Investigating the Potential Incorporation of Multimodal Biometrics into Fully Automated Entry-Exit System for the European Union

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Abstract: - In this paper a cost model with accompanying calculations about the multimodal biometrics application within the automated entry-exit system of the European Union is presented. A fusion among facial, fingerprint and fingervein features of the travelers is considered expecting to produce higher verification/identification accuracy and improving the level of reliability of border crossings. The model suggests significant cost savings based on the difference from the expected investment in current infrastructure, its operation, maintenance and support from one hand and the reduction of the number of border officers on the other. It has been verified with sample data for the past two phases of the Smart Borders initiative where close values are obtained between the predicted and already registered financial results.

Key-Words: - multimodal biometrics, entry-exit system, cost model, automated border check, European citizen, third country national

1 Introduction

The Smart Borders initiative [1] is a product of the European Commission (EC) vision for more fast, secure and cost effective way for border crossing in the European Union (EU). It started in February 2013 as natural continuation to the proposal for the establishment of Entry-Exit System (EES) [2] and Registered Traveler Program (RT) [3] from February 2008.

The automation of the whole process for EU citizens, third country nationals - visa holders (TCNVH) and visa exempts (TCNVE) is the ultimate goal to be achieved. So far, a number of biometric features were incorporated partially in the process to different degrees in various member states (MS) [4]. They include face, fingerprints, and iris, the latter of which seems to have the narrowest use, even as records in e-passports around the Union. Evaluations of the reliability and cost efficiency of their actual application has been undertaken [5] revealing that more efforts are needed up until the point of a full-scale automated multimodal biometric verification during border crossing.

In this study, the possibility of introducing such multimodal biometric verification is analyzed based on a cost model described in Section 4. It includes a new biometric feature – fingervein, which could be easily captured and matched along with the fingerprint of a traveler with one scan in a combined reader and shared matcher from the EES. Computational simulation is made with this model aiming to predict costs and savings expected for the year 2020. On that basis, further, conclusions are derived for the promising use of this particular biometric pattern.

2 Entry-exit information flows interchange

The information flows associated with the border entry of a TCNVH are related to the main stages of data processing in systems outer for the EES (Fig. 1.a).

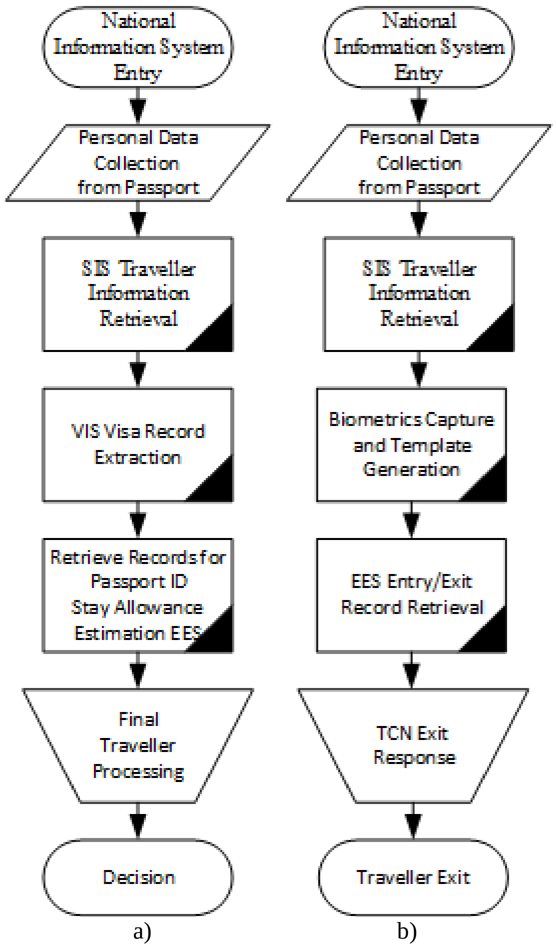


Fig. 1. Information flows during a traveler's entry and exit

After collecting personal details from the passport within the National Information System (NIS) interrogation is made with the Schengen Information System (SIS) on that basis and additional info is gathered about the traveler. Then, again in SIS, visa number collection, biometrics capture and quality assessment of image(s) is performed. Visa Information System (VIS) interrogation follows based on VISA ID and biometric image(s) from where visa record and possible biometrics match are retrieved. All that information is returned to the NIS. EES, after interrogation from the NIS, supply records for passport ID and calculated period of legitimate stay, taken later by NIS and it returns to EES after further traveler processing the entry record with already checked passport ID, Visa ID, traveler data and fingerprint template. This final insertion needs to be confirmed from SIS which concludes the process.

Exit recording (Fig.1.b) starts in the same way by collecting personal data from the passport. Traveler data is checked within the SIS by interrogating and response is expected about it. Capturing biometrics with its quality assessment and template generation is the next set of data leading to TCN exit request to EES. There, retrieval of entry/exit record is made, matching the biometrics template, detection of possible overstay and updating the personal record of the traveler. TCN exit response is then passed to NIS. The existing information flows could be incorporated in a system similar to that from Fig. 2.

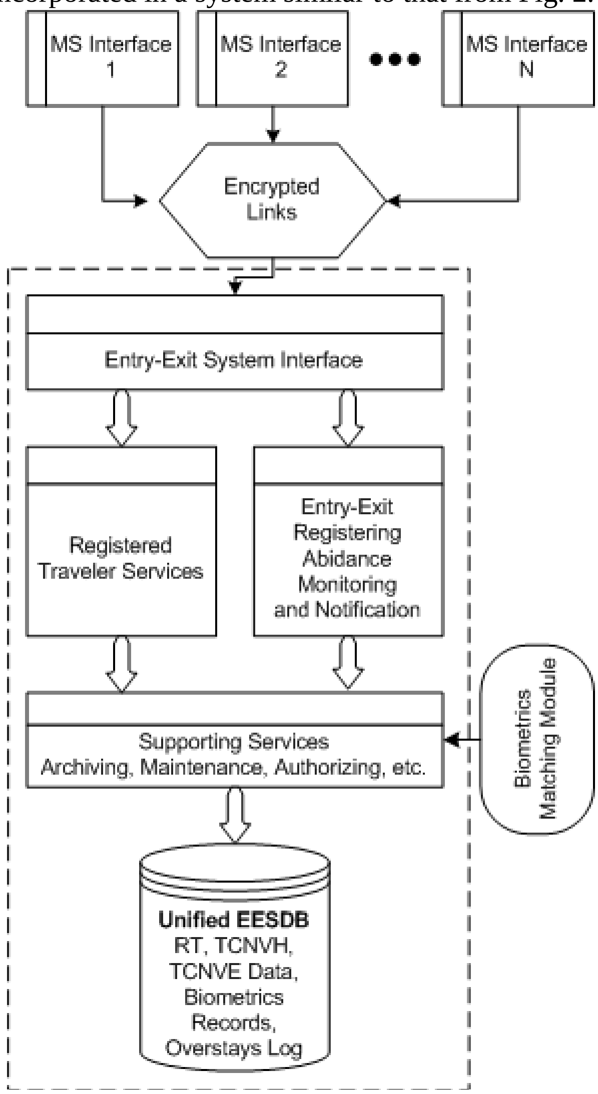
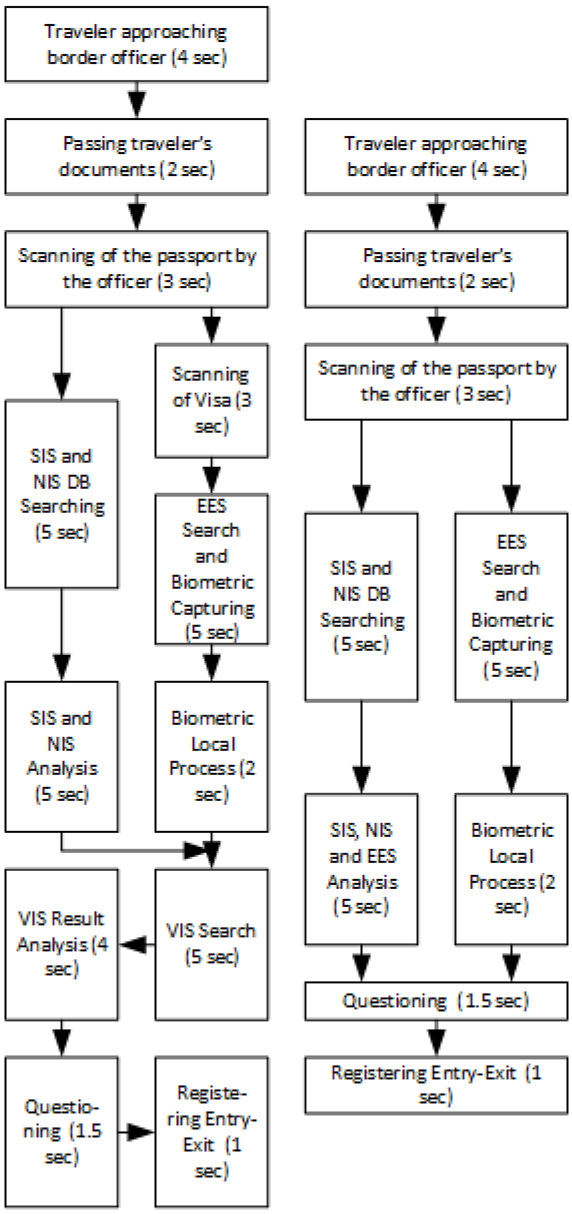


Fig. 2. Targeted System Architecture

3 Automated entry-exit system architecture and processing stages

Two types of architectures are possible for granting the information exchange described above. First, it could be left the RT system and EES to co-exist separately and establish interconnections only for the common portions of data they need to share [6]. The second approach, approved by the EC is to build a fully integrated EES encapsulating the RT system with one common database (Fig. 2).

The inherited entry-exit system with manual processing (Fig. 3) of travel documents offer low efficiency and not always that reliable results due to insufficient training of border officers and other subjective factors. The checking time for TCNVH takes 30.5 sec (Fig. 3.a) and for TCNVE – 21.5 sec (Fig. 3.b). The envisioned, fully automated, EES will take 22.5 sec per TCNVE (Fig. 4) and 30.5 sec per TCNVH (Fig. 5).



a) b)

Fig. 3. Manual entry process: a) TCNVH, b) TCNVE

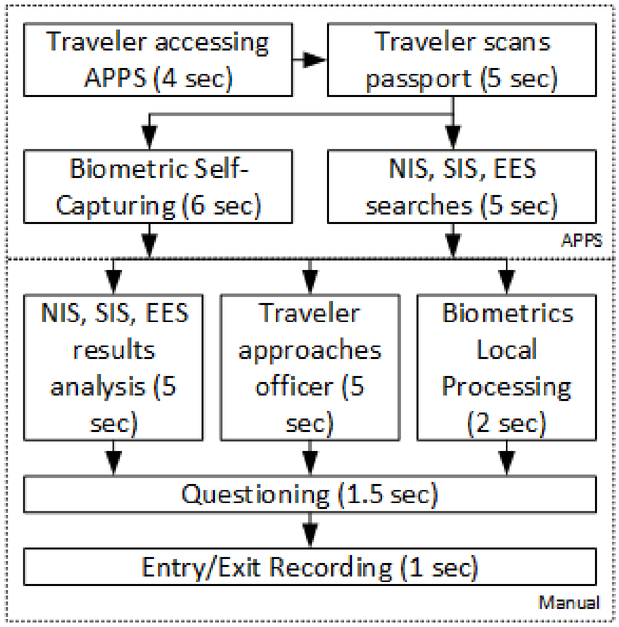


Fig. 4. Automated entry process TCNVE

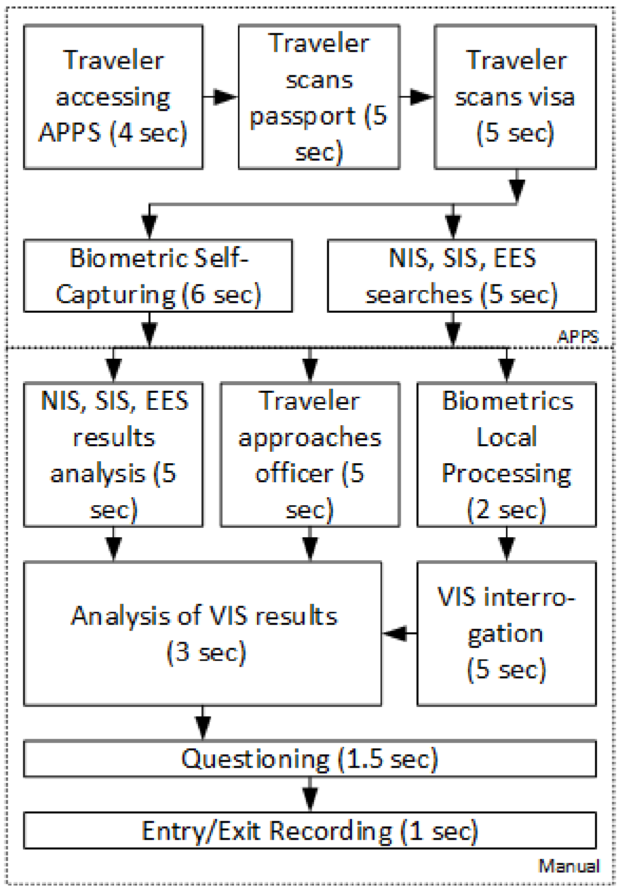
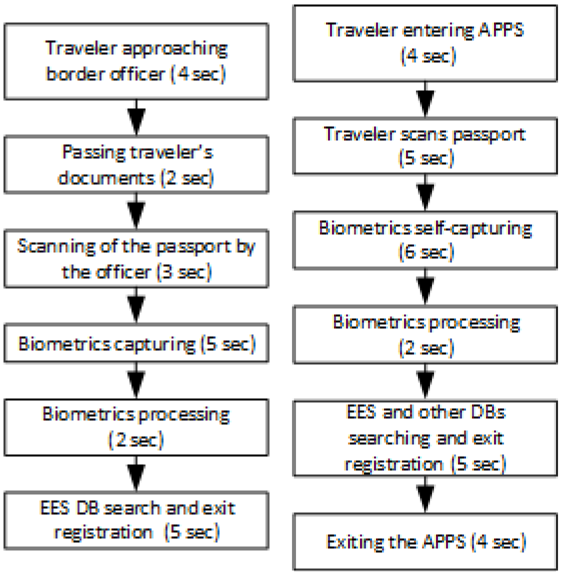


Fig. 5. Automated entry process TCNVH

Reliability is expected to increase considerably due to the use of biometrics and highly protected electronic records within the Machine Readable Travel Documents (MRTDs).

Both types of TCNs use one and the same approach on exiting the Schengen area which takes manually up to 21 sec (Fig. 6.a). It is predicted that automatically exiting will take 26 sec without the presence of officers (Fig. 6.b).



a) b)

Fig. 6. Manual a) vs. automated b) exiting

4 Multimodal biometrics entry-exit system predicted costs for 2020

In this section, an attempt is made to predict the expected costs starting with the year 2020 up to 5 years period. The proposed model include EES infrastructure costs (Table 1).

Table 1. Predicted entry-exit system infrastructure costs in 2020

Component	Cost, EUR	Minimum	Mode	Maximum
EE Database Server	407 551	350000	400000	450000
Database Software	105 846	90000	100000	110000
Storage	14511,81103	14000	15000	16000
Biometric Software	652046,1841	635000	655000	675000
Biometric Matchers	60768,38713	54000	60000	66000
Middleware and Application Servers	57759,92004	54000	56000	58000
Middleware and 3rd party application software	304761,9874	292000	312000	332000
Network and Communications	96237,08446	90000	100000	110000
Other	276948,7437	274000	280000	286000
Total EESIC	1 976 431			

RT system (yet not fully integrated with the EES) infrastructure costs follow in Table 2, Biometric Matching System (BMS) capacity expansion costs (Table 3), and maintenance and support costs (Table 4). The new component here is the application of finger vein patterns instead of iris ones benefitting from a number of advantages investigated in [7]. It is supposed that this particular biometric could be successfully exploited along with the well-established fingerprints, possibly with a single scan from an unified reader.

Currently it takes 30 kB for storing 10 fingerprint templates, 15 kB for a face, 5 kB for an iris and presumably there are 10 kB free for other biometrics from the data groups allocated for the purpose on the 2nd generation of e-passport [8]. Fingerveins templates are known to take less than 2 kB [9], so at least 5 fingers could be incorporated per individual in the contemporary chip.

Supposing that permanently there will be a need for storage of at least 100 million records within the EU based on predicted number of border crossings (Table 5), at least 8 TB of data storage would be needed for all biometrics. Considering nowadays hard disk drives (HDD) capacities, around 20 HDDs are going to be used. Two distinctive sites of co-location are preferable solution in order to have diversity for security reasons.

Table 2. Predicted registered traveler system infrastructure costs in 2020

Component	Cost, EUR	Minimum	Mode	Maximum
RT Database Server	276147,4195	270000	300000	330000
Database Software	104546,9087	90000	100000	110000
Storage	6285,310037	6000	6250	6500
Biometric Software	131161,8155	130000	135000	140000
Biometric Matchers	19599,84694	19000	20000	21000
Middleware and Application Servers	71689,66521	68000	72000	74000
Middleware and 3rd party application software	199207,639	198000	200000	202000
Network and Communications	99852,09155	90000	100000	110000
Other	123411,7673	122000	125000	128000
Total RTSIC	1031902,464			

Updating document and biometrics readers is the next element of the necessary upgrade. No matter of applied biometrics type it is done every 5-7 years due to amortization. The only strict demand is to have the same interface to the central system preserved which will guarantee its integrity and no further costs over it.

If fingerprints and fingerveins are left alone as multimodal biometrics check, multiple matching algorithms and a fusion engine must produce the final score for the verification and in rare cases – for identification. Without iris integration up to 60 kB of space would be free from previous allocation specification. Processing initially 50 million travelers with the new biometrics, additional 3 TB of info capacity should be supplied. Up to 10 HDDs would be enough. Resilient storage area network can guarantee replication of data for reliability. Based on average prices from the market [10] the cost for this feature is around 100 000 EUR. Server park is the other essential component of the system. Presuming 10% growth of the number of travelers every year [11] some 4500 data transactions per second are required from fusing these two particular biometrics. According to the time schedule of automated EES process (Fig. 4 and 5) 5 sec should be the upper bound for response, at least 50 matchers using 4 CPUs each ae required. The matching hardware then amounts to 500 000 EUR and the supporting periphery of around 2/5th of it given contemporary market levels [12]. The licenses for matching software of the kind [13] based on total number of Border Crossing Points (BCPs) on annual basis cost at least 3 million EUR.

Table 3. Predicted biometric matching system capacity expansion costs in 2020

Component	Cost, EUR	Minimum	Mode	Maximum
Biometric Software	655893,767	625000	655000	685000
Biometric Hardware	119280,3701	116000	120000	124000
Other	195334,6373	194000	195000	196000
Total BMSSCEC	970508,7744			

EES capacity expansion is inevitable regardless of the biometric types involved. The prognosis is of a growth from 8 processors to 20 with available memory rising from 800 GB to 1 TB. The middleware and I/O applications need 18-26 additional processing units. Given lifetime of 5 years for the database host, it renders 20 new machines for the new period from 2020 on. In parallel to that, 35 new units will support 3rd party applications. Biometric matchers would rise from 28 to 48. Storage capacity expansion is evaluated to maximum of 9 TB. Decrement of ¼ in price for permanent records is the diminishing factor over the costs on these components.

Demands on RT system expansion are not that onerous. The associate database could continue to operate over 4 processors and 16 GB memory. Applications and middleware need no more than 4 additional units. Five years later 4 more will be introduced for renewal. The 2 operational biometric matchers are enough for the beginning of the predicted period but by the end of it another 4 must be introduced. Outer storage will rise with 2.5 up to 6 TB. Price forming depends on factors which are the same as the EES.

BMS capacity expansion and especially updating will take the most in relation to the previous two systems. With the presumable introduction of the fingervein patterns this dedicated system will contain roughly 44 million records – used during entry/exit procedures with possible retention. The average matches rate is the product of the number of records, the number of searched persons and the number of biometric templates per individual. Statistically, around 0.05% of all travelers are obligated to such extensive check, so 386 000 matches need to be performed annually. It yields substitution of most of the current matchers and capturing equipment. The latter would consist of no more than 40 000 units assuming 10% of the checks to be done simultaneously at most during the year. Server side processors rise in number to 11 with at least 16 GB of memory. Software licenses extend in price with the increase of capacity and add to the overall cost 655 000 EUR annually. After 5 years of processing 25 new database stations must be installed. Based on previous experience [15] maintenance and support generates 5% increase per year leading to 1380000 EUR cost.

Table 4. Predicted maintenance and support costs in 2020

Component	Yearly cost, EUR	Minimum	Mode	Maximum
Maintenance and Support	382609,0025	375000	380000	385000
Hardware and Software Maintenance Fee	1002866,738	990000	1000000	1010000
Total Annual Costs MS	1385475,74			

The potential savings from the transition to fully automated EES and the introduction of this particular biometrics leading to lower False Acceptnce Ratio (FAR) and False Rejection Ratio (FRR) are estimated based on the predicted border crossings for 2020 (Table 5) [11] and the related reduction of the number of needed border officers (Table 6).

Currently there are 1505 BCPs within the EU. With the average of 2021 border officers needed per a million travelers at that number of BCPs supposing manual processing, the reduction of 1226 from them is the mode expected when transiting to autonomous regime.

Table 5. Predicted border crossings in 2020

Border Crossings per Year	Crossings In	Crossings Out	Total Crossings
EU Citizens	238500000	238500000	477000000
TCNVH	70500000	70500000	141000000
TCNVE	52000000	52000000	104000000
Total BCpY	361000000	361000000	722000000

Supposing the manual approach is preserved the increase of needed officers is around 105. The minimum values for the first and second case are 100 and 1276 respectively, and 115 and 1176 – as an upper bound in our model.

For all variables a triangular distribution is set with the following parameters: minimum = 1, mode = 2, and maximum = 3. Then, Monte-Carlo simulation is run with 1000 iterations over the input data and the results on total cost and savings could be seen in Table 6. Given the reduction of the number of needed officers and the annual inflation index for the EU [14] the total benefit on a year basis is expected to be around 74 million EUR.

Table 6. Predicted border officers' employment costs in 2020

Number of employed border officers	Manual EES	Automated EES
Previously needed officers	2021	< 2021
Entries TCNVE	411	197
Entries - TCNVH	776	409
Exits - TCNVE	402	81
Exits - TCNVH	537	108
Total number of border officers	2126	795
Difference	107,2908206	-1219,746026
Yearly Cost, EUR	6973903,341	-79283491,7
Total Investment, EUR	0	5 364 318
Total Benefit per Year, EUR	6973903,341	-73 919 173

The probability density of the savings along with the frequency of it are given in Fig. 7.

The cumulative probability density (CPD) and the cumulative frequency (CF) are shown in Fig. 8.

The statistical parameters obtained from simulating the model for the year 2020 are given in Table 7.

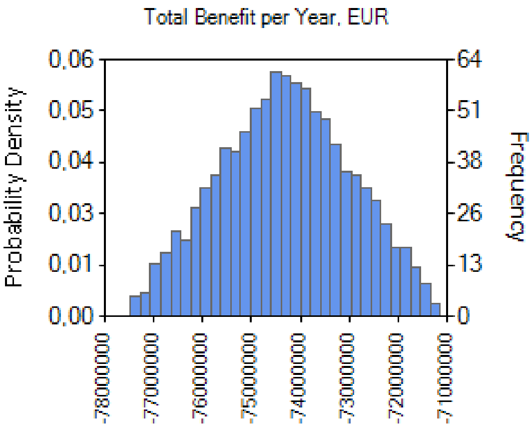


Fig. 7. Probability density and frequency of the total investment benefit in 2020

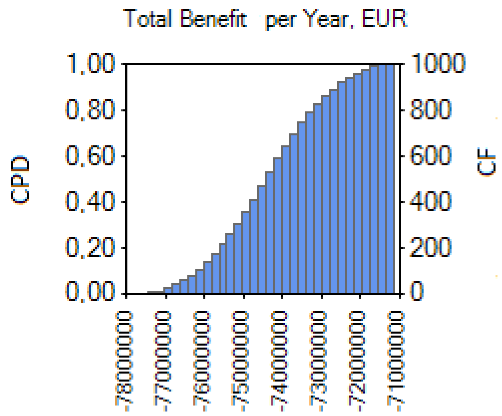


Fig. 8. CPD and CF of the total investment benefit in 2020

Sensitivity analysis, using Pearson correlation coefficient and the top-down approach, reveals most influence from hardware and software maintenance fee (0.0576), followed by middleware and application servers for RT sub-system (0.0501), biometric hardware (0.486), biometric software (0.0460), and fifth - middleware and application servers for EES (0.0449).

Table 7. Resulting parameters of the model for 2020

Mean	-74304368,72
Standard Deviation	1327679,506
Variance	1 762 732 871 361,460000
Coefficient of Variance	-0,017868
Skewness	-0,000908
Kurtosis	-0,594164
Mode	NaN
Standard Error	41 984,912425
Maximum	-71141506,3
Minimum	-77468390,54
Range	6326884,244

5 Validating the model for the past two phases of Smart Borders

In order to verify the validity of the proposed model it has been applied over the same data components for the past two phases of the Smart Borders initiative [16]. The first one was the technical study undertook by the EU Commission in 2009 followed by a testing phase (pilot) from 2014. Significant difference between these 5 years periods is the limited use of biometrics in the e-passports issued within the EU and lack of such in the passports (some of which not being electronic at all) of TCNs.

The infrastructure cost for the EES and RT are given in Tables 8 and 9.

Table 8. Validating the model for the entry-exit system infrastructure costs for 2014

Component	Cost, EUR	Minimum	Mode	Maximum
EE Database Server	415 433	350000	400000	450000
Database Software	92 929	90000	100000	110000
Storage	14814,76603	14000	15000	16000
Biometric Software	230925,732	220000	230000	240000
Biometric Matchers	24327,6545	23000	24000	25000
Middleware and Application Servers	53114,45152	50000	52000	54000
Middleware and 3rd party application software	172207,8084	170000	175000	180000
Network and Communications	99580,82528	90000	100000	110000
Other	83094,57645	80000	82000	84000
Total EESIC	1 186 427			

Table 9. Validating the model for registered traveler system infrastructure costs for 2014

Component	Cost, EUR	Minimum	Mode	Maximum
RT Database Server	300475,975	270000	300000	330000
Database Software	101390,2888	90000	100000	110000
Storage	6297,690832	6000	6250	6500
Biometric Software	57549,02365	54000	56000	58000
Biometric Matchers	15868,90482	15000	16000	17000
Middleware and Application Servers	31433,23048	30000	32000	34000
Middleware and 3rd party application software	175655,6107	173000	175000	177000
Network and Communications	97123,28601	90000	100000	110000
Other	102495,4996	98000	101000	104000
Total RTSIC	888289,51			

BMS capacity expansion and the maintenance and support costs are included in Tables 10 and 11.

Less intensive border crossings rate has been registered noted in Table 12.

Table 10 Validating the biometric matching system capacity expansion costs for 2014

Component	Cost, EUR	Minimum	Mode	Maximum
Biometric Software	223635,0844	217500	227500	237500
Biometric Hardware	67761,60488	66500	68000	69500
Other	74172,98426	73500	74000	74500
Total BMSSCEC	365569,6736			

Table 11. Validating the model for maintenance and support costs for 2014

Component	Yearly cost, EUR	Minimum	Mode	Maximum
Maintenance and Support	296233,7777	290000	295000	300000
Hardware and Software Maintenance Fee	642936,4132	640000	645000	650000
Total Annual Costs MS	939170,1909			

Table 12. Border crossings for 2014

Border Crossings per Year	Crossings In	Crossings Out	Total Crossings
EU Citizens	129000000	129000000	258000000
TCNVH	55000000	55000000	110000000
TCNVE	40500000	40500000	81000000
Total BCpY	224500000	224500000	449000000

Table 13. Validating the model for border officers' employment costs for 2014

Number of employed border officers	Manual EES	Automated EES
Previously needed officers	1956	< 1956
Entries TCNVE	398	190
Entries - TCNVH	751	397
Exits - TCNVE	389	78
Exits - TCNVH	519	104
Total number of border officers	2057	769
Difference	98,92810291	-1168,041936
Yearly Cost, EUR	6232470,483	-73586642
Total Investment, EUR	0	3 379 456
Total Benefit per Year, EUR	6232470,483	-70 207 186

The number of BCPs at the time was 1456 [17]. The estimated growth of border officers' number supposing manual processing alone is 101 on average per country. Taking into account the automated border gates spread at the time the predicted reduction number of officers tends to be 1187. The minimum number is 96 for the first case and 1137 – for the second, expanding to a maximum of 106 and 1137, respectively.

From 2009 on there has been introduction of facial images for biometric matching in some automated border systems and in smaller scale – of one or two fingerprints. Their application has grown from 2014 when the 3rd generation of e-passports received wider spread.

Running the model over this input produced the point density and frequency distribution for the total benefit of using automated EES shown in Fig. 9. It tot up to approximately 70.2 million EUR. The CPD and CF are presented in Fig. 10.

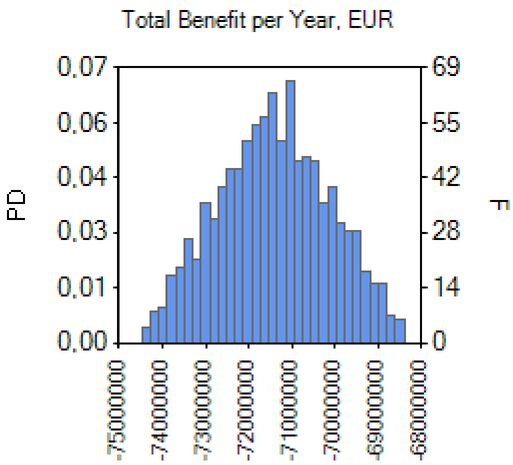


Fig. 9. Point density and frequency of the total benefit for 2014

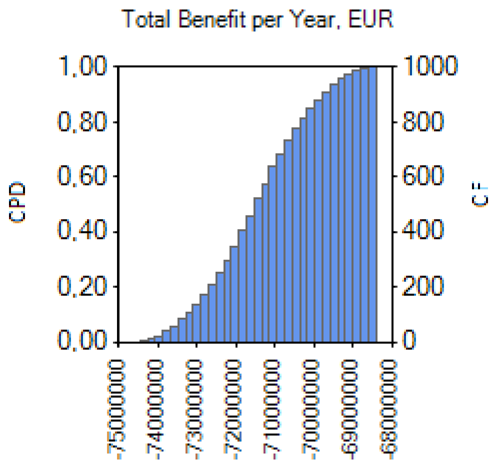


Fig. 10. Cumulative point density and cumulative frequency of the total benefit for 2014

All statistical moments from the model for 2014 are given in Table 14.

The sensitivity analysis made using the same methodology as that for the model of 2020 places the storage costs first with correlation of 0.0925, then comes the RT database software (0.0741), other costs for the RT sub-system with 0.0613, the biometric matchers (0.0547), and finally the maintenance and support of the whole system (0.0502).

Table 14. Resulting parameters of the model for 2014

Mean	-71407241,49
Standard Deviation	1286243,945
Variance	1 654 423 486 988,360000
Coefficient of Variance	-0,018013
Skewness	-0,002396
Kurtosis	-0,59554
Mode	NaN
Standard Error	40 674,604940
Maximum	-68404110,46
Minimum	-74472433,86
Range	6068323,403

The testing phase of fully equipped automated BCPs included only 12 of 27 MS. Given a factor of 1/2.25 from all the border crossings made in the EU during that year the average number of border officers involved in the process is estimated to be 787 [4]. The total costs they generate are approximately 47.22 million EUR. The absolute difference between the realized and predicted cost (Table 13) is 1.08 million EUR or 2.3% relative offset. It appears to be the error from validation of our model for that particular year.

Another validation test concerns the initial period of introducing biometric passports around 2009. In Table 15, 16 and 17 are the infrastructure costs for the EES and RT system along with the BMS capacity expansion, still undergoing major extension.

Table 15. Validating the model for the entry-exit system infrastructure costs for 2009

Component	Cost, EUR	Minimum	Mode	Maximum
EE Database Server	392 597	350000	400000	450000
Database Software	484 450	450000	500000	550000
Storage	10085,80498	9000	10000	11000
Biometric Software	430628,5059	426000	436000	446000
Biometric Matchers	52467,83976	50000	52000	54000
Middleware and Application Servers	32517,46746	30000	32000	34000
Middleware and 3rd party application software	260025,4677	220000	250000	280000
Network and Communications	93254,0624	90000	100000	110000
Other	290589,8491	276000	286000	296000
Total EESIC	2 046 615	350000	400000	450000

Given the maturity of the technology at that time, the limited use of biometrics, mainly facial features with a few exceptions of fingerprints and the limited spread of BCPs with biometric readers and interconnectivity to the central system, one can expect certain disparity with theoretically predicted results.

Maintenance and support costs with the predicted border crossings and the related costs for border guards activities are presented in Table 18, 19 and 20.

Table 16. Validating the model for registered traveler system infrastructure costs for 2009

Component	Cost, EUR	Minimum	Mode	Maximum
RT Database Server	99114,76764	90000	100000	110000
Database Software	103306,3873	90000	100000	110000
Storage	6260,889605	6000	6250	6500
Biometric Software	39739,98059	38000	39000	40000
Biometric Matchers	16709,4531	15000	16000	17000
Middleware and Application Servers	31013,00985	30000	32000	34000
Middleware and 3rd party application software	149357,146	140000	150000	160000
Network and Communications	104426,8078	90000	100000	110000
Other	59002,6233	58000	59000	60000
Total RTSIC	608931,0652			

Table 17. Validating the biometric matching system capacity expansion costs for 2009

Component	Cost, EUR	Minimum	Mode	Maximum
Biometric Software	435136,1304	430000	436000	472000
Biometric Hardware	47886,97743	47000	48000	49000
Other	120850,9889	120000	121000	122000
Total BMSSCEC	603874,0967			

Table 18. Validating the model for maintenance and support costs for 2009

Component	Yearly cost, EUR	Minimum	Mode	Maximum
Maintenance and Support	226223,1282	220000	225000	230000
Hardware and Software Maintenance Fee	880447,9119	870000	878000	886000
Total Annual Costs MS	1106671,04			

The BCPs in 2009 were 1407 [18]. The mode of the difference in number of border officers for the manual and automated variants of EES is 98 and -1147, respectively. The minimum for both are 93 and -1197, while the maximums are 103 and -1097.

Table 19. Border crossings for 2009

Border Crossings per Year	Crossings In	Crossings Out	Total Crossings
EU Citizens	80000000	80000000	160000000
TCNVH	40000000	40000000	80000000
TCNVE	30000000	30000000	60000000
Total BCpY	150000000	150000000	300000000

Table 20. Validating the model for border officers' employment costs for 2009

Number of employed border officers	Manual EES	Automated EES
Previously needed officers	1890	< 1890
Entries TCNVE	385	184
Entries - TCNVH	726	384
Exits - TCNVE	376	75
Exits - TCNVH	501	100
Total number of border officers	1988	743
Difference	96,38684834	-1143,05403
Yearly Cost, EUR	5783210,9	-68583241,81
Total Investment, EUR	0	4 366 092
Total Benefit per Year, EUR	5783210,9	-64 217 150

The total benefit per year appears to be around 64.2 million EUR due to the introduced automation of the entry-exit process. The probability density and frequency of that parameter are shown in Fig. 11 and 12.

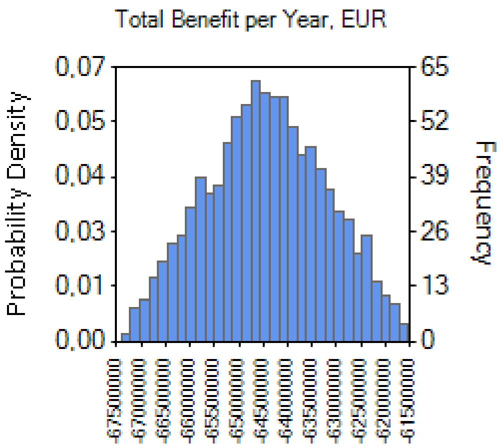


Fig. 11. Point density and frequency of the total benefit for 2009

All resulting statistical parameters from the Monte-Carlo simulation at the same number of steps are given in Table 21.

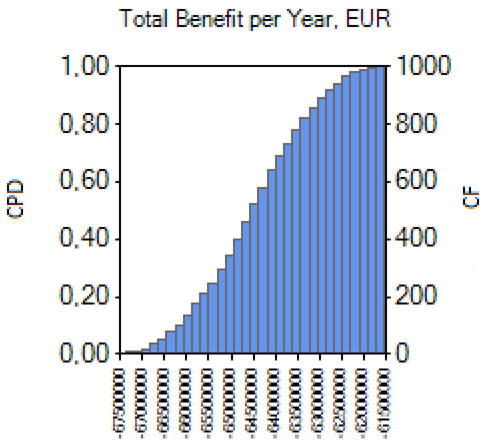


Fig. 12. Cumulative point density and cumulative frequency of the total benefit for 2009

Table 21. Resulting parameters of the model for 2009

Mean	-64433658,51
Standard Deviation	1227298,991
Variance	1 506 262 814 247,820000
Coefficient of Variance	-0,019047
Skewness	-0,00243
Kurtosis	-0,587857
Mode	NaN
Standard Error	38 810,601828
Maximum	-61528155,86
Minimum	-67399727,8
Range	5871571,939

The sensitivity analysis show that the most influential elements are the database software for the EES (0.0703), hardware and software maintenance fee (0.0653), middleware and application servers of the EES (0.0616), EE database server (0.0587), and the biometric hardware (0.0538).

The registered number of border officers during the initial phase of introducing biometric passport in 2009 on average for MS is 890 [18]. That leads to actual savings from automated border checks, although in a much smaller scale, of 60 million EUR. The absolute difference with the presented here model is around 4.2 million EUR or relatively 6.5%. Obviously, with the wider spread of the technology over the 5 years up until the beginning of 2015, when the error drops with 4.2%, the various elements of the framework increase their influence to the intended degree.

6 Conclusion

The presented cost model and related numerical simulations about the applicability of multimodal biometrics for automated entry-exit system in the European Union reveal the plausibility of the proposed approach for border control. The mutual implementation of fingerprint and fingervein verification would affect the existing infrastructure to a degree that generates expenditure within the capacity of the European Comission to handle. It is comparable to the costs needed for other types of biometrics, such as iris recognition. Some benefits may be discovered from using fingervein patterns – integrated readers usable for fingerprints in one scan, common matcher architectures and interconnections, fast and reliable enroll process and others. The level of verification accuracy is expected to be increased after employing this technique with complex score fusion.

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