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EVALUATION PROJECT FOR INTEGRATION OF ICD-11 INTO IRIS *FINAL REPORT*

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Summary

1. BACKGROUND

With its adoption by the e Seventy-second World Health Assembly in May 2019, ICD-11 will become the new standard for coding diseases and health problems. In mortality, the ICD coding is performed with the use of automated coding systems, mainly Iris. It is necessary to assess the needs for transitioning to ICD-11 before engaging in a full implementation project. This evaluation project will serve that need.

The core component of Iris are the decision tables, currently based on ICD-10 codes. For the transition of Iris to ICD-11, it will be necessary to translate the decision tables and to allow them to include all the features of the new revision.

This report illustrates the analyses performed in order to identify: main quality gaps in the tables, priority area for starting the translation, different logical rules needed for translating from ICD-10 to ICD-11 with consequences from the point of view of automation and human expert intervention, overview of the prototype implemented for the expertise support, and evaluation of efforts needed.

1.1.Objectives

In summary, the aims of this evaluation project are:

- Evaluate the most frequently reported pairs of ICD codes in cause-of-death data in order to provide a prioritization scale of parts of the tables to be translated.
- Focusing on the due to relations, highlight the most significant causal relations reported by physicians and compare the findings with the information included in the tables.
- Evaluate the possibilities of ICD-11 tool integration into Iris.
- Evaluate the necessary post-coordinated codes to be used in Iris in order to arrive at the correct underlying and multiple cause outputs, the IT solution for integrating such codes in Iris processing, and the impact of the flexibility of the post-coordination feature on Iris processing.
- Study the potential of the mapping between ICD-10 and ICD-11, aimed at highlighting possible problems in the use for the translation of the decision tables and proposing correction solutions.
- In an iterating process, evaluate the possible transition of the rules that can be done automatically, based on the ICD-10 to ICD-11 mappings, test the success of the automatic transition and evaluate the amount of refinement needed.
- Evaluate the effort to be done for the translation of the "DUETO" rules of the decision tables. In particular, a numerical estimate of the "DUETO" rules that can be automatically translated and of those for which an intervention by experts is necessary.

- Additionally, the maintenance of the decision tables should be visited to ensure that the maintenance process implemented for ICD-10 is sufficient for ICD-11.

1.2. Decision tables[1]

The decision tables are a tool used during the selection of the underlying cause of death according the rules of the International Classification of Diseases and Related Problems (ICD) of the World Health Organization (WHO). They are central to the function of mortality automated coding systems but they are also used in manual coding, allowing a consistent and harmonized application of the ICD rules.

The decision tables form a knowledge base of relations between pairs of codes (representing the causes of death reported on the death certificate) that must be taken into consideration during the application of the steps for the selection of the underlying cause. This knowledge base was first developed by the NCHS (US National Center for Health Statistics) for the ACME system (ACME tables). Successively it has been embedded in the new automated coding system Iris and, since 2011, the Iris Institute maintains the tables according the WHO official updates of the ICD and on the basis of the recommendations of groups of international experts, namely the Mortality Reference Group, which operates in the network of the WHO Collaborating centers for the Family of international Classifications (WHO-FIC)[2]. The tables have evolved together with the Iris software and currently include new functions compared to the original version.

In practical terms the decision tables are a list of possible kind of relations between pairs of codes. In each step of the selection, in fact, it is necessary to evaluate if between two codes a given kind of relation exists. The different kind of possible relation useful during selection are referred to as “rules-types”. For each given rule-type the tables list all possible relations between pairs (“rules”). As an example, one of the most used rules in the selection of the underlying cause is the “due to” used in steps called SP3, SP4 and SP5. In these steps it is necessary to evaluate if the sequence reported by the physician on the death certificate (in part1) corresponds to a causal sequence where each element of the sequence, a condition coded into an ICD code, can be considered “due to” the successive. The tables contain all possible pairs of codes for which a possible causal relation may exists. In particular, for each

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[1] For further details on decision tables: Iris User Reference Manual V5.6.0S1 or Information about coding rule types for mortality at the iris website www.iris-institute.org

[2] For more details see: Navarra S, Cappella M, Johansson LA, Pelikan L, Frova L, Grippo F. Decision Table Editor: a web
application for the management of the international tables for mortality coding. Istat working papers 6/2016. (available online https://www.istat.it/it/archivio/184113)

code the list of possible codes[3] to which the first one is due to is provided. This latter list, is referred to as "subcodes" of the first code, for the rule-type "due to".

In table 1 the list of the existing rule-types is provided, with the indication of the steps of the selection where this is applied[4]. Moreover the number of occurrence of each rule-type in the tables is shown, i.e. how many pairs of code this rule-type actually refers to. The codes (addresses) and subcodes are generally presented as spans of ICD codes (for instance I600-I64 DUETO C000-C969), nevertheless, if all these spans are resolved we can count the relations between each pair, i.e. the actual number of rules included. The most represented rule is the "DUETO", with more than 29 million records.

The second most represented are the DS and DSC, including more than 2 million records. These rules are applied in SP6, a very important step for the quality of the underlying cause selected.

For this evaluation, 2019 tables are taken into account, since they include the most recent ICD-10 updates. It is recommendable, for the translation project, to use the most recent version produced by the Iris Institute.

[3] The first code in tables rules is also referred to as "address", the second one is also referred as "subaddress".

[4] For more retail see: Information about the coding rule types for mortality coding with Iris (available at www.iris-institute.org)

Table 1. Description of the rules included in the decision tables, with the indication of the steps of the underlying cause selection in which each rule is used and number of pairs of codes involving that rule in the tables

Rule	Description	Step of selection rule	Number of relations between single codes (a)
DUETO	Due to	SP3-SP5	20,433,525
DS	Direct Sequel	SP6	2,026,631
DSC	Direct Sequel with Combination		17,257
IDDC	Ill-defined in Due to with Combination	SP7	2,250
IDMC	Ill-defined with mention with combination		127
LDC	Linkage in Due to with Combination	M1	50,682
LDP	Linkage in Due to with Preference		6,194
LMC	Linkage with Mention with Combination		31,608
LMP	Linkage with Mention with Preference		36,697
SDC	Specificity in Due to with Combination	M2	5,504
SMC	Specificity with Mention with Combination		1,513
SMP	Specificity with Mention with Preference		46,830

(a) 2019 edition.

Besides address code, subaddress code and rule type, decision tables have other variables that could have implication in ICD-11 implementation:

- The maybe flag indicates ambivalent relation between two codes that need to be resolved manually by expert coders. The reason for the ambivalence is explained in a message field as in such example:

  C813 DUETO B200-B24 If malignant neoplasm is specified primary in brain

  This means that C813 (Lymphocyte depleted (classical) Hodgkin lymphoma) can be accepted as due to B20-B24 (HIV disease) only if it is primary in the brain. The maybe is necessary because the ICD-10 code does not contain information on the site.

- Field condition. By means of this field it is possible to restrict the application of a rule to a condition such as the presence of specific flags used for enhancing the specificity of codes.

1.3.Mapping table

In June 2018, WHO released a version of ICD-11 for starting programs for implementation. Along with the release of ICD-11, the WHO releases the mapping table that can be used for the mapping between codes of ICD-10 and ICD-11. The mapping tables available are from both MMS and Foundation. Here, only MMS mappings are considered, although Foundation mappings could provide extra information.

The mapping table is a list of possible kind of relations between pairs of codes, where the relation defines the set relation between the entity of ICD-10 and the entity of ICD-11. From a logical point of view in the mapping table, the ICD codes are sets, where the relation between sets can be: equivalent, subclass, superclass and intersects.

Table 2. Example of some pairs with the relation taken from the mapping table of MMS

ICD-10 Code	ICD-11 Code	Relations
A01	1A07	Superclass
A01	1A08	Superclass
A01	1A0Z	subclass
A01.0	1A07	equivalent
A01.1	1A08	Subclass
A01.2	1A08	Subclass
A01.3	1A08	Subclass
A01.4	1A08	Subclass

The interpretation of a pair is the following:

The ICD-10 **A01** code is **superclass** of ICD-11 **1A07** code.

The relation of superclass involves that the categories were split into multiple categories. The relation of subclass unifies different categories of ICD-10 in a unique ICD-11. With the equivalent relation, we have the same category of ICD-11 as for ICD-10. The intersects involve that the classification changed the structure and that categories intersect each other.

2. DELIVERABLE D1B: MOST FREQUENT *DUE TO* RELATIONS

Objectives

- To provide a prioritization scale of due to rules to be translated.
- To refine the decision tables, in particular identifying patterns of causal relations reported by physicians on death certificate in order to highlight new due to rules that could be included in decision tables.

2.1.Materials

Multiple cause of death data resulting from certificates of deaths occurred in seven countries were analyzed: Italy (IT) provided by the Italian National Institute of Statistics; Hungary (HU) provided by Hungarian Central Statistical Office – KSH; Mexico (MX) provided by Ministry of Health/General Direction of Health Information/Mexican WHO-FIC CC (CEMECE); Spain (ES) provided by Institudo Nacional de Estadística – INE; South Africa (ZA) downloaded from Statistics South Africa – STATS website; United Kingdom (UK), sample provided by Office for National Statistics – ONS; United States (US) downloaded from Centers for Disease Control and Prevention – CDC website. Data, referred to years 2016, 2017 or 2018, were completely anonymous and consisted of the complete multiple cause information coded according ICD-10 and the indication of the position of each ICD code on the record. Since data are coded with Iris by all countries, the record format used was that included in the Iris database in the variable "ACMECodes" where a special syntax is used to identify the part and line of the death certificate where each code was allocated. In most of the cases, ICD-10 version 2016 was used. Nevertheless, since the reference decision tables used are those of 2019, a check of valid codes in 2019 was performed on records. When invalid codes (in 2019 version) were found, these were substituted by the most similar code valid in 2019. All countries provided to Italian team data on all deaths occurred in one year, except UK which provided a sample. Some descriptive analysis of data analyzed is presented in able 3.

2.2.Methods

The analysis mainly focused on due to rules. These rules represent the vast majority of the tables and are the most critical rules for coding. The second most relevant kind of rule is the direct sequel, DS, while the other rules –linkage and specificity- are strictly connected to the structure of classification.

Descriptive statistics were carried out by country: number of different codes reported on certificates, average number of codes reported on each certificate, average number of filled lines, number of different pairs of codes reported in due to position.

For the analysis of due to rules, only part 1 of certificates was taken into account. Nearly all death certificates analyzed (4,811,844 out of 4,812,100 certificates) contained part 1 with at least one condition. In order to identify the rules to prioritize in the translation process, as a first step, for each pair of codes reported in due to position (i.e. in different lines of part 1), the frequency on certificates was calculated. In order to identify rules that are not included in the decision tables but that could be included, first of all, for each pair of codes it was evaluated if it is reported on certificates in a certain causal order more than expected (under the assumption that the causal order is casual). This analysis was performed by two steps.

1. For each possible pair of ICD-10 codes, it was evaluated if the two codes are jointly reported on certificates more than expected (under the assumption that codes are casually reported on certificates).
2. For the pairs of codes which are jointly reported on certificates more than expected, it was evaluated if they are reported in a certain causal order more than expected (under the assumption that the causal order is casual).

The methodology is the same used in the preliminary analyses performed only on Italian data and it is described in detail in the mid-term report. Since for the final analysis small adjustments have been made to the methodology, Annex A describes the methods finally applied to data.

The results were compared with the current version of decision tables, evaluating if they are in agreement with the information contained in the tables. In particular, pairs which are reported on certificates in due to position more than expected, but for which the corresponding rule is not accepted by decision tables, were identified.

2.3.Results

Table 3 shows the results of descriptive analyses. As shown in table 4, of all 463,939 different pairs of codes, about 41% resulted significantly associated, i.e. jointly observed in part 1 more than expected. More than 51 thousand pairs are reported in a causal order more than expected on the basis of the chance. Generally the agreement with decision tables is high (78% of the pairs which result in due to are accepted in the tables). Nevertheless some discrepancies are observed and will be discussed later.

Table 3. Descriptive analyses

	IT	ZA	ES	MX	HU	UK	US	All countries
Death certificates	618,083	473,938	424,523	307,433	131,668	36,421	2,820,034	4,812,100
Different codes reported	4,029	3,17	3,577	2,539	3,204	1,405	5,553	6,786
Different codes reported in part 1	3,576	3,169	3,326	2,375	2,775	1,102	5,008	6,292
Average number of codes	4.4	1.7	3.7	2.9	4.6	2.7	3.2	3.2
Average number of codes in part 1	3.4	1.7	3.1	2.4	3.4	1.6	2.2	2.4
Average number of filled lines	3.1	1.7	2.7	2.4	3.2	1.4	1.9	2.2
Different pairs in due to position	172,897	62,057	127,779	51,501	58,012	6,577	272,555	463,939

Table 4. Number of pairs of ICD-10 codes reported in due to relation by agreement with decision tables

	N	%
Number of different ordered pairs found in death certificates	463,939	
Of which		
Resulting significantly associated (X2 test, p<0,05)	189,734	
Of which		
Pairs reported in a given causal order (due to) more than expected (X2 test, p<0,05)	51,059	100,0
Of which:		
In agreement with decision tables	39,819	78,0
In disagreement with decision tables	11,240	22,0

Figure 1 shows the cumulative frequency curve for pairs ordered by increasing frequency. The curve allows to estimate the percentage of completeness of translation if the translation is done starting from the most frequent pair reported. As an example, the figure shows that, if the first most frequent 60,000 pairs are translated, about 95% of all pairs of codes reported on certificates is covered. On the basis of the cumulative curve we assigned each pair of codes found in due-to in multiple cause data to a priority group. We considered:

- priority group 1 the rules that rank within the 95% of all rules mentioned on the death certificates analyzed;
- priority group 3: rules ranking between 95 and 90% of all rules mentioned;
- priority group 3: all other pairs found in data;
- priority 4: pairs of codes included in decision tables but not observed.

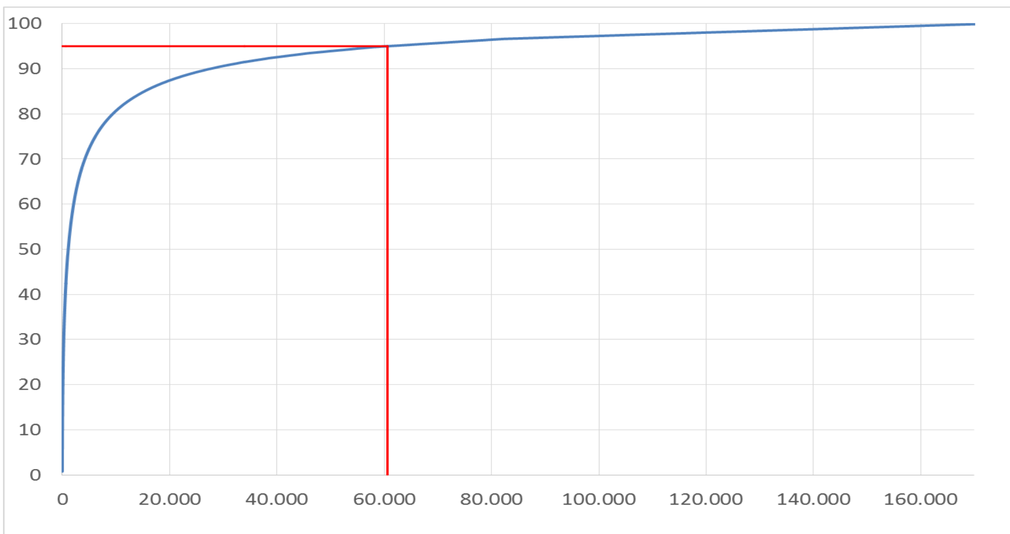

Figure 1**.** Cumulative frequency curve for pairs of codes ordered by increasing frequency

Figure 2 shows the pairs which are reported on certificates in due to position more than expected, but the corresponding rule is not accepted by decision tables. Each red dot represents a pair of code where the code in *x* axis is reported as due-to the code in *y* axis, but this relation is not included in decision tables. For these cases, the indication is that experts should revise the tables, evaluating the opportunity to include these rules.

The annex B provides the list of pairs found in the data.

Among pairs reported in due to position significantly more than expected but not included in the tables it is possible to highlight different situations:

1. in some cases the clinical relation may exist but the classification explicitly provides not to accept the due to, for instance cancers due to some risk factors or viral diseases;
2. wrong reporting by certifiers such as:
    a. well defined diseases are reported as due to symptoms or ill-defined condition, such as stomach cancer reported due to gastritis;

   b. chronological order preferred over causal order such as COPD due to hypertension;
3. different clinical stages, such as neoplasm of unspecified behavior causing malignant neoplasm;
4. diseases due to a very similar disease (diagonal in the graph).

One of the due to relation most frequently reported is cancer cachexia (C80.9) due to secondary neoplasm and this is not accepted according to the decision tables. On the basis of this evidence in the data, the decision to classify cancer cachexia among symptoms and signs in ICD-11 seems appropriate.

Well defined conditions are often are reported as due to symptoms and signs in the certificates, but these relations are not accepted by the tables. A frequent case is senility (R54) reported as due to many other conditions; this indicates that the mention of senility on the certificates should be seen as a synonym of "general frailty" and should be accepted as due to other conditions. Another frequent case is hemorrhage (R58) due to injuries and external causes.

Moreover, relations involving complications of medical and surgical care are reported, but these conditions are not included in tables.

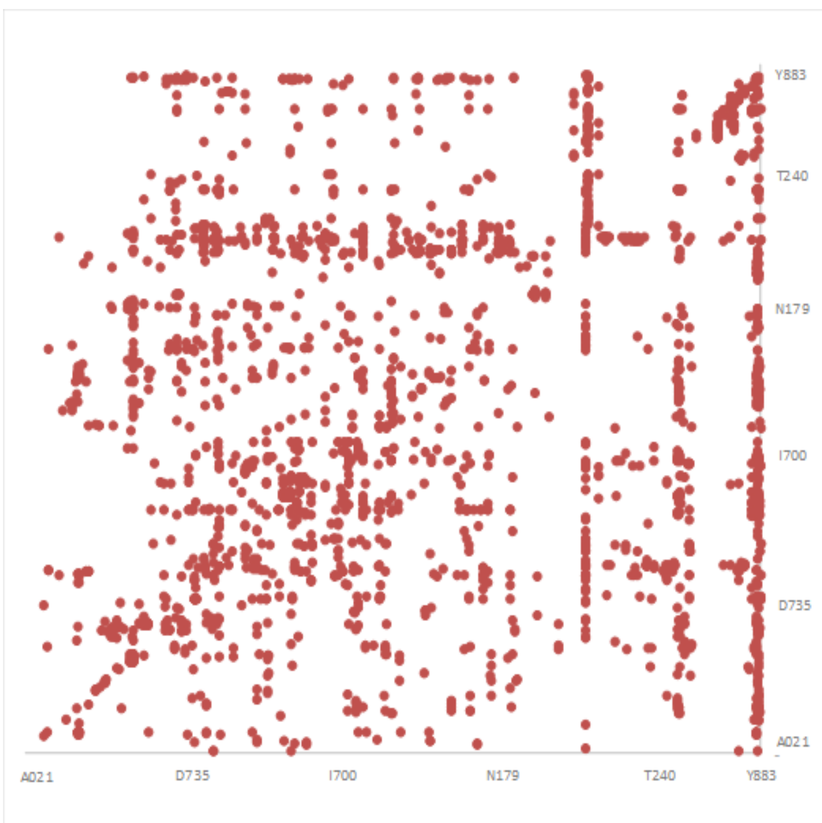

Figure 2. Pairs reported in due-to position in multiple cause data but not included in decision tables.

2.4. Most frequent associations for prioritizing DSs

Within rule-types included in decision tables, DS (direct sequel) and DSC (direct sequel with combination) are the second most frequent. These are applied at step SP6 when the tentative starting point selected with preceding steps can be considered an obvious consequence of another condition mentioned on the death certificate. The prioritization of obvious consequences is respectively: first, codes on the same line of the tentative starting point are checked (from left to right), then codes in successive lines below (from left to right), and lastly in part 2 (from left to right). The obvious cause rules are well described in the ICD-10 instruction manual (as well as ICD-11 user guide) and decision tables reflect these instructions very closely. For this reason, we will not assess discrepancies with decision tables for this rules, but we will set a priority scale.

Objectives

- To provide a prioritization scale of DS(C) rules to be translated.

Methods

We define that two codes (C_A and C_S) are in "obvious consequence" position when C_S is found on the same line, below or in part 2 compared to C_A. Obvious consequence rules are used in the selection process step SP6, after the evaluation of causal relations (due to) in part 1 are evaluated. For this reason, for the evaluation of most frequent obvious causes reported, our methodological approach takes into account only codes that in part 1 can be potentially selected as tentative underlying cause according to selection steps SP1-SP4. For this purpose we developed a SAS program which eliminates from part 1 all codes that can be considered in acceptable due to relations with others; we considered a due to relation as accepted if it is included in decision tables (2018 version). Similarly to what was done for the due to relations, also for DS(C) we established a cumulative frequency curve and described three levels of priority for the translation.

In addition, we evaluated the association between condition and the most significan obvious cause reported on certificates, using the same approach adopted for the due to but taking into account also part 2. For this part of the evaluation we used all the conditions reported without any selection of codes.

Results

In decision tables there are about 2 million obvious cause rules. Of these, 28,886 where found on data. The most frequent obvious causes, those reported in 90% of death certificates (priority 1) are 3,923 while those classified as priority 2 are 4,264.

Concerning the most significant pairs of codes reported in position of obvious consequences, there are some frequent cases that are not considered in decision tables (figure 3). Among these there are disorders related to tobacco use (F17) often reported as cause of respiratory condition as well as hypertension reported as cause of circulatory conditions. The absence of these causes from the DS reflects the need to select a more informative cause and can be considered correct. On the other hand there are some cases that could need some attention for a possible revision. Among these there is sepsis (A41.-) found as obvious consequence of respiratory conditions.

Annex C reports the results of obvious cause analysis.

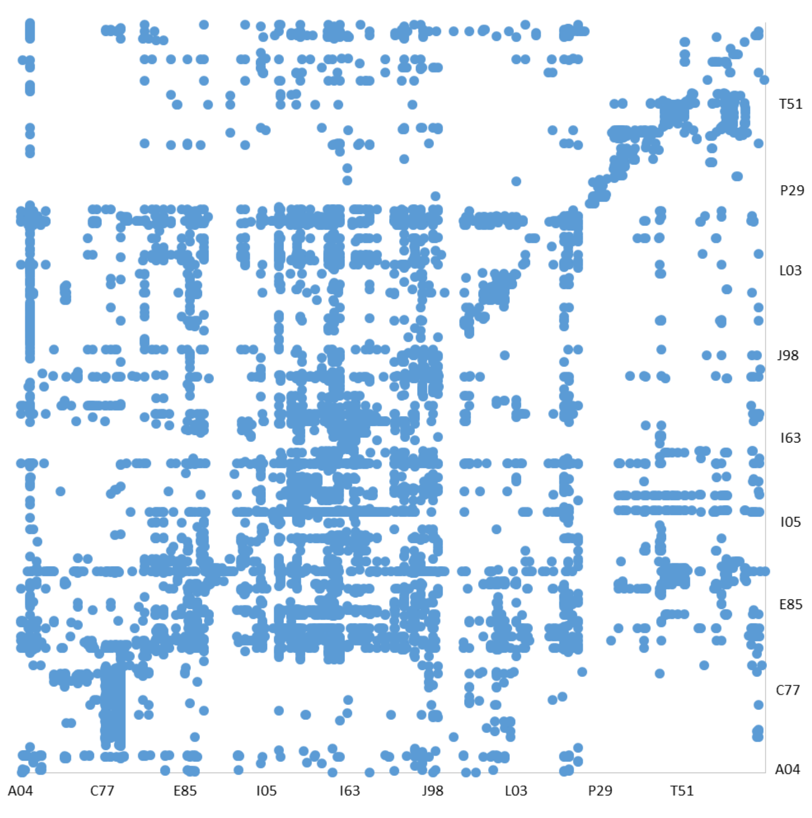

Figure 3. Pairs reported in obvious cause position in multiple cause data but not included in decision tables.

3. DELIVERABLE D3A: ANALYSIS OF THE DIFFERENT LOGICAL RULES NEEDED FOR TRANSLATING FROM ICD-10 TO ICD-11, WITH CONSEQUENCES FROM THE POINT OF VIEW OF AUTOMATION AND HUMAN EXPERT INTERVENTION

A preliminary analysis was made with the purpose of better compression of the decision tables and efficient planning. From the decision tables was emerged that one of the most used rules in the selection of the underlying cause is the “due to” that cover approximately 93% of the total rules. For the sake of clarity and relevance, the “due to” rule-type was decided to be used for the initial study of the transition.

The relation of “due to” can shortly be described as:

> *Code A is "due to" relationship with respect to code B if B is an acceptable cause of A (according to ICD provisions), where A is the anchor code (also called codeDef) that is due to another code B (subcodeDef).*

A practical example:

codeDef (XXX.X)	**Rule-type**	**subcodeDef** (YYY.Y)
I46.9 (Cardiac arrest, unspecified)	“**due to**”	**R26.3** (Immobility)

Figure 4. Representation of "due to" rules. The green color is used to specify ICD-10 codes.

For the sake of translating, some rules can be ignored. The “due to” rule-type have some rules that can be generated on the new tables of ICD-11 without the need of translating. The way the algorithm of Iris works, the decision tables need to contain all the “due to” rules with the same code as codeDef and subcodeDef. Those rules can be ignored for the translation and be generated directly on the new ICD-11 tables.

Formally if *x* is an ICD-10 code, then exists a “*due to*” rule where *x* is “*due to*” *x*.

Thus, if we consider the Figure , the XXX.X and YYY.Y are the same category.

This study aims at identifying the rules that can be automatically translated and which need manual support.

3.1.Material

In additional to the decision tables for this pre project it has been used the mapping table between ICD-10 and ICD-11. The two classifications were used for the reasoning on the structure for the translation but also for the hierarchy that is needed for the improvement and maintenance of the rules. Other information was used for the prototype.

3.2.Possible method

Given a rule, the basic idea is to verify whether a mapping exists between single codes for both codeDef and subcodeDef and of which kind. A rule can be translated automatically if both sides can be translated automatically. In some cases, we could need to differ the translation of codes between codeDef and subcodeDef, since the consequences of the rule-type could be different.

Without considering the consequences of the rule-type, it is trivial to understand that the rules that can be translated automatically are the categories that has no changes between ICD-10 and ICD-11. This kind of map has the relation of equivalence.

With the assistance of some figures, let's examine how the different kind of relation between the mappings can influence the translation of the rules.

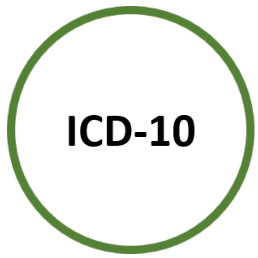

Figure 5. Current decision tables, based on ICD-10 category. Representation using green color.

Figure 6. Future decision tables, based on ICD-11 category. Representation using orange color.

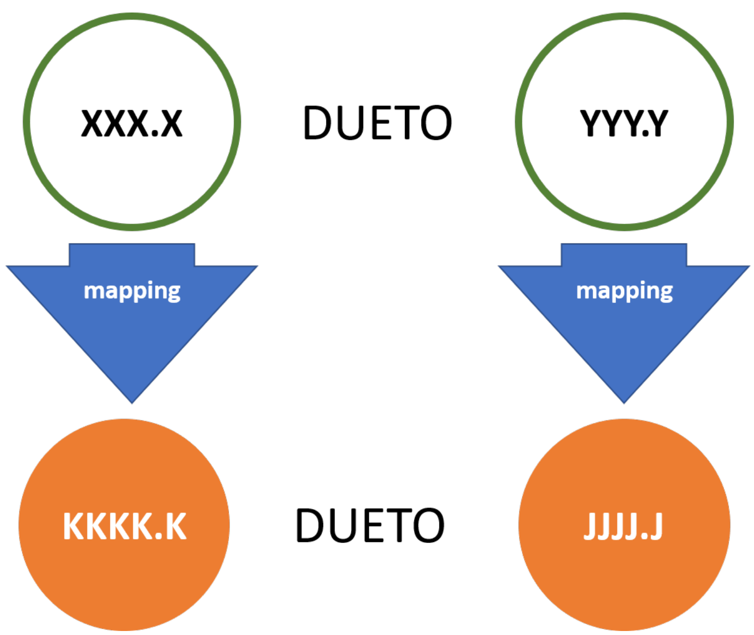

Figure 7. General representation of the translation of a rule.

Our goal is to translate the single rules from ICD-10 to ICD-11. In Figure we tried to represent a general translation, where on the top we can see the ICD-10 rule, and at the bottom the translated ICD-11 rule. To archive our goal, we are using the mapping table where XXX.X is mapped as KKK.K, and YYY.Y is mapped as JJJ.J. Following we will show the different kind of mapping for both codeDef and subcodeDef, which new rules are still valid, and which need support.

The relation between ICD-10 category and ICD-11 category can be of 4 types:

- Equivalent, where the category has no changes between ICD-10 and ICD-11, refigured in the first image of Figure . The green and the orange circle are equal.
- Subclass, where multiple categories of ICD-10 are grouped to form a bigger category of ICD-11. In this case the classification of ICD-11 is less specific compared to the classification of ICD-10 regard the mapped category. In Figure we can see 3 green circle (3 ICD-10 categories) that are grouper to form an orange circle (single ICD-11 category).
- Superclass, where a single category of ICD-10 was split to form multiple categories of ICD-11. In this case the classification of ICD-11 is more specific compared to the classification of ICD-10 regard the mapped category. In the third image of Figure we can see it refigured with 3 orange circle that form the green circle.
- Intersects, the structure of some categories of ICD-10 intersects with some categories of ICD-11, in this case the structure of the classification changes.

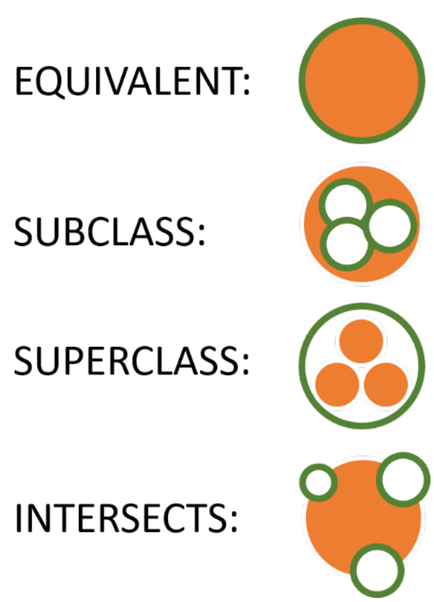

Figure 8. Relation between ICD-10 and ICD-11 mapping

Some examples related to Figure 8:

- Equivalent: B81.0 (Anisakiasis) ≡ 1F61 (Anisakiasis)
- Subclass:
    - A21.1 (Oculoglandular tularaemia)
    - A21.2 (Pulmonary tularaemia)
    - A21.3 (Gastrointestinal tularaemia)

      $\sqsubseteq$
    - 1B94.Z (Tularaemia, unspecified)
- Superclass:
    - A18.8 (Tuberculosis of other specified organs)

      $\sqsupseteq$
    - 1B12.3 (Tuberculosis of endocrine glands)
    - 1B12.7 (Tuberculosis of the digestive system)
    - 1B12 (Tuberculosis of other systems and organs)

Before going deep in the analysis and show how we applied the mapping relation on the Figure , we need to make some logical reasoning of the meaning of the “due to” consequences. A proper interpretation of the “due to” rule is needed to archive the correct results for the translation.

The rules were created for statistical purpose and only part of the rules are clinically proved and derived from the WHO classification. The interpretation of XXX.X “due to” YYY.Y is: there is a possibility that XXX.X can be due to YYY.Y (YYY.Y is an acceptable cause of XXX.X). With this interpretation is important to consider the “possibility”, in fact if we consider Figure where YYY.Y is mapped to a broader category JJJ.J and XXX.X is equivalent to KKK.K, we can affirm that also KKK.K “due to” JJJ.J since there is at least a case where this stands and we know that YYY.Y is contained in JJJ.J where YYY.Y is an acceptable cause of KKK.K.

A practical example could be:

B20.5 (HIV disease resulting in other mycoses)	DUETO	D55.2 (Anaemia due to disorders of glycolytic enzymes) D55.3 (Anaemia due to disorders of nucleotide metabolism) D55.8 (Other anaemias due to enzyme disorders) D55.9 (Anaemia due to enzyme disorder, unspecified) D58.0 (Hereditary spherocytosis) D58.2 (Other haemoglobinopathies)
≡		⊑
1C62.1 (HIV disease clinical stage 2 without mention of tuberculosis or malaria)	DUETO	3A10 (Hereditary haemolytic anaemia)

Figure 9. Example of case presented in Figure .

In this example we can notice that there is no rule B20.5 “due to” D58.0 or D58.2 but D55.2, D55.3, D55.8, D55.9, D58.0 and D58.2 are grouped to form 3A10. From a logical point of view the new rule 1C62.1 “due to” 3A10 is acceptable since there is at least a case where 3A10 is an acceptable cause of 1C62.1, that comes from D55.2, D55.3, D55.8 and D55.9.

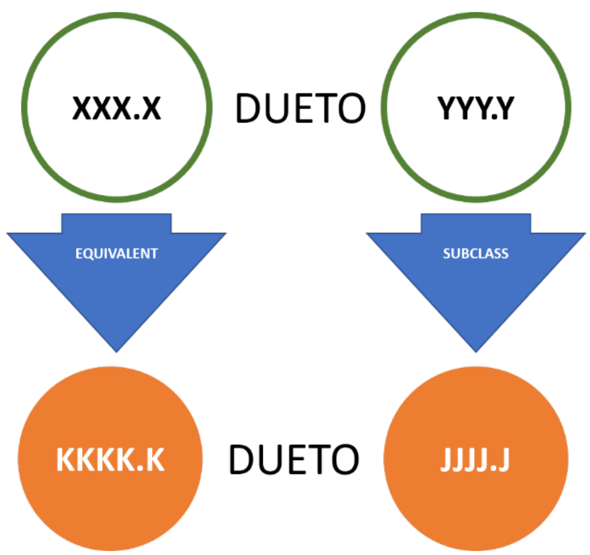

Figure 10. Broader mapping for the subcodeDef.

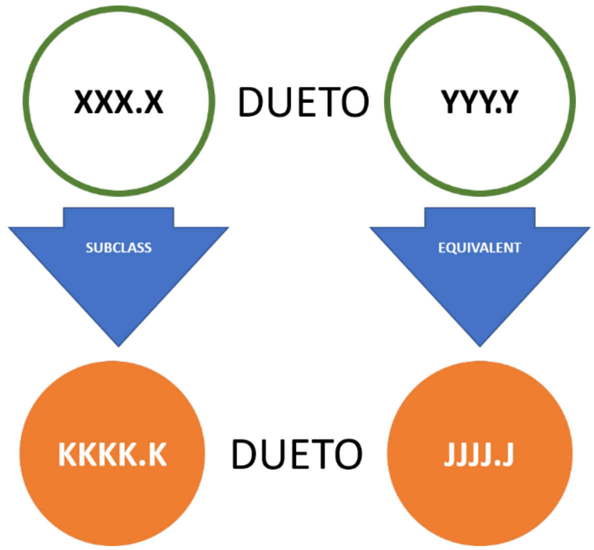

Figure 11. Broader mapping for the codeDef.

With the same interpretation if we consider a broader category for the codeDef as Figure the new rule KKK.K due to JJJ.J is acceptable since there is at least a case where JJJ.J is an acceptable cause of KKK.K, which is the XXX.X.

With the description before we shown the cases of mapping with the relation of subclass for both codeDef and subcodeDef, where do not create any problem and we can generally accept the new rules. Now we will evaluate the cases of superclass which are the opposite of the subclass.

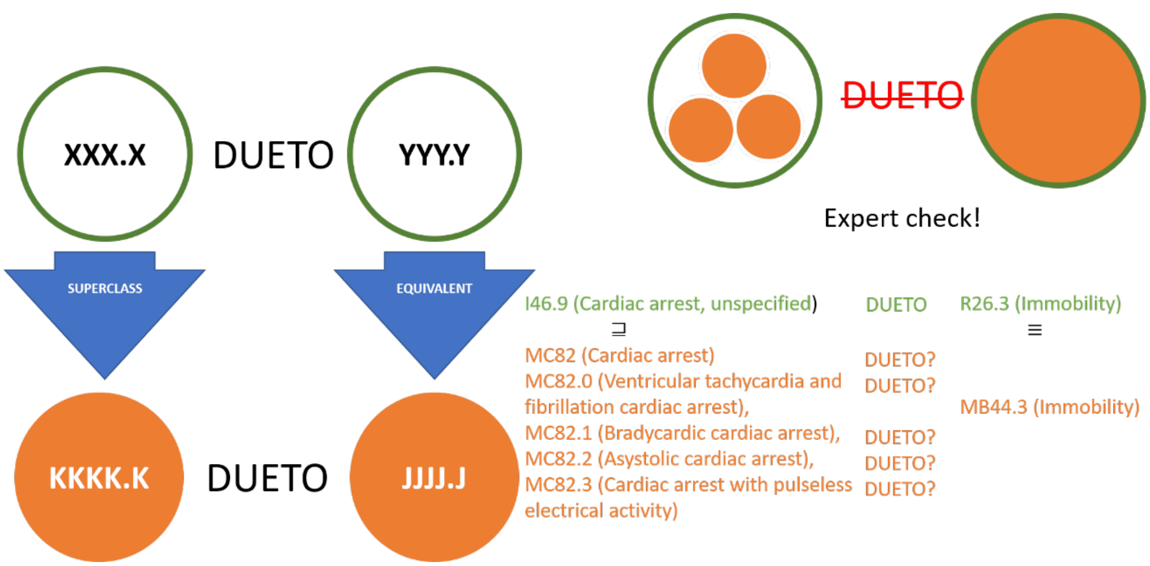

Figure 12. Illustrate case with codeDef mapped as superclass, and an example associated.

In this case we have XXX.X that is mapped to KKK.K as superclass, then we know that XXX.X was split to multiple category KKK.1,..,KKK.N. Since this split, we cannot affirm that JJJ.J is an acceptable cause of KKK.K with k category of range 1-N. We know for sure that JJJ.J is an acceptable cause of at least one category of the range KKK.1 – KKK.N, but we cannot affirm which. For this reason, KKK.K "due to" JJJ.J need expert check. The expert should decide which codes of the range can be accepted.

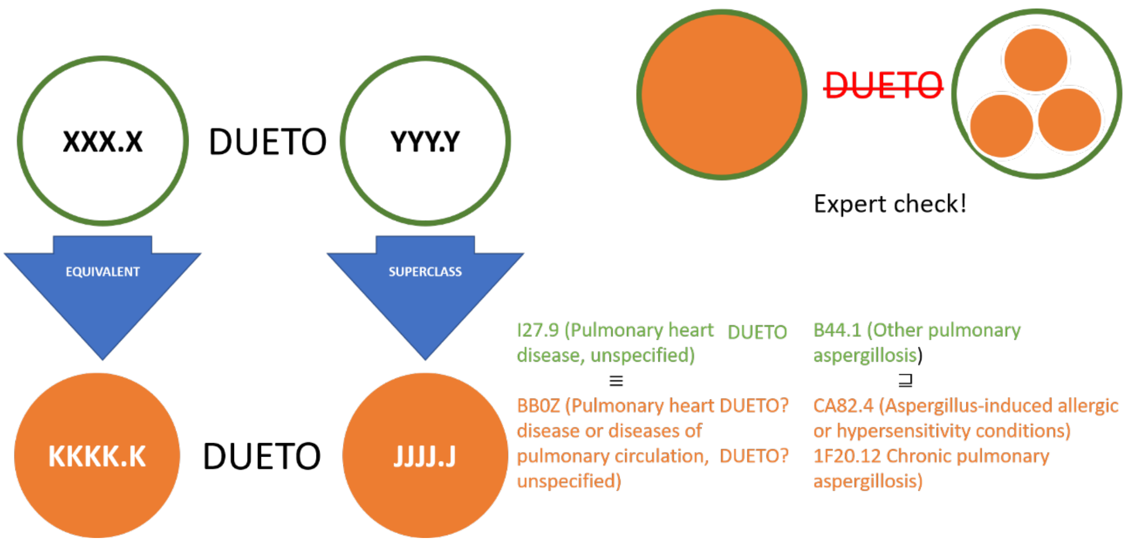

Figure 13. Superclass of subcodeDef, with example.

The same problem also occurs for the subcodeDef. If we consider Figure , we know that YYY.Y was split to multiple categories JJJ.1,..,JJJ.N with J in range 1/N, so we cannot accept the rule KKK.K "due to" JJJ.J since we cannot know which are the category of the range that can be acceptable cause of KKK.K, we just know that there is at least one of them, but which? For this reason, the experts need to validate the new rules.

The last case is the intersects, where need manual support since the Classification axis changed (Figure).

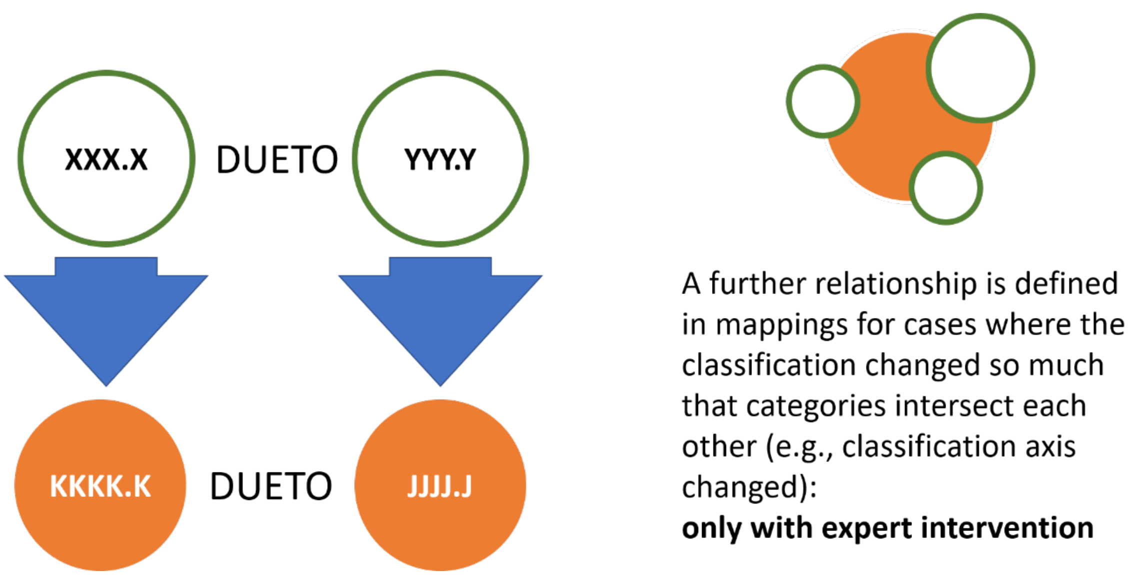

Figure 14. Intersects for codeDef or subcodeDef.

4. IMPLEMENTATION

In the previous section we analyzed the possible implication of the mapping relation for the translation of the "due to" rule-type. The solution we described can be used for the translation of single rules, but in this chapter, we will see that it is possible to improve the results considering multiple rules in the decision making. The decision tables are organized as pairs of codes in a specific relationship, but for specific use the codeDef can be associated with the same relation to a list of subcodeDef where adjacent categories can be grouped to obtain range of categories.

Example:

A01.3 "due to" B20.0		
A01.3 "due to" B20.1	to	A01.3 "due to" B200-B24
…		
A01.3 "due to" B24		

In the WHO Classification the codes are organized within a hierarchy, where the root of the Classification is the Classification itself. On the first level then we have the Chapters, blocks and categories. Some of the categories are called terminal, those categories are the most specific categories of the classification. The decision tables are based on this kind of categories. Since the mapping table contain mapping for all levels of the hierarchy (where possible, where the structure change, there is no mapping) we could improve and add detail for the translation of the rules using higher categories, blocks or even chapters where the subcodeDef are grouped to form big blocks.

Grouping the subcodeDef under the same codeDef is important also to facilitate the translation of the rules, in fact the codeDef need to be translated once and not for each pair. In the same way once we translate and validate a range on the subcodeDef side we can reuse the results for the translation of other rules with the same range of categories. Using the hierarchy as translation is very important also for the maintenance of the decision tables which is one of the objectives of this project.

4.1.Algorithm for codeDef

On codeDef, we generally evaluate single category independently, in fact there is only one case where we need to evaluate other categories associated to refine the result. Taken a category we will translate it using the mapping table and annotate it when needed.

For the relation of equivalence, we have the associated translated ICD-11 category and no annotation.

For the relation of superclass as we saw in the previous chapter is not accepted and we add an annotation to set this rule as manual. From some analysis we think that this could be only partial manual, in fact if the category is split to multiple categories under the same parent category probably, we can just add a new rule for each category and set the same subcodeDef for each of them, and only if the new categories goes in different blocks or chapters we will need a manual check, but we want to have some feedback from the experts before accept this theory.

If we found a relation of subclass logically it stands and we can accept the new rule with the union of all the subcodeDef of the unified categories, but we still want to associate an annotation as a warning where the unified categories have different subcodeDef categories. There is at least one category that is an acceptable cause of one of the unified categories but not for all of them.

With the relation of intersects we add an annotation as manual for the new rule.

4.2. Algorithm for subcodeDef

The implemented algorithm can be divided in different subroutine. All the subroutines are called repeatedly at each level of the hierarchy from the bottom up to the highest category which is the common category of all the terminal categories.

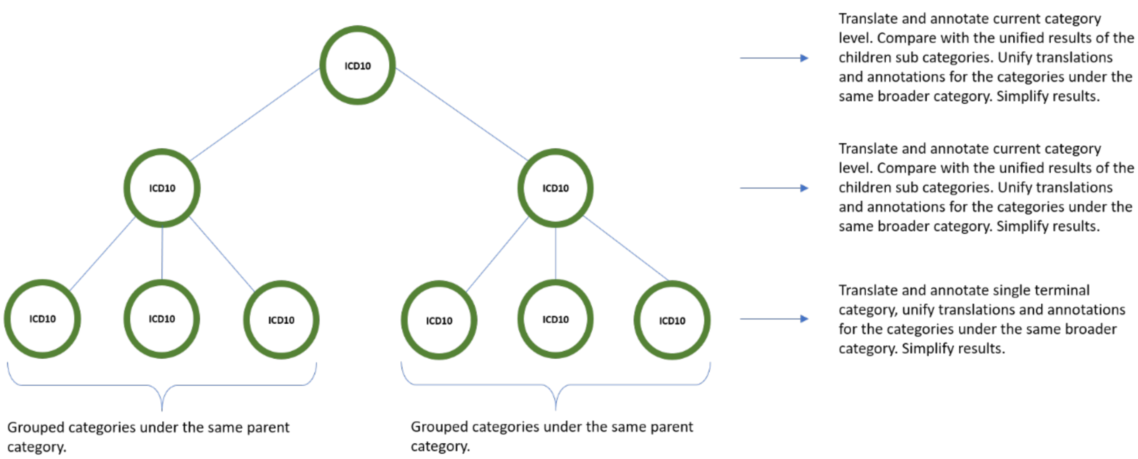

Figure 15. Possible overview of range hierarchy.

The first subroutine is the translation and annotation (*sub1*) of single codes started from the terminal codes. The translation comes from the mapping table where a single category of ICD-10 is in relationship with one or more ICD-11 categories (in some mapping is missing the mapped category of ICD-11). From the single mapping we obtain the ICD-11 translations rules and from the relation between them we obtain the annotations. Therefor for each single ICD-10 category we have associated a list (one or more elements) of ICD-11 categories and some annotation, but we also maintain a list of the evaluated ICD-10 categories. The annotations we add for the single translations are:

- Equivalent: no annotation
- Subclass: warning, category mapped to broader.
- Superclass: manual, the experts need to choose which categories maintain for the new subcodeDef rule.
- Intersects: manual.

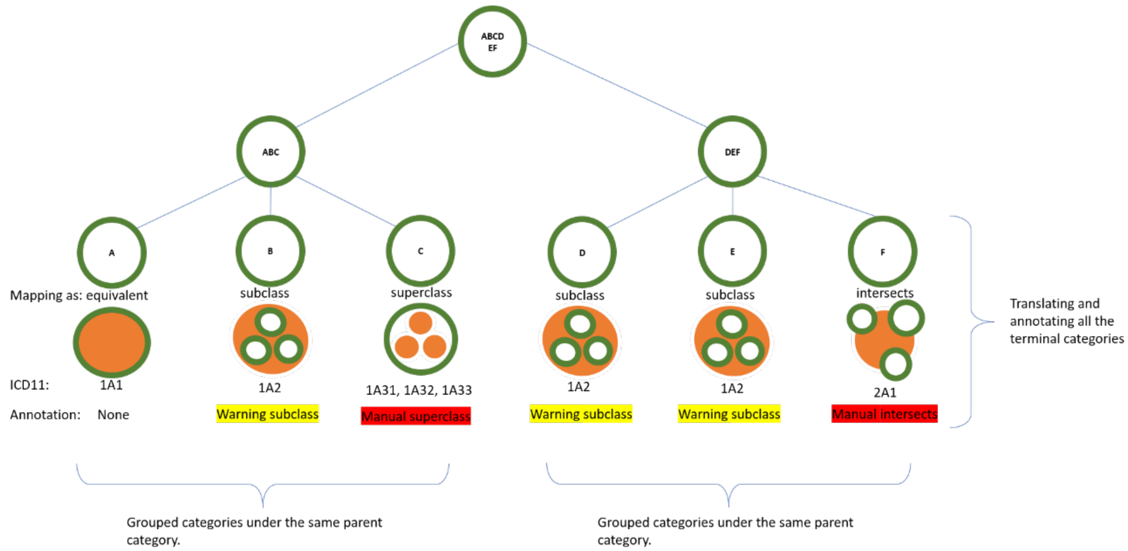

Figure 16.Translation and annotation of all the terminal categories.

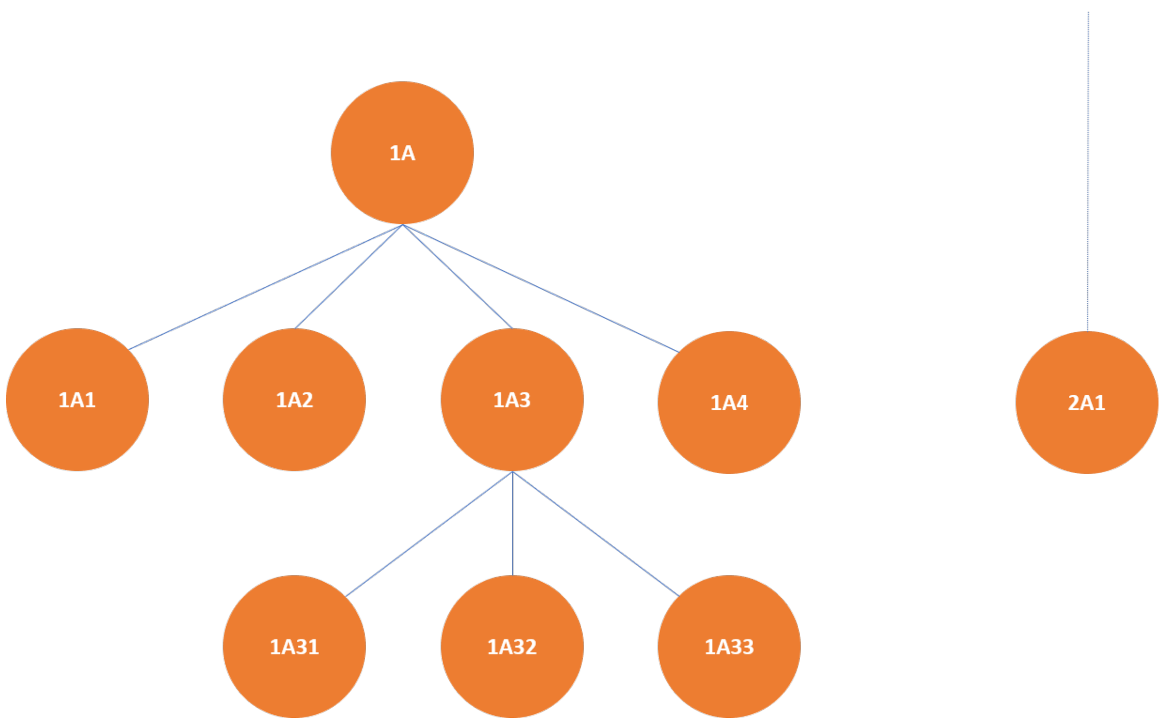

Figure 17. Hierarchy of the categories in ICD-11.

On the simplify subroutine (*sub2*) we will see that some annotations can be omitted, but some others can be added to provide more support to the experts.

Once the terminal categories are translated, the algorithm unify the results in groups where the categories have the same parent. The results then are ready to be simplified.

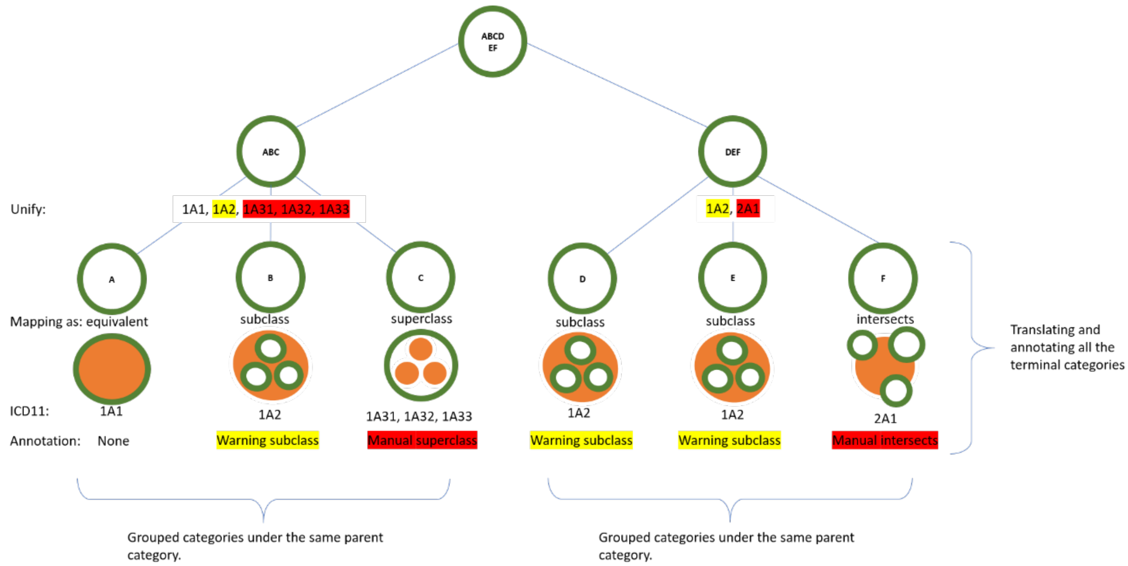

Figure 18. Unify results under same parent category.

The simplify algorithm take each annotation and with some computation decide if it can be deleted from the list of annotations.

In the annotation is as subclass we going to check if all the involved ICD-10 categories mapped to the broader ICD-11 category are in the list of the evaluated. If all the categories are included, we can delete the warning annotation.

For the intersects we need to check if all the category involved for both CD10 and ICD-11 are included to delete the annotation. Being all the categories that change structure involved make the manual check.

When evaluate superclass annotation we maintain it. Unlike the other annotations this cannot have system assistance.

With the simplify the terminal categories are fully evaluated, next we start evaluating the parent categories of the terminal categories (in Fig. 15, the second layer of the hierarchy).

There is only one difference between the layer of the terminal categories and the other layers, the check between the current translation and the sub categories result. The algorithm starts translating and annotating the current layer of categories in the same way as for the single terminal category. From a logical point of view the results should be always equal between parent category and sub categories, but this is it not true. It happens that the children translation is a subset of the parent translation, the parent translation is a subset of the children translation but also that there are differences of both directions. In the case (case 1) where the children translation is a subset of the parent means that in ICD-11 was introduced a new category that stay on the same group with the other children categories. In the case (case 2) of parent subset of the children translation a sub category of the broader category was moved under other block/chapter. It could happen that both case 1 and case 2 occur.

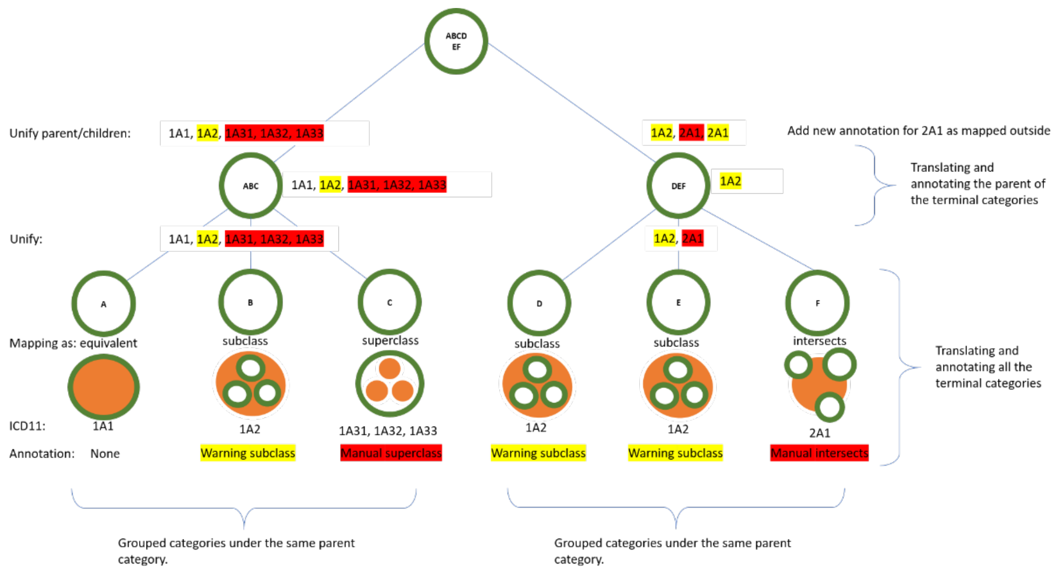

Figure 19. Translating and annotation the parents of the terminal categories. To be noticed that DEF not containing 2A1.

For the differences between parent category and subcategories we introduced two annotations that are suggestions to obtain better results. From a logical point of view all the codes should be considered and the translation evaluated as automatable, but we prefer to add a warning annotation for both cases and check what is the expertise interpretation. We will identify the annotation referring case 1 and case 2 for the simplification of the annotation.

After the check between parent/children we will unify the results as for subcategories and then start simplifying the annotation with the same rules we seen before but also adding two new simplify rules for the new annotation we just introduced.

For the first case we can delete the annotation if all the mapping to the new code are included in the ICD-10 categories evaluated, for case 2 we can delete the annotation if there are other codes near the annotated code. For example, if a code was moved to another chapter, the annotation remain if there aren't other codes mapped to the same block with that code.

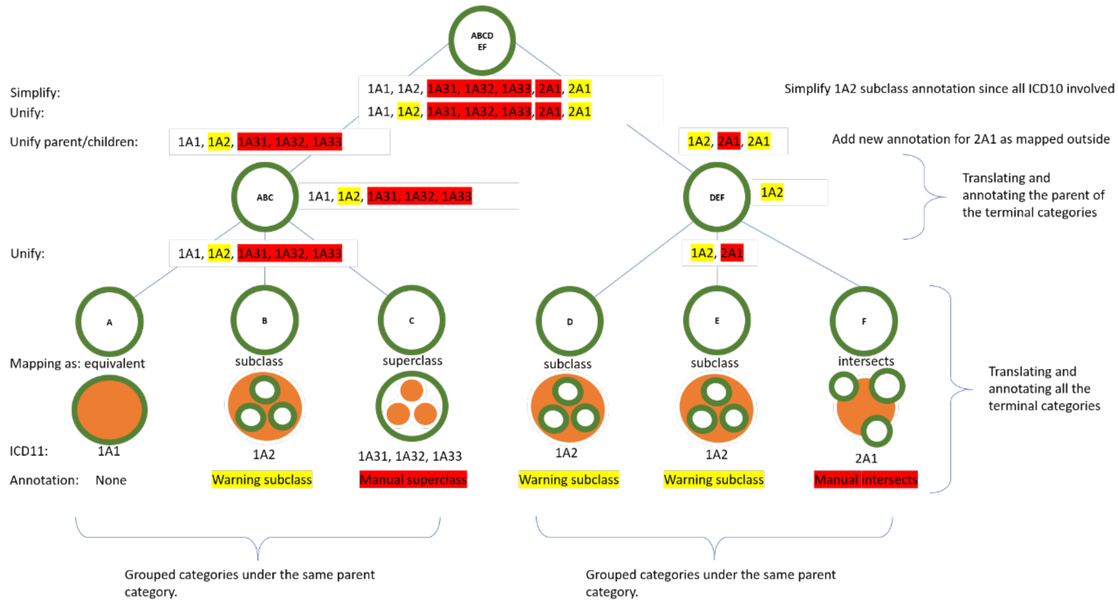

Figure 20. Unifying and simplifying results.

Then the algorithm starts evaluating recursively the other layers up to the top layer where we will have the result of the range.

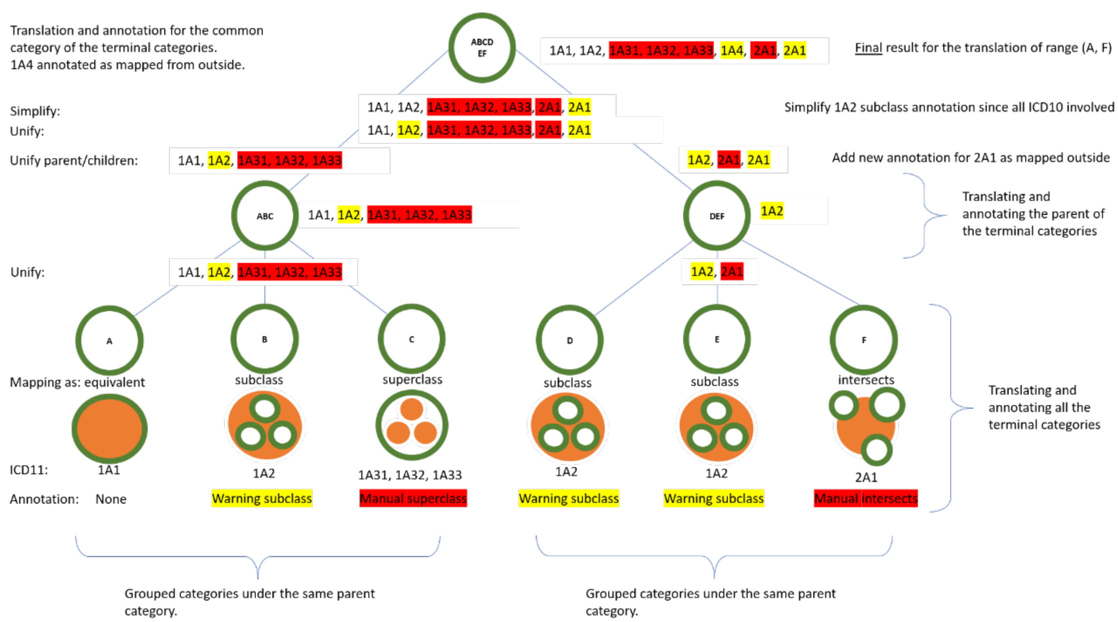

Figure 21. Result for the translation of the range A-F. We must interpret the various passages from the bottom to the top.

The algorithm then makes a final step of unifying the results of the different ranges under the same codeDef and simplify the same way we seen before.

4.3.Other rule type analysis

From the preliminary analysis we saw that approximately 93% of the total rules are covered by the “due to” rule type. With the study of the “due to” rule type we analyzed most of the total rules. The results are not important only for the percentage of the rule covered but also for the understanding of the impact that the mapping has on the translation of the single rule and the understanding of all the possible logical consequences for the translation for both codeDef and subcodeDef. We tried to identify all the elements that can be important to the translation in general of all the rule types, unless new elements are found.

The main elements we found are:

- Translation of single codes are always automatized.
- The translation become problematic translating the codes with a specific relation (“DUE TO”, “DIRECT SEQUEL”) and the cardinality of the mapping is not equivalent. Need to analyze the relation and describe the impact for each cardinality of the mapping.
- The flags need to be analyzed and translate. Some of the flags or partial rules can be converted to more specified codes.
- On the mapping can make difference between terminal/not terminal code and for the cardinality of the mapping.

With these elements, we should be able to categorize all the translation rule types, but there are specific methods to improve the results. For the “due to” rule type can be improved as we seen translated ranges.

From a first analysis we have found that codes generally can be translated and be categorize the points we listed, the main difference that could affect the results are the different flags of the tables.

4.3.1. Direct Sequel (DS) and Direct Sequel with Combination (DSC) rule

Direct sequel and direct sequel with combination were analyzed together since have a similar behavior.

The DS rule type can shortly be described as:

> *Code A is obviously caused by another condition code B, where A is the anchor code (also called codeDef) that is obviously caused by another code B (subcodeDef).*

Where DSC rule type can be described as DS with the addition of the recoding of the provisional initial cause code (subcodeDef) with the combined code reported in subcodedefNew field.

A practical example:

codeDef (XXX.X)	**Rule-type**	**subcodeDef** (YYY.Y)	**Maybe**
A32.7 (Listerial sepsis)	DS	**E15** (Nondiabetic hypoglycaemic coma)	**0**
A32.7 (Listerial sepsis)	DS	**I00** (Rheumatic fever without mention of heart involvement)	**1**

Direct sequel relation has a flag (*Maybe*) that need to be evaluated. The *Maybe* flag is described as a warning, where the system require supervision with a specific message. If the flag is set to 0, there is no need of supervision, otherwise with flag set to 1 it needs. The rules with the flag set to 1 has a text message associated. The Maybe flag has impact on the translation and from the preliminary analysis we have found that the rules other the translation of codes need to translate also the flag with the message. Since the message is textual cannot be automatized translated. The system can support this translation for the codes involved (codeDef and subcodeDef). With expertise support we could try to automatize also the translation of the message where possible extracting the coves involved that are present in the message, but this need some analysis from the expertise.

The other rules with the flag set to 0 can be divided as well in manual/automatic based on the translation of the codes. The difference with the "due to" rules can be seen with the number of pairs involved. The DS rules have less codes involved and for this reason we can understand that are targeted on specific terminal codes, and less ranges are involved. Generally, the ranges involved are short, and include just a few codes.

Example:

- A150-A169
- E850-E859
- I00-I029
- M350-M352

As for the "due to" also DS rule type has a pattern of subcodeDef recur, multiple times we have found consecutive codeDef that are *obviously caused* by the same group of codes (subcodeDef). For the same reason as for the "due to" the rules can be grouped to speed translation and support maintenance of the rules.

The translation method for the "direct sequel" rule type is similar to the "due to".

Translation method for the Direct Sequel rule type
Given a rule, the basic idea is to verify whether a mapping exists between single codes for both codeDef and subcodeDef and of witch kind. A rule can be translated automatically if both sides can be translated automatically and the *Maybe* flag is set to 0.

The codes with the relation of equivalence and superclass for the mapping can be translated automatically for both codeDef and subcodeDef. Here we can see a first difference with "due to" relation.

Subclass (nx1) mapping has a different translation compared to the "due to" relation. The main change is for the nx1 mapping to ICD-11 codes that are not terminal or not have all the mapping codes involved.
The codeDef is automatically translated with the mapping of subclass if the code translated is terminal and if all the codes involved are *obviously caused* by the same codes. Otherwise the translated need manual supervision. For the other case that are manual, the system will suggest the intersection of the translated subcodeDef, instead of the union as for the "due to".
The subcodeDef is automatically translated if the code is translated to terminal code and all the involved codes of the mapping are present, otherwise the translation is manual.

The rules with intersects mappings relation need manual supervision for the translation.

Direct Sequel with Combination (DSC)
The DSC rule type are rules like the DS with the difference of a third code involved used for the substitution of the subcodeDef. A rule is automatically translated if maintain the same consequences of the DS as automatic and the third code is translated automatically. The third code is automatically translated if has a mapping as equivalent. The other cases are manual, also for the superclass. Since the third code should be the replace of the subcodeDef it should maintain the same consequences, but the substitution can be made by a unique code, and this is the reason that also the 1xn mapping need manual supervision.

Ill-defined in Due to with Combination (IDDC)
IDDC is described as:

> *When the tentative starting point is an ill-defined condition in the due to position to another condition, and the codes for the tentative starting point and the other condition combine into a third code.*

The relation of the IDDC is the "due to" with the substitution of the anchor code with a third code for the specific ill defined in the table. For this reason, the codeDef and subcodeDef are translated as the normal "due to" relation. For the complete translation of the rule we need to translate the third code, and the flag *Maybe*. The flag *Maybe* is described alike for all the rule type (0 without manual supervision, 1 manual supervision with a message associated). The rules of IDDC with the flag Maybe set to 1 need manual supervision, with the flag set to 0 the rule is automatically translated in the three codes are translated as automatic (codeDef, subcodeDef, codeNew).

The codeNew can be translated in a single code, which mean all the codeNew mapped in multiple codes need an expertise support with the selection of a single code. We can subdivide the translation in two cases:

1. codeNew with a single mapping,
2. with multiple mapping.

In the case with a single mapping the code is automatically translated if the mapped code is terminal, with manual supervision otherwise.

In the case with multiple mapping, is automatically translated if the code has a single mapping with the relation of equivalence, which is the code that can be accepted and the other codes can be rejected, otherwise it needs manual supervision.

5. DELIVERABLE D3B: OVERVIEW OF THE PROTOTYPE IMPLEMENTED FOR THE EXPERTISE SUPPORT

The prototype is aimed at providing decision support in the translation of mortality rules from ICD-10 to ICD-11. For the implementation, we choose a web-based model where experts can work collaboratively from a different location but also for the consistency of the results. Since the system should not be open for unwanted users, we decide to manage the registration of new users by the administrator of the system. It has a full implementation of the visualization and editing of the "DUETO" translation rules of the decision tables.

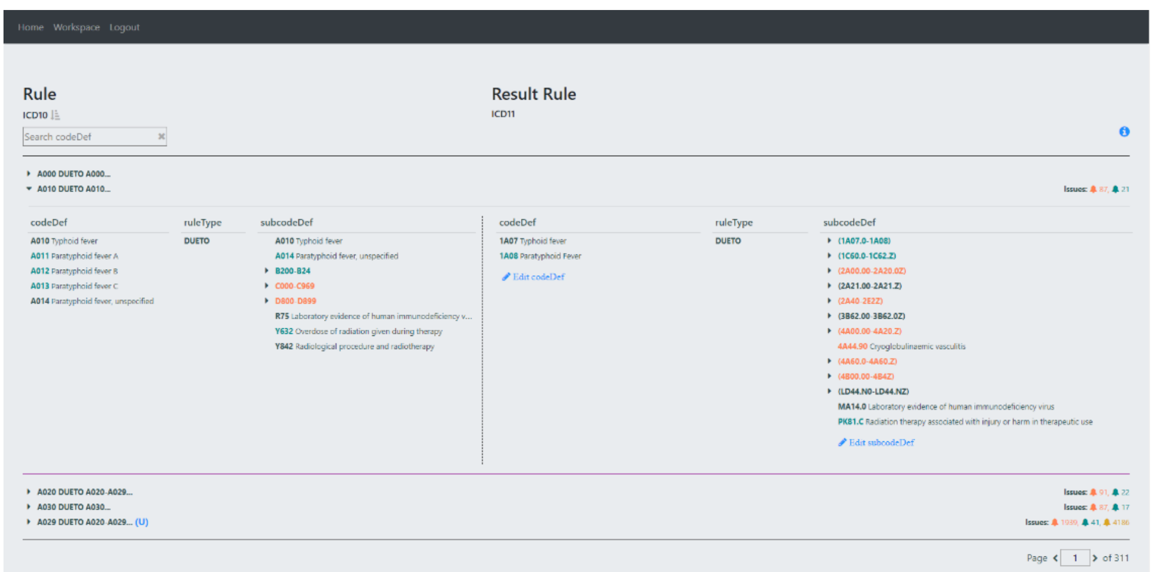

Figure 22. Overview of the prototype

Rules are grouped where possible with the same subcodeDef to ease the translation and facilitate maintenance over time. The system has the possibility to be extended for easy integration of the other rule types. On the translation rules, it is possible to overview issues with the translation, mapping between codes, partial range translation and frequency of usage on a specific rule. For each issue type, we have a specific set of actions that can be done. For the editing, we have a special view for the different actions to perform, and it is possible to identify codes with no mapping to facilitate them integration. For the overview of the prototype and its usage we made disponible a tutorial and a user test.

5.1.Considerations on post-coordination in Iris decision tables

Post-coordination is a feature of ICD-11 used to enhance the content of a stem code in representing a single cause of death reported on the death certificate or the underlying cause of death. It consists in the combination of two (or more) different stem codes or a stem code with one (or more) extension codes. Combination of these two types are also possible (eg more than one stem code together with multiple extension codes). The post-coordination leads to a series of codes linked together by separators referred to as cluster codes.

In this section we discuss the implication of post-coordination and cluster coding for the tables when such codes are reported in multiple cause because it has essential implications on tables transition. Post-coordination in underlying cause is not analyzed here.

In the ICD-11 tabular list, the use of post-coordination is triggered by specific instructions at terminal code levels: "*code also*" and "*use additional code if desired*". By mortality perspective it is possible to distinguish these two situations.

1. Post-coordination between stem codes. This can be subdivided in:
    a. Mandatory post-coordination, i.e. "*code also*"
    b. Suggested post-coordination: "*use additional code if desired*"
2. Post-coordination between a stem code and an extension code, is always suggested: type "*use additional code if desired*"

<u>Post-coordination between stem codes. Mandatory post-coordination.</u>

Instruction "*code also*" (for instance axis "*has causing condition*") signals that the code under analysis is not suitable alone (it is generally a manifestation code) and another code (alternative code) should be also used in combination with it. The alternative code is always another stem code which represent the causing condition – etiology – (it cannot be an extension code).
For the *multiple cause* coding, this instructions should be used to appropriately code the causing condition if reported in the text that is being coded (in the ICD-10 this situation is similar to dagger/asterisk system). It is not necessary to use this kind of post-coordination if the code reflects the text under coding.

Examples:

P1a Heart failure BD1Z

The code BD1Z has a "code also" instruction. Nevertheless, it is not necessary to add another code because there is not information about the etiology in the text.

P1a Diabetic heart failure 5A14/BD1Z5

The code BD1Z has a "code also" instruction and in the text it is reported the causing condition. This should be coded as well as indicated.

On the contrary, for the selection of the underlying cause, this rule is very important since the alternative code is the one to be preferred as UC when the first one is selected as tentative UC. If the alternative code is present on the record, this one should be preferred, otherwise a default code should be used instead.

Examples:

P1a Heart failure BD1Z
P2 Diabetes mellitus 5A14

The code BD1Z is selected as tentative underlying cause, but the "code also" instruction implies that is the diabetes (reported in part 2) to be selected. The UC is 5A14.

P1a Heart failure BD1Z

The code BD1Z is selected as tentative underlying cause, but the "code also" instruction implies that this code is not suitable as UC. An alternative code should be selected instead. Nevertheless in this case the alternative code is not present on the record. Currently, not clear instuctions are provided concerning to whether an alternative should be selected in this cases and the default code to be selected as UC

Post-coordination between stem codes. Instruction "*use additional code if desired*" (axis "*has manifestation*", "*associated with*")

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[5] In current version of the user guide it is recommended to put the etiology code first in the cluster.

When the instruction "*use additional code if desired*" appears it is possible to post-coordinate another stem code or an extension code. In case a stem code is used the additional code will be added to the multiple cause but it will have little influence on the selection of the UC.

Implication for tables: proposed approach for Iris tables development: Due to tables

Since possible combinations of codes generating clusters are theoretically endless, it is not possible to include in decision tables all post-coordinated codes. One possible solution is to include in decision tables separately both etiology and manifestation codes. If post-coordinated codes are used in multiple cause coding into Iris, only the etiology part of the cluster should be used for the verification of causal relation in the tables.

Example:

P1a Diabetic heart failure	5A14/BD1Z
P1b Pneumonia	CA40.Z

For the selection of the UC, it is necessary to verify if the code .5A14/BD1Z can be due to the code CA40.Z. As only the etiology part of the cluster should be used for the verification of causal relation, if the causal relation "5A14 due to CA40.Z" is accepted by the tables then the tentative UC is CA40.Z; if the causal relation "5A14 due to CA40.Z" is not accepted by the tables then the tentative UC is 5A14.

Actually, the due to tables are oriented to the etiology (the causing condition is the key principle for the underlying cause of death). In the transition of decision tables from ICD-10 to ICD-11 the "due to" relation between etiology codes should be prioritized. From the ICD-11 the list of codes with "code also" instruction could be extracted as an additional table to be provided to ICD-11 Iris.

Linkages tables (M1 – LMP, LMC, LDP, LDC)

For the UC selection it could be possible to construct "linkage" rules (rule M1) where the address code is represented by the list of ICD-11 codes with "code also" instruction and the preferred code is the alternative code provided by the ICD.

The classification (user guide) should provide a list of default codes to be used when the subaddress is not present.

This feature is found also in ICD-10. In the section *Special instruction*s there are some codes that cannot be used as UC, for instance R57.2. These kinds of codes can be used in multiple cause coding, but according to instructions in the user guide such as:

R57.2 Septic shock, or

R65.0 Systemic inflammatory response syndrome of infectious origin without organ failure, or

R65.1 Systemic inflammatory response syndrome of infectious origin with organ failure, or

R65.9 Systemic inflammatory response syndrome, unspecified

Not to be used for underlying-cause mortality coding. Code to the originating infectious disease (A00–B99). If no originating infectious disease is mentioned, code to Sepsis, unspecified (A41.9).

<u>Post-coordination between a stem code and an extension code (use additional code if desired)</u>

This instruction signals that it is possible to add specificity to the stem codes in order to capture all the information contained in the original text reported by the certifier. Although this additional specificity is useful for national and international purposes, it is not always necessary for coding purposes. It must be mandatory for Iris use in the cases where it is necessary, but it should be not considered if coding by Iris could be performed with the same level of quality using the stem code.

<u>Implication for tables: proposed approach for Iris tables development</u>

In general, decision tables should not include the extension codes. However in some cases the use of extension codes is needed to coding following cases deriving from WHO instructions (user guide) or Iris special instructions. Below there is a list of possible use of extension codes.

- *ICD-11 less specific than ICD-10 (mapping type: subclass)*
  When different ICD-10 codes with different due to rules are mapped in the same ICD-11 code (loss of specificity between ICD-10 and ICD-11), it could be necessary to include the extension code in the decision tables.

  Example:

  In ICD-10 codes for valve disease, unspecified valve (I091, I098, I099, I38, I398) are mapped to BC0Z which does not include the rheumatic etiology, while in ICD-10 the rheumatic etiology is a primary axis also for unspecified valve. According to clear instructions in ICD-10 rheumatic valve disease have different “due to” tables compared to non-rheumatic. To carry this instruction in ICD-11, it could be necessary to code the rheumatic etiology of valve which currently is not available in the ICD-11.

- *Iris flags (table 5)*
  Sometimes the ICD code misses important information needed during code(s) substitution and/or UC selection. Flags help to overcome this issue. Additional information is retained in a flag and attached to ICD-10 codes. The flag information appears as an abbreviation included in round brackets (table 5).

  Examples of flagged codes:
  Glioblastoma C719(P)
  Thrombosis of arteria media cerebri I660(TH)
  Embolism of arteria media cerebri I660(EM)

- *Created codes*
  Created codes have been discussed in the interim report.

- *Connected codes*
  Connected codes are formed by the connection of two existing ICD-10 codes. The second code enhances the specificity of the first one. The most common connected codes used in Iris are those of neoplasm of uncertain behavior. In this case the connected code is formed by the addition of a malignant neoplasm code to the unspecified one in order to provide more anatomical detail. Anatomy extension codes in ICD-11 could be used for this purpose.

- *Maybe*
  Another possible use of extension codes could be the solution of maybes present in the tables. In the example (already shown):

  C813 DUETO B200-B24 If malignant neoplasm is specified primary in brain

  C813 (Lymphocyte depleted (classical) Hodgkin lymphoma) can be accepted as due to B20-B24 (HIV disease) only if it is primary in the brain. The maybe is necessary because the ICD-10 code does not contain information on the site.

  The translation of this rule in ICD-11 is the following:

  2B30.13 DUETO 1C60.0-1C62.Z If malignant neoplasm is specified primary in brain

  In ICD-11 as well the corresponding code for Lymphocyte depleted classical Hodgkin lymphoma -2B30.13- does not include information on the site, but it can be added using the extension code XA9738 (brain), so the maybe can be avoided:

  2B30.13& XA9738 DUETO 1C60.0-1C62.Z

Table 5. Flags used in Iris by presence in ICD-11

Iris Flag		Present In ICD-11/ position		Comment
A	Acute	Yes	X Extension Codes /Temporality/Course of the Condition/XT2082570273 Course /Acute	
C	Chronic	Yes	X Extension Codes /Temporality/Course of the Condition/XT2082570273 Course /Chronic	

CON	Congenital	Yes	X Extension Codes \Aetiology\Causality \XB1048408993 Congenital	
SEQ	Sequela	Yes	Currently in: X Extension Codes \Temporality\Course of the Condition \XT69890123 Pattern / Activity / Clinical Status \XT472249438 Consequence of sequelae	
P	Primary	No		This flag is used for the correct selection multiple cause modification, Not sure if it is of international interest for the classification. Ask the JTF to consider inclusion. Possible places could be: - Histopathology section of extension code such as: "Other indication of primary malignant histopathologies"? - Diagnostic code descriptor?
PIN	Primary in	No		Too specific Iris use
CSM	Common sites of metastasis	No		Flag automatically assigned by Iris to identify neoplasm that are common sites of metastasis, I don't think it can be an extension code
MET	Metastatic	No		Used for identifying cancers specified as "metastatic". I don't think it can be an extension code
EM	Embolic	No		Non needed in Iris for ICD-11 since the application of it that we currently do (distinction at fourth digit level of cerebral infarction in embolic or thrombotic) will not survive in ICD-11. I currently cannot foresee other uses of this flag in ICD-11.
TH	Thrombotic	No		
RH	Rheumatic	No		The classification of rheumatic valve disease will change a lot. In ICD-11 there is also place for unspecified aetiology valve disease. We might not need the flags in ICD-11
nRH	Non-rheumatic	No		
TR	Traumatic	No		These are necessary flags in ICD-11 too. Since the traumatic and non-traumatic nature of conditions is pre-coordinated I don't know if that could be added in the extension codes, we can ask the task force.
nTR	Non traumatic	No		

6. DELIVERABLE D4A: PROPOSALS FOR NOVEL IMPLEMENTATIONS OF IRIS

For testing purposes, it is necessary to create a prototype of Iris that could function with ICD-11 codes and use the decision tables under development. In particular:

- Establish the list of ICD-11 stem codes to be used for testing: at least the most frequent should be implemented in Iris. ICD-11 stem codes could be either at 5 or 6 digit;
- Post-coordinated codes:
    - stem codes with extension codes: Iris should be able to retain the relevant part of the cluster and use the additional information as it does in the current version with flags and connected codes. In fact the information carried by flags and connected codes, when relevant, regulates the application of decision tables rules according the restrictions of the condition field;
    - multiple stem codes: the *code also* and *use additional code* instructions result in some post coordinated codes such as 5A14/8A20 containing at least one stem code that must be retained by Iris for looking in the tables - in this case 5A14 - and another that should be carried as additional information;
- the current Iris uses the "/" in the string of multiple cause code to indicate separate lines of part 1 of the death certificate. A new separator for line must be used, since the "/" is part of the syntax of post-coordination;
- Iris dictionary in ICD-11 or certificates coded as direct coding ICD-11.

7. DELIVERABLE D4B: RECOMMENDATIONS FOR THE INTEGRATION OF IRIS WITH THE ICD-11 PLATFORM

7.1. Coding tool

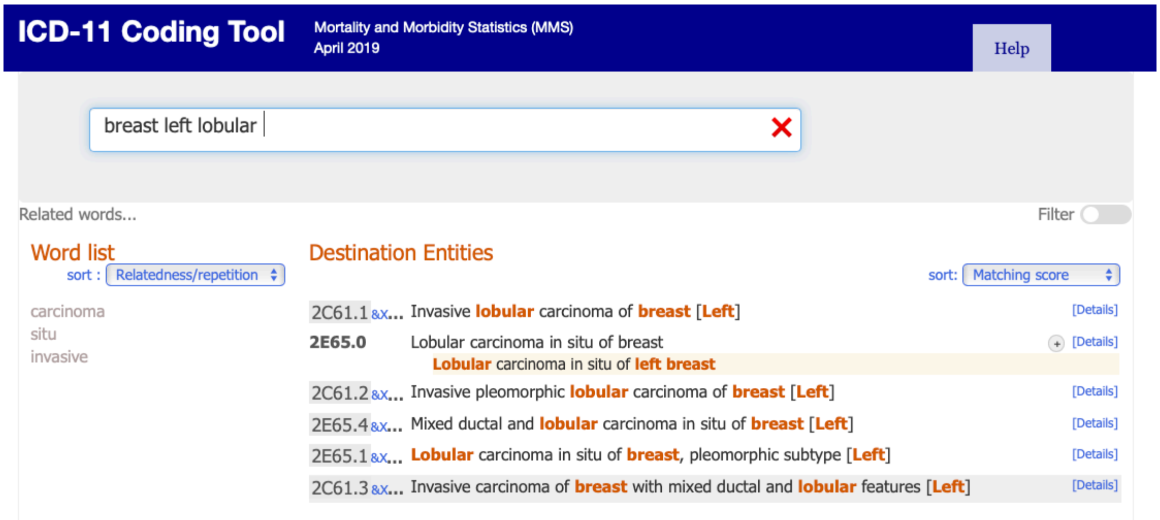
The coding tool of ICD-11 is very powerful, and the WHO designed this tool in order to be used on the official platform (https://icd.who.int/ct11/icd11_mms/en/release) but also for external projects.

The tool works by searching as the user continues typing. It generates (and dynamically updates) three different outputs as the search continues:

1. On the left, a panel shows a list of related words.
2. The main panel shows matching entities.
3. The third, optional, panel is the chapter distribution, and allows to filter results by chapter.
4. From many points a full ICD-11 browser in a window can be directly accessed, that in addition to browsing, allows also to postcoordinate codes.

The coding tool is able to provide postcoordinated codes when possible, and in any case allows the user to postcoordinate codes autonomously.

More information can be found on the official portal (https://icd.who.int/ct11/Help?state=Release&lang=en).



The coding tool is designed to be flexible on its use for the external projects, and there are two methods of integration:

1. Embedded coding tool: the full web interface of the WHO coding tool can be easily embedded in any web application with few lines of HTML and Javascript code.
2. ICD API: for non-web technologies and when there is need for strict control of the interface, the search functionality of the coding tool can be reached through a set of REST-based web services, usable upon registration.

7.1.1. Coding tool limitations and future developments

At present, the coding tool works for English and soon Spanish editions of ICD-11. However, since it is based on an open source, well known framework (Lucene and ElasticSearch), adapting to other languages is mostly matter of having the ICD-11 translation ready and providing some extra resources that enhance the coding tool functionality (mostly, list of equivalent words).

Postcoordination through the coding tool is functioning when sanctioning rules are available. The full rule base for that is not yet complete, but at some time it will be.

7.2.ICD API

The APIs use OAuth 2 client credentials for authentication.

Most of the service methods can be directly accessed through the URI of an entity (either classification or classification entity), with the exception of the search functionality, which has its own URIs.

Top level	https://id.who.int/icd/entity
Returned Properties:	Title, Definition, Release Date, Child
Individual Entity	https://id.who.int/icd/entity/{id}
Example:	https://id.who.int/icd/entity/1766440644
Returned Properties:	Content model properties
Searching	https://id.who.int/icd/entity/search?q={searchText}

Specific methods are available for linearizations, like MMS.

The engine behind the search methods is the same as the search engine used in the web frontend of the ICD-11 platform. It is based on Lucene and ElasticSearch, and exploits the classification content and in particular the set of index terms associated to each entity for providing support in locating classification entities.

7.3.Deployment

The current WHO approach tends to openness and transparency. Thus, coding tool and ICD API are freely available, provided that no changes are made at the classification. Furthermore, an additional way of using them is by installing them locally:

1. Remote deployment: anyone can use the WHO cloud deployment of coding tool, ICD_11 browser and ICD-11 API by simply accessing them in their endpoints.
2. Local deployment: everything can be obtained in form of a Docker container for local deployment in a private server, on some other cloud service, or in any way considered relevant.

The first solution is the best one for the maintenance of the system. Since the coding tool is stored on WHO server, the maintenance is handled by the WHO and there is no need for local updates. The second one can be needed when national policies do not allow access to externally hosted applications, of for performance purposes. However, both solutions are highly interchangeable, because the difference in the web interface is just a couple of parameters.

7.4. Our experimentation

For the purpose of testing, we experimented with the coding tool in the prototype translation system. The coding tool was integrated inside the prototype as new tab in the navigation menu. It can be used to navigate into the classification, but also has the potential to select codes, and reuse those codes inside the rest of the system. This integration is made just as demonstrative purpose, however the power of the tool it can be seen integrating it inside with the rest of the system, where the users can use it together for these tasks. It could be integrated within the search of the ICD-11 codes in the workspace, however the main aim of the demonstration was to explain how to embed it in a third-party, independent tool such as the Iris transition prototype.

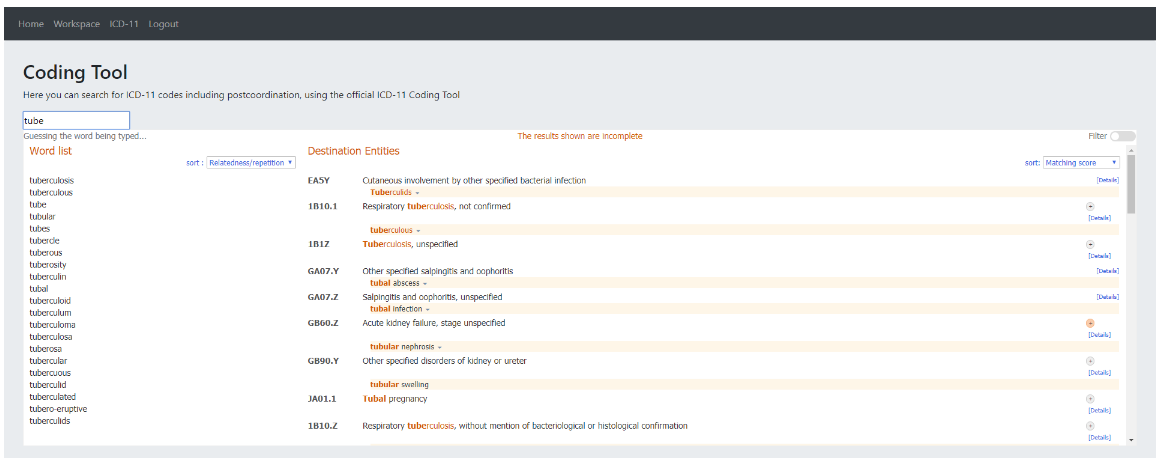
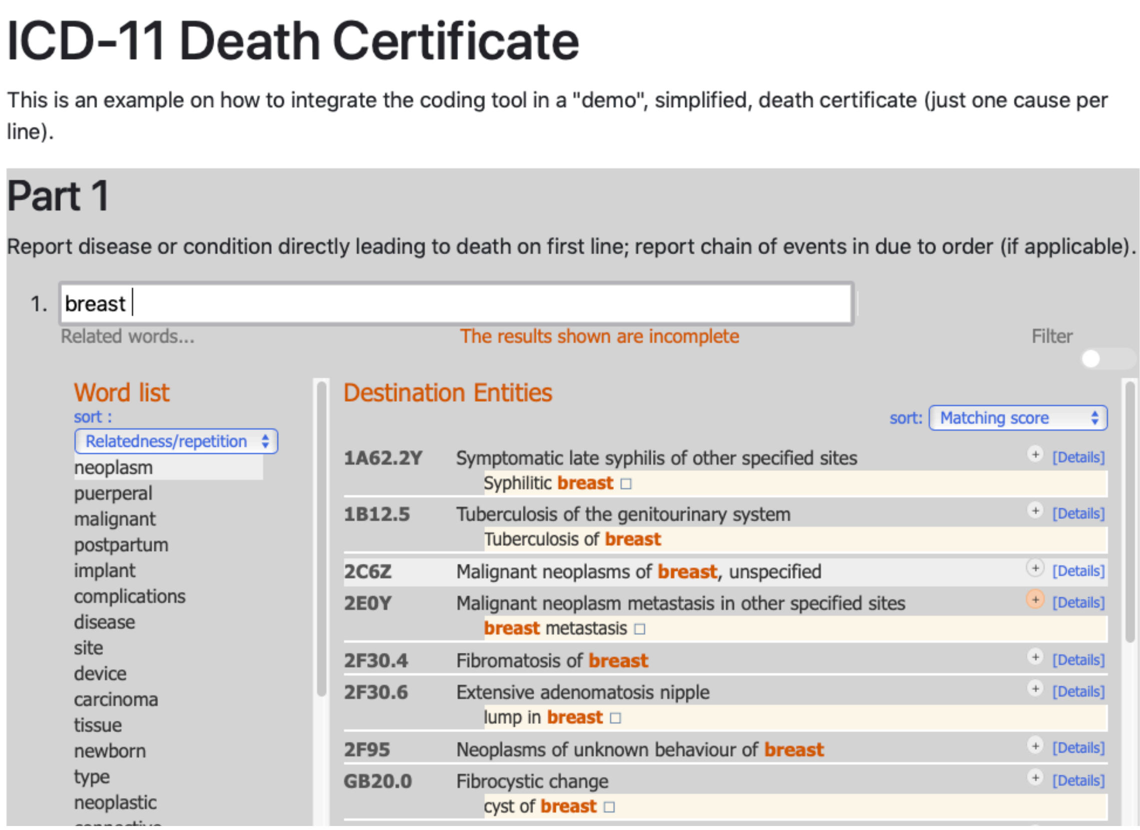


Figure 23. Coding tool integration.

In a second demo implementation, the coding tool was inserted in a form simulating, in a simplified way, a death certificate. Six fields (5 for Part 1 and 1 for Part 2) can be used to activate the coding tool and appropriately set a code field, like can be seen in the next screenshots, where also a postcoordinated code has been automatically selected.


ICD-11 Death Certificate
This is an example on how to integrate the coding tool in a "demo", simplified, death certificate (just one cause per line).
Part 1
Report disease or condition directly leading to death on first line; report chain of events in due to order (if applicable).
1.
2.
3.
4.
5.
Part 2
Other significant conditions contributing to death.


ICD-11 Death Certificate
This is an example on how to integrate the coding tool in a "demo", simplified, death certificate (just one cause per line).
Part 1
Report disease or condition directly leading to death on first line; report chain of events in due to order (if applicable).
1. breast
Related words...
The results shown are incomplete
Filter
Word list
sort :
Relatedness/repetition
neoplasm
puerperal
malignant
postpartum
implant
complications
disease
site
device
carcinoma
tissue
newborn
type
neoplastic
Destination Entities
sort: Matching score
1A62.2Y Symptomatic late syphilis of other specified sites [Details]
Syphilitic breast
1B12.5 Tuberculosis of the genitourinary system [Details]
Tuberculosis of breast
2C6Z Malignant neoplasms of breast, unspecified [Details]
2E0Y Malignant neoplasm metastasis in other specified sites [Details]
breast metastasis
2F30.4 Fibromatosis of breast [Details]
2F30.6 Extensive adenomatosis nipple [Details]
lump in breast
2F95 Neoplasms of unknown behaviour of breast [Details]
GB20.0 Fibrocystic change [Details]
cyst of breast

8. Evaluation of effort needed: approach based on terminal codes

For the analysis of the effort needed Istat used an approach based on normalized (the list of all possible relation between pairs of terminal codes present in the tables). For such approach, only the information on terminal codes (both in ICD-10 and ICD-11) was selected from the mapping tables by WHO. The evaluation is therefore based on the hypothesis of translating the tables by pairs of codes, i.e. in the most disaggregated form of the tables (normalized). The reasons for this approach are the following:

- we expect that the mapping at terminal level is more specific and really takes into account the difference between the two classification, less assumptions need to be undertaken when mapping at terminal level, while mappings higher hierarchic groups could be biased;
- generally, the grouping in the tables do not represent "nosological entities" but it is heterogeneous grouping;
- during manual translation, when evaluating the quality of "automated translation" by experts, it is more clear to look at terminal codes instead at heterogeneous grouping.
- as in the normalized tables, also the information on the most frequent pairs of codes found on data analysis is based on terminal ICD pairs;
- the evaluation of possible implications of post-coordination can be performed only at terminal level;

The main disadvantage of this approach is the big number of pairs of codes to be evaluated.

8.1.Objectives

- Estimate the proportion of decision tables rules (due-to) that can be translated automatically and to which degree of confidence.
- Estimate the burden for manual translators.
- Verify the appropriateness of the available material and propose solutions for the operative phase of table transition (IT requirements, additional documentation required and skills required).

8.2.Materials

The following tools were used for the analysis:

- Normalized ICD-10decision tables , that is related to single codes; these tables contain rules of the type X DUE TO Y, where X and Y are ICD-10 terminal codes, consisting in about 20 x 10^6 records;
- Mappings between ICD-10 and ICD-11 provided by the WHO.

Since the WHO mappings are not based on terminal codes, to obtain terminal-level mappings that can be used for the analysis purposes the following operations have been carried out (the 5-digit categories were considered as the terminal level of the ICD-11 classification, considering that the fifth digit should be sufficient for the construction of the tables).

1. From the WHO mappings tables only lines about ICD-10 terminal codes have been selected.
2. If an ICD-10 code maps to a 6-digit ICD-11 code, the 6-digit code has been replaced with the higher-level (5-digit) code.
3. If an ICD-10 code maps to an ICD-11 non terminal category, it has been assumed that it mapped to all terminal children of the non-terminal category.

8.3.Methods

8.3.1. Analysis of the types of rules based on mappings

The following features have been defined for each line of the mappings table at the terminal code level.

a. Type of ICD-10 code mapping
   1: The ICD-10 code maps to a single ICD-11 code
   2: The ICD-10 code maps to more than one ICD-11 code
   0: The ICD-10 code does not map to any ICD-11 code
b. Type of ICD-11 code mapping
   1: The ICD-11 arrival code maps from a single ICD-10 terminal code
   2: The ICD-11 arrival code is the result of the mapping of more than one terminal codes in ICD-10
   0: The ICD-11 code does not come from any ICD-10 code.

Therefore each line of the mappings table at the terminal code level belongs to a "type" that can be represented by a pair of numbers:

- the pairs containing a 0 indicate the absence of mapping;
- the pair 11 indicates the mapping "one to one";
- the pair 21 indicates the "one to many" mapping, in these cases the ICD-11 is more specific than the ICD-10;
- the pair 12 indicates the "many to one" mapping, in these cases the ICD-11 is less specific than the ICD-10;
- the pair 22 indicates the most complicated cases ("many to many" mappings).

Consequently, the application of mappings to both address and subaddress of each rule will result in different types of rules, based on the combinations of address and subaddress mapping type. These types can be represented by 4 numbers, the first two indicate the type of mapping of the address, the third and fourth the type of mapping of the subaddress. All possible combinations are listed in table 6.

Table 6 – Type of rule mappings between ICD-10 decision tables and ICD-11

	Address		Subaddress		Rule(s) in ICD-10	Possible translation in ICD-11	Automatic translation
Case Transition type	N of ICD-11 codes in which X is mapped	N of ICD-10 codes from which Z is mapped	N of ICD-11 codes in which Y is mapped	N of ICD-10 codes from which W is mapped			
1111	1 X <-> Z	1	1 Y <-> W	1	X DUETO Y	Z DUETO W	Yes*
2111	>1 X <-> $Z_1 \dots Z_k \dots Z_p$	1	1 Y <-> W	1	X DUETO Y	Z_k DUETO W p rules	Yes*
1121	1 X <-> Z	1	> 1 Y <-> $W_1 \dots W_l \dots W_q$	1	X DUETO Y	Z DUETO W_l q rules	Yes*
2121	>1 X <-> $Z_1 \dots Z_k \dots Z_p$	1	>1 Y <-> $W_1 \dots W_l \dots W_q$	1	X DUETO Y	Z_k DUETO W_l pxq rules	Yes*
1211	1 $X_1 \dots X_i \dots X_n$ <-> Z	>1	1 Y <-> W	1	X_i DUETO Y n rules	Z DUETO W	Yes*
	1 $X_1 \dots X_i \dots X_n$ <-> Z	>1	1 Y <-> W	1	X_i DUETO Y <n rules	Z DUETO W	No
1112	1 X <-> Z	1	1 $Y_1 \dots Y_j \dots Y_m$ <-> W	>1	X DUETO Y_j m rules	Z DUETO W	Yes*
	1 X <-> Z	1	1 $Y_1 \dots Y_j \dots Y_m$ <-> W	>1	X DUETO Y_j <m rules	Z DUETO W	No
1212	1 $X_1 \dots X_i \dots X_n$ <-> Z	>1	1 $Y_1 \dots Y_j \dots Y_m$ <-> W	>1	X_i DUETO Y_j n *x* m rules	Z DUETO W	Yes*
	1 $X_1 \dots X_i \dots X_n$ <-> Z	>1	1 $Y_1 \dots Y_j \dots Y_m$ <-> W	>1	X_i DUETO Y_j <n *x* m rules	Z DUETO W	No
2112	>1 X <-> $Z_1 \dots Z_k \dots Z_p$	1	1 $Y_1 \dots Y_j \dots Y_m$ <-> W	>1	X DUETO Y_j m rules	Z_k DUETO W p rules	Yes*
	>1 X <-> $Z_1 \dots Z_k \dots Z_p$	1	1 $Y_1 \dots Y_j \dots Y_m$ <-> W	>1	X DUETO Y_j <m rules	Z_k DUETO W p rules	No
1221	1 $X_1 \dots X_i \dots X_n$ <->Z	>1	>1 Y<->$W_1 \dots W_l \dots W_q$	1	X_i DUETO Y n rules	Z DUETO W_l q rules	Yes*
	1 $X_1 \dots X_i \dots X_n$ <->Z	>1	>1 Y<->$W_1 \dots W_l \dots W_q$	1	X_i DUETO Y <n rules	Z DUETO W_l q rules	No
2211	>1 $X_1 \dots X_i \dots X_n$ <->$Z_1 \dots Z_k \dots Z_p$	>1	1 Y <-> W	1	X_i DUETO Y n rules	Z_k DUETO W p rules	Yes*
	>1 $X_1 \dots X_i \dots X_n$ <->$Z_1 \dots Z_k \dots Z_p$	>1	1 Y <-> W	1	X_i DUETO Y <n rules	Z_k DUETO W p rules	No
1122	1 X <-> Z	1	>1 $Y_1 \dots Y_j \dots Y_m$ <-> $W_1 \dots W_l \dots W_q$	>1	X DUETO Y_j m rules	Z DUETO W_l q rules	Yes*
	1 X <-> Z	1	>1 $Y_1 \dots Y_j \dots Y_m$ <-> $W_1 \dots W_l \dots W_q$	>1	X DUETO Y_j <m rules	Z DUETO W_l q rules	No
2221	>1 $X_1 \dots X_i \dots X_n$ <->$Z_1 \dots Z_k \dots Z_p$	>1	>1 Y<->$W_1 \dots W_l \dots W_q$	1	X_i DUETO Y n rules	Z_k DUETO W_l pxq rules	Yes*
	>1 $X_1 \dots X_i \dots X_n$ <->$Z_1 \dots Z_k \dots Z_p$	>1	>1 Y<->$W_1 \dots W_l \dots W_q$	1	X_i DUETO Y <n rules	Z_k DUETO W_l pxq rules	No
2212	>1 $X_1 \dots X_i \dots X_n$ <->$Z_1 \dots Z_k \dots Z_p$	>1	1 $Y_1 \dots Y_j \dots Y_m$ <-> W	>1	X_i DUETO Y_j nxm rules	Z_k DUETO W p rules	Yes*
	>1 $X_1 \dots X_i \dots X_n$ <->$Z_1 \dots Z_k \dots Z_p$	>1	1 $Y_1 \dots Y_j \dots Y_m$ <-> W	>1	X_i DUETO Y_j <n *x* m rules	Z_k DUETO W p rules	No
2122	>1 X <-> $Z_1 \dots Z_k \dots Z_p$	1	>1 $Y_1 \dots Y_j \dots Y_m$ <-> $W_1 \dots W_l \dots W_q$	>1	X DUETO Y_j m rules	Z_k DUETO W_l pxq rules	Yes*
	>1 X <-> $Z_1 \dots Z_k \dots Z_p$	1	>1 $Y_1 \dots Y_j \dots Y_m$ <-> $W_1 \dots W_l \dots W_q$	>1	X DUETO Y_j <m rules	Z_k DUETO W_l pxq rules	No
1222	1 $X_1 \dots X_i \dots X_n$ <->Z	>1	>1 $Y_1 \dots Y_j \dots Y_m$ <-> $W_1 \dots W_l \dots W_q$	>1	X_i DUETO Y_j n *x* m rules	Z DUETO W_l q rules	Yes*
	1 $X_1 \dots X_i \dots X_n$ <->Z	>1	>1 $Y_1 \dots Y_j \dots Y_m$ <-> $W_1 \dots W_l \dots W_q$	>1	X_i DUETO Y_j <n *x* m rules	Z DUETO W_l q rules	No
2222	>1 $X_1 \dots X_i \dots X_n$ <->$Z_1 \dots Z_k \dots Z_p$	>1	>1 $Y_1 \dots Y_j \dots Y_m$ <-> $W_1 \dots W_l \dots W_q$	>1	X_i DUETO Y_j n *x* m rules	Z_k DUETO W_l pxq rules	Yes*
	>1 $X_1 \dots X_i \dots X_n$ <->$Z_1 \dots Z_k \dots Z_p$	>1	>1 $Y_1 \dots Y_j \dots Y_m$ <-> $W_1 \dots W_l \dots W_q$	>1	X_i DUETO Y_j <n *x* m rules	Z_k DUETO W_l pxq rules	No

* Except rules with Maybe, which should be manually revised in any case

The groups of 4 numbers containing at least one 0 indicate the rules for which it was not possible to map address and/or subaddress. The other 16 types of rules are described in table 6. Here the description, as an example, of some types.

- Type 1111 indicates the simplest case in which both the address and the subaddress map in a single ICD-11 code and the arrival ICD-11 codes derive only from those ICD-10 codes. That is, both the address and the subaddress have a "one to one" type mapping. From an ICD-10 rule it derives one in ICD-11.
- Type 1121 indicates that the address is mapped "one to one", but the subaddress maps in different ICD-11 codes, i.e. ICD-11 is more specific than ICD-10.
- Type 1112 indicates that the address is mapped "one to one", but the subaddress maps in an ICD-11 code that comes from several ICD-10 codes, i.e. ICD-11 is less specific than ICD-10.

Analysis of rules that can be automatically accepted

To evaluate which rules can be translated automatically the following considerations have been made.

If both the address and the subaddress of an ICD-10 rule have a one to one mapping, the corresponding ICD-11 rule can be accepted automatically.

If the address of an ICD-10 rule has a one to many mapping, i.e. if the ICD-11 is more specific than the ICD-10, all the ICD-11 rules obtained from the translation in ICD-11 of address and subadress can be automatically accepted, unless there is some specification in the ICD1 rule (maybe). If there are maybe the rule needs to be revised, but these are just a few cases. This applies also if the subaddress of the ICD-10 rule has a one to many mapping.

If the address or the subaddress of an ICD-10 rule has s many to one mapping, i.e. if the ICD-11 is less specific than the ICD-10, the ICD-11 rule obtained from the translation in ICD-11 of address and subadress can be accepted automatically if it is valid for all ICD-10 codes from which the ICD-11 code is mapped.

Based on these considerations, the rules for which it was not possible to map address and/or subaddress cannot be translated automatically. For the other rules, starting from the decision tables and the terminal code mappings, for each ICD-10 rule all possible ICD-11 translations were generated. Given an ICD-10 rule "X DUE TO Y", where X is mapped to ICD-11 codes Z_i (i> = 1) and Y is mapped to ICD-11 codes W_j (j> = 1), all possible ICD-11 translations of "X DUE TO Y", meaning "Z_i DUE TO W_j", were generated. The ICD-11 rules obtained can therefore derive from the translation of one or more ICD-10 rules.

For each of the ICD-11 rules obtained, it has been assessed whether it can be accepted automatically or it needs to be reviewed by an expert. An ICD-11 rule "Z DUE TO W", where Z is mapped from ICD-10 codes X_i (i = 1 ... n, n> = 1) and W is mapped from codes ICD-10 Y_i (j = 1 ... m, m> = 1), can be accepted automatically if:

- all the nxm ICD-10 rules "Xi DUE TO Yi" are included in the ICD-10 decision tables
- and none of the ICD-10 "Xi DUE TO Yi" rules have a maybe.

In other cases it is necessary that an expert revise the ICD-11 rule "Z DUE TO W" in order to evaluate if it can be accepted.

8.4.Results

ICD-10 decision tables include 20,433,525 normalized due to rules. About 5% of the ICD-10 DUETO rules cannot be mapped due to lack of ICD-10 mappings. In fact, out of 10,630 ICD-10 existing terminal codes, 845 are not included in the WHO mappings. Applying the WHO mapping tables to both to address and subaddress of ICD-10 due to tables, only 1.7% of the rules could be translated with the highest degree of certainty (translation type of table __6=1111) since both address and subaddress map 1 to 1 between ICD-10 and ICD-11 (are equivalent concepts). Nevertheless, assuming the methodology described above 66% of them could be automatically translated to ICD-11. The rest of ICD-10 rules are mapped to at least one ICD-11 rule that need manual revision to be approved.

The application of the mappings to the Codedef and Subcodedef of the ICD-10 tables, generated ICD-11 tables containing 18,425,463 records. The WHO mappings do not contain information about the ICD-10 derivation of 3,476 ICD-11 terminal codes (29% of the 12.010 codes at the 5th digit available in the classification). Out of the total number of generated records 14,894,363 (81%) can be accepted automatically.

8.5.Evaluation of effort needed

About 66% (more than 13 million) of ICD-10 rules could be automatically translated to ICD-11, resulting in 14.9 million records in ICD-11.

Therefore, 34% of rules (6 million) - generating 4 million records in ICD-11 - need to be revised manually.

Nevertheless, considering the results on the most frequent due to rules, the translation could primarily focus on the most frequent pairs according to the finding of data analysis described above. In addition, some rules do not need to be translated because the instructions in ICD-11 user guide are clear and translatable into codes: infectious diseases, neoplasms, and codes due to all other or to nothing. Not considering rules involving these codes, the effort need has been estimated as follow.

- To cover 90% of all pairs in due to found in the certificates, it is necessary to translate 12,416 pairs of codes. We can estimate that translating these pairs 78% of death certificates[6] are completely solved (only for due to relations).

[6] Estimate obtaining by elevating 0.9 (probability of a pair to be translated) to 2.3 (average number of different pairs in due to position in a certificate).

- To cover 95% of all pairs in due to found in the certificates, it is necessary to translate 27,176 pairs of codes. We can estimate that translating these pairs 89% of death certificates are completely solved (only for due to relations).
- To cover all pairs in due to found in the certificates, it is necessary to translate 115,540 pairs of codes.
- To translate all rules in decision tables, it is necessary to translate about 20 million pairs of codes.

For the complete functioning of Iris, besides decision tables also MUSE tables must be translated.

Assessment of the code depth necessary in decision tables

ICD-11 terminal (or leaf) stem codes (Chapters 1-23) can have up to three level of depth. In practical terms this means that the categories used in mortality can have four, five and sometimes six digit. As discussed previously, we used the fifth digit in table translation simulation, assuming that this level of detail could be sufficient for mortality. This level of detail was chosen in order to avoid the excessive burden that would be generated by the use of the sixth digit without a significant improvement of quality for mortality statistics.

In fact, if we consider all possible levels, there are about 13.8 thousand of terminal codes available in the MMS. On the other hand, if we limit to the depth level 2 (maximum 5 digit) the number reduces to 10.7 thousand[7].

In order to evaluate in which cases further detailed codes are needed, we applied the methodology of table translation using also 6-digit stem codes. After this we compared the two ICD-11 tables generated and evaluated if there was any improvement of the mapping type (see table 6).

Our result show that only a few codes would be necessary for having an improved translation of the tables. The codes implicated in the improvement of table translation are the following:

1F0020 - - - - Herpes simplex meningitis
2C1210 - - - - - - Intrahepatic cholangiocarcinoma
3B8171 - - - - Abscess of spleen
4A0130 - - - - Immunodeficiency due to defects of the thymus
4A0134 - - - - Hyperimmunoglobulin E syndromes
8A4500 - - - - Human T-cell lymphotropic virus-associated myelopathy
8A4501 - - - - Subacute sclerosing panencephalitis
8A4502 - - - - Progressive multifocal leukoencephalopathy
8A4521 - - - - Subacute necrotising myelitis
8A4531 - - - - Central pontine myelinolysis
8D2010 - - - - Spastic quadriplegic cerebral palsy

[7] Version:2019 Jun 30

8D2011 - - - - Spastic diplegic cerebral palsy
DC7000 - - - - - Diverticulitis of small intestine with perforation and abscess
GA3420 - - - - Cyclic pelvic pain
GA3440 - - - - Premenstrual tension syndrome
JA0020 - - - - Unspecified abortion, incomplete, complicated by genital tract or pelvic infection
JA0021 - - - - Unspecified abortion, incomplete, complicated by delayed or excessive haemorrhage
JA0022 - - - - Unspecified abortion, incomplete, complicated by embolism
JA0023 - - - - Unspecified abortion, incomplete, with other or unspecified complications
JA0024 - - - - Unspecified abortion, incomplete, without complication
JA0025 - - - - Unspecified abortion, complete or unspecified, complicated by genital tract or pelvic infection
JA0026 - - - - Unspecified abortion, complete or unspecified, complicated by delayed or excessive haemorrhage
JA0027 - - - - Unspecified abortion, complete or unspecified, complicated by embolism
JA0028 - - - - Unspecified abortion, complete or unspecified, with other or unspecified complications
JA0029 - - - - Unspecified abortion, complete or unspecified, without complication
LD2D10 - - - - Neurofibromatosis type 1
MB2500 - - - - Circumstantiality
MB4750 - - - - - Myokymia
MD8110 - - - - - Pain localised to upper abdomen
MD8111 - - - - - Pelvic or perineal pain
MD8112 - - - - - Pain localised to other parts of lower abdomen
ME1000 - - - - - Hepatomegaly, not elsewhere classified
ME1001 - - - - - Splenomegaly, not elsewhere classified
ME1002 - - - - - Hepatomegaly with splenomegaly

The described assessment is only based on the improvement of table translation and does not take into account any need for a better representation of mortality statistics, but confirm that at least for the evaluation of causal relations, codes at fifth digit would be generally sufficient.

Evaluation of post-coordinated codes needed

The methodology described in the previous section could be used also for evaluating which post-coordinated codes would be necessary for table translation. For such assessment, mappings containing post-coordinated codes would be necessary and in current mappings such feature is not provided. It is recommendable to carry out such evaluation as soon as the complete mappings are available.

Translation at block level

An attempt was made also in evaluating the possibility to use the mappings at block level. Nevertheless the WHO mapping tables generally provide mappings from ICD-10 blocks to ICD-11 category, so it was not possible to apply the described methodology to the tables represented at block level.

8.6.Evaluation of effort needed: approach based on intervals of codes

On the prototype we have available the ICD-11 rules translated from the original ICD-10 decision tables. For each translation we can identify the codes of the rules suggested as automatic, and which need manual support from the expertise. We can subdivide the codes that need manual support in three categories:

1. Manual, codes that need manual support, where the expert need to choose if the code belong to the rule.
2. Warning, codes that are potentially correct from a logical point of view, but since multiple codes of ICD-10 are mapped on the same code and not involved in the original rule, need initial supervision to check if the results maintain the needed level of detail. The expertise has the possibility to remove the code from the translated rule, if experts consider it is not necessary those issues can be deleted.
3. Inconsistent, codes of ICD-10 that has no mapping on ICD-11, and codes of ICD-11 that has no mapping from ICD-10. The expertise needs to update the mapping table or add each code of ICD-11 not covered in the mapping for each rule.

We tried to make some statistics to identify the cases that need manual support. We evaluate each category presented before and tried to understand which codes the experts need to test each time for different rules, or the result that the experts can reuse.

In this way we identified the worst case, and the best case. From these statistics we can also understand the need of the reuse of the results, and the reason we tried to group up rules.

For the "DUETO" we identified 27.338.256 pairs on the starter decision tables, which become 21.879.168 pairs on the translated decision table.

Considering each pair, we identified 3.255.115 errors, 348.824 warnings and 4.210 codes with no mapping from ICD-10. When we consider the total of the codes that experts need to verify it is almost unrealized.

From a logical point of view this is unnecessary. In fact, the experts need not check those cases as pairs.

We identify two possible ways to validate those cases:

1. The first one is on mapping side (which we consider is the best case) where we have 2.868 errors, 2.216 warnings and 4.210 codes with no mapping. The mapping side are all the cases that are accepted (handled) on the codes that generated the issue. Handle the issue on the code that generate it will propagate the result on all the ranges that include that code, and automatically manage the issue at each level.
2. And the worst case is where we consider the issues on ranges level. In this way the codes need validated only once for range. For this case we have 87.007 errors, 21.291 warnings and 4.210 codes with no mapping. At range level it is possible to reuse the results, and each translated range can be reused to

translate the same range on all the others anchor codes. Or for all the other larger ranges that include the range translated.

We expect that the real case stays between the two cases presented. We can notice that for each mode we present the inconsistent issues are always 4.210, since the codes with no mapping should not need more than one evaluation.

9. MAINTENANCE OF ICD-11 DECISION TABLES

Since 2013, the Iris Institute maintains current ICD-10 tables by means of a web application referred to as Decision Table Editor (DTE). Before this time[8], tables were updated manually using exel based tools. DTE is a web-based system developed by Istat in the framework of the international collaboration for the Iris Institute. By means of this application, experts from different countries can collaborate on the coordinated and simultaneous maintenance and update of the decision tables used for the underlying cause-of-death selection. One of the major achievements of the DTE is the improvement of transparency and documentation of changes introduced in the tables, which have a direct impact on mortality statistics.

The DTE is a tool that allows to track and control each step of a predefined work-flow for table updating. Potentially, many experts can contribute in the updating process and a single person can coordinate the activities of all the steps. This organization of updating work can be suitable also for ICD-11 tables.

Another characteristics which contributed to the facilitate the maintenance of the tables is the structure of the database. In fact, in the main table containing the decision tables, the relation between each single pair of codes is stored (normalized tables) and not represented by intervals of address and subaddress. This structure allows to extract and manipulate parts of the tables easily. Nevertheless this structure has some drawbacks discussed below.

Nevertheless some limits for the use in ICD-11 should be highlighted:

1. The different structure of ICD-11 compared to ICD-10 should be taken into account. Besides the code length and structure, the most significant difference is the use of postcoordinated codes that will be available in ICD-11. The current tool has already a function that could serve the needs of allocating the postcoordination feature. This function is the management of the field “Condition” within the tables (Neocode function in DTE). This tool should be enhanced for ICD-11.

[8] Described in Istat, 2016. Decision Table Editor: a web-application for the management of the international tables for mortality coding.
https://www.istat.it/it/archivio/184113

2. The DTE has been developed in the early time of MUSE, the new multiple cause and selection engine of Iris. For this reason, most of the functions of the DTE are still based on MICAR-ACME concepts and do not completely include all the potentials of the MUSE tables. The renewing of the tool is recommendable. In particular:
   a. All the variables of current decision tables should be added. Further analysis with IT developers should be done in order to simplify table structure.
   b. Also rules for substitution should be included. Currently the DTE handles only decision tables for selection of the UC.
   c. The DTE allows to use only terminal codes. It would be important to add also codes of higher hierarchical order such as chapter, blocks and 4-digit both for updating and for the visualization of compressed tables.
   d. Some improvements in the outputs are welcomed such as better reporting and clear outputs.
   e. The database which includes the relation between single codes has proven to be an advantage for table maintenance. Nevertheless this characteristic requires the allocation of enough database memory space. This need could increase with the increased detail of ICD-11.

For ICD-11 the development of a tool for table maintenance will be needed. Iris Institute should engage in the re-designing. The new tool should be strongly based on the previous one.

10. CONCLUSIONS

On the basis of the analyses and the evaluations performed, the structure of work for integration of ICD-11 into Iris could have the following phases.

10.1. Revision of current WHO mappings and/or cross-walk mapping construction

As mentioned before the translation use the mapping given and maintained by the WHO. Before the validation of the translation tables it is necessary to validate and complete the mapping. This is necessary to check if the mappings are usable for the purpose of the Iris rule tables translation. The mappings are still incomplete, and it is needed to complete them to cover all the codes from ICD-10 to ICD-11. After completing the mapping, it is necessary to identify the ICD-11 terminal codes that are still with no mapping. The ICD-11 that have no mapping from ICD-10 need to be manually inserted in the rules, and it is not possible to estimate the impact and time needed without have the exact number of codes involved. In the translation project it is necessary to create the mapping also for the created codes to ICD-11 when possible or create the associate entities and codes in the ontology to maintain the ICD-11 created codes.

The current WHO mappings were analyzed in order to evaluated their applicability for the tables translation. The analysis lead to the following observations.

- In current WHO mappings, some ICD-10 do not have corresponding mapping and some ICD-11 codes are not included. Mapping from ICD-10 block to ICD-11 block is also often missing.
- Documentations on the current WHO mappings should be enhanced, in particular the meaning of variables should be better described and the methodology of construction of the mappings should be better clarified.
- It would be useful to have mappings based on the double coding (ICD-10 and ICD-11) of the most frequent medical expressions such as those contained in the ICD-10 index (or Iris dictionary) in order to evaluate the real changes (cross-walk).
- Use of post-coordination in mappings would be beneficial.

After completing the validation of the mapping, it is possible to start the translation of the tables. The rule types analyzed were just a few, so first it is necessary to complete the analysis of the rule types. Most of the work should be possible to reuse the analysis made in this pre-project.

10.2. Creation of a prototype of ICD-11 Iris for testing

For testing, it is necessary to create a prototype of Iris that could handle ICD-11 codes, as previously described.

10.2.1. Translation

The translation activity could be organized in the following phases.

1. Automated translation of the tables
   effort needed: approximately 12 person-months
   experts needed: IT/statisticians
   (due to has been established but needs to be verified for other rules)
2. Testing
3. Manual procedure
   Effort needed, considering that an expert coder, working full time, can translate/revise about 200 rules (pairs of codes):
   a. priority 1 rules: 3 person-months
   b. priority 2: 7 person-months
   c. priority 3: 28 person-months
   Experts needed: experts of classification/coding/iris tables
   It could be useful to preliminarily translate frequent patterns of subaddresses found in tables (codesets such as nutritional diseases, aids-related conditions, and so on)
   d. Additional 5 person months would be needed for the revision of obvious causes most used in the data.

10.2.2. Translation based on intervals of codes

Since an expert coder can translate/revise about 200 rules (pairs of codes) per day, the same expert can handle less issue per day using the system. To evaluate an issue of the system the expert should start analyzing the codes associated to the issue, then need to identify the actions that must be done for the validation. Last the expert need to identify the level where to handle the issue. This process should take more time to be processed than translate a pair, but the cases that need to be translated using the issue for the system are less. For the time needed for the translation it needed to consider also further time to check the completeness of the translated rules and the correctness of the automatized rules (validating the mapping).

10.2.3. Complementary approach

The above mentioned translation approaches can be considered bottom-up, starting from the most specific rules (i.e., pairs at first, and intervals as a slightly more abstract approach). However, complementing this approach with a parallel effort that starts from the most general rules present in the ICD-11 Reference Guide could be of help in reducing the number of rules to be translated at the lower levels. In fact, many rules are just expression of some general fact (e.g., cancer is not caused by other conditions apart very few exceptions), and generating pairs from these general rules may reduce the work needed by experts.

10.3. Prototype testing

For testing, statisticians should be involved for evaluating the changes compared to ICD-10 as well as public health experts to evaluate if the changes are in line with public health requirements.

In case the prototype will be adopted to support experts, a preliminary testing phase is needed to check its functioning and modify what is needed to better support experts. Unfortunately, the testing phase started during the last summer has produced almost no results due to the scarce participation of volunteering experts.

10.4. Quality control and validation

Following the translation process it is necessary to perform quality control and validation of the translation, in particular:

1. refine the list of codes valid for mortality. During the assessment we mostly used categories with maximum depth level of 2, corresponding to 5 digit codes, assuming that this level could be sufficient for mortality statistics. Nevertheless, this assumption did not take into account possible needs for public health. During this

phase of work the level of codes to be used for international mortality statistics should be outlined.

2. verification of the adherence of the ICD-11 tables to the ICD-11 provisions;
3. revision of ICD-11 tables based on discrepancies between tables and data reported on death certificates found by Istat.

10.5. Maintenance of decision tables

Once the ICD-11 tables are ready, it is necessary to maintain them, in particular:

- translate the remaining rules;
- refine them on the basis of user's guide.
- Envision a model for continuous update of rules, synchronized with ICD-11 MMS updates.

10.6. Extend the prototype

The system needs to be extended to implement the new rule types and them support into the actual prototype. The prototype handle and present the pre-compiled translation rules, where specify the suggestions and issue associated to the codes. This is done in a NO-SQL database (MongoDB) by a set of scripts written in Python. The prototype is web based for the reasons already presented in the specific section. It is divided in two modules, one for the presentation (written in *typescript/html* using Angular framework) of the results and one that handle the middleware between the database and the presentation (written in PHP using Laravel framework). The source code for the three mini projects that implement the prototype are available together with the report.