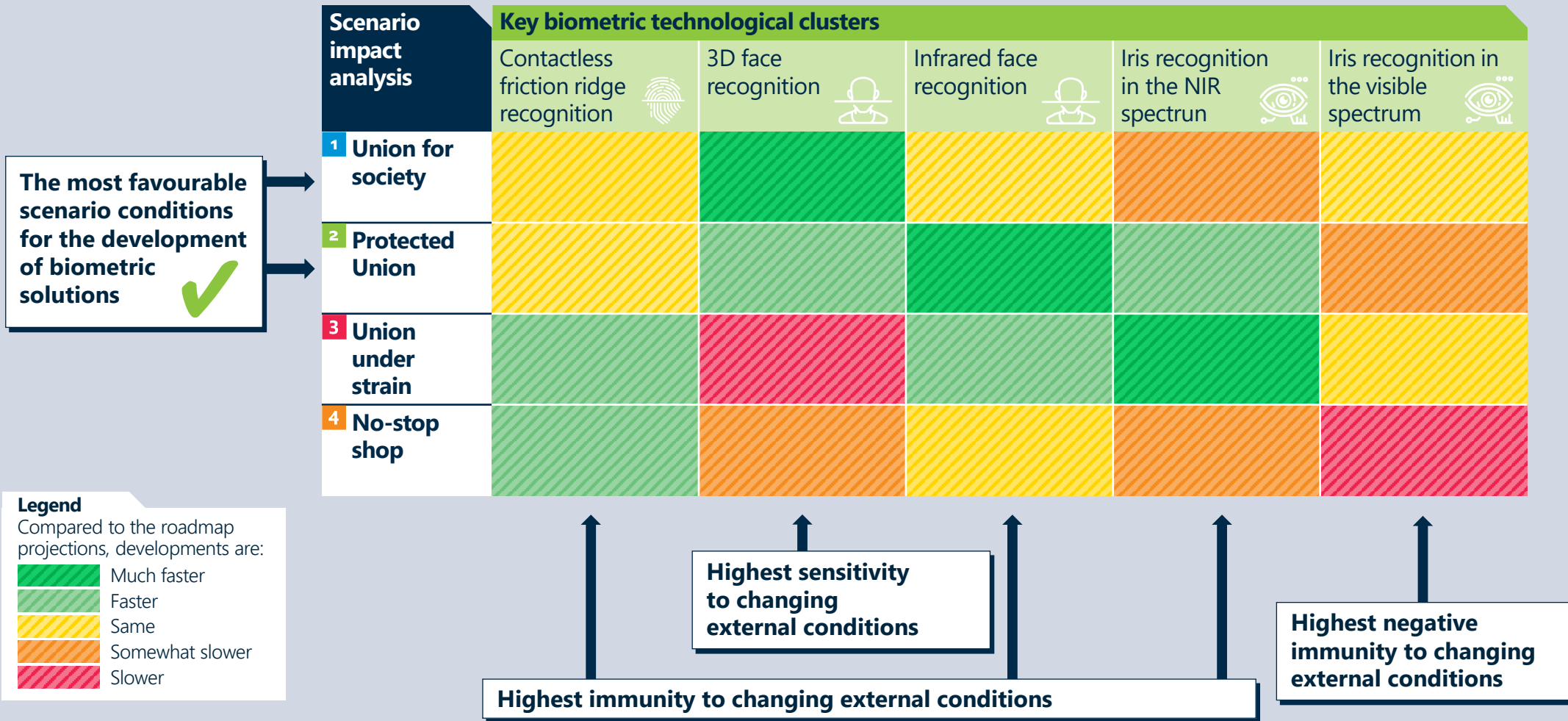
2030 – 2040

3D facial image stored in the chip of e-passports

3D face recognition	2021 (ETM:6,7)	2022-2027			2028-2033			2034-2040		
		2022-2023	2024-2025	2026-2027	2028-2029	2030-2031	2032-2033	2034-2035	2036-2037	2038-2040
APPLICATION AREAS OF TECH CLUSTER (Where is it used?)	Physical access control Use in smartphones for unlocking the device, making payments and accessing sensitive data 3D facial recognition in healthcare (e.g. COVID-19 quarantine apps)	Pre-enrolment for seamless travel (e.g. mobile-based solutions for starting the passenger check-in remotely)								
		Physical access control to critical areas (e.g. military zones)								
		Identity verification for payment and bank account access								
		Seamless border checks using 2D and 3D face recognition (after check-in, biometric data is acquired and stored; it is removed after the passenger leaves the airport/BCP)								
		Surveillance and forensics (biometric data collected on specific people e.g. criminals and suspects)								
FUNCTIONS OF TECH CLUSTER (what can it do?)	Verification of identity	3D face identification (technology capable of searching against biometric enrolment database of 3D face images)								
		Recognising face images acquired from different camera angles								
		Short-distance 3D face recognition on-the-move for seamless border crossing								
		Detection of abnormal behaviours (i.e. detection of people in need of assistance or special care within the limited space of BCPs)								
		Long-distance 3D face recognition on-the-move for seamless border crossing								
PRODUCTS / OR SYSTEMS USING TECH CLUSTER (what is it?)	Smartphones (esp. for unlocking the phone) 3D-assisted 2D (reconstructing 3D faces from 2D images)	Improved sensors for 3D image acquisition								
		Cameras recording 3D videos								
		3D cameras to acquire images from afar, with a larger field of view, and to assess distance								
		3D facial image stored in the chip of e-passports								
		Placing sensors for 3D face acquisition on drones								
3D image of face integrated in digital identity solutions and digital travel documents										

Roadmaps of key biometric technological clusters

Cross-cluster comparison of scenario impact



5. Mapping Capabilities

Project Overview

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2. Insight Hunt

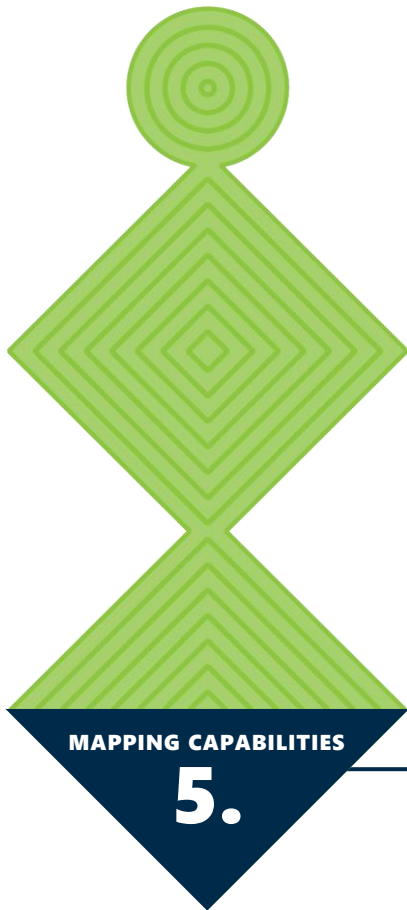
3. Filtering Results

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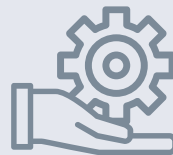


Capability Readiness Analysis



Aim

- Explore existing EU capability landscape
- Identify capability gaps and opportunities across the various timeframes and scenarios



Outcomes (for each KTC)

- Capability readiness heatmap

METHODOLOGY



Step 1

Identification of objectives



Step 2

Identification of capabilities



Step 3

Identification of capability-related needs



Step 4

Assessment of capability readiness

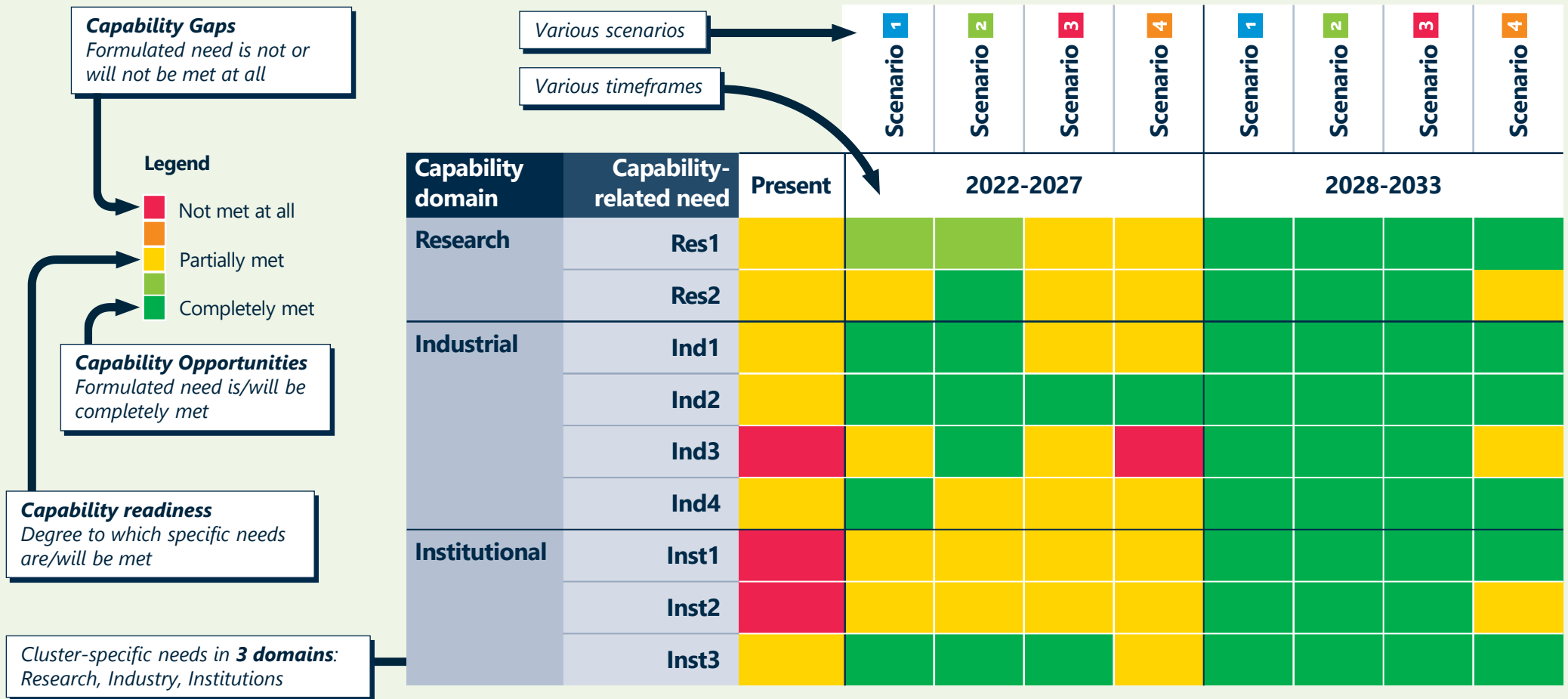


Step 5

Identification of capability gaps and opportunities

Capability Readiness Analysis

Heatmaps – 3D face recognition



Conclusions

Project Overview

1. Analysis of Research Context

2. Insight Hunt

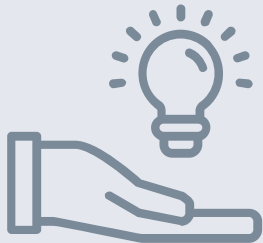
3. Filtering Results

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Main Outcomes

Each of the phases of this complex Research Study produced its own set of future-oriented insights with the intention of supporting the EBCG community in decision-making processes that:



exploit opportunities

mitigate associated threats



result in the implementation of new biometrics-enabled technological solutions

5 Key Technological Clusters



Infrared Face Recognition



3D Face Recognition



Contactless Friction Ridge Recognition



Iris Recognition in the NIR Spectrum



Iris Recognition in the Visible Spectrum

Main Outcomes

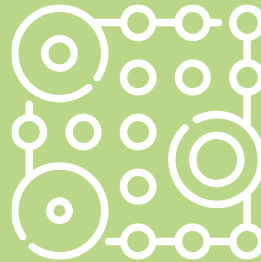
Set of scenarios for the future of travel and border checks

[DOWNLOAD Executive Summary](#)

[DOWNLOAD Research Study](#)



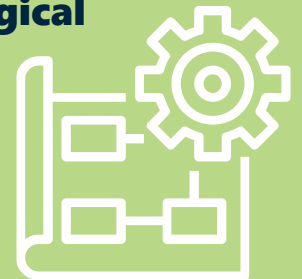
Prioritisation Matrix of biometric technological clusters



Set of roadmaps developed for the key biometric technological clusters



Heatmaps reflecting capability readiness for the key biometric technological clusters



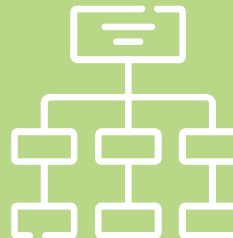
Technology Foresight Manual describing the TF Process, the Methods and the Tools

[DOWNLOAD Annex I](#)



Taxonomy of Biometric Technologies and Biometrics-Enabled Technological Systems

[DOWNLOAD Annex II](#)



Analyses conducted over the patents, scientific literature and EU-funded projects

[DOWNLOAD Annex III](#)



Project Newsletters

Project Fiche

Technology Foresight on Biometrics for the Future of Travel

Objective
In December 2022, Frontex Research and Innovation launched an open procurement procedure for the provision of a Technology Foresight Research Study on Biometrics for the Future of Travel. The main objective of the study is to identify a set of key technologies for the future of travel, to assess their maturity and to identify the key actors in the field. The study will also identify the key actors in the field and the key technologies for the future of travel.

Purpose
The research study will support Frontex in identifying specific research and innovation projects that will contribute to the development of biometrics-enabled technological solutions for border control. The study will provide a strategic overview of the biometrics-enabled technologies for the future of travel, and will identify the key actors in the field and the key technologies for the future of travel.

Deliverables
The research study will be delivered by producing a research report that will include the project overview and recommendations of the study. The report will also include a list of key technologies for the future of travel, and a list of key actors in the field.

Service provider
Frontex commissioned Scenario 2.10 to undertake the research study. Scenario 2.10 will work closely with three other subcontracted companies: Scenario 2.11, Scenario 2.12, and Scenario 2.13. The research study will be delivered by producing a research report that will include the project overview and recommendations of the study. The report will also include a list of key technologies for the future of travel, and a list of key actors in the field.

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NEWSLETTER #1 - METHODOLOGY

TECH FORESIGHT ON BIOMETRICS

PHASE 1: DEFINING THE METHODOLOGY AND SETTING THE CONTEXT

The project
In February 2023, Frontex Research and Innovation launched an open procurement procedure for the provision of a Technology Foresight Research Study on Biometrics for the Future of Travel. The main objective of the study is to identify a set of key technologies for the future of travel, to assess their maturity and to identify the key actors in the field. The study will also identify the key actors in the field and the key technologies for the future of travel.

The means
Frontex commissioned Scenario 2.10 to undertake the research study in cooperation with three other subcontracted companies: Scenario 2.11, Scenario 2.12, and Scenario 2.13. The research study will be delivered by producing a research report that will include the project overview and recommendations of the study. The report will also include a list of key technologies for the future of travel, and a list of key actors in the field.

Foresight: Strategic insights from the future
Foresight is a discipline that delves into insights by analyzing possible future scenarios. Conducting foresight research involves a multi-step process that allows for the identification of trends and opportunities, understanding of long-term impacts, and strategic decision-making regarding the future. There is no single way of conducting a foresight study, as it is a highly customized based on a wide assessment. However, you will find an outline of the 'Tech Foresight on Biometrics' study, which includes a description of some of the tools and methods used in the study.

Project phases
1. IDENTIFICATION OF KEY TECHNOLOGIES
2. ASSESSMENT OF MATURITY
3. IDENTIFICATION OF KEY ACTORS
4. IDENTIFICATION OF KEY TECHNOLOGIES

Tools & methods
Delphi method
Scenario analysis
Key technologies identification
Delphi method
Scenario analysis
Key technologies identification

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NEWSLETTER #2 - SCENARIO ANALYSIS

TECH FORESIGHT ON BIOMETRICS

Scenario analysis

Scenario analysis is a method that allows us to explore different possible future states of the world. It is a tool that helps us to understand the potential impact of different decisions and actions. In this newsletter, we will explore the different scenarios for the year 2040 and how they might impact the future of travel.

Scenarios for the year 2040
Scenario 1: Union for society
Scenario 2: Protected Union
Scenario 3: Union under strain
Scenario 4: No-Stop-Ship

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NEWSLETTER #3 - SCENARIO ADAPTATION

TECH FORESIGHT ON BIOMETRICS

Scenario analysis workshop

The scenario analysis workshop is a key component of the research study. It allows us to explore different possible future states of the world and to understand the potential impact of different decisions and actions. In this newsletter, we will explore the different scenarios for the year 2040 and how they might impact the future of travel.

Scenario 1: Union for society
Scenario 2: Protected Union
Scenario 3: Union under strain
Scenario 4: No-Stop-Ship

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NEWSLETTER #4 - TAXONOMY

TECH FORESIGHT ON BIOMETRICS

Taxonomy of biometric technologies

A taxonomy of biometric technologies has been developed in the early stages of the research study. It allows us to understand the different types of biometric technologies and how they might be used in the future. In this newsletter, we will explore the different types of biometric technologies and how they might be used in the future.

1. BIOMOLECULAR BIOMETRICS
1.1 DNA biometrics
1.2 Other biomolecular biometrics

2. MORPHOLOGICAL BIOMETRICS
2.1 Face recognition
2.2 Fingerprint recognition
2.3 Iris recognition
2.4 Vascular pattern recognition

3. Physiological signals biometrics
3.1 Heart rate variability
3.2 Respiration rate
3.3 Blood pressure
3.4 Acoustic characteristics of the ear canal

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NEWSLETTER #5 - 4CF MATRIX

TECH FORESIGHT ON BIOMETRICS

Technological clusters in the ring

The technological clusters in the ring are a key component of the research study. They allow us to understand the different types of technological clusters and how they might be used in the future. In this newsletter, we will explore the different types of technological clusters and how they might be used in the future.

Relative Advantage (RA)
10: Relative Advantage (RA) is a metric that allows us to understand the different types of technological clusters and how they might be used in the future. It is a metric that allows us to understand the different types of technological clusters and how they might be used in the future.

Relative Advantage (RA)
10: Relative Advantage (RA) is a metric that allows us to understand the different types of technological clusters and how they might be used in the future. It is a metric that allows us to understand the different types of technological clusters and how they might be used in the future.

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NEWSLETTER #6 - RESEARCH STUDY

TECH FORESIGHT ON BIOMETRICS

Research Study

The research study is a key component of the research study. It allows us to understand the different types of research study and how they might be used in the future. In this newsletter, we will explore the different types of research study and how they might be used in the future.

Key biometric technological clusters
1. Infrared face recognition
2. 3D face recognition
3. Contactless friction ridge recognition
4. Iris recognition in the NIR spectrum
5. Iris recognition in the visible spectrum

Main outputs
The research study will produce a research report that will include the project overview and recommendations of the study. The report will also include a list of key technologies for the future of travel, and a list of key actors in the field.

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Thank you for your attention!

If you have any questions regarding this research study please contact Frontex Research and Innovation at research@frontex.europa.eu

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