

# Color Combination Criteria in Le Corbusier's Purist Architecture Based on Salubra claviers from 1931

Juan Serra,\* Jorge Llopis, Ana Torres, Manuel Giménez

Department of Architectural Graphic Expression, School of Architecture, Polytechnic University of Valencia, Valencia, Spain

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*Abstract:* We have carried out a new study of the color combinations selected by Le Corbusier in 'les claviers de couleurs' for the Salubra wallpaper company in 1931, by analyzing them in the Natural Color System, which allows us to understand the perceptive variables of colors (hue, blackness, and chromaticness) as well as their combination criteria. Regarding the perceptive variables, we have discussed the selected hue ranges in relation to other color proposals of Le Corbusier himself, and we have shown the extensive presence of earthy hues, or the noteworthy absence of other colors such as yellows, violets, black, and white. We have also analyzed the chromaticness of colors, which is generally low, and the blackness, also very limited. In relation to the combination criteria, we aim to find out the underlying order in the color combinations by studying the similarities and contrasts of their perceptive variables. We demonstrate graphically, by a navigable three-dimensional model, and with statistical support, some principles in Le Corbusier's color preferences, such as the combination of colors with equal chromaticness, the search of some contrast in blackness, or the usual resource of contrasting cool with warm colors, something slightly different to the contrast of complementary colors. We have also discussed other compositional criteria held by Le Corbusier to use color in his Purist architecture, which are related to the position and proportion of the surfaces to be colored, the connotations associated to different hues, or the use of plain colors, among others. © 2015 Wiley Periodicals, Inc. Col Res Appl, 41, 85–100, 2016; Published Online 28 January 2015 in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/col.21940

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## PROBLEM

Modern architecture developed between 1920 and 1960 was erroneously identified with the almost exclusive use of white color, and it was exemplified with the Purist architecture of Le Corbusier.<sup>1</sup> However, not any building by Le Corbusier was only white, anyway.<sup>2</sup>

Le Corbusier studies the architectural color with much interest, and he uses it in his work in a very appropriate way. In 1931, the Salubra wallpaper company, based in Basel (Switzerland), commissioned him to make a first color chart collection for architecture which is completed in 1959 with a second version. The first of these collections was thought as a harmonic series, in a similar way to the distribution of the sounds in a piano, and hence its designation as *claviers de couleurs*.<sup>3</sup> In 1997, both color collections, Salubra 1931 and 1959, are reissued together with Le Corbusier's unpublished text *Polychromie architecturale*, dated between late 1932 and early 1933.<sup>4</sup> This is, without doubt, the most important document for understanding the color in the work of the Swiss architect.

There are several authors who have carefully studied the Salubra color collection: Caivano explains its organization and use; Colli explains the order of colors in the claviers<sup>5</sup>; Ruegg analyzes in depth the charts along with the text *Polychromie architecturale*; and de Heer<sup>6</sup> develops a thorough study of the color aspects in the writings and the Purist architecture of Le Corbusier, showing the high degree of freedom in the final color solutions in his buildings beyond the Salubra color keyboards.

However, there is a matter that has not been worked so far, which consists of an analysis of the combinations of

\*Correspondence to: Juan Serra (e-mail: juaser11@ega.upv.es)

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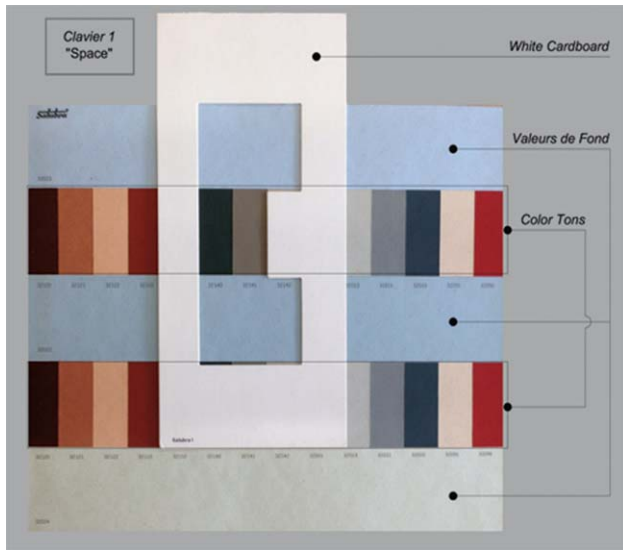


Fig. 1. Photo of one of the *claviers* of the Salubra 1931 color collection, indicating the *valeurs de fond* and the *Color Tons*.

the selected colors in the keyboards, by using a standard color notation space as NCS, and which allows us to understand the perceptive characteristics of colors and their combination criteria. We aim to unravel the underlying order in the color combinations of the Salubra *claviers* by studying their perceptive variables in NCS: *hue*, *blackness*, and *chromaticness*.<sup>†</sup>

This analysis is consistent with Le Corbusier's thought, at least during his Purist period, in which this collection of colors belongs. He believed that beauty in architecture responded to a series of universal laws based on numbers, which could be known and studied.<sup>7</sup> In fact, the architect developed a system of numerical proportions for the architectural elements based on the golden ratio and on the measures of an ideal person, known as *The Modulor* (1948 and 1953).<sup>8</sup> In this regard, his approach to the ideal beauty is linked to what we can consider a *positivist* paradigm, and it is based on rational criteria of order and proportion.<sup>9</sup>

Le Corbusier does not conceive the Salubra charts as an open system that could serve to combine any color of nature. Instead they are a sort of *manual*, very well delimited, with only 43 colors, which all have guarantees to be "appropriate for architecture" and which he determines how to combine. Le Corbusier does not search for a classification system for all possible colors, but rather an instrument to restrict them and guarantee their suitable combinations. Hence, the color charts are made in the manner of a piano keyboard, in which the keys are limited but provide the basis of any musical harmony.

<sup>†</sup>More information to understand NCS can be found at <http://www.nescolour.com/en/>.

In any case, Le Corbusier limits the leeway to choose the architectural colors according to a uniquely personal criterion of color combination, which can only be explained from his sensitivity as an architect and a painter, as well as from his desire to rationalize the most of his creative processes. Hence, our numerical approximation will not let us build a true "color Modulor," understood as an open and universal system, but it will let us a more accurate approach to some color combination rules pointed out by other authors regarding Le Corbusier's colors. For this purpose, we will rely greatly on Heer's work, which we consider very rigorous and well documented.

## EXPERIMENTAL METHOD

This study has been conducted from the documentation available at the Le Corbusier Foundation in Paris, where the original color charts were visually and technically evaluated (contact spectrophotometer Konica Minolta CM 700d, Munsell and NCS colorimeter).<sup>‡</sup> In the Foundation, we could access to the writings, letters, technical specifications of the buildings, and other graphic and written material, in which the architect reflects on the use of color in his study.

We focus on the first Salubra color collection from 1931, which is the culmination of the reflection on Purist polychromy and the searching for harmony laws. It expresses all those interests that Le Corbusier<sup>§</sup> and Ozenfant started to investigate 6 years before in their text *Nature et création*.<sup>10</sup> Both considered that beauty was based on the search for order and formal clarity.

There is a second version of the Salubra chart conceived and published in 1959, when the historical, personal, and artistic context of Le Corbusier has substantially evolved and he has abandoned much of the rationality of his initial thoughts. The second collection contains significantly fewer colors, and there is not a combination criterion for selecting them.

On the contrary, the first Salubra collection of colored papers (1931) has 12 different color charts named *claviers*, and provides an exact criterion to choose them, in groups up to four colors. These are some of the reasons why we have centered our research in this first Salubra collection from 1931 (Fig. 1).

Our methodology has consisted in extracting all possible color combinations in the collection, which ended up being 312 combinations of four colors (1248 pairs of colors), and to represent them in the three-dimensional (3D) color space NCS. This representation is a navigable 3D

<sup>‡</sup>In the cases where the time had deteriorated the original color samples available at Le Corbusier Foundation, like in the blue 32040, we have measured the color in the new version re-edited in 1997 as we consider it a very good reinterpretation of the original colors.

<sup>§</sup>We use the pseudonym *Le Corbusier* referring to the Swiss architect here to avoid confusion, but at the time of the text the Swiss architect used his real name Charles-Eduard Jeanneret. He started signing as Le Corbusier from 1925 onward.

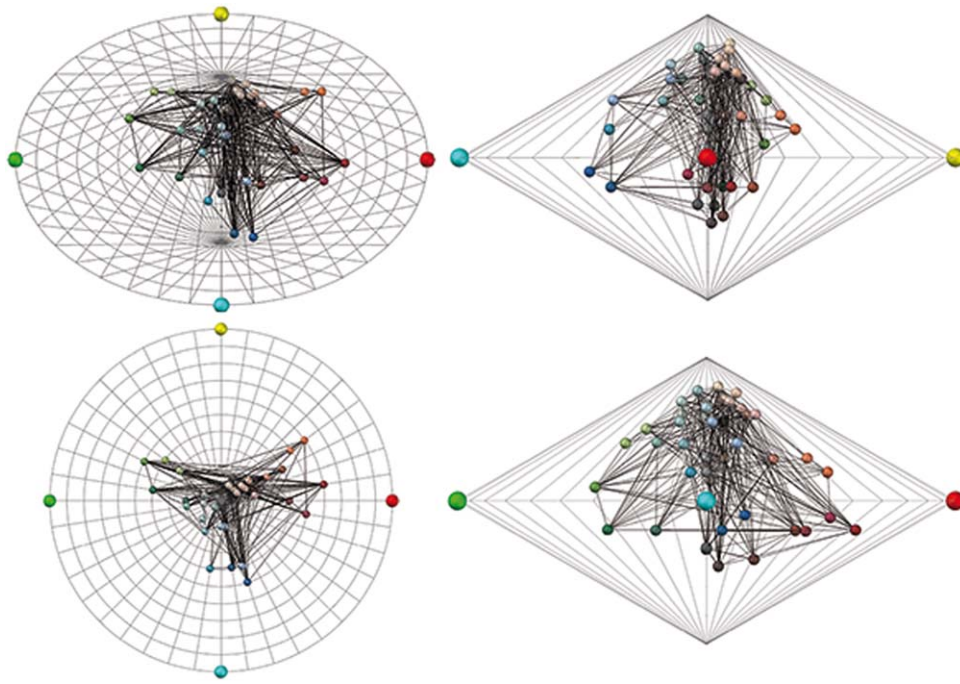


Fig. 2. 3D Virtual model with all Salubra pairs of colors in the NCS color space.

virtual model that can be observed from any point of view (Fig. 2). After that, we have made diagrams where we have carried out a visual and statistical analysis of the combinations, identifying whether there exist similarity or contrast criteria, this is, similarities or differences regarding the colors' NCS *hue*, *blackness*, or *chromaticness*. To process the information, we have used usual Cad software for architecture, Autodesk Autocad, as well as database management software, Microsoft Excel.

In a theoretical framework, the search of color combination criteria has been carried out by following the usual models of positivist paradigm, which are the closest to Le Corbusier's thought. On the one hand, the search of similarities among colors as proposed by Munsell<sup>11</sup> or later by Itten<sup>12</sup>; on the other hand, the search of balances between opposite forces, as claimed by Munsell, Chevreul,<sup>13</sup> or Goethe,<sup>14</sup> among others. We should mention Newton himself, who suggested that color harmonies rely on proportional order of colors, in a similar way to the mathematical principles that hold any musical composition.<sup>15</sup> It is true that all color-grouping models that are based on the similarities and contrasts have limitations, especially when they aim to give universal answers, valid for any context or any observer, as O'Connor<sup>9</sup> correctly advises.

Nowadays, the notion of *color harmony* is problematic because it assumes that an irrefutable causal link exists between color and human response, and that responses to color are universal and deterministic. This positivistic approach to color is no longer valid under the more recent postpositivistic paradigm. Now, it is accepted that responses to color are always open to individual differences, cultural, and social variations as well as contextual, perceptual, and temporal factors.

Le Corbusier's intention was not to predict the human answer to his color combinations, but to settle his own criteria for this color grouping, based on his personal preferences. In this sense, our aim is to understand better some color combinations that Le Corbusier himself already considered appropriate for architecture. To avoid further confusion, we will elude the term *color harmony* and just refer to *color combination criteria* in Le Corbusier's Salubra charts. In any case, it is difficult to make the mistake of considering the Salubra charts as the universal solution to the problem of color combinations in architecture when even Le Corbusier himself does not seem to use them in a strict way.

#### ANALYSIS OF THE PERCEPTIVE VARIABLES OF COLORS IN THE SALUBRA COLLECTION FROM 1931

##### Analysis of the Hues

The 43 colors of the first Salubra collection are organized into 12 charts named *claviers*. Each one of them consists of three background colors that we will name *valeurs de fond* by following Le Corbusier's nomenclature, and two horizontal strips of *color tons* placed in a sequence that resembles a keyboard. To facilitate the selection of colors, charts are accompanied by two white cardboards which allow isolating two *valeurs de fond* together with one or two *color tons*, so that the selected colors, with a maximum of four, should be observed isolated with a white cardboard. The fact that the cardboards are white is not a chance, and we will insist on the importance of white as a previous color, necessary for the architectural polychromy in Le Corbusier's thinking.<sup>16</sup>



Le Purisme (1918)			Noble range (1932)	Salubra I (1932)	Coloures Types (1951)	Salubra II (1959)
Large Gamma	Dynamic Gamma	Transition Gamma				
yellow			yellow		yellow	
	lemon-yell.					
Earthy colors				Yell. ochre	ochre	Yell. ochre
			Sienna	Sienna	Sienna	Sienna
				Brown		Brown
			Bunt sienna	shades	shades	shades
	Orange chr			Orange	Orange	
	Orange cadm					
Red ochre			Red ochre	Red ochre		
			Vermilion	Vermilion	red	Vermilion
			Carmine	Carmine		
			English red			English red
					Violet	
Ultramar			Ultramar	Ultramar	Ultramar	Ultramar
		Cobalt Bl.		Cobalt Bl.		
			Blue	Blue	Blue	Blue
	Emerald					
			Verones			
			Engl. Green	Yell. green	Yell. green	Yell. green
						Greenish Yell.
white			white			white
				Greys	Grey	Grey
Black			Black			

Fig. 3. Color ranges pointed out by Le Corbusier in different moments.

Nor it is a coincidence limiting the maximum number of colors selected to four as we will discuss later as well.

In the different color charts, it seems evident that the *valeurs de fond* give the “pitch” to each *clavier*, and they are somehow linked to the names that identify them: Space; Sky; Velvet I and II; Masonry I and II; Sand I and II; Landscape; and Checkered I, II, and III. By means of an associative mechanism, the *valeurs de fond* are linked to a concept, an idea of secondary order. Thus, the blue colors are associated with the concepts of “Sky” and “Space,” the ochre colors with the “Sand,” the red ones with “Masonry,” and the green ones with “Landscape.” This associative role of color is evident in projects like the Housing State in Pessac (1931), where green is linked to the idea of a distant forest or a vegetal roof, blue to the sky background, and red is used to “fix” the façade as a *masonry* and to strengthen its presence.

All 43 colors in the original Salubra collection derive from 14 initial colors, which we will call *main colors*. From each one of these *main colors*, Le Corbusier obtained several extra nuances<sup>§</sup> by adding white pigment and moving the *main colors* to a softer version with just three or four steps. Hence, we find groups of colors which

<sup>§</sup>Following the NCS System notation, the *nuance* is the percentage of blackness and chromaticness of a color. In the text, we use the term *nuances* to refer to those colors with different NCS *blackness* and *chromaticness*, but originated from the same *main color*: Carmine, Vermilion, Cobalt blue, and so on. For example, we find that Salubra color chart has five *nuances* for Ultramarine *pigment-hue* family: 020, 021, 022, 023, and 024. Not all these colors belong to the same NCS *hue*, but all of them are obtained adding white to the *main color* Ultramarine blue (020). We will talk about *pigment-hue* family to avoid further confusion.

are originated from the same *main color*, and we will say that they belong to the same *pigment-hue* family (Cobalt blues or Vermilion-reds, for example). Each of the colors of the original Salubra collection was denoted by a three-digit number, corresponding with the *main colors* the following notations: 001, 010, 020, 030, 040, 050, 060, 080, 090, 100, 110, 120, 130, and 140. The units of each reference number approximately indicate the color nuance, whereas the tens and hundreds identify each of the 14 *pigment-hue* families\*\* (Fig. 5). Following Colli’s designation for each *pigment-hue* family, we will use the following names<sup>‡</sup>: ≈White<sup>‡‡</sup> (first two digits 00: 001), Grays (first two digits 01: 010, 011, 013), Ultramarine blues (first two digits 02: 020, 021, 022, 023, 024), Cobalt blues (first two digits 03: 030, 031, 032, 033, 034), Veronese greens (first two digits 04: 040, 041, 042), Yellowish green (first two digits 05: 050, 051, 052, 053); Yellow Ochre (first two digits 06: 060); Oranges (first two digits 08: 080, 081, 081), Vermilion-reds (first two digits 09: 090, 091), Carmine-reds (first two digits 10: 100, 101, 102), Red Ochre (first two digits 11: 110, 111, 112); Sienna (first two digits 12: 120, 121, 122, 123), Brown (first two digits 13: 130, 131), and *Shadows*<sup>‡‡</sup> (first two digits 14: 140, 141, 142, 150).

Selecting these 14 *pigment-hue* families and not any other, Le Corbusier wants to avoid colors that are not fully “architectural” which can neutralize the visual effect of architectural forms. In relation to the easel painting, Ozenfant and Le Corbusier prioritized volumes and the drawing of shapes against color, and they wanted to avoid the destructive character of color which they criticized in other artistic movements such as *De Stijl*. Also, in architecture all impressionist effect of color that could distort the geometry of pure forms should be avoided.

### Present Colors

In the text, *Le Purisme*,<sup>17</sup> prior to the first Salubra color collection, Ozenfant and Le Corbusier describe the three ranges of color for easel painting. The first is the *large gamma*, containing all those *constructive* colors that were used by the great painters of the history of art, from Michelangelo or Ingres, through Seurat or Cezanne, to the Cubists Picasso and Gris. These are well-liked painters because they all, from Le Corbusier’s view, subordinated color to drawing and gave priority to the shape modeling by means of the *chiaroscuro*. In Le Corbusier’s

\*\*Note that colors belonging to the same *pigment-hue* family still can have characteristically different NCS hues, and also colors from different *pigment-hue* families can have the same NCS hue.

<sup>‡‡</sup>Colli calls this first color “white” although it does not belong strictly to the NCS Neutral colors (S0510 Y30R). To avoid confusion, we call this *pigment-hue* family with just one member “≈White.” We discuss later the absence of an authentic white color in Salubra charts.

<sup>‡‡</sup>We keep Colli’s designation for the last *pigment-hue* family *Shadow* although these colors have NCS chromaticness percentages and are not strictly NCS neutral colors. To avoid confusion, we will write this term starting with a capital letter and italics.

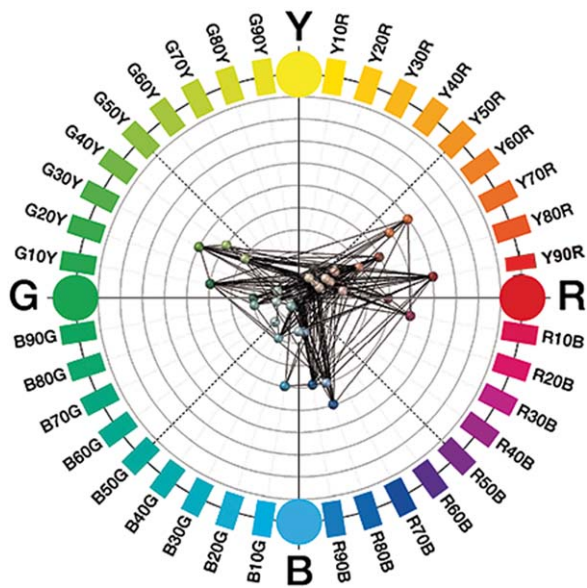


Fig. 4. All Salubra pairs of colors plotted in the NCS color circle.

thinking, they all opted by the *disegno* versus the *colore*, reinforcing the opposition between these two concepts, which was started in the Renaissance with Vasari and was extended till the end of the 19th century in France. The *large gamma* includes Yellow, Red Ochre, Earthy colors, White, Black, Ultramarine, and the colors originated from those. The second is a *dynamic gamma* and, different from the previous one, it contains colors that are not “static” but give the impression of continuous change of plane. The Lemon-Yellows, Oranges (Chrome and Cadmium), Vermilion, Veronese Green, and light Cobalt Blue belong to it. The third is a *transitional gamma* that contains the Emerald Green and all Enamel colors, without constructive characteristics. Le Corbusier suggests that he just wants to use the *large gamma* (Fig. 3).

In the text, *Polichromie Architecturale* (1931) which accompanies the first Salubra color charts, the criteria for selecting colors also reflects a desire to restrict them to only those which are “truly architectural,” but this time Le Corbusier talks about the selection of a *noble range*<sup>18</sup>: White, Black, Ultramarine, Blue, English Green, Yellow Ochre, Natural Sienna Earth, Vermilion, Carmine, English Red, and Burnt Sienna Earth. Therefore, the initial distinction among the three ranges of color is abandoned and it can be seen that in the Salubra 1932 collection, Le Corbusier adds to the *large gamma*, some colors belonging to the *dynamic gamma*, that is, the *agile, restless gamma*, which gives the sensation of continuous change.

If we look at the 43 selected colors existing in the first Salubra, we see that approximately the half of them (17) belong to the NCS hues included between R80B and G40Y, that is, cool colors, and the other half (17) belong to the families located between NCS Y30R and R10B, that is, warm colors. Grays and *Shadows* (9) would be apart from them. We must note that warm ranges include only six NCS hues, organized around the Y80R red,

whereas cool ranges contain twice the number of NCS hues, six around the R80B blue, and six around the G30Y green. Hence, warm colors that are too close to yellow or violet are avoided (Fig. 4). As we will discuss later, the opposition between cool and warm hues was important in Le Corbusier’s thinking.

In addition, the warm ranges that Le Corbusier selects are mostly brownish and grayish, that is, tertiary colors corresponding with low percentages of NCS *chromaticness*. These colors can be explained by Le Corbusier’s desire to link them with natural pigments. For Le Corbusier, these colors extracted from earth are those that have accompanied architecture since its origin. They are “eternal” colors and differ from the chemically synthesized pigments, and hence popular in the paintings of the second half of the 19th century and which he considered too chromatic and nonarchitectural. However, recent research of historical centers of many cities, at least in the Mediterranean arc, show that traditional architecture contained widest ranges of NCS hues, with more yellowish hues, close to the Y30R or Y40R NCS hues, and generally with less *blackness*.<sup>19</sup>

### Absent Colors

It is interesting to observe not only the selected colors existing in the first Salubra collection, but also the absent colors. One of them is black, which is replaced by other colors, quite dark, but that actually belong to other *pigment-hue* families: Brown and Sienna. There are four grayish *pigment-hue* colors, but just two of them strictly belong to the neutral colors *N* in NCS nomenclature (011, 012). These four grayish colors have different percentages of blackness (20, 35, 40, and 65); however, the most blackness percentage belongs to a color Brown (130) corresponding with NCS Y80R hue.

The absence of white is also striking, being the most similar the 001, which is a yellowish color with NCS Hue Y30R. The white color is absent precisely because it has an exceptional status. White is previous to polychromy, it is the necessary color to purify the look toward the architectural form as Wigley<sup>20</sup> states. Le Corbusier thinks that the white color is the necessary background for all other colors to take their meaning. Hence, he says about the Villa Albert Jeannerette (Paris, 1923–1925): *The base will be white; but we will paint two of the walls pale pink (clear burnt Sienna earth), another one opposite, pale green; the rest white, the ceiling white*.<sup>12</sup> The white color is the one of the stucco which is applied directly to the ceilings and walls, that is the reason why it is not necessary to include a white-painted paper in the Salubra collection. We note again that the cardboard used to select the *color tons* is white, and not a medium gray as it should be advisable to avoid the phenomenon of simultaneous contrast when observing a color. The architectural polychromy must be observed over the white color, but we can still go further as Le Corbusier not only mentions the white as the necessary

Color Id.	Pigment-Hue Family designation (M. Colli)	NCS Notation	Number of times combined	Claviers where this is a valeur de fond (times combined as a valeur de fond)
001	≈White	05 10 Y30R	110	Velvet 1, 2 and Variegated 3 (78)
010	Grays	65 02 B	22	
011	Grays	40 00 N	41	Variegated 1 (13)
012	Grays	35 00 N	26	Velvet 1, 2 (26)
013	Grays	20 02 G50Y	50	Velvet 1, 2 (26)
020	Ultramarine blues	30 50 R80B	27	Variegated 3 (13)
021	Ultramarine blues	10 30 R80B	18	
022	Ultramarine blues	15 15 R90B	30	Space (26)
023	Ultramarine blues	10 15 B	17	Space (26)
024	Ultramarine blues	08 04 B50G	25	Space (13)
030	Cobalt blues	40 40 R90B	34	Variegated 1 (26)
031	Cobalt blues	20 40 B10G	4	
032	Cobalt blues	20 20 B30G	34	Sky (26)
033	Cobalt blues	15 15 B50G	25	Sky (13)
034	Cobalt blues	10 10 B90G	19	Sky (13)
040	Veronese greens	50 20 G	14	
041	Veronese greens	20 20 B90G	14	
042	Veronese greens	15 10 G20Y	12	
050	Yellowish greens	40 40 G10Y	21	Variegated 3 (13)
051	Yellowish greens	20 50 G30Y	40	Landscape (26)
052	Yellowish greens	10 40 G40Y	17	Landscape (13)
053	Yellowish greens	10 30 G40Y	25	Landscape (13)
060	Yellow Ochre	05 15 Y30R	26	Sand 1, 2 (26)
080	Oranges	10 60 Y60R	8	
081	Oranges	10 50 Y60R	4	
082	Oranges	05 15 Y60R	30	Sand 1, 2 (26)
090	Vermilion reds	30 60 Y90R	27	
091	Vermilion reds	10 10 Y70R	52	Wall 1 and Wall 2 (26)
100	Carmine reds	40 40 R	18	
101	Carmine reds	30 50 R10B	12	
102	Carmine reds	10 20 Y90R	14	
110	Red Ochre	40 40 Y70R	37	Variegated 2 (13)
111	Red Ochre	20 30 Y70R	14	
112	Red Ochre	10 15 Y70R	52	Wall 1 and Wall 2 (26)
120	Sienna	60 20 Y80R	43	Variegated 2 (26)
121	Sienna	30 30 Y70R	43	Variegated 2 (13)
122	Sienna	10 20 Y60R	80	Wall 1 y Wall 2 (52)
123	Sienna	10 10 Y50R	12	
130	Brown	70 05 Y80R	25	Variegated 1 (13)
131	Brown	30 10 Y50R	60	Sand 1 and 2 (52)
140	Shadows	65 02 Y	22	
141	Shadows	40 05 Y20R	19	
142	Shadows	20 05 Y40R	23	

Fig. 5. Colors sorted by pigment-hue families, showing NCS notation, the times that they appear in the 312 combinations of four colors, and if the color is a valeur de fond in any clavier.

background, but also as the purpose itself, of all the architectonic color organization. In this sense, Le Corbusier notes about the *Pavilion de L'Esprit Nouveau* (1925): *the calcimine shines through the wall surface that is dark (burnt or natural terra-umbra), through a wall that is warm (ochres), through a wall that yields (blues, etc.).*<sup>21</sup> In this statement, it seems that Le Corbusier wants to work like the Impressionist painters, who arranged color accents around the white to emphasize its luminosity.

Also, we note the absence of several color families, corresponding to greenish yellow and orange yellow, whose nomenclature would correspond with numbers 06 and 07 in the Salubra notation. Indeed, there are no colors between NCS hue G40Y and Y60R, with the exception of four *Shadow* colors (060, 140, 141, and 142). It seems as if Le Corbusier moves *cadmium yellow* ranges to earthy ones, rather dark, and *greenish yellow* ranges to *hardly yellowish green* ones. There is also an apparent absence in the hues located between R20B and R80B,



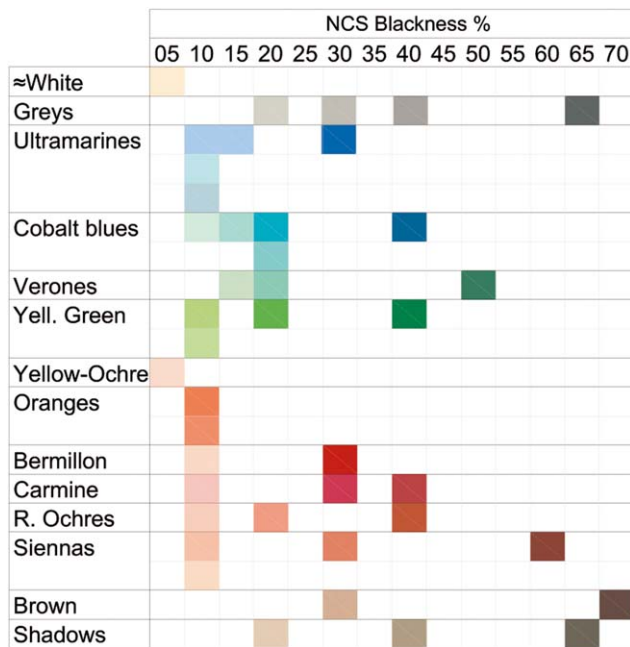


Fig. 6. NCS blackness for each Salubra color.

that is, the violet colors, which are rejected from the Purist architectural consideration.

In 1951, Le Corbusier corrects these absences of hues in his new color palette, *the types couleurs*, which he used in the *Unité d'Habitation*, the Swiss Pavilion, or other buildings.<sup>§§</sup> In this palette, all colors of the spectrum are represented, including chromatic yellow, violet, and black (Figs. 3, 5). When the second Salubra color collection is published, 8 years later, some of these colors that were absent in 1931 appear in 1959: black (4320E), cadmium yellow (4320W), which belongs to the NCS hue Y10R, and also a yellowish green NCS hue G80Y with big percentage of *chromaticness* (4320F). In general, the new Salubra colors move their nuances toward more NCS *blackness* and *chromaticness* percentages. Soft colors are abandoned and substituted for bolder ones.

As Rugg<sup>4</sup> notes, Le Corbusier's architecture that belongs to the period after the Second World War is dominated by a strong coloration, sometimes in the form of *color accents*. The pure black color is now located close to the white, when, at the beginnings, it hardly appeared as a surface (except certain floors made with black tiles) and, in general, the textures of materials start to become important. Definitely, it is an evident evolution of architectural polychromy, which becomes less rigid and more expressive.

### NCS Blackness Characteristics of the Colors

Most of the colors belonging to the Salubra 1931 collection have a low NCS *blackness* percentage, between 10 and

<sup>§§</sup>In the color palette for the *Maison du Pelerin* in Ronchamp (FLC 01–7), two *cadmium yellow* nuances are shown, together with a *blue ultramarine* and a *gray* color that have nothing to do with the scarcity of *yellow* colors in Salubra I.

30% (30 colors) or close to 5% (3 colors). The remaining 10 colors are between 40 and 70% in NCS *blackness* (Fig. 6). As noted above, there is no pure black color nor a pure white, being the least NCS *blackness* percentage 05 for the ochre 001 (0510 Y30R), and the most *blackness* percentage 70 for the brown 130 (7005 Y80R). The latter is followed in NCS *blackness* by the colors belonging to *Shadow*, *Brown*, *Sienna* and *Gray pigment-hue* families, to which we can add the Veronese green.

We have already noted that in Salubra 1931 collection each *pigment-hue* family is formed from a *main color* to which white color has been progressively added to obtain two or three nuances. Thus, we note that for each of the 14 *pigment-hue* families, Gray, Ultramarine, Cobalt, Veronese green, and others, the most *blackness* percentage always corresponds to the *main color* (010, 020, 030, 040, 050, 060, 080, 090, 100, 120, 130, 140). In no case, nuances have been obtained adding black to these *main colors*. In addition, these *main colors* end up being the most *chromatic* of each *pigment-hue* family, in the most of cases. For example, there is no color with more NCS *chromaticness* or *blackness* than the 100 Carmine itself, no Cobalt blue color with more NCS *chromaticness* or *blackness* than the 030 blue itself, being both *main colors* of their respective *pigment-hue* families.

Heer<sup>6</sup> questions the reason that Le Corbusier does not mix *main colors* with black pigment, but he does with white, and he notes that it could be a residue of the impressionist painter's idea that black color is not in nature as such. But he also points to the fact that, in architecture, colors may already be "darkened" if we arrange them in a dimly illuminated area, by the effect of the shadows cast and the light interacting with the volumes. Obviously, this is true but we must not forget that, on the contrary, an increased area of color itself tends to reduce its NCS *blackness* to the observer.

It seems that Le Corbusier did not differentiated between perceptive variables of color such as *chromaticness* and *blackness* when making up his color ranges. Hence, the variations in NCS *chromaticness* and *blackness* among the colors of the same *pigment-hue* family are the direct consequence of adding different proportions of pigment white to the *main color* of such a color family. The result is that the color with most NCS *chromaticness* and *blackness* in each *pigment-hue* family is the *main color*.

### NCS Chromaticness Characteristics of the Colors

In general, colors belonging to the Salubra 1931 collection have low NCS *chromaticness* (Fig. 7). The highest percentage of NCS *chromaticness* is 60% and it corresponds to the 090 Vermilion-red and to the 080 Orange, and are followed by the *main colors* for Carmine, Veronese Green, Yellow Green, and Ultramarine blue *pigment-hue* families, with NCS *chromaticness* of 40% (020, 051, 081, 101). Only 12 colors have a NCS *chromaticness* placed between 40 and 60%. The other colors (29), have a NCS *chromaticness* equal to or lower than 30%, and

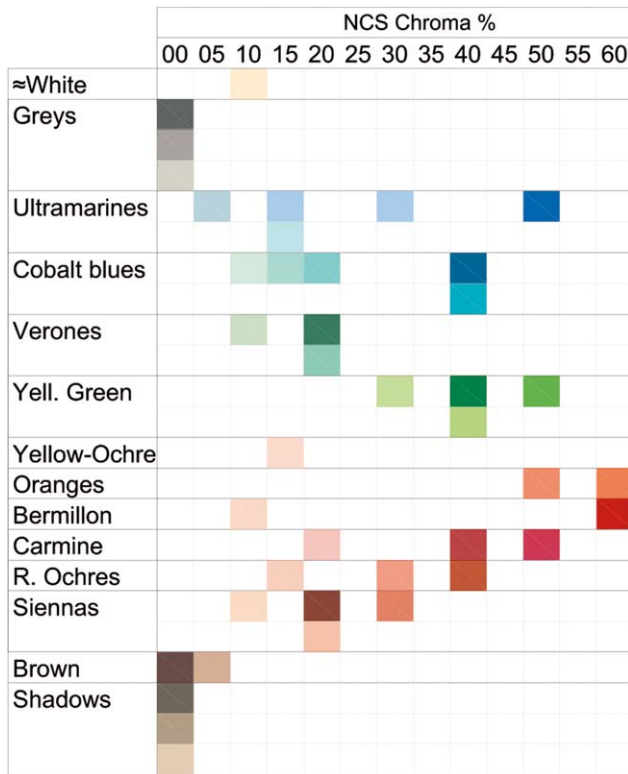


Fig. 7. NCS chromaticness for each Salubra color.

they include the *main colors* of Sienna, Earth, and Brown families, as well as the ranges of Gray colors which have a NCS *chromaticness* percentage equal to 0%.

If we pay attention to the two colors with highest NCS *chromaticness* percentages, we can notice that the 090 Vermilion is very recurrent in the *claviers*, being only absent in three of them (Velvet I, Wall I, and Sand I), whereas the 080 orange is used only in three cases (Velvet II, Sand II, and Variegated III). The other Orange colors, 081 and 082, have even a minor role, as they only appear in Velvet II accompanying the 080. Hence, the ranges of warm colors in the *claviers* are formed using Carmine (100) and Vermilion (090) reds as the outstanding colors, that is, with the most NCS *chromaticness*, and avoiding the Oranges. In the case of cool ranges, the colors with the most NCS *chromaticness* are Green (051) and Ultramarine (020), but the recurrence of one over the other is not significant.

## COLOR COMBINATION CRITERIA IN THE SALUBRA COLLECTION FROM 1931

### Color Combinations Based on the Hue Similarity

We have represented in a graph all color combinations, taking colors in pairs from the 12 Salubra *claviers*. In the abscissa and ordinate axis, we have located the 43 available colors, organized in the 14 *pigment-hue* families. We have made circles of different diameters, with a number indicating how many times each color combination appears in the whole of the charts (Fig. 8), giving an idea of the

recurrence of each pair of colors. The pairs formed by two colors from the *valeurs de fond* are represented separately and considered apart from the remaining combinations as these pairs of *valeurs de fond* are far more numerous. In the graph, we mark with a striped gray the geometric place for those combinations with the same NCS *hue*.

If we observe the combinations based on the similarity of NCS *hue*, looking at this graph, it is evident that a large number of them are in the area close to the diagonal, that is, most of these combinations happen between colors that belong to the same NCS *hue*. This is so especially in those pairs formed by two *color tons*. When a *color ton* and a *valeur de fond* take part, the dispersion is slightly higher. Hence, we can state that the first criterion of combination for Le Corbusier is to use colors with similar NCS *hue* or belonging to the same *pigment-hue* family, especially in the pairs of *color tons*.

It is interesting to observe certain combinations between *pigment-hue* families that are little recurrent or nonexistent. Thus, among the blue colors, those belonging to the Ultramarine family are almost never combined with the Cobalt blues, and exceptionally a blue with a green. The combination of blue colors with Oranges and Carmine-reds is not usual either, using instead the Vermilion-red colors, or others such as Ochre, Sienna and *Shadows*.

In the case of green colors, we can observe combinations between two *pigment-hue* families, the Veronese green, which is more bluish, and the Yellowish green, and of course the pairs of green colors belonging both to the same *pigment-hue* family. The combinations of green colors with Sienna, Ochre, Vermilion-reds, and Carmine-reds, and exceptionally with *Shadows* or Brown, are also frequent. In addition, the ranges of Yellowish green seem to be preferred against Veronese green although this is largely because of three yellowish green *pigment-hues* being selected as *valeurs de fonds* in the “Landscape” keyboard. If we pay attention only to the pairs consisting of two *color tons*, there is no combination between the Yellowish green and the Vermillion-red or Orange *pigment-hues*. It seems that together with the warm green colors (Yellowish greens), the Carmine, which is a cooler red, is chosen, and not Vermilion: a preference for a subtle warm-cool contrast enhancement.

The colors of the Orange family are combined together, and with Carmine, Ochre, some Gray colors, Ultramarine blues, and Veronese greens, but always between nuances with little NCS *blackness*. We have already stated above, the little recurrence of these ranges of Orange colors, compared to the much more important role for the Vermilion and Carmine reds, both as a counterpoint to the cool ranges.

It is noted that the colors of the red families are the most versatile as they are combined with nuances of all other *pigment-hue* families, and there is more presence of Vermilion-red colors than Carmine ones. Carmine color, which is more bluish, is reserved as a counterpoint to the oranges and the Yellowish-greens, which are warmer than the Veronese greens: again a preference for a subtle warm-cool contrast enhancement.



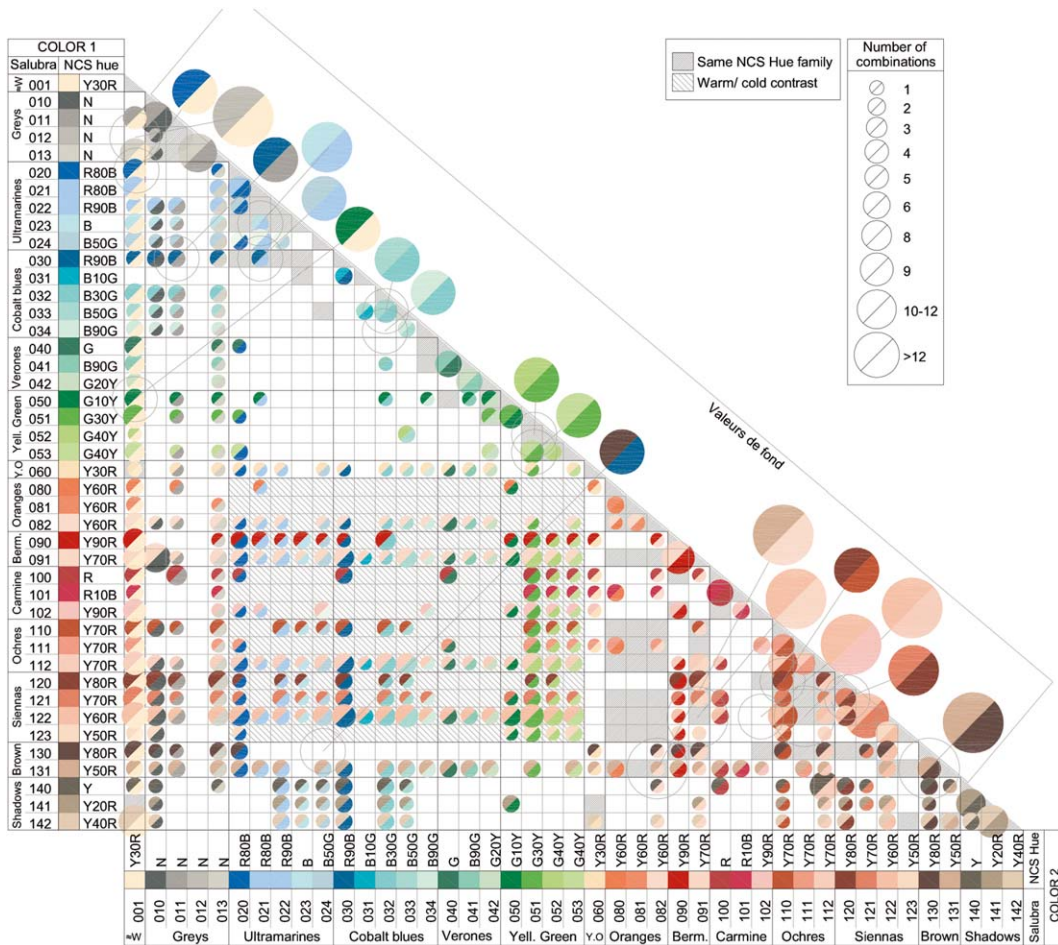


Fig. 8. All Salubra pairs of colors, showing the number of combinations, and the geometric space for the same NCS hue pairs and the complementary pairs of colors.

For the other earthy pigment-hue families (Ochres, Siennas, Brown, and Shadows), the most frequent combinations, as in previous cases, happen between colors of the same pigment-hue family, except in the case of the numerous *claviers* where they are used as *valeurs de fond*. Ochre and Sienna are combined with all other pigment-hue families, and to a much lesser extent, with Carmine reds and Oranges. For example, we never observe a combination of Sienna with Oranges. Shades and Brown colors are also combined with all the rest of the pigment-hue families, being more exceptional the pairs of Green with Orange colors.

We can conclude that the combinations based on two colors belonging to the same pigment-hue family are common in the first Salubra charts especially if we consider the pairs of two *color tons*. This is particularly significant for the Orange, Veronese green, and even Carmine red pigment-hue families for which it seems to be the most preferred color combinations criterion. On the contrary, as a counterpoint to the Vermilion-red and Orange colors, a cool green (Veronese green) is preferred, and as a counterpoint to the Carmine reds, which are cooler than Vermilion, the Yellowish greens or Oranges are preferred.

### Color Combinations Based on the Hue Contrast

One possible criterion of color combination lies in the use of complementary colors. Chevreul, Goethe, Munsell, or Itten studied this principle of harmony that had great influence on the Impressionists and Postimpressionist painters, such as Signac or Seurat. Le Corbusier certainly should have been aware of these principles of color complementarity, but his Salubra charts are not made up with an ordered system of colors where we can observe the existence of opposite or complementary colors following Itten's criteria: red-green, blue-orange, and yellow-violet. Among these complementary pairs, the yellow-violet has to be rejected as there are no violet hues in Salubra charts. The orange-blue could be a bit significant and the red-green the most, but Le Corbusier's combinations seem not to be selected by searching a strict opposition between complementary colors.

They also do not fit with the opposing color pairs that underlay the construction of the NCS color space: red-green, blue-yellow, and black-white. If we project the Salubra colors and combinations on a two-dimensional (2D) plane, just a few lines cross the figure exactly through the center (Fig. 3). The connection between the

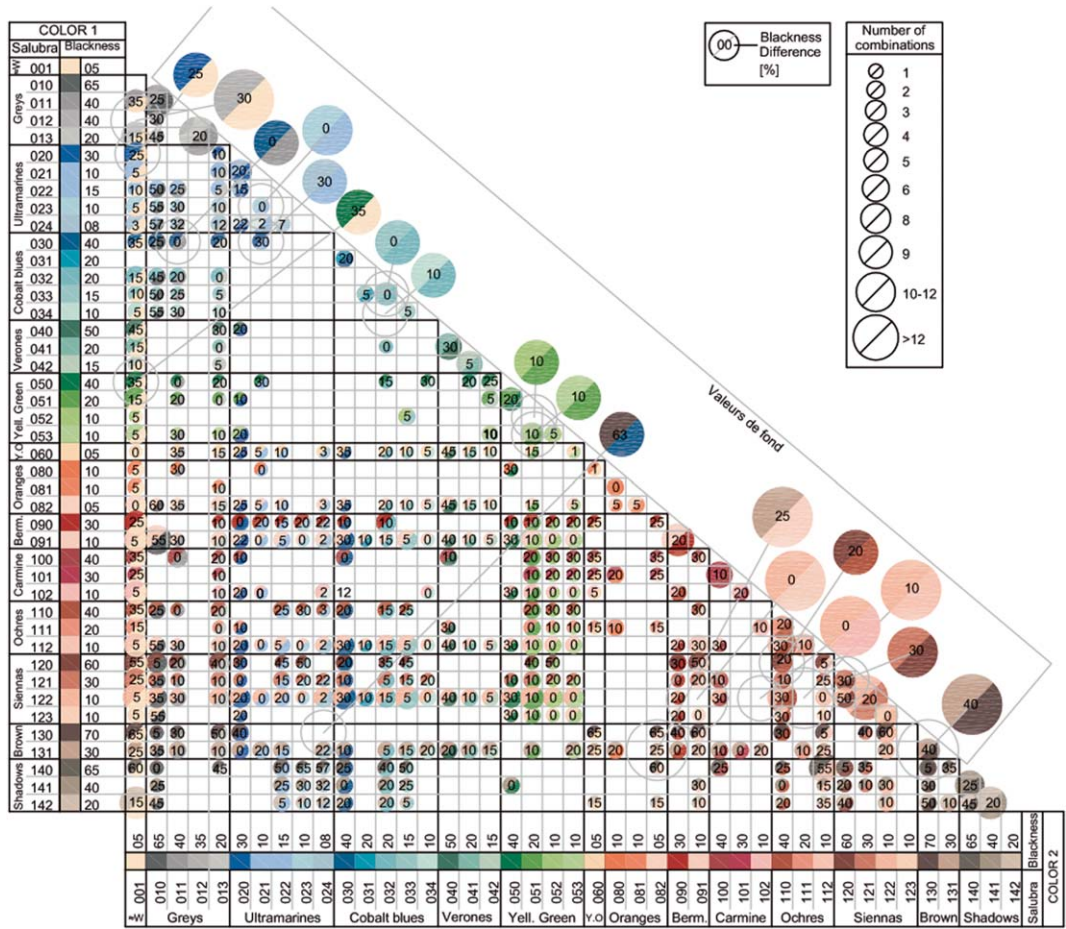


Fig. 9. All Salubra pairs of colors, showing the difference of NCS *blackness* among them.

Salubra colors draw a figure with a similar geometry to triangles, with a series of vertexes linked with the *main color* of each *pigment-hue* family, those colors with the most NCS *chromaticness* and *blackness*.

Nevertheless, it seems that there exists a criterion of color combination that seeks the balance between cool and warm colors, rather than a strict criterion of complementarity or perceptual opponent pairs. Heer<sup>6</sup> claims that blue and red constitute these basic pair of colors for Le Corbusier's, and they symbolize a contrast which goes beyond the pure optics and reaches psychological, associative, and architectural issues. Le Corbusier himself states that *Red (and its brown, orange, etc... combinations) fixes the wall, affirms its exact position, its dimension, its presence. Moreover, to blue are attached subjective sensations, of softness, calm, of water-landscape, sea or sky. To red are attached sensations of force, of violence. Blue acts on the body as a calmative, red as a stimulant. One is at rest, the other is action. [...] The classification into two large categories of warm tones and cold tones brings order: every color (tone & value) heads either towards the light side (warmth, gaiety, joy, violence), or towards the shadow side (freshness, serenity, melancholy, sadness).*<sup>12</sup> It should be noted that this duality between two opposite colors, red-blue, in terms of light-shadow, warmth-freshness, happiness-

serenity, joy-melancholy, violence-sadness, is a literal translation of Goethe's<sup>22</sup> theory of color and his pair of opposite colors, yellow-blue, to which he assigned the qualities of distance-proximity, power-softness, repulsion-attraction, and others. Le Corbusier simply replaces Goethe's yellow by the red.

The balance between cool and warm colors explains properly the criteria for many of the existing combinations in the first Salubra collection. In Fig. 8, we can observe in a striped area, the geometric place of the combination with opponent cool-warm color pairs, and we find a large number of samples in it. We have considered as cool colors the *pigment-hue* families of Ultramarine blue, Cobalt blue, Yellowish green, and Veronese green; and as warm colors, the *pigment-hue* families of Orange, Vermilion-red, and Carmine red. These cool colors belong to the range between NCS *hue* R80B to G40Y, and the warm colors belong to the range between NCS *hue* Y30R to R10B. We do not include Brown and Shadows among the warm colors because, although they may have a significant proportion of red, they have low NCS *chromaticness*. Any of these dull colors combined with a cool hue would be more notable by its contrast in NCS *blackness* or *chromaticness*, than by its *hue* contrast. We consider them neutral colors, regarding the cool-warm opposition, along with Gray colors.



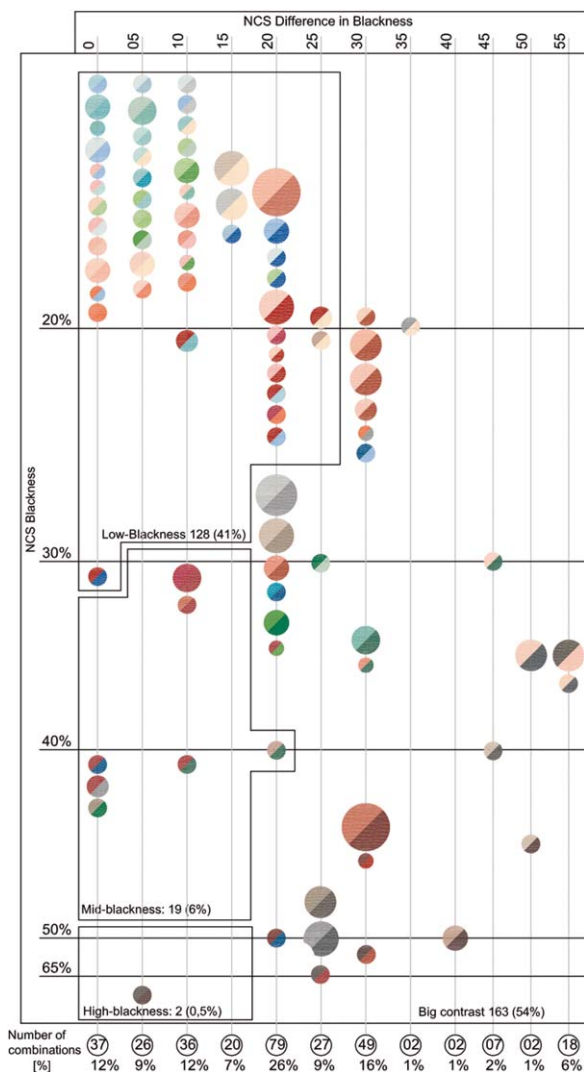


Fig. 10. Connection between the difference in NCS blackness and the medium blackness between the two color tons of all pairs.

In his study about Salubra charts, Colli<sup>5</sup> considered the nuances of the Yellowish green pigment-hue family as warm colors, whereas the nuances of the Carmine reds were considered as cool colors. Certainly, the Yellowish green is warmer than the Veronese green, and that explains why Le Corbusier prefers combining the Yellowish green with Carmine, which is cooler, and not with Vermilion-red, as noted above. But we consider both Vermilion and Carmine reds, warm pigment-hue families and both Yellowish green and Veronese-green, cool pigment-hue families. This is because the cool-warm color opposition in Le Corbusier is more conceptual than perceptive. If the red color matches with the role of “fixing the wall,” then this description adapts to both the Carmine and the Vermilion, and both have to be considered warm colors, despite the slight content of blue in the case of Vermilion. Examining the green colors, both the Yellowish green and the Veronese-green match with the concept of “giving space,” and they both have to be considered cool color families despite the slight amount of yellow in the case of Yellowish greens.

### Color Combinations Based on the Similarity or Contrast of NCS Blackness

NCS Blackness percentages of Salubra 1931 colors range from a minimum of 5% corresponding to the pigment-hue families  $\approx$ White (001), Yellow-Ochre (060), and Orange (080), to a maximum of 70% corresponding to a Brown color (130), so that the maximum contrast of blackness between two colors could be 65%. In Fig. 9, the NCS blackness difference for each of the pairs of colors present in the claviers is represented.

In addition, we have developed a detailed study about the contrasts of NCS blackness for the pairs of two color tons. In Fig. 10, we observe the difference in the NCS blackness percentages between each pair of colors in the abscissa axis ( $\Delta B$ ), and the NCS blackness percentage in the ordinate axis ( $B$ ). In the upper left part of the figure, we see the colors with the smallest NCS blackness percentage and equal NCS blackness percentage between them. The further to the right we look, the pairs with a higher difference of blackness we see, and the lower, the more blackness the combinations have.

We observe that most of the Salubra pairs respect a criterion of combination based on the contrast of chiaroscuro, having only 40% of the combinations an equal NCS blackness  $\Delta B$  [0, 15], whereas 51% have a high contrast of blackness  $\Delta B$  [20, 40], and 9% very high  $\Delta B$  [45, 60]. Hence, we can say that the contrast of NCS blackness between both colors is a criterion of combination used by Le Corbusier.

The combination of colors with similar NCS blackness can be organized, likewise, into three groups. (1) Pairs of colors with low blackness, where the blackness of both colors is  $B$  [0, 30] and which are 41% of the total. (2) Pairs of colors with mid blackness, where the blackness of both colors is  $B$  [30, 50] and which are 6% of the total. (3) Pairs of colors with high blackness, where the blackness of both is  $B$  [50, 70] and which are 0.5% of the total.

This result is not surprising since Le Corbusier believed that the visualization of architectural forms and its sculptural nature was expressed precisely, thanks to the modeling of the chiaroscuro. In the arrangement of the Purist form, the chiaroscuro has priority over the color. Also we should not forget that the colors of the claviers are intended to be part of an architecture that is assumed white, and to which it corresponds, therefore, 0 as the NCS blackness percentage. Over this background, hardly all combinations of colors are perceived as contrasting, regarding the percentage of NCS blackness, being those with high NCS blackness only 40% of the total.

### Color Combinations Based on the Similarity or the Contrast of NCS Chromaticness

NCS chromaticness ranges from a minimum 0% corresponding to the Gray colors, up to a maximum of 60% corresponding to the Orange colors, so that the maximum possible contrast of NCS chromaticness is 60%. In Fig.



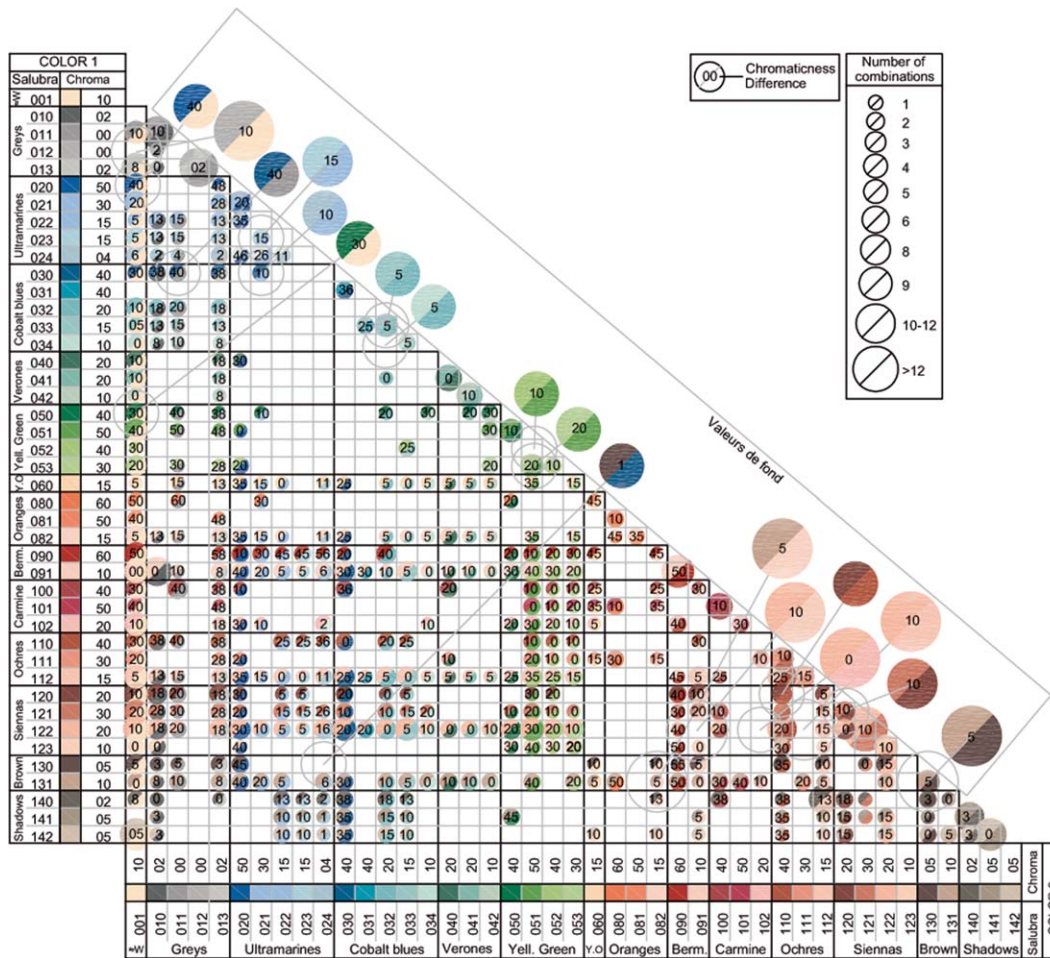


Fig. 11. All Salubra pairs of colors, showing the NCS *chromaticness* difference between them.

11, we observe the difference of *chromaticness* for each of Salubra color pairs.

In addition, we have developed a detailed study of the contrasts of *chromaticness* for the pairs of two *color tons*. In Fig. 12, we can observe, in the abscissa axis, the difference in NCS *chromaticness* of each pair of colors ( $\Delta C$ ), and in the ordinate axis, the *chromaticness* expressed as percentage (*C*). Hence, in the top left part of the figure, we see the color pairs with lower NCS *chromaticness* and equal *chromaticness* percentage for both colors in the pair. The further to the right we look, we find the pairs with more difference in *chromaticness*, and the lower we look we find the more *chromaticness* percentage of the colors.

We note that most of the pairs of *color tons* respect a criterion of combination based on the similarity of *chromaticness* between both colors. A total of 68% have a *chromaticness* difference  $\Delta C$  [0, 15] and only 10% have  $\Delta C \geq 40\%$ . Hence, we can say that the similarity in the NCS *chromaticness* between colors is a criterion of combination used by Le Corbusier.

Pairs with similar NCS *chromaticness* can likewise be arranged into three groups. (1) Pairs of *dull colors*, where the *chromaticness* of both is *C* [0, 30] and which represent 61% of the total. (2) Pairs of colors with *middle*

*chromaticness*, where the *chromaticness* of both is *C* [30, 50] and which represent 12% of the total. (3) Pairs of *high chromaticness*, where the *chromaticness* of both is *C* [50, 60] and which represent 2% of the total.

Hence, regarding the colors NCS *chromaticness*, Le Corbusier prefers the pairs of dull colors (with low *chromaticness*) and which are not opponent (similar *chromaticness*).

### Simultaneous Study About the Cool–Warm and the Chiaroscuro Contrast

In Fig. 13, the *color tons* of the 12 *claviers* are represented, showing in each one of them the percentage of NCS *blackness* and if they belong to the *cool*, *warm*, or *neutral hues*, as we have mentioned above. The purpose is to observe the inflection points in the percentage of *blackness* as well as the transitions between warm and cool colors. As if it were a sort of harmony line, we can note the presence of patterns, symmetries, or gaps, considering as well the *valeurs de fond*, which give an idea of the general “atmosphere” of the composition.

We note that when a *main color* is introduced, it usually is accompanied by others of the same *pigment–hue* family,

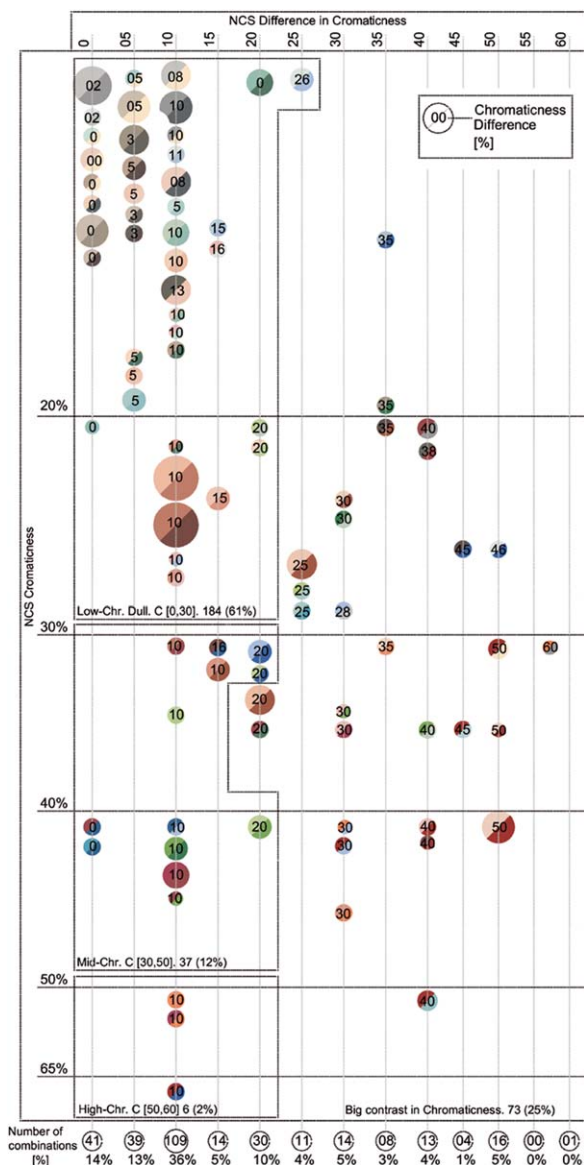


Fig. 12. Connection between the difference in NCS chromaticness and the medium chromaticness between the two color tones of all pairs.

drawing ascending or descending lines of two or three colors regarding the *chiaroscuro*. It is common, for example, the sequence of Sienna colors 120-121-122-123, or *Shadows* and Gray colors 140-141-142-001-013-011-010.

When we read them in a continuous way, these pieces draw graphs with peaks and valleys which sometimes are symmetrical as it occurs in “Space,” “Sky,” and “Velvet I,” and other times are perfectly ruled, as in “Velvet II.” In “Variegated III,” it is remarkable that the similarity of NCS blackness of a series of colors that belong to different NCS hue families, and which draw an approximately horizontal line: 091-001-034-102-021-080.

We also note that the Vermilion-red color (090) often serves to resolve the transition between difficult ranges or, as seen above, between those color pairs that are not preferred: it stands between the Cobalt blues and the Ultramarine blues in “Sand II,” as well as between the Sienna and the Carmine reds in “Landscape.” Also in

“Variegated III,” it stands between the Cobalt blues and the Sienna colors.

It is remarkable the scarcity of green and blue colors in *claviers* such as “Variegated III,” as well as among the *color tones* of those *claviers* where the *valeurs de fond* are cool colors, such as in “Space,” “Sky,” and “Variegated I, II, III.”

#### OTHER COMPOSITIVE CRITERIA TO PROVIDE COLOR IN THE ARCHITECTURE OF LE CORBUSIER

We have developed a study about the criteria of color combinations used by Le Corbusier in his first Salubra charts from 1931, regarding the NCS hue, blackness, and chromaticness, but the truth is that there is still a gap between the selected colors and the way they must be applied in architecture. In his writings, Le Corbusier does not clearly show this issue although it is possible to deduce some compositional criteria that seem to be respected. A comprehensive study in this regard exceeds our investigation, but we want to point out some general criteria for the composition of colors in the architecture of Le Corbusier.

First, we must insist on a key aspect, although it may seem obvious; it is the desire to limit the colors used in the buildings to just a small palette that is “truly architectural.” Le Corbusier wants to prevent the use of certain inadequate colors. In addition, these colors must be arranged with moderation as polychromy is always understood in a white-color architectural context.

We have pointed out the fact that the maximum number of colors to be selected in Salubra *claviers* with the white cardboards is four. If we consider a six-sided prism as the elemental space, which constitutes the Purist architecture, what Le Corbusier is implicitly pointing out is that at least two of these faces are assumed white and up to four colored (1/3 white and 2/3 in other colors). Heer argues that the Salubra colors were primarily intended for the four walls of a room, whereas the ceilings used to be white. That is, at least, what Le Corbusier indicates in projects such as *Villa Baizeau* (1928) or *Centrosoyus* (1928). Nevertheless, it is noteworthy that the cardboard area assigned to isolate the *valeur de fond* is twice as large as the one for the color ton (2/3 background color and 1/3 color ton). Ruegg points to the possibility that the color ton was reserved for secondary elements of the composition, and therefore it should be in smaller proportion than the *valeurs de fond*, but Le Corbusier does not talk about this issue at all. We have just found a short note describing the paint for the *Maison du Brésil* (1958), where it is indicated a proportion of 1/2 for white and 1/2 for polychromy, in which a maximum of 15% should be for “vivid colors,” in Le Corbusier’s own words. This ratio cannot be considered immovable as it is explained in the same text that the final proportion should be evaluated on site by Le Corbusier himself.<sup>11</sup> Hence, we can conclude that white is

<sup>11</sup>Monsieur Le Corbusier déterminant lui même sur place la distribution des différentes couleurs et ceci au moment où l’entrepreneur devra commencer les travaux, il est donc impossible de définir à l’avance avec







It is important to insist that one of the fundamental principles that govern Le Corbusier's polychromy is his desire to submit architecture to an accurate compositional order, so that the colors show a hierarchy in the interpretation of the different pure volumes that make up a building and help in the reading of architecture. Although the "blue is space and the red is fixing the space," we can understand many color operations, which are carried out to increase the spatial perception, limit the dimensions of the geometry, separate one volume from another, correct dimensional errors, or other shaping intentions.

We should not forget either the symbolic connotation that Le Corbusier matches to color, that is, the ability of linking ideas, so that the green may represent nature, the red a wall, or the blue the sky. This capacity of linking explains the presence of red colors on walls, which he wants to act as a limit to the perception of a space, and also the presence of green colors in the vegetal roofs of some villas, as well as in the ground floor of the *Ville Savoie* (1931) which camouflages with the vegetal background, or in the medians of the gardens of the Housing in Pèssac, to name a few.<sup>23</sup>

The use of *plain colors* and the renunciation of the color gradients that could alter the 2D character of the planes that make up the architecture can also be established as a basic compositional criterion. Despite the ability of color of moving forward or backward, Le Corbusier does not want to break the spatial box, but to introduce some tension in the *rectangle élastique*, following the term coined by Fernand Léger and rightly pointed out by Rüegg. This fact differentiates Le Corbusier from the polychromy of *De Stijl*.

It is also usual that colors cover the entire surface of the architectonic element: wall, ceiling, and so on. In the exceptional cases, where this does not happen, the colors are finished in a coherent way with other compositional aspects of the architecture. For example, in the *Pavilion for L' Esprit Nouveau*, where the same wall is painted with two colors, one fitting with the double height part, the other with the covered zone. Besides, Heer notes Le Corbusier's preference for arranging the blue colors in the darker areas of the buildings and the red colors in the lighted ones. All these colors on surfaces are finalized after considering the visuals that Le Corbusier finds along the *promenade architecturale* when he walks around the building during the construction phase, and he ends up specifying colors by following his own intuition. The final combination of colors is not perfectly defined in the conception phase, but it is settled at the end, on-site.

## CONCLUSIONS

We have carried out a new study of the color combinations selected by Le Corbusier in the *claviers* for the Salubra wallpaper company in 1931, by analyzing them in the color space of the NCS, which allows us to understand the perceptive variables of colors (*hue*, *blackness*, and *chromaticness*) as well as their combination criteria.

Regarding the *hue*, we have observed that the 43 colors are derived from 14 *main colors*, which are mixed with white in different proportions to obtain all the nuances. Beyond the Gray and neutral colors, half of the remaining colors belong to cool NCS hues (R80B to G40Y) and half to warm hues (Y30R to R10B). We note the difference of these brownish and tertiary colors, with those typical of the traditional architecture, despite Le Corbusier's desire of linking them with the "eternal colors."

To complete the color wheel, we would still need colors from the yellow (G40Y to Y60R) and violet (R10B to R80B) NCS *hue* ranges. Neither white color appears, as it is presupposed for architecture, nor black. Some of these absences are covered in the second Salubra collection from 1959, and in Le Corbusier's buildings constructed after the Second World War.

In general, colors from the Salubra collection 1931 have low NCS *chromaticness* ( $C \leq 60$ ) and low *blackness* ( $B \leq 70$ ). The highest *chromaticness* corresponds to the 090 Vermilion and 080 orange, whereas the highest *blackness* corresponds to the 130 brown. The least NCS *blackness* percentage corresponds to the 001 Ochre.

In relation to the combination criteria, it is shown that color combinations based on the similarity of *pigment-hue* are common especially if we consider the pairs of two *color tons*. This is especially significant for the Oranges, Veronese greens, and even Carmine *pigment-hue* families, for which it seems to be the preferred color grouping criterion.

There are also many color pairs whose combination is based on the contrast of their NCS *hues*, not between complementary neither opposite perceptive colors in the NCS color Space, but between cool and warm colors. This opposition was reported by Le Corbusier himself, and it explains many of the combinations in the first Salubra collection. Blue and red are considered antonyms in a psychological, symbolic, and architectural level.

If we study the color grouping based on the similarity or the contrast of NCS *chromaticness*, we notice that Le Corbusier prefers the pairs of *dull colors* (with low *chromaticness*), and with little contrast between them (same *chromaticness*).

Regarding the NCS *blackness*, most of the Salubra grouping respect a combination criterion based on the contrast of *chiaroscuro*, with special dominance of pairs of colors with low *blackness*. This is especially significant in the combinations of two *color tons*.

In a comparative study about the cool-warm and the *chiaroscuro* contrast, the presence of rhythms and patterns in the *claviers* is demonstrated, because a *main color* is usually accompanied by other nuances from the same *pigment-hue* family. In addition, we can note that the Vermilion-red is used to resolve the transition between the conflicting ranges or those color combinations which are not preferred.

Finally, we can point out other compositional criteria to provide color in the architecture of Le Corbusier: (1) The architect limits the palette to 43 colors and the white, which is assumed as a background in a minimum ratio

between 33 and 50%, whereas the more vivid colors (with more *chromaticness*) should be limited to a ratio between 7.5 and 22%. (2) The colors have to help the understanding of the different pure volumes that make up a building and its hierarchy. (3) The architectural color is often explained by its associative connotations. (4) Plain colors are used and the color gradients are rejected. (5) The colors usually cover the entire surface of the architectural element to be colored, except in some few cases.

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