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"A method to classify W-UI situations in Europe: towards a common catalogue"

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1. Introduction

The experience in the Mediterranean countries reveals that forest fire episodes which happen in forest areas with urbanised zones are subjected to a series of conditions which determine different Wildland-Urban Interface (W-UI) risk situations.
To perform such identification, a methodology has been developed based on the elaboration of a **catalogue/key** of W-UI situations**.** The catalogue is based on the characterisation of W-UI/RA **components**.
In second place, the methodology has been carried out, in order to establish the **component variables measurement** and their **spatial relationships**, which will allow to identify the W-UI, generating an associated database.
Two groups of components, structural components and modifiers have been classified.
The STRUCTURAL components are those which cause the **change of the casuistry** with the variation of the same ones. They will be analyse as structural elements, the forest fuels, both surface and aerial fuels, the topography and the settlement, understanding urbanisation such as rural settlement inside the forest areas.
The MODIFIER components are those that introduce **variations in the situations** determined by the structural ones.
The next step consists on developing the W-UI/RA situations catalogue, and to accomplish this task in a systematic way, it is necessary firstly to identify components which are significant in W-UI and their spatial relationships (relative position).
Several sub-tasks have to be completed:

- To identify the most frequent/meaningful cases for each component and gather it in forms (key)
- To obtain the supporting information (maps or databases) for the Study Area for each component
- To identify the most frequent/meaningful cases of relative spatial distribution of components and reflect that in forms (key)

Afterwards, and applying such catalogue/key in each Study Area, the objective is to identify in which W-UI situation each urban area or housing is. In this way a complete database of W-UI situations will be produced.

2. METHODOLOGY

The objective of field inventory and spatial analysis has been to gather information about the different components (structural and modifier ones) and their spatial

relationships, in order to identify subsequently the situations of Wildland-Urban Interface and Rural Areas in the study area.
The analysis of the information gathered in this first stage leads to the elaboration of WARM Catalogue, which shows the different situations of Wildland-Urban Interface existing in each study area, based on the characterization of W-UI/RA components.
After a qualitative preliminary study related to inventory results and spatial analysis, it has been concluded that modifier components (potential and real causes of fire, historical fires, population density, infrastructures, fire fighting forces, and land use changes) do not discriminate different W-UI/RA situations.

2.1 Characterization of W-UI/RA structural components

WARM Catalogue is a systematic, practical guide of W-UI/RA situations in Europe. It's a document which contains the parameters or components that define and, therefore, characterize each one of the W-UI/RA situations, accompanied by some pictures and aerial photographs of representative settlements.
In order to carry out WARM Catalogue, the characterization of W-UI components has been carried aut, defined as structural or discriminating components in the *Project Inception Rationale* document. Settlement typology, Surface Fuels typology and Topography classification, as well as their spatial relationships, will allow us to identify which W-UI/RA situations are really different and which ones are equal inside the study area.
The characterization of structural components is carried out by assigning indexes and sub-indexes of risk or danger, so that the spatial relationship of the three structural components is a combination of indexes of risk that allows to know which W-UI/RA situations are really different (up to now four different situations have been identified).

2.1.1. Settlements Classification Model

Settlement typology is established based on the analysis of four variables:

- *Percentage of lots in contact to forest fuel*
- *Vegetation just surrounding the house.*
- *Percentage of vulnerable lots.*
- *Security.*

Sub-index 1: Percentage of lots in contact to natural vegetation.

This sub-index is defined as the number of lots in contact to forest fuel in the settlement in relation to total number of lots in the settlement as percentage.
Lots in contact with forest fuel are those lots that have unless one side in contact to forest fuels, either inside the settlement or in a perimeter situation. When lots in the perimeter of the settlement are surrounded by a road, they are not considered in contact with forest fuel.

Lots **not** in contact to forest fuel (natural vegetation)

Lots **in contact to** forest fuels in a perimeter situation

Lots **in contact to** forest fuel inside the settlement

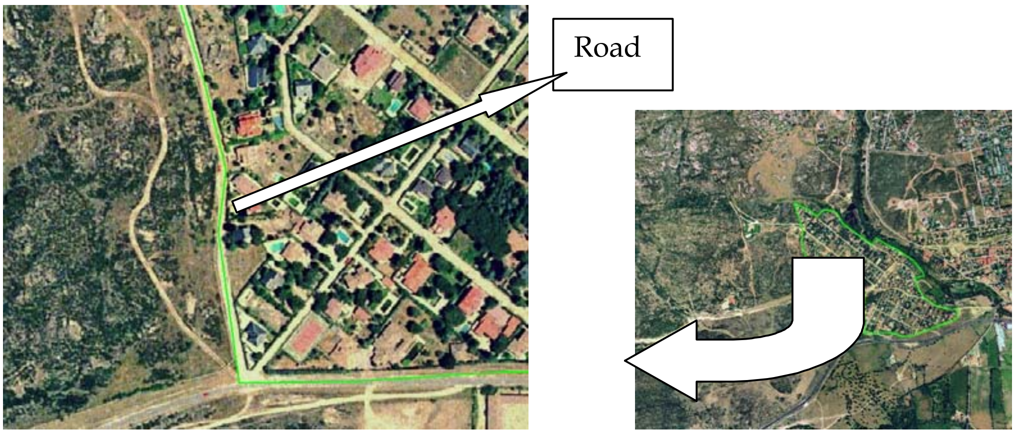

Fig1.- . Settlement with lots in the perimeter which are not considered in contact to forest fuel because they are surrounded by a road.

The values for sub-index1: Percentage of lots in contact to forest fuel are:

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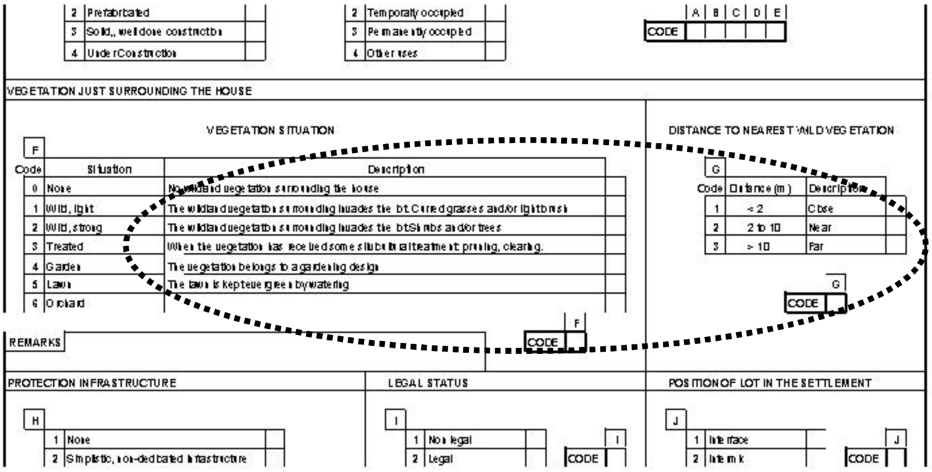
Sub-index 1. **Percentage of lots in contact to forest fuel**
Value 1: interface (< 30%)
Value 2: medium interface (30-60%)
Value 3: interface/intermix (60-80%)
Value 4: intermix (> 80%)

Sub-index 2: Vegetation just surrounding the house.

The quantification of this sub-index is carried out based on two factors from WARM Inventory Settlement forms:



2.1. Vegetation situation (Code F).

This factor is also obtained from aerial photograph. The six vegetation situations which appear in the forms are grouped into two classes regarding to the risk for forest propagation. On the one hand, codes 0, 3, 4, 5, 6, are considered lots with low risk vegetation, on the other hand, codes 1, 2 (*wild light* and *wild strong*) are considered **lots with high risk vegetation**.

Those lots with risk vegetation are counted using aerial photographs, (*wild light* and *wild strong* as defined in the *Project Inception Rationale* document).

The values for this factor are:

Vegetation situation
Value 1: < 25% of lots with risk vegetation
Value 2: > 25% of lots with risk vegetation

2.2. Distance to wild vegetation.

Distance to nearest wild vegetation code which appears in the forms, are also reclassified into two new groups. These are:
G1< 2 meters; 2<G2<10 meters; and *far G3>10 meters*
This factor is obtained from aerial photograph and field work. The value for this factor is:

2.2. Distance to nearest wild vegetation
Value 1: < 60% of lots have wild vegetation less than 2 meters from construction
Value 2: > 60% of lots have wild vegetation less than 2 metres from construction

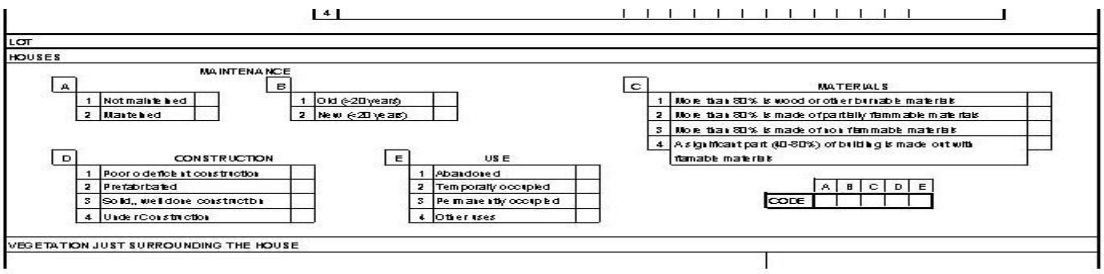
2.3.- <u>Factors integration to obtain sub-index 2 ("Vegetation just surrounding the house")</u>

These two factors are integrated so that Sub-index 2 ("Vegetation just surrounding the house") takes three different values (values 1, 2 and 3).
The way of integration is as follows: the preponderant factor is "Vegetation situation" and Sub-index 2 takes its value, except for the case factor "Distance to nearest vegetation" is 2-valued, what provokes an unitary increase of Sub-index 2 "Vegetation just surrounding the house"
The possible combinations of factors "Vegetation situation" and "Distance to nearest vegetation" are shown below:

Sub-index 2. Vegetation surrounding the house	2.1. Vegetation situation	2.2. Distance to nearest vegetation
1	1	1
2	1	2
2	2	1
3	2	2

Sub-index 3: Percentage of vulnerable lots.

This sub-index is based on houses
<u>Material</u> (C) and <u>Constructions</u> (D) and are taken into account in order to define **Vulnerable lots**. So that **Vulnerable lots** are considered those with Material codes C1, C4 and Construction codes D1, D2, D4. (See the following table)


LOT
HOUSES
MAINTENANCE
A
1 Not maintained
2 Maintained
B
1 Old (>20 years)
2 New (<20 years)
C MATERIALS
1 More than 80% is wood or other burnable materials
2 More than 80% is made of partially flammable materials
3 More than 80% is made of non flammable materials
4 A significant part (40-80%) of building is made out with flamable materials
D CONSTRUCTION
1 Poor or deficient construction
2 Prefabricated
3 Solid, well done construction
4 Under Construction
E USE
1 Abandoned
2 Temporally occupied
3 Permanently occupied
4 Other uses
A B C D E
CODE
VEGETATION JUST SURROUNDING THE HOUSE

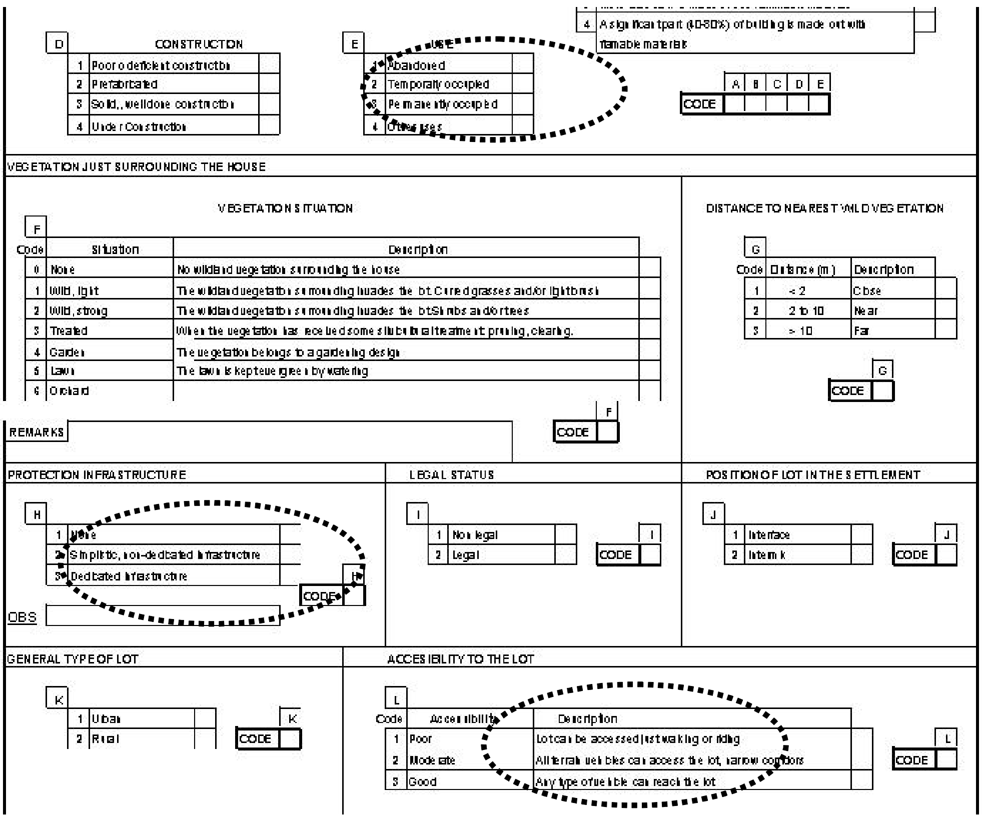
Vulnerable Lots
Code C 1.- *More than 80% made of wood or other burnable materials*
Code C 4 .-*40-80% of the house is made out with flammable materials*
Code D 1.- *Poor or deficient construction*.
Code D 2.- *Prefabricated*.

The number of vulnerable lots in each settlement is counted in field work and they are divided by number of lots in the settlement to get percentage of vulnerable lots in the settlement. The following values are assigned to settlements according to percentage of vulnerable lots.

Sub-index 3. Vulnerability
Value 1: < 20% are vulnerable lots
Value 2: > 20% are vulnerable lots

Sub-index 4: Security.

The quantification of this sub-index is carried out based on three factors that also come from WARM Inventory Settlement forms. These are: Protection infrastructure (Code H), Accessibility to the lot (Code L), Use (Code E)



4.1. Protection infrastructure.

This factor is evaluated using field inventory. The codes for this factor are grouped into two. On the one hand, Codes H1, H2, on the other hand, Code H3 (*Dedicated infrastructure*).

4.1. Protection Infrastructure
Value 1: Dedicated infrastructure (Code H3)
Value 2: None, Simplistic, non dedicated infrastructure

4.2. Accessibility to the lot.

Using both aerial photographs and field visits, Accessibility to the lot is regrouped into two.

4.2. Accessibility to the lot
Value 1: Good (Code L3)
Value 2: Moderate and Poor (Codes L1 and L2)

4.3. Use.

This factor belong to houses (Code E). Starting from field inventory, the information related to the occupation degree is obtained. The following values are assigned to the settlement:

4.3. Use
Value 1: > 50% of lots are permanently occupied (Code E3)
Value 2: < 50% of lots are permanently occupied (Code E3)

4.4. Factors integration to obtain sub-index 4 ("Security")

In order to develop "Security" Sub-index integration into three final values (1, 2 or 3), all the studied settlements must be considered.
Each settlement is characterized by one vector with three components. Vector components are the factors mentioned so far, in the following order: Protection infrastructures, Accessibility to the lot and Use. All settlement vectors are ranked in ascending way, and reclassified into final values: 1, 2, 3, having in mind that "Protection infrastructures" and "Accessibility to the lot" have the same weight, but "Use" values modulate the resulting type.
A real case it is developed in the following table. The easiest way to perform the integration is just assessing first, best and worst situations, and modulate intermediate ones.

Sub-index 4. Security	4.1. Protection infrastructures	4.2. Accessibility	4.3. Use
1	1	1	1
2	1	1	2
2	1	2	1
2	1	2	2
2	2	1	1
3	2	1	2
3	2	2	1
3	2	2	2

5. Final Integration.

Final Settlement Sub-indexes integration, classifies all settlement into 5 types (types 1, 2, 3, 4 and 5). It follows the same methodology as in Sub-index 4 integration.
A sub-index vector is assigned for all settlements according to sub-index values obtained before. All vectors are ranked in ascending way, and reclassified. In order to classify correctly, it have to be considered that the sub-indexes are not equally weighted. They are ordered from more important to less as follows: Sub-index 1.- Percentage of lots in contact to forest fuel; Sub-index 2.- Vegetation just surrounding the house, Sub-index 3.- Percentage of vulnerable lots and Sub-index 4.- Security).

Some results for Settlement Class in Madrid study area are shown in the following table:

Settlement name	Settlement Class	Sub-index 1. Percentage of lots in contact tonatural vegetation	Sub-index 2. Garden vegetation	Sub-index 3. Percentage of vulnerable lots	Sub-index 4. Security
Camorritos	5	4	3	2	2
Abantos	4	4	3	1	3
El Ramiro	4	3	3	2	3
Reajo el Roble	3	3	2	1	1
San Muriel	3	3	1	2	2
El Retamar	3	4	1	1	3
Las Marías	2	3	2	2	3
Valdencina	2	3	1	1	1
Los Linos	2	2	2	2	2
Bella Vistas	2	2	2	1	1
Las Colinas	2	2	1	2	3
Pinosol	2	2	1	1	2
El Berrocal	2	2	1	2	2
La Pizarra	2	2	1	1	1
Palacios	1	1	3	1	2
Vista Real	1	1	2	1	3
Sierra Bonita	1	1	2	1	2
Montellano	1	1	1	1	2

Surface Fuels Classification Model

Surface Fuels typology is settled down based on the analysis of two variables:
Settlement Fuels.
Topography.
Sub-index 1: Settlement Fuels.

The quantification of this sub-index is carried out based on two factors:

1.1. Fuels in contact to settlement.

Using aerial photographs, it has been determined the perimeter length in which natural vegetation (for each type of fuel), SPECIFIC LENGTH which is in contact to settlement or urban area; if there are some roads between certain parts of the settlement and natural vegetation, the length of these roads is not considered when computing this factor.
Starting from calculating the perimeters for each fuel group, and dividing them by settlement perimeter, pondered perimeter is obtained.
On the other hand, for each group of surface fuel is assigned a value numbered from 0 to 4 (0 for smaller-risk fuel groups and 4 for those ones with more risk). This value is increased in ONE unit if overstory cover is more than 70%. In the next table there are some fuel examples for the different values.

	Fuel groups
Value 0	Incombustible areas (riverside vegetation, urban areas, quarries)
Value 1	Grasslands, pine leaves, *Fraxinus* and *Quercus* meadows
Value 2	Grassland with *Spartium*, *Retama* and holm oak shrubs, *Cistus* shrubs with oak trees, grassland with pines
Value 3	Dense shrubby area of *Cistus*, alone or mixed with *Retama*
Value 4	Dense shrubby area of *Cistus ladanifer* and oak
+ 1 if overstory cover > 70%	

Next, we have to multiply these fuel group values for a coefficient depending on valued perimeter (see table below) in order to obtain an integrated value for each fuel group.

Weighed perimeter	**Coefficient**
80% – 100%	1
60% – 80%	0.8
< 60%	0.6

Finally, by summing the different values of *weighed value* —and rounding decimals— it's obtained the value for "Fuels in contact to settlement".

Computing example for factor “Fuels in contact to settlement”:

Settlement name	Settlement perimeter (m)	Perimeter in contact to natural vegetation (m)	Weighted perimeter	Coefficient	Fuel Group value	Overstory cover greater than 70%	Weighted contact
Los Linos	2021	322.641	0.16	0.6	1	No	0.6
Los Linos	2021	519.565	0.26	0.6	1	No	0.6
Los Linos	2021	403.863	0.20	0.6	2	No	1.2
							$\sum = 2.4 \rightarrow 2$

1.2. Forest fuels inside 500-meter buffer area.

In a similar way, it has been determined the surface corresponding to each fuel group inside 500-metre buffer area. It is computed in order to consider the percentage by each fuel group occupies inside this buffer area, and next it is multiplied for the value assigned to each group of fuel (values from 0 to 4) in order to obtain a *pondered value*. The sum of *weighed values* gives the value for “Fuels inside 500-metre buffer area”.

Computing example for factor “Fuels inside 500-metre buffer area”:

Fuel Group value	Settlement name	Settlement area (m^2)	Fuel Group area (m^2)	Percentage of each Fuel Group	Weighted value
2	Los Linos	1699231.5	54541.177	0.032097556	0.064195111
1	Los Linos	1699231.5	329960.164	0.194181999	0.194181999
1	Los Linos	1699231.5	253979.054	0.149467014	0.149467014
1	Los Linos	1699231.5	395379.952	0.232681631	0.232681631
1	Los Linos	1699231.5	344712.410	0.202863715	0.20+2863715
					$\sum = 0.84338947 \rightarrow 1$

It is carried out the weigh of these two factors to obtain the final value for sub-index “Settlements Fuels”. In the integration of these factors two different situations can be considered:

“Fuels in contact to settlement” is greater or equal than “Fuels inside 500-metre buffer area”: then sub-index “Settlement Fuels” adopts value from first factor.

“Fuels in contact to settlement” is less than “Fuels inside 500-metre buffer area”: then “Settlement Fuels” sub-index adopts value from first factor plus an unitary increase.

Sub-index 1. Settlement Fuels	1.1. Fuels in contact to settlement	1.2. Fuels inside 500-metre buffer area
1	1	1
2	1	2
2	2	1
2	2	2

Sub-index 2: Topography.

Starting from spatial analysis of settlements, it is known the percentage corresponding to each slope type (flat, smooth, rough, extreme) inside settlement area. Based on these spatial analyses, sub-index “Topography” is classified into two classes: favourable slope and adverse slope.

Slope type
Flat (< 10%)
Smooth (10% - 25%)
Rough (25% - 45%)
Extreme (>45%)

Sub-index 2. Topography
Value 1: favourable slope (valley bottom, plain zone, more than 60% of settlement with slope < 10%)
Value 2: adverse slope (middle-slope location, canyons, less than 60% of settlement with slope > 10%)

Finally, once analysed the two sub-indexes (Settlement Fuels and Topography), they are integrated in order to obtain the **Typology of Surface Fuels**. The way of integration is the following: Surface Fuels will take “Settlement Fuels” value, but for “Topography” equals two, in which case “Settlement Fuels” will unitarily increase to obtain the final value for Surface Fuels.

Surface Fuels	Sub-index 1. Settlement Fuels	Sub-index 2. Topography
1	1	1
2	1	2
2	2	1
3	2	2

FUELS/SETTLEMENT INTEGRATION MODEL

Settlement typology, Surface Fuels typology and Topography classification, as well as their spatial relationships, will allow us to identify which W-UI/RA situations are really different and which ones are equal inside the study area.
Once characterized the structural components, it is the integration model the one that allows to discriminate the spatial relationships between **Typology of Settlements** and **Typology of Surface Fuels** (since spatial relationships between Surface Fuels and Topography have already been contemplated previously).
Integration model is a 2-entrance matrix which determinates a final index of risk for the analysed W-UI/RA situation. The values for this index of risk oscillates from 1 (settlements with less risk) to 6 (settlements with more risk).

Surface Fuels					
6	6	5	5	4	3
5	6	5	4	4	2
4	5	5	4	3	2
3	5	4	3	3	2
2	4	4	3	2	1
1	4	3	2	1	1
Settlement Class	5	4	3	2	1

Computing example for FUELS/SETTLEMENT INTEGRATION MODEL in Madrid study area:

Settlement name	**Surface Fuels**									
El Ramiro	**3**	**4**								
Reajo el Roble	**3**	-	**3**							
Vista Real	**3**	-	-	**2**						
San Muriel	**1**	-	-	-	**2**					
Los Linos	**2**	-	-	-	-	**2**				
Valdencina	**1**	-	-	-	-	-	**1**			
El Berrocal	**1**	-	-	-	-	-	-	**1**		
Los Palacios	**1**	-	-	-	-	-	-	-	**1**	
Sierra Bonita	**1**	-	-	-	-	-	-	-	-	**1**
	Settlement name	**El Ramiro**	**Reajo el Roble**	**Vista Real**	**San Muriel**	**Los Linos**	**Valdencina**	**El Berrocal**	**Los Palacios**	**Sierra Bonita**
	Settlement Class	**4**	**3**	**1**	**3**	**2**	**2**	**2**	**1**	**1**