EVALUATION OF CRITICAL AND EMERGING SECURITY TECHNOLOGIES FOR THE ELABORATION OF A STRATEGIC RESEARCH AGENDA

DELIVERABLE D4.2

Report on the Comparative Analysis of Three Methods to Assess Emerging Technologies

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1 Assessment based on Comparison

In this document the results of task 4.1 of the EU FP7 project ETCETERA are assessed in order to derive strengths and weaknesses of three technology identification methods that were applied during the course of work package WP4. According to the ETCETERA description of work (DoW) task 4.2 is defined as follows:

"*Strengths and weaknesses of the methods used will be assessed* ***based on a comparison of the findings****. Criteria for this assessment are, whether the* ***results cover all relevant areas of technology*** *and if the* ***specificity is comparable between these methods*** *and in* ***general useful*** *for this task.*" [Source: Etcetera WP4 DoW, version 14.07.2012, p. 46]

Consequently the structure of this document reflects the aforementioned assessment criteria. Whether the results cover all relevant areas is addressed in section "Completeness", section "Specificity and usefulness" deals with the last mentioned topic. The first part of task 4.2, the comparison between the findings, is fulfilled in the first three sections. Since the task of WP4.1 was to identify emerging technologies with first security implications in time frame 2020 to 2030, in sections 1.2 and 1.3 it is examined whether there are differences between the methods concerning the security relevance of the identified technologies and concerning the ability to match a prescribed time window.

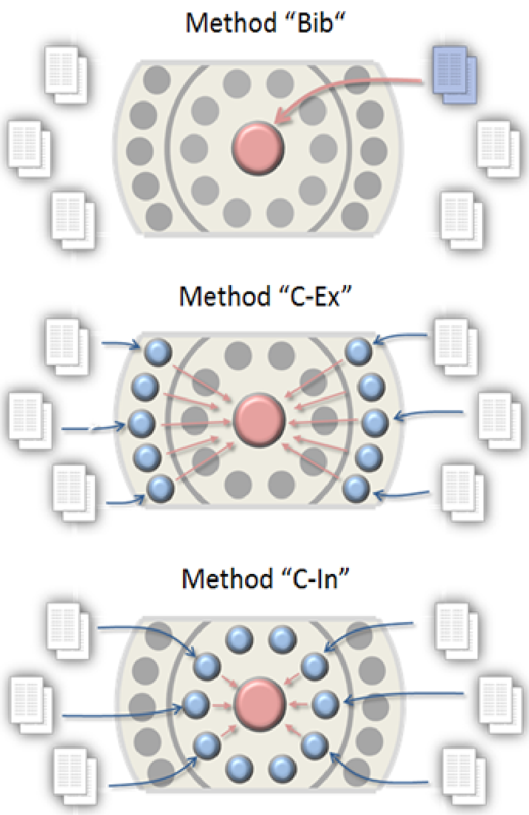


Fig. 1.1: Schematic depiction of the technology scanning methods applied in Etcetera WP4.1. [Source: Fraunhofer INT]

Method "Bib": Core team assessing web based scientific literature data bases.
The Austrian AIT uses a proprietary bibliometrics software package BibTechMon that analyses keywords and further information of articles in scientific literature data bases, e.g. Elsevier 'Scopus' or Thomson-Reuters 'Web of Science'.

Method "C-Ex": Core team involving external technology experts.
The Spanish consulting and engineering firm Isdefe organises a continuous technology monitoring process called "Observation and Prospective Technology System (SOPT)" by an in-house process management team with access to external technology experts.

Method "C-In": Core team integrated in a unit of technology experts.
The German research facility Fraunhofer INT continuously updates its overview of the general technology landscape (WTV) by an in-house team of technology experts lead by a core team.

Details about the three methods applied by AIT, Isdefe and Fraunhofer INT (short INT) are given in deliverable WD4.1. In foregoing figure 1.1 their principal differences are illustrated.

Although there are distinct differences between the described three technology scanning methods, it has to be emphasized here that the approach to compare these three methods relies on some simplifying assumptions. At first it must be stated that the description of the methods neglects that e.g. the core team members themselves of all three institutions are to more or less extent technology experts in certain fields too and as such can be involved in the technology identification or assessment. For Fraunhofer INT this is in fact completely the case, but for Isdefe and AIT this accounts at least partly too. Since Fraunhofer INT in special cases sometimes involves external experts and Isdefe possesses and uses technological expertise in its core team too, the description of the two methods “C-Ex” and “C-In” overstates the general differences. At Fraunhofer INT the regular technology foresight process furthermore to some extent makes use of an in-house developed bibliometrics software package, although for the Etcetera project neither the bibliometrics software nor external experts were involved. And at the Austrian Institute for Technology AIT there are a number of technology experts at least belonging to the same research institution, giving the AIT access to technology experts in a way somehow comparable to Isdefe.

Hence, for any statement in this document on general characteristics or the performance of one of the methods one has to pay regard to the fact that it is impossible to separate the results achieved by one of the methods from the effect of the precise implementation of it at the executing partner institution. A pure scientifically perfect assessment of the performance of technology foresight methods under “ideal” or “laboratory” conditions can never be achieved as long as human beings in form of technology experts or core team members are integral elements of the experimental chain. Even an approach to just come close to this aim would mean to involve a statistically significant number of participating teams who strictly adhere to a detailed common instruction how to execute their tasks exactly and who precisely document any activity over weeks and months. Even if this theoretical setting does not seem impossible itself, at least it seems impractical to find funding for such an experiment, especially since the benefit of such effort and expenditure seems questionable compared to the more pragmatic approach chosen in the Etcetera project.

After this preface a brief description on how the methods will be assessed in this document follows. The central part of the comparison of the three technology scanning methods and the assessment of their weaknesses and strengths primarily is based on results obtained by an inquiry among a number of technology experts in the three institutions participating in task 4.1. These experts were asked to rate among the technologies identified during the course of WP 4 those belonging to their field of expertise. For this purpose in task 4.2 a special questionnaire had been prepared. All answers were gathered and processed according to a certain schematic. Details on this Weighted Bit Assessment Method (WBAM) are given in ETCETERA deliverable D4.1.

In the course of the WP4 WBAM process the experts were asked to rate the technologies contained in the provisional list D4.1 with respect to:

- the relevance for security issues ("Security Relevance"),
- the time until implications for security issues will occur ("Time frame"),
- the potential for usage in security related applications ("Application Potential"),
- the potential they could have to be commercial successful ("Market Potential")
- and possible implications concerning ethical aspects ("Ethical Consideration").

Neither the number of expert votes in total nor the WBAM procedure itself is sufficient to claim a complete unbiased and impartial evaluation of the applied technology scanning methods. But in order to derive conclusions about weaknesses and strengths of the methods some charts will be discussed in the following that are derived from the aforementioned WBAM results. These charts need to be interpreted with care, since each of them alone is not suited to characterise the overall performance of one of the applied methods or institutions uncorrelated from the rest of this assessment. Nevertheless the usage of the WBAM results seems a feasible basis for an open minded assessment.

The task in ETCETERA WP4 was to identify "*emerging technologies with security implications in years 2020 to 2030*". Consequently the WBAM results for parameters "security relevance" and "time frame" were used in a first step to sort out those technologies that did not match these requirements. After applying the WBAM method to assess all identified technologies some of these technologies were rejected because of one or both of the following reasons:

- security relevance to low
- technology is likely to be implemented either before 2020 or after 2030

Therefore, in the following, especially in sections 1.1 to 1.3, the assessment differentiates between two groupings of technologies:

- "all technologies":
  This term designates all technologies that were put on the "provisional list" by one of the three partners in the first process step (i.e. deliverable WD4.1).

- "valid technologies":
  This term refers to only those technologies from the "provisional list" that in the WBAM assessment were rated as being of at least moderate security relevance (i.e. if the WBAM value "security relevance" is bigger than zero) and lying in the correct time frame (i.e. the value for parameter "time frame" is equal or bigger than zero).

Technologies with possible ethical concerns are considered as "valid technologies" in this sense, as long as they were not rejected for one of the other two reasons too. Both criteria "security relevance" and "time frame" are the only necessary conditions to evaluate the performance with respect to the given task 4.1. However, in a similar way the criterion "ethical consideration" played a non-neglectable role for the selection of technologies in succeeding work packages of WP 4. The reason is that it needed to be excluded to foster technologies that are in conflict with EU research guidelines concerning "Dual Use Technology" or with a strong conflict potential regarding ethical issues. In section 1.6 the assessment addresses this aspect.

Section 1.5 “Specificity and Usefulness” puts the focus on the question whether the delivered results describe concrete technologies or rather generic topics on the one hand, on the other hand whether or not the specificity of the results is sufficient for the needs of downstream work packages and in general suited to derive conclusion for the elaboration of a research agenda. This second aspect involves the consideration of parameters “Market Potential” and “Application Potential”. However, here no concrete value can be defined as a prerequisite for further consideration in e.g. following work package WP5 and consequently a similar methodological comparison as for the aforementioned parameters is not possible.

Section 1.4 “Completeness” addresses the question whether the individual methods and the approach as a whole discovered emerging technologies in the overall range of the technology landscape or only in specific areas, maybe neglecting some important technologies.

In all following charts each of the three applied methods is represented by the abbreviation “Bib”, “C-Ex” and “C-In”, as explained in figure 1.1.

1.1 Comparison of Numbers

Deliverable WD4.1 contains a so called “provisional list” of 127 technologies that were identified by methods Bib, C-Ex and C-In. Five out of these technologies were identified by several methods. The total number of technologies contained in the three individual partner lists thus accounted to 132, composed of 37 entries by Bib, 29 by C-Ex and 66 by C-In. The following graph shows on the left side the relative share of all found technologies for each method.

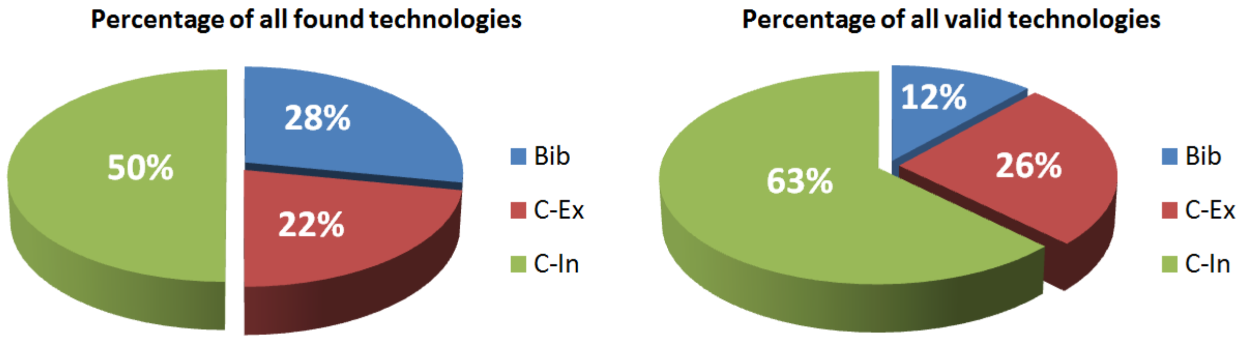


Fig. 1.1.1: Left side: Comparison of relative share (percentage) of all 132 technologies found by each method. Total numbers of found technologies are 37 (Bib), 29 (C-Ex) and 66 (C-In). **Right side:** comparison of relative share of 94 valid technologies (i.e. WBAM rating “1” or higher for parameter “security relevance”, rating “0” or higher for parameter “time frame”). Total numbers of valid technologies are 11 (Bib), 24 (C-Ex) and 59 (C-In). [Source: Fraunhofer INT]

In contrast to the a priori expectation the amount of overlapping entries in the individual technology lists was very low, 5 out of 132 entries or below 4%. That means the three methods worked rather complementary. In sections “1.4 Completeness” and “1.5 Specificity and Usefulness” this finding is addressed again, where also the efforts and thus time efficiency of the methods used for identification of emerging technologies is discussed. It also will be an interesting fact for deliverable D4.3, which shall derive conclusions for an improved technology scanning methodology.

When assessing the effectiveness and complementary character of the scanning methods also the situation after the sorting process to validate the found technologies needs to be considered. On the right side of figure 1.1.1 a comparison is shown for the share of valid technology entries after WBAM evaluation. A total number of 94 technologies were judged as security relevant and within the targeted time frame. These technologies are labelled “valid” and include those technologies that are rated as ethically critical (see explanation in introduction of section 1).

One can see from the right part of figure 1.1.1 that C-Ex and C-In both gain in relative share after the sorting of technologies based on the WBAM method. Although in every individual list technologies where sorted out, through the disproportional loss of entries in the Bib list the relative share of C-Ex and C-In rises. The following figure illustrates the ratio of valid technologies compared to found technologies for each individual list, showing that around 80% of all technology entries in the lists by C-Ex and C-In were judged valid, compared to around 25% of the Bib's entries. How far this assessment is dependent on the threshold for parameter "security relevance" can be assessed by comparison with the right part of figure 1.1.2, where also technologies with zero value for parameter "security relevance" are counted as "valid". The range for parameter "security relevance" and "time frame" extends from -3 to +6.

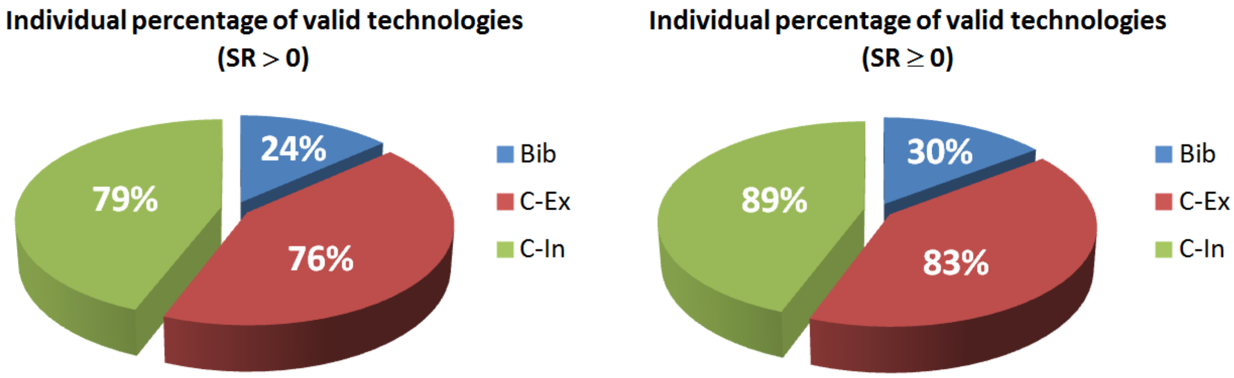


Fig. 1.1.2: Comparison of individual percentages of found technologies versus valid technologies for each partner. **Left side:** result if technologies are rated valid if WBAM rating for parameter "security relevance" is "1" or higher. **Right side:** result if technologies are rated valid if WBAM rating for parameter "security relevance" is "0" or higher. [Source: Fraunhofer INT]

The discrepancy between the above results from C-Ex and C-In on the one hand, and the Bib results on the other hand, must be correlated to one or both of the sorting criteria "security relevance" or "time frame". This is addressed in the following two sections.

1.2 Security Relevance

In the following graph average WBAM ratings for the security relevance of the identified technologies are given. The average value (blue resp. upper bars) is calculated summing up the WBAM security relevance ratings for all entries of one method and dividing thus value by the number of technologies contained in the respective list. On the left side this is done for the security ratings of all identified technologies of a method, on the right side of the graph this is done counting only valid technologies. Green (or lower) bars show the average over a reduced number of list entries. The reason for this is explained in the text below the figure.

It is obvious that the average rating of security relevance does not differ significantly between the methods when comparing all technology entries (blue resp. dark bars on left side). Value range is between 2 and 3. Comparing the same values for the average of only the valid technologies (blue resp. dark bars on right side) of course shows that all methods gain higher average values after the sorting, now between 3 and 5. Outstanding is the fact that the entries in the Bib list now even surpass the average security rating in both other lists. However one needs to consider the effect of quantitative differences in the total numbers that feed in the calculation.

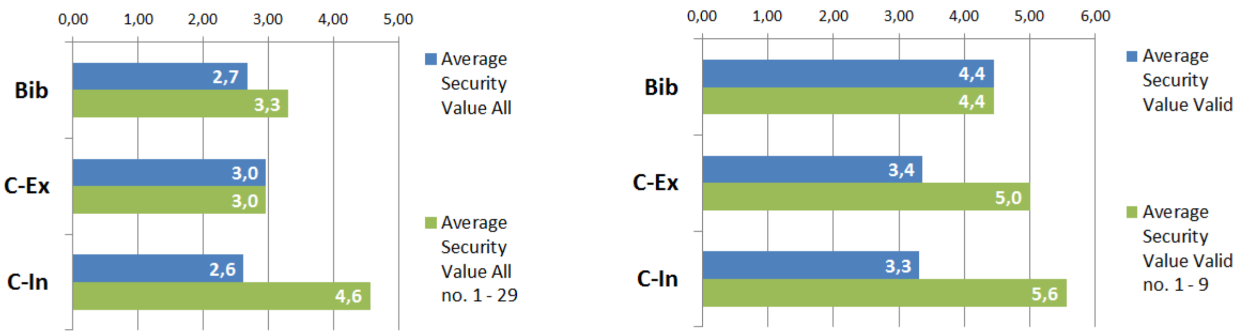


Fig. 1.2.1: Comparison of average values for security relevance ratings. Theoretical range of ratings goes from -3 to +6. Left side compares values for all identified technologies. Right side compares values for valid technologies. Blue bars (dark) indicate summing over all technologies contained in an individual list. Green bars (bright) indicate result when summing up over the first 9 resp. 29 list entries of each list. [Source: Fraunhofer INT]

Therefore the green (or lower) bars in the above figure show the average value calculation, when only the first 9 respectively 29 list entries are taken. In one case the limit is set to 9 because after the sorting process the Bib list contains a total of 9 valid technologies. In the other case the limit is 29 entries since the C-Ex list consists of 29 found technologies in total.

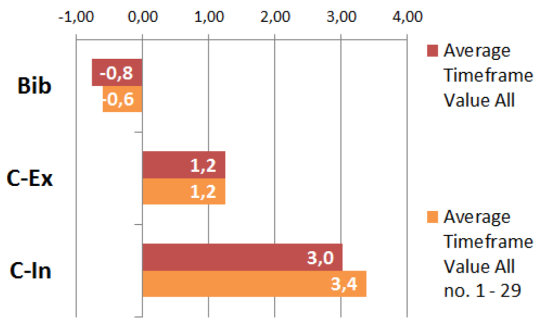
Inspecting the left side of the graph one sees that with equal numbers of list entries for the average calculation the security values of all found technologies for Bib and C-In increase. The same accounts with respect to the average calculation for the valid technologies concerning the security values for C-Ex and C-In, at the right side of the graph.

Although one can identify differences between the methods when restricting the average calculation to smaller numbers of entries, it can be stated that for the calculation of the average security ratings based on the individual list size the resulting values are rather comparable. So the disproportional loss of entries in the Bib list when comparing “all technologies” versus “valid technologies” cannot be explained by a weakness of the Bib bibliometrics method to identify technologies with security relevance. The reason therefore must be linked to the remaining relevant sorting criterion “Time Frame”.

1.3 Time Frame

The following figure 1.3.1 illustrates the same comparison between average WBAM ratings for “all” and “valid” technologies as foregoing figure 1.2.1, however with respect to parameter “time frame”. Comparing the red (dark) and the orange (bright) bars on the left side shows that when considering each method alone the differences between the mean values for “all” and “the first 29” technologies are more or less negligible. But the comparison across the methods reveals clear differences. The average ratings are negative for Bib, about 1 for C-Ex and about 3 for C-In. Considering only “valid” technologies, on the right part of the figure, the picture is different, due to a much better Bib value around 3 now.

Concerning the average values of the time frame ratings in figure 1.3.1 it must be explained that the average over the first 9 respectively first 29 technologies is summed up over the sorting order according to the ranking of parameter “security relevance”, i.e. the same order of technologies than used for figure 1.2.1. If the list is rearranged according to a primary sorting parameter “time frame” the average for value “time frame” of the first 29 technologies for Bib and C-In on the left side of the graph would account to -0.15 and 5.1 respectively. For C-Ex the result stays the same, as all 29 entries are counted independent from the order. On the right side of the graph the first 9 values for C-Ex and C-In would account to 3.7 and 6.0 respectively. Here the Bib result remains unaffected.



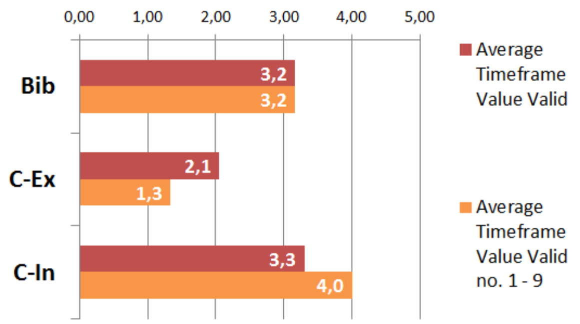


Fig. 1.3.1: Comparison of average values for time frame ratings. Theoretical range of time frame rating goes from -3 to +6. Left side compares values for all found technologies. Right side compares values for valid technologies. Red bars indicate summing over all technologies contained in an individual list. Orange bars indicate result when summing up over the first 9 resp. 29 list entries. [Source: Fraunhofer INT]

From figure 1.3.1 one can state that the disproportional discrepancy between the number for “all technologies” and for “valid technologies” in the Bib list (see discussion in section 1.1 and figure 1.1.2) is related to difficulties in the assessment of the development status of emerging technologies.

The following figure 1.3.2 helps to verify this statement. Here bars indicate the relative amount of votes that rated a technology as “too close to application” (“< 2020”), “matching the targeted time frame” (“2020 – 2030”) or “coming too late for the sake of the research agenda” (“> 2030”).

In the WBAM process each partner had one vote to assess each of the technologies contained in the provisional list WD 4.1. Counting the number of these votes delivers a total of 360 assessments for each of the WBAM questions.

If now for all statements concerning parameter “time frame” it is counted how often a rating for method A, B or C said “technology xy is too close to application”, “technology xy matches the targeted time frame” or “technology xy comes too late”, figure 1.3.2 is the result. The conclusion of figure 1.3.2 is that of all 360 single votes in the WBAM evaluation 19% judged Bib entries as “too close”, 12% entries from C-Ex and 9% from C-In. With respect to the number of technologies found by each partner this accounts to 76% of the votes for Bib entries, 51% for C-Ex and 18% for C-In.

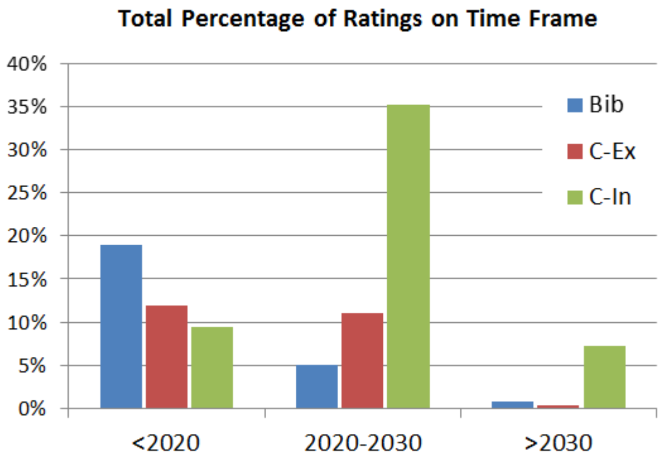


Fig. 1.3.2: Comparison of WBAM votes for parameter “time frame”. Left three bars characterise number of ratings for technologies too close to application, right three bars number of ratings for technologies being too late. The middle group constitutes technologies in the targeted time frame. The sum of all values accounts to 100%, meaning 360 votes. [Source: Fraunhofer INT]

From the comparison of the results concerning “time frame” in this section and “security relevance” in the foregoing section it can be derived that the problem to identify emerging technologies with security relevance is less challenging than assessing the development status of the identified technologies. Such an assessment strongly depends on specific expert knowledge. A pure bibliometrics approach cannot be expected to compete in this relation with the assessment of a specialist or a group of technology experts constantly monitoring special fields of technology.

The following figure 1.3.3 illustrates the dominance of the parameter “time frame” (TF) against “security relevance” (SR) with respect to the validation of all found technologies by use of the WBAM method. On the left side the share of technologies that is sorted out is given, when minimum requirement for parameter SR is value “1”. The equivalent value for TF is “0”. Obviously the estimation of the time until an emerging technology will be available for first applications is much more critical to judge than the implication of this technology for security issues.

On the right side the threshold for parameter SR now corresponds to the minimum requirement for parameter “time frame”, i.e. value “0”. With a share of 3% parameter “security relevance” now is of significant minor impact compared to the assessment of the future technology development. For roughly a quarter of all found technologies, i.e. 32 out of 132 identified topics or a share of 23%, the WBAM assessment denies an opportunity window of years 2020 to 2030, as was demanded by the task description. Since for both parameters – time frame and security relevance – the range of the WBAM weighting factors is from -3 to +6 this result cannot be attributed to the choice of the WBAM weighting factors. This shows that the challenge of the given task lies in the foresight aspect of technology identification and not only in technological expertise.

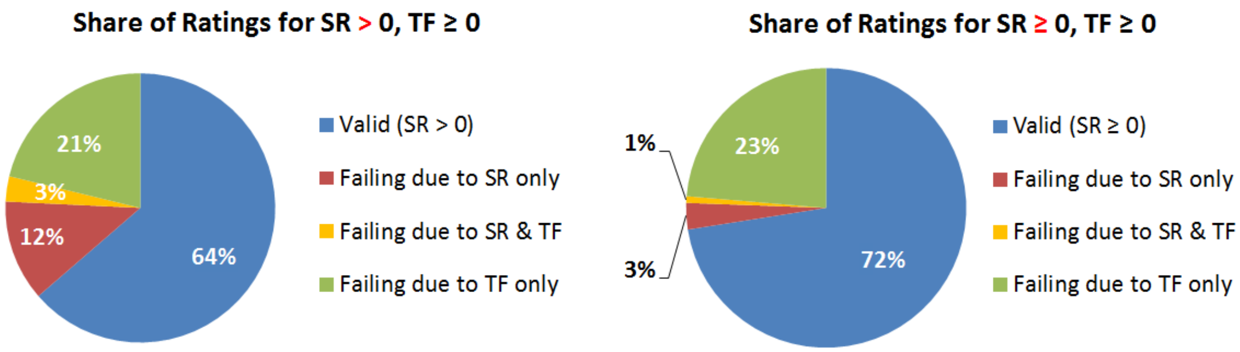


Fig. 1.3.3: Comparison of the influence of parameters “time frame” (TF) and “security relevance” (SR) for the quality of the technology identification process. Left side: valid technologies here comprise any technology with a rating of “1” or higher for parameter SR. This is compared to rejection of a technology due to one of three reasons: only value for SR too low, only value for TF too low or both values, for TR and SR as well, are too low. Right side: same comparison as on left side, with the difference of a threshold for parameter SR of “0”. [Source: Fraunhofer INT]

1.4 Completeness

One central question that matters in technology foresight is whether there can be any certainty that the identified technologies deliver a complete picture about the relevant future developments. However, since any domain “technology xy” is not a well-defined region with concrete boundaries one cannot define a measure describing the extent to which all current technological trends are captured. Consequently, in the following the results of WP4 in total are compared to results of other EU activities in order to assess the completeness of the combined approach. Additionally the individual methods are assessed by a comparison based on the “technology areas” (TA) defined in work package 4.

One way to judge the completeness of the Etcetera results is to look how the results of Etcetera WP4 fit to the technology domains that are of strategic interest in the EU. During the past years the EU has run through a process that led to the identification of strategic technology fields which shall be focused upon in the future. These so-called key enabling high technologies (KET) that have been identified by Member States and the Commission's Key Technologies expert group[1] as priority to improve European industrial competitiveness are:

- Advanced Materials
- Nanotechnology
- Micro- and Nano-Electronics
- Industrial Biotechnology
- Photonics and
- Advanced Manufacturing Systems

With the exception of the last entry, all key enabling technologies are clearly represented in the Etcetera WP4 technology list (see deliverable D4.1 for details). These latter “advanced manufacturing technologies” are recognised as a "cross-cutting" KET[2]. Since manufacturing processes – with exception like forms of rapid prototyping, e.g. “3D-Printing Technology” - usually do not imply security relevance, the Etcetera technology list does not contain technologies specifically addressing production or manufacturing techniques. The aforementioned example “3D-Printing Technology” was not included in the list because the development here has already progressed too far to fit in the selected timeframe of years 2020 to 2030.

The key enabling technologies are rather generic terms with a broad range of technology sub-sections. Therefore an assessment on a more detailed scale of technologies is done by contrasting the technologies to the taxonomy of the past EU project Staccato[3].

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[1] Source: European Commission: "Preparing for our future: Developing a common strategy for key enabling technologies in the EU - Current situation of key enabling technologies in Europe“, COM(2009) 512, Brussels, 30.09.2009

[2] Source: European Commission: “A European strategy for Key Enabling Technologies – A bridge to growth and jobs“, COM(2012) 341 final, Brussels, 26.06.2012

[3] Source: AeroSpace and Defence Industries Association of Europe: „Deliverable D 1.2.2 - STACCATO Final Taxonomy“, EU project PASR – Preparatory Action on the enhancement of the European industrial potential in the field of Security research, 2008

As the Staccato project was performed by a consortium that substantially consisted of industrial corporations from the defence technology sector the taxonomy contains some specific elements not applicable for research activities in the domain of civil security as is the purpose of the ETCETERA project, like e.g. "missile equipment". In figure 1.4.1 the degree of accordance with the scope of the Staccato taxonomy is illustrated.

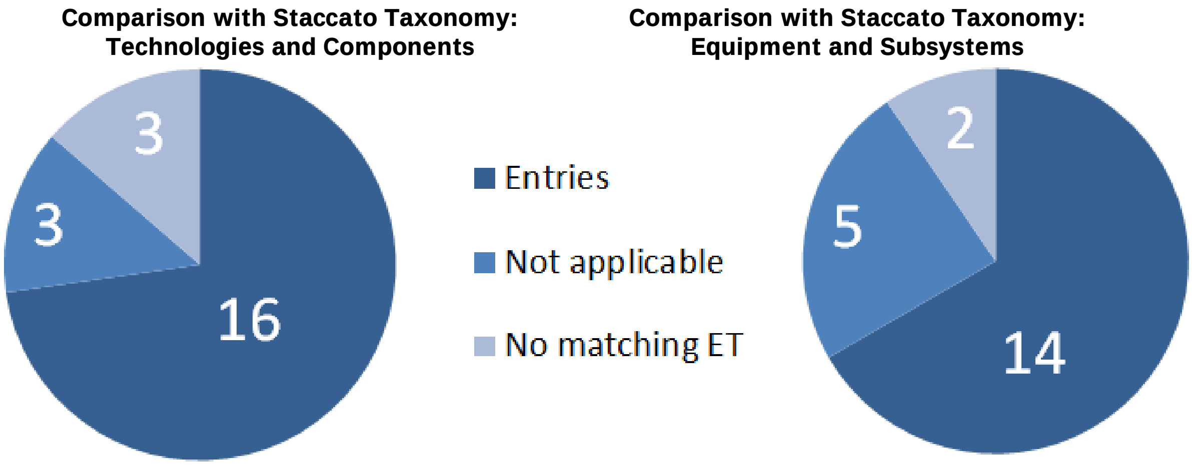

Fig. 1.4.1: Assessment of technology fields in Etcetera WP4 by comparison with the results of the EU project Staccato. Left side: from 22 sections in level "Technologies and Components" in the Staccato list, the Etcetera result addresses 16 sections for found emerging technologies ("entries"). Three Staccato sections did not match the Etcetera scope of civil technologies ("not applicable"), for another three sections there was no matching emerging technology found ("no matching ET"). Right side: same assessment for level "Equipment and Subsystems". [Source: Fraunhofer INT]

To assess the disparities in the scope of the Staccato project and the Etcetera results concerning emerging technologies, the Staccato sections for which no matching emerging technologies were found are listed below for the levels „Technologies and Components" and „Equipment and Subsystems". Some topics within these two sections had a focus beyond the scope of civil research, e.g. "nuclear weapons testing" or "warheads", and were therefore excluded as "not applicable".

For section "220 Human Resources"the Staccato taxonomy only lists requirements instead of technologies. For other categories like " 115 Simulation Tools and Techniques" the listed technology "Augmented Reality" was excluded, since the targeted timeframe lies beyond the initial application.

Therefore, considering the fact that only for 3 out of 22 Staccato fields "Technology and Components" and for only 2 out of 21 Staccato fields "Equipment and Subsystems" no entries could be found, one can state that the results of the Etcetera project quite satisfactory cover the range of applicable sections defined in the Staccato taxonomy.

Table 1.4.1: Staccato taxonomy sections not matched by technologies found in Etcetera WP4.

Level "Technologies and Components"

Category "Not applicable":

Section	Topic	Example
102	Materials for Deterrence	e.g. Nuclear Materials processing
104	Survivability and Hardening	e.g. Nuclear Weapons Testing
105	Energetic Materials	e.g. Explosives

Category "No matching emerging technology":

Section	Topic	Example
106	Plasma technology	No example defined
112	Signal Processing Technologies	e.g. Analogue Signal processing Techniques
115	Simulation Tools and Technologies	e.g. Augmented Reality

Level "Equipment and Subsystems"

Category "Not applicable":

Section	Topic	Example
202	Identification Equipment	e.g. Non-co-operative IFF systems and techniques
207	Munition Devices and Energetic Contents	i.e. Weapons of different kind, e.g. hand guns
209	Weapon Systems	e.g. Guns, Artillery and other Launch Platforms
218	Missile Equipment Subsystems	e.g. Warheads
220	Human Resources	e.g. Facilities for Recruitment and Selection of Personnel

Category "No matching emerging technology ":

Section	Topic	Example
212	Forensic Technologies, others	e.g. Fire arms and projectiles identification
213	Buildings Platforms	i.e. critical buildings specific architecture

Since the results of the three individual lists provided by AIT, Isdefe and INT had to be harmonised with respect to designation of technologies and overlapping content, entries with strong topical correlation were grouped in clusters. This was done in a joint effort during a workshop at AIT. The resulting 12 technology areas and one additional cluster, named as "Technology Areas", are listed in table 1.4.2. This latter cluster does not list technologies but rather corresponds to social demands, like "social security" or "water resources management", that hint at future technological requirements with relation to security issues. This last group "Cross Sectional Themes" is a special result of the bibliometrics activity at AIT. The 127 technologies identified in the first step of Etcetera WP4 (see deliverable WD4.1 for details) were assigned to these technology areas. The distribution of these technologies among the aforementioned 13 areas is depicted in figure 1.4.2.

Table 1.4.2: Clustering of technologies in Technology Areas (TA) in Etcetera WP4.

TA 1:	Biometrics	TA 7:	Human Science
TA 2:	Communication Technology	TA 8:	ICT and Electronics
TA 3:	CBRN Identification	TA 9:	Mobile Platform Technologies
TA 4:	Energy Technology	TA10:	New and Smart Materials
TA 5:	Environmental Security	TA11:	Non-lethal Means
TA 6:	Human Machine Interface	TA12:	Sensor Technologies
		TA13:	Cross Sectional Themes

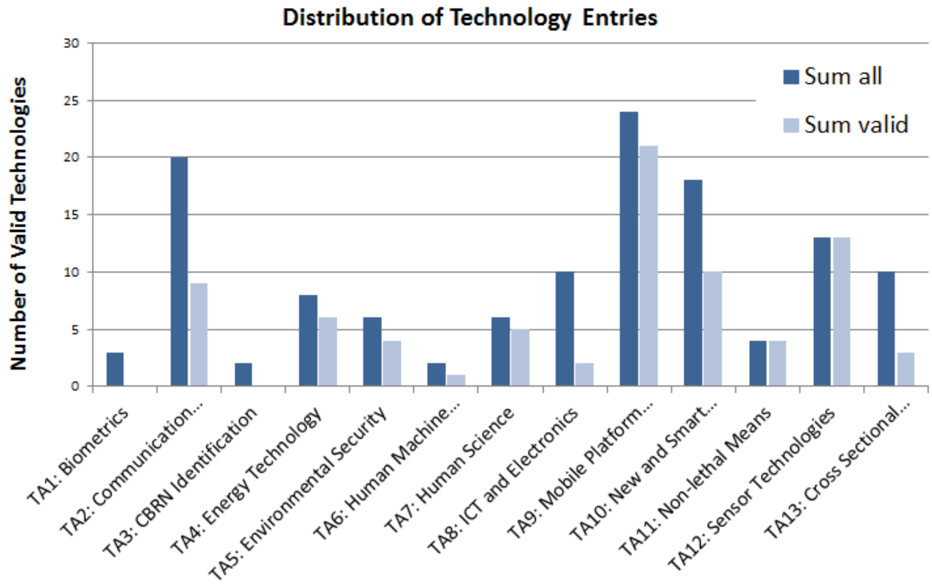

Fig. 1.4.2: Individual distribution of technologies in different technology areas TA1 to TA13. Left hand or dark blue columns give numbers of all found technologies in an area. Right hand or light blue columns give numbers for technologies (resp. social demands) with valid security relevance (SR ≥ 1) and time frame (TF ≥ 0). [Source: Fraunhofer INT]

In figure 1.4.2 one can see that the numbers of assignments to the TA's vary. From the twelve technology oriented areas four comprise less than five technologies, four comprise five to ten technology entries and another four more than ten technologies. After sorting of technologies found not to be valid the distribution of course gets smoother. Now, in eight technology areas there are five or less entries, with TA1 and TA3 without any entry after the WBAM assessment. In two technology areas the entries are between five and ten, and only two technology areas lay still above.

The differences in the mere numbers between the areas could either be assigned to a possible bias in the accumulated results or different dynamics concerning the technological development in the respective technology domains. However, from this distribution alone one cannot deduce a specific selectivity or focus of the technology identification process, since the dynamics of technological developments and the implication for security related applications is not necessarily balanced between the defined clusters.

To investigate the matter further the accumulated result in figure 1.4.2 is split up into the respective shares of the different applied methods in figure 1.4.3. Now one can try to assess the question of completeness with respect to the individual results. For each technology area the three columns now represent the number of technologies found by each of the three methods[4].

[4] In figure 1.4.3 technologies that were found by different methods are counted several times, so there is a seeming discrepancy in numbers (when comparing e.g. “TA2: Communication Technology” in figure 1.4.2 vs. figure 1.4.3, with 9 valid entries vs. 10 valid entries in total).

Since for TA1 and TA3 after the WBAM assessment no valid technology entry remains, it is open whether the methods did possibly miss some technologies or whether in fact there is no relevant development to detect. For the rest of the technology areas there is always at least one entry with rating "valid" based on the WBAM evaluation process.

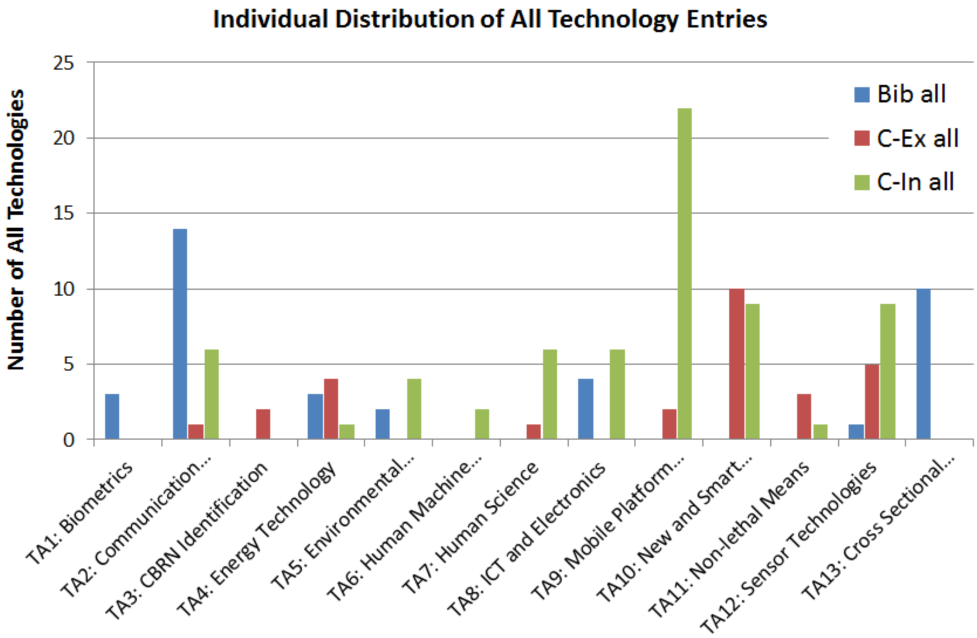

Fig. 1.4.3: Individual distribution of technologies in different areas TA1 to TA13. Share of the respective method is illustrated by coloured columns (see legend). [Source: Fraunhofer INT]

Concerning the individual distribution of technologies in the different technology areas it can be stated that there are clearly differences in the coverage of the technology areas between the methods. The number of entries of the individual methods in the different areas ranges from 1 to 3 (Bib), 1 to 6 (C-Ex) and 1 to 19 (C-In). Due to the considerable disparities between the methods concerning entries in certain technology areas and the lag of reasonable expectancy values the calculation of any measure as e.g. standard deviation does not make sense here.

The average number of identified technologies (calculated as the total number of entries of one method divided by the number of areas with entries of the respective method) is 6/4 = 1.5 for Bib, 21/7 = 3.0 for C-Ex and 52/10 = 10.2 for C-In. If one accounts for the effect that in TA9 there is an extraordinary high number of entries from C-In and substitutes this number with the second biggest number (i.e. 9 entries in TA9) the result for C-In is 43/10 = 4.3. However, this measure is influenced through the effect that the total number of identified technologies differs markedly between the individual methods.

With respect to the question whether or not a method could identify emerging technologies in all of the technology areas one has to compare both numbers, the number of technologies found in total and the number of technologies that were rated as valid regarding security ~ and time relevance later on. This assessment is done in figure 1.4.4, where the coverage of the twelve technology areas is depicted for the three methods.

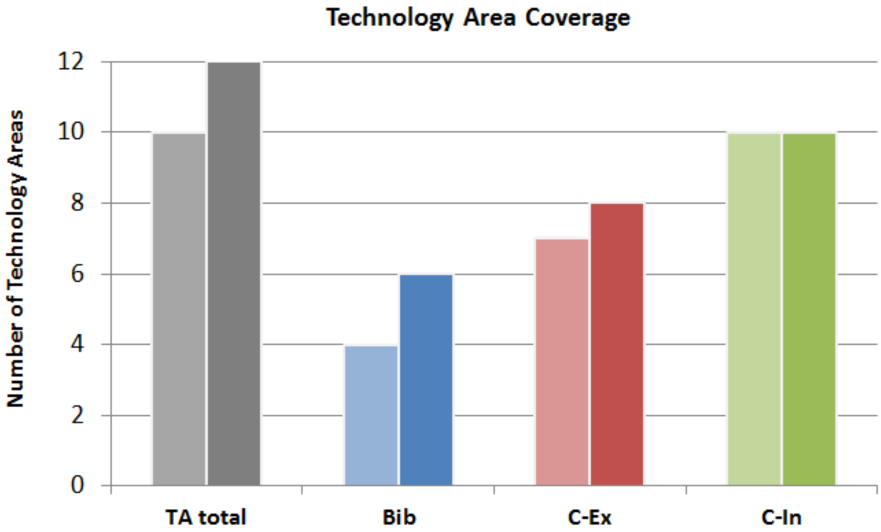

Fig. 1.4.4: Illustration of how the three methods cover the technology areas in WP4. Right hand columns show in how many of the twelve technology areas (TA13 not considered here) a method did find any technology. Left hand columns show the coverage with respect to only valid technologies in the ten technology areas that contain valid entries. [Source: Fraunhofer INT]

In figure 1.4.4 the result of course is influenced by the somewhat arbitrary definition of the technology areas and the degree of coverage is inversely correlated to the number of technology areas. Besides there is a statistical advantage for methods that deliver a higher number of entries.

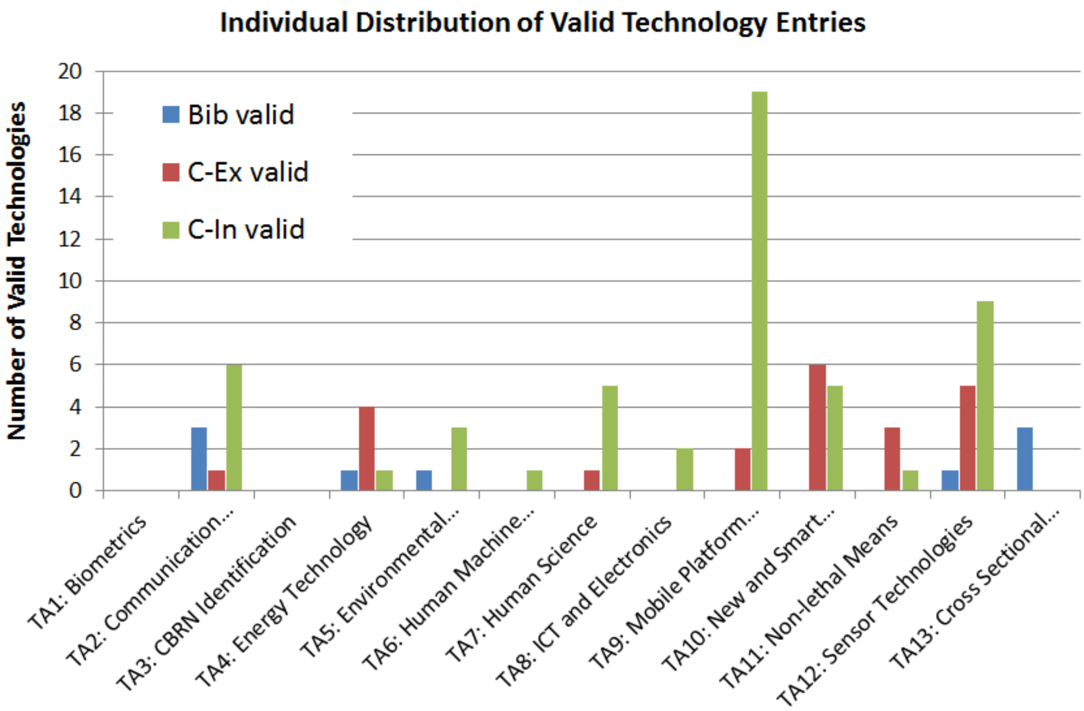

Fig. 1.4.5: Individual distribution of technologies in different areas TA1 to TA13. Share of the respective method is illustrated by coloured columns (see legend). [Source: Fraunhofer INT]

Since in figure 1.4.3 each method dominates in at least one technological field one could conclude that each method tends to prefer certain areas or is biased by some fields of specialisation. This would support the argument that in total the methods work primarily complementary. But with a view on figure 1.4.4 and to the distribution of valid entries in the technology areas (figure 1.4.5) this hypothesis must be confined to methods Bib and C-Ex, since for C-In the coverage of the technology landscape seems to be sufficient.

Nevertheless, in deed the methods work complementary however with respect to the identified technologies themselves, since among the valid technologies only four out of 94 (see figure 1.1.1) were found by more than one method. This validates the argument to use different methods to raise the probability that no technological development is missed.

1.5 Specificity and Usefulness

Regarding the criterion *usefulness*, the first and obvious question to answer is: were there enough technologies handed over to the downstream work packages and could the participants of these packages make use of it?
This question can be clearly affirmed, since for the downstream packages at least nine technologies were compulsory and work package 4 delivered a multiple of that. The differences concerning the individual share of each method to that number were already detailed in section 1.1.

From an outside perspective one must consider that one driver for the EU research framework is the stimulation of economic growth. As an EU FP7 research project Etcetera is addressing this goal and consequently the results of task 4.1 should contribute to this interest. One indication for this is the correlation of the results of Etcetera WP4 with the technology domains that are of strategic interest in the EU. As already described in section 1.4 there are six key enabling high technologies (KET) that are regarded as important areas for European competitiveness. For five out of these six areas there are technologies contained in the WP4 results. For the sixth area, which addresses manufacturing and production technologies, no technology could be found that fulfilled both necessary criteria “security relevance” and “time frame”. It can be stated that with respect to the strategic interest of the EU research funding the technology scanning methods proofed to be useful. If one wants to differentiate between the three methods and rate their individual contribution to the process with respect to the ratio of investment or efforts compared to the usefulness for the project, a measure of effectiveness would be needed.

From the total numbers of identified and/or valid technologies one could only deduce on the effectiveness of the respective scanning method, if the efforts behind the scanning activity are taken into account, i.e. how many persons were involved and how much time did they spent in total on the task. As a rough estimate for these values one could use the allocated budgets for a first assessment, given in Person Months (PM). According to the ETCETERA DoW for task WP4.1 the three partners allocated 3.5 PM (AIT), 1.5 PM (Isdefe) and 3 PM (INT). One could tend to calculate a kind of effectiveness measure based on the ratio “numbers of found technologies divided by person months”. However this approach would neglect the interesting fact that against the a priori expectation the amount of overlapping entries in the individual technology lists was very low, 4 out of 94 valid entries as already stated before in section 1.4. This is an interesting fact for deliverable D4.3, which shall derive conclusions for an improved technology scanning methodology.

The criterion *specificity* addresses the question, whether found technologies were concrete enough to derive useful conclusions on application or market potential of a certain technology. It would be impractical to investigate general technology areas like “biometry” or else, since the development and features of technologies belonging to that field can be completely different.
On the other hand it needed to be avoided that the degree of differences between the individual technologies was too low, meaning that in fact only different aspects of the same underlying technology would be considered. In that case there would have been no really choice for the downstream packages to examine different alternatives and to derive useful conclusions for a future research agenda.
Additionally the technologies in best case should be relevant for civil applications that finally – when it comes to marketable products – can serve everybody, not only a very confined group of specialists with exotic demands.

Inspecting the list of valid technologies found in WP4 it can be stated that in general there is a well suited specificity, complying with the project needs and meeting the expectations. There are some similarities between technologies in some areas, e.g. there were different encryption technologies, different flying platforms or some sensor technologies based on micro- or nanotechnology. However the addressed application areas and the security implications are different, meaning that each entry has its specific eligibility.

A special role in this respect played the entries of technology area “cross sectional themes”. On the one side they were rather abstract, like “social security”, on the other side they complemented the entries of both other methods, which were driven by a technology push perspective, by a perspective from the demand side.
The bibliometrics analysis used by AIT had the advantage of giving an excellent overview of scientific literature in a given field with only little input from experts being needed, thus being independent and non-partisan. The results provided input to the scientific bases and a back cast of the topic in question in literature derived from Web of Science. The intentional application of the search term “security” meant that a very good overview about published work was gained including all publications using this term in title, abstract or keywords. That way cross sectional themes, such as food insecurity, social security, unstable quality of financial markets or threats due to climate change were identified, that do not represent a single technology, but rather a technological area or basis for necessary technological development in the near and far future. These research fields are of high importance for social security all over the world and particularly for Europe.

1.6 Ethical Assessment

Parameters “Ethical Consideration” as well as the already mentioned parameters “Market Potential” or “Application Potential” were no direct target parameters for the first process step, i.e. the identification of emerging technologies with security implications.

Nevertheless to ensure the applicability of technologies in all downstream work packages it seemed reasonable to concentrate on those technologies found in the first process step (i.e. the “prioritised list” of technologies D4.1) that fulfilled all three criteria “Security Relevance” and “Time frame” and “Ethical Consideration” at the same time. Parameters “Market Potential” and “Application Potential” become important in the following package WP5 and are more difficult to judge. Their WBAM results consequently are not weighted the same way for the methodological comparison as the aforementioned parameters.

Two technology areas (TA1, TA3) are without entry after the assessment of security relevance and time frame. In a third area (TA6) the result depends on whether or not ethical considerations are included. Including the ethical considerations three technology areas (TA6, TA9, and TA11) are affected.

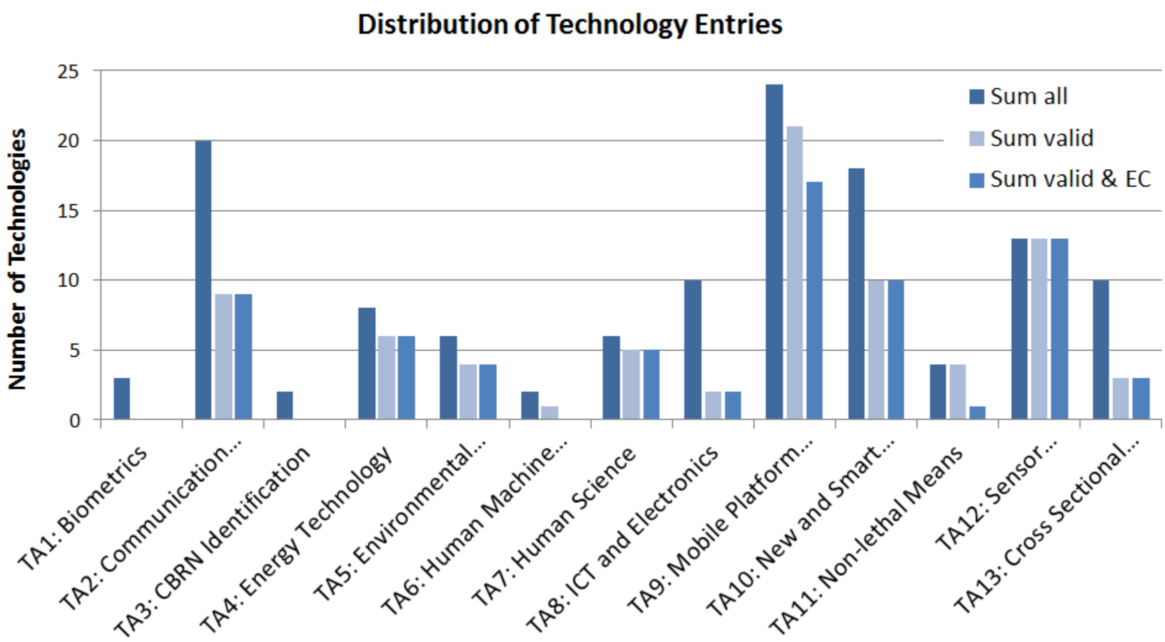

Fig. 1.6.1: Distribution of all found technologies (see deliverable WD4.1) in different technology areas TA1 to TA13. Dark columns represent all 127 found technologies. Medium coloured columns show all entries that were evaluated as “valid technologies” using the Weighted Bit Assessment Method (see deliverable D4.1 for further explanation). The flag “valid” here denotes that these technologies were rated to be security relevant, complying to the wanted timeframe and without ethical concerns. Light blue columns, labelled “Sum valid SR+T”, show all entries that were evaluated as “valid technologies” only taken into account parameters “security relevance” and “timeframe”, neglecting “ethical considerations”.

The three different coloured groups of columns correspond to the depiction of either all technologies (dark coloured), all technologies that were rated as “valid” with respect to security relevance, time frame and ethical considerations (medium coloured) or those technologies that were rated as valid only taken into account the parameters security relevance and time frame (light coloured).

In general one can state that ethical considerations did only in a few cases lead to concerns about the further consideration of technologies in downstream packages. Since the complete list of technologies was available for all project partners the marking of a technology as ethically critical was only an indication in the sense of a possible risk factor. Besides this indication for each in-depth technology analyses an ethical assessment was performed by project partner CSSC, who are specialists in assessing ethical, societal and judicial aspects. A complete report about their activity and conclusions is given in deliverable WD5.1.