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COLOUR CONTROL FOR RETROREFLECTIVE TRAFFIC SIGNS PRODUCED BY DIGITAL PRINTING APPLICATIONS

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Rezumat. *Dezvoltarea tehnologiilor de tipar digitale facilitează metode alternative de producție pentru imprimarea foliilor reflectorizante certificate folosite la fabricarea fețelor indicatoarelor rutiere retro-reflectorizante. Astfel de produse se aprobă și se testează în conformitate cu standarde specifice precum SR EN 12899-1:2007, indiferent de metoda de producție, iar coordonatele cromatice și factorul de luminanță sunt normative pentru validarea produsului. Această lucrare propune o metodă de control de proces și asigurare a calității culorii folosind instrumente de măsură și unelte specifice tehnologiei grafice. Elementul cheie este corelarea spațiului de culoare de referință specific acesteia (CIELAB, D50) cu cel de referință din SR EN 12899-1:2007 (CIExyY, D65), luând în calcul și diferența conceptuală dintre toleranțele circulare/eliptice utilizate tipic în procesele tipografice și cele de tip patrulater definite de standard*.

Abstract. *The advancement of digital printing technologies facilitates alternative production methods to print certified reflective foils used to produce the faces of retroreflective traffic signs. Such products are approved and tested for certification in accordance with standards such as SR EN 12899-1:2007, regardless of production methods while the chromaticity and luminance factors are normative to qualify the product. This paper presents a method for process control and quality assurance using measurement devices and tools employed specifically by graphic technology. The core element is the correlation of the reference colour space (CIELAB, D50) with the standard reference from SR EN 12899-1:2007 (CIExyY, D65), also considering the conceptual difference from circular/elliptical tolerances typically used in printing processes and the colour box coordinates defined by the standard*.

Keywords: retroreflective foil, traffic signs, digital printing, quality, colour measurement

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1. Introduction

Traffic signs are critical for traffic public safety and serve not only the purpose of warning about potential impending dangers, but also communicate rules that shall be observed and abided, and other relevant information thus making roads safer for all traffic participants, including pedestrians and bicyclists. The appearance in terms of colour, size and shape used for traffic signs symbols and text is designed to be easily and quickly identified and/or read by the traffic participants.

To extend their functionality when little light is available and overall visibility is decreased (e.g., during the night and/or adverse weather conditions that affects visibility) and to improve visibility from greater distances, the traffic signs are produced using retroreflective materials containing spherical or prismatic elements that direct light from any light source (e.g., the headlights of a vehicle) in a cone back toward the direction of the light source to increase overall visibility.

Traditionally, traffic signs manufacturing is done using conventional imaging methods (e.g., screen printing), but in the more recent times there is a shift towards digital printing applications driven by the more economical on-demand ordering choice and the increased scrutiny of performance requirements that results in the replacement of damaged or non-conform signs. Also, there is an influx of low-volume custom signage for seasonal events, temporary traffic control, tourist information, wayfinding and a plethora of other informational purposes.

2. Problem statement

The performance requirements and test methods related to traffic signs are regulated by standards such as SR EN 12899-1:2007 [1] that are designed to be used primarily by road authorities for public roads signs, but it can be also used by any other private entities using signs for various purposes. Regardless of production methods the chromaticity and luminance factors, alongside the coefficient of retroreflection R_A and durability requirements are normative to qualify the product. While the R_A and durability is covered by the manufacturer of the retroreflective material using the pertinent approval and certification testing criteria defined in the reference standards, the method to reproduce the 8 traffic sign colours plus black, depends entirely on the colorant and colour management associated with the printing condition used for the reproduction process. The first challenge posed by the standard is the correlation of the reference colour space (CIELAB, D50) used in general by GA with the standard reference from SR EN 12899-1 (CIExyY, D65). Furthermore, there is a conceptual difference from circular/elliptical tolerances typically used for process control and quality assurance in printing processes and the colour box coordinates defined by the SR EN 12899-1 standard.

There are two use cases that could also benefit from an adapted data set and methodology in terms of colour definition and control adapted from SR EN 12899-1 requirements:

A. traffic signs manufacturers that are integrating digital printing applications into their workflow;
B. signage and advertising digital printing manufacturers that are occasionally receiving low-volume custom signage orders for temporary events and informational purposes.

In case of the former, the concept of certified materials extends also towards the used inks, so the manufacturers already rely on their suppliers for approved and certified inks as part of the supplier own warranty framework that includes colour references specification and conventional printing process control methods. And it is very likely that such a manufacturer will integrate digital printing systems that are already part of similar conceptual warranty frameworks. Suppliers of such certified materials, like 3M [2] and Orafol [3], already partnered with printing systems manufacturers to develop and promote turnkey solutions for digital printing traffic signs.

But in case of the latter, the printers must weigh in how to better integrate the traffic signs manufacturing application with the existing general purposes digital printing systems and decide which reflective materials that are available from a wide selection, is better suited to be used. Creating a traffic signs manufacturing workflow in such case would certainly benefit from the guidance of a dedicated framework. Another question that arises in this context, is the usability of the specified digital printing system for the traffic signs manufacturing with obvious limitations in terms of colour gamut, printability and durability.

Nevertheless, for both cases, the choice of retroreflective materials, colour references specification, print-ready document preparation, process control and quality assurance should result in a workflow setup that ensure the pertinent colour reproduction conformity while using the colour specification system, measurement devices and applications specific to GA.

3. Retroreflection and retroreflective materials used for traffic signs

3.1. Definition of retroreflection

A retroreflector is a device or a surface that reflects radiation (usually light) back to its source with minimum scattering [4].

Alongside specular (mirror-like) and diffuse (scattering), it is one of the three types of reflections (Fig. 1).

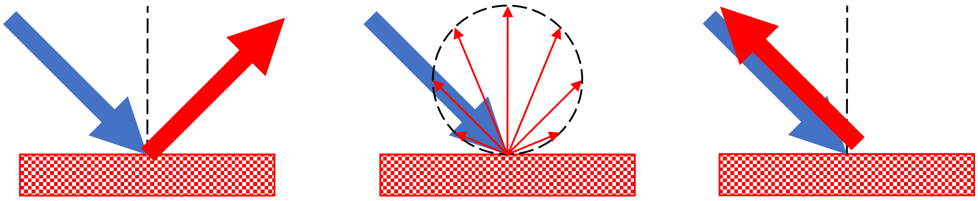

Fig. 1. Types of reflection:
a. Specular **b.** Diffuse **c.** Retro

In case of traffic signs, the retroreflection effect must be very efficient considering that at night, the light coming from the headlights is directed mostly downward and just a small amount of light ends up upward toward the traffic signs that reflects it back in a "cone of reflectivity" or "cone of returned light" allowing the driver to see it (Fig. 2). Retroreflective materials appear brightest to the driver as the closest observer to the centre of cone to improve night-time visibility. The further away the observer is from the central axis of the cone, the more traffic sign will appear dimmer and will be more difficult to be spotted at night. Also, the less efficient is the retroreflective material, the more light is diffused away basically getting wasted and not being reflected inside the cone, impending the driver observation ability.

Fig. 2. The "cone of reflectivity" or "cone of returned light" [5]

3.2. Material classification

Currently, there are three R_A classes of photometric performance for traffic signs using different compositions and technical constructions (Fig. 3) of retroreflective sheeting to achieve a certain R_A [6],[7],[15],[16] and having various appearances (Fig. 4) due to the used components:

- RA1 are retroreflective materials using embedded glass beads or air-backed/metalized prims and are typically used for traffic signs in slow moving traffic zones (e.g., no- or short-term parking signs), tourist information signs, street signs and advertising signs; typical R_A for glass beads materials is around of 70 $cd{\times}lx^{-1}{\times}m^{-2}$ and around 200 $cd{\times}lx^{-1}{\times}m^{-2}$ for materials with prisms;

- RA2 are retroreflective materials using encapsulated glass beads or air-backed/metalized prims and are established as a de-facto standard for traffic signs providing higher R_A values around of 250 cd×lx^{-1}×m^{-2} for glass beads materials and around 500 cd×lx^{-1}×m^{-2} for prisms ones, providing clear visibility for important traffics signs (e.g., stop signs and speed restriction signs), even from a wide viewing angle (e.g., at roundabouts), and improved long-distance visibility at night;

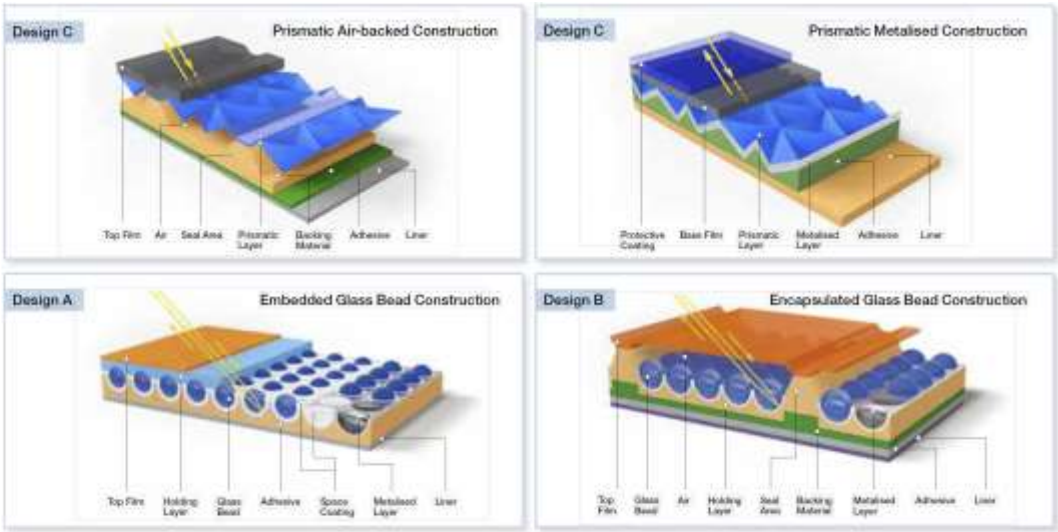

Fig. 3. Technical illustrations of the basic composition of different retroreflective materials [6]

- RA3 are retroreflective materials with the highest R_A performance values of around 700 cd×lx^{-1}×m^{-2} and are only constructed using air-backed/metalized prims. These materials are used for traffic signs in areas where a particularly high degree of reflectivity is required (e.g., highways, brightly illuminated environments) even under day/night adverse weather conditions; retroreflectivity for this class is only described in various national standards as DIN 67520 [15] and ASTM D 4956 [16].

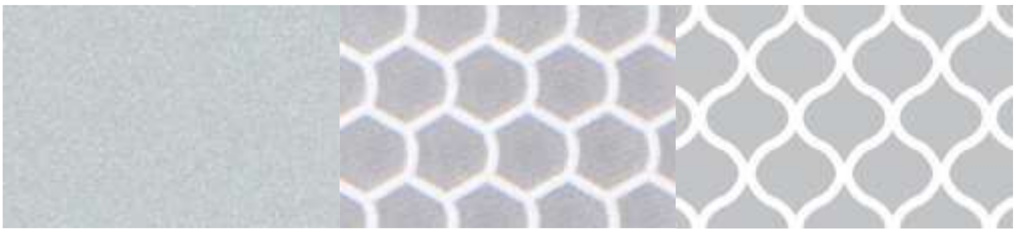

Fig. 4. Appearance of retroreflective materials

a. Glass beads **b.** Micro-prisms **c.** Micro-prisms

These classes are directly linked to the sign type requirements and usage based on functionality, installation location and environment and while differs slightly from country to country, the below guidelines are quite representative for Europe as a whole (Table 1):

- RA1, RA2, RA3 – retroreflection grades,
- be – illuminated from inside or outside,
- / – selection according to boundary condition,
- left – if the sign is only located on the left, a higher-value performance class is recommended compared to installation location on the right.

Table 1. Typical guidelines for which material class to use for which sign type [8]

No.	*Signs according to section 39 to 43 of the German Road Traffic Act*		*Normal environment*			*Brightly lit environment and/or many external light sources*		
1.			motorway	suburban	urban	motorway	suburban	urban
2.	All signs other than those listed below	Installation location: right	RA2	RA1/RA2	RA2	RA2/RA3	RA2	RA3/be
3.		Installation location: high/left	RA2	RA2	RA2	RA3	RA2/RA3	RA3/be
4.	Waiting and stop signs at railway crossings		-	RA2/RA3	RA2/ RA3	-	RA3	RA3
5.	Waiting and stop signs at intersections; junctions and road narrows signs; signs for the specified direction of travel and passing of vehicles		RA2/RA3	RA2	RA2/ RA3	RA3	RA3	RA3/be
6.	Construction signing		RA2	RA2	RA2	RA2/RA3	RA2	RA2
7.	Special routes, no stopping and parking; tourist information signs		RA1					

4. Traffic signs colour process control requirements and recommendations

The traffic signs digital printing application follows up the recipe of any digital printing application, but there are certain steps into the workflow (Fig. 5) where colour definition and control shall be unambiguously and properly defined so that any (intermediary or final) states of the product can be evaluated with applicable metrics in respect to colour quality assurance and process control methods.

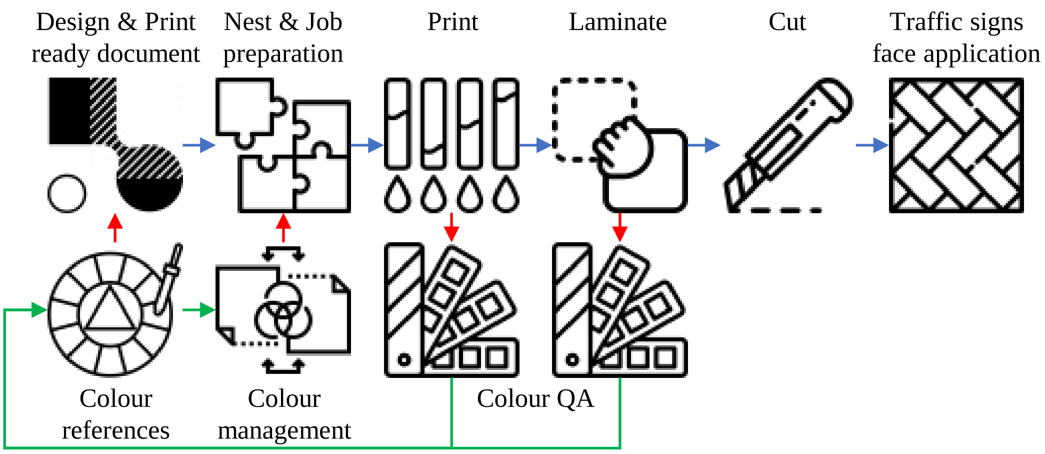

Fig. 5. Production workflow for traffic signs digital printing application

The next subchapters specify the requirements and make recommendations related to the integration of colour references, colour management and quality assurance into production workflow.

4.1. Traffic signs surface colours

In GA, colour references are used to formulate spot colour inks or to characterize process colours combinations using appropriate colour management tools, that allow reliable printing and proofing of products that have been designed to use these colour references. But SR EN 12899-1 does not define such references, the approach being to define chromaticity limits and the luminance factor β for each of the traffics sign types using CIE standard daylight illuminant D65 and the standard CIE 45/0 viewing conditions as indicated in Table 2:

Table 2. Daylight chromaticity and luminance factors tables as indicated in SR EN 12899-1

No.	*Traffic sign type*	*Retroreflective*		*Non-retroreflective*		*Transilluminated and externally illuminated*
1.	SR EN 12899-1	Table 1	Table 2	Table 16	Table 17	Table 18

As examples, Table 3 and Table 4 presents the chromaticity limits and the luminance factor β for retroreflective traffic signs faces.

The limits specified in Table 3 (corresponding to Table 1 from SR EN 12899-1), with the exception of dark green, brown and grey, are recommended in CIE 39.2 [9] as surface colours for visual signalling. When colours deteriorate beyond these chromaticity limits the signs can be unsuitable for the intended purpose.

Table 3. Class CR1 daylight chromaticity and luminance factors

No.	*Colour*	*1*		*2*		*3*		*4*		*Luminance factor ß*	
1.		x	y	x	y	x	y	x	y	Class RA1	Class RA2
2.	White	0,355	0,355	0,305	0,305	0,285	0,325	0,335	0,375	≥ 0,35	≥ 0,27
3.	Yellow (RA1)	0,522	0,477	0,470	0,440	0,427	0,483	0,465	0,534	≥ 0,27	
4.	Yellow (RA2)	0,545	0,454	0,487	0,423	0,427	0,483	0,465	0,534		≥ 0,16
5.	Orange	0,610	0,390	0,535	0,375	0,506	0,404	0,570	0,429	≥ 0,17	≥ 0,14
6.	Red	0,735	0,265	0,674	0,236	0,569	0,341	0,655	0,345	≥ 0,05	≥ 0,03
7.	Blue	0,078	0,171	0,150	0,220	0,210	0,160	0,137	0,038	≥ 0,01	≥ 0,01
8.	Green	0,007	0,703	0,248	0,409	0,177	0,362	0,026	0,399	≥ 0,04	≥ 0,03
9.	Dark green	0,313	0,682	0,313	0,453	0,248	0,409	0,127	0,557	0,01 ≤ *ß* ≤ 0,07	
10.	Brown	0,455	0,397	0,523	0,429	0,479	0,373	0,558	0,394	0,03 ≤ *ß* ≤ 0,09	
11.	Grey	0,350	0,360	0,300	0,310	0,285	0,325	0,335	0,375	0,12 ≤ *ß* ≤ 0,18	

Table 4. Class CR 2 daylight chromaticity and luminance factors

No.	*Colour*	*1*		*2*		*3*		*4*		*Luminance factor ß*	
1.		x	y	x	y	x	y	x	y	Class RA1	Class RA2
2.	White	0,305	0,315	0,335	0,345	0,325	0,355	0,295	0,325	≥ 0,35	≥ 0,27
3.	Yellow (RA1)	0,494	0,505	0,470	0,480	0,493	0,457	0,522	0,477	≥ 0,27	
4.	Yellow (RA2)	0,494	0,505	0,470	0,480	0,513	0,437	0,545	0,454		≥ 0,16
5.	Red	0,735	0,265	0,700	0,250	0,610	0,340	0,660	0,340	≥ 0,05	≥ 0,03
6.	Blue (RA1)	0,130	0,086	0,160	0,086	0,160	0,120	0,130	0,120	≥ 0,01	
7.	Blue (RA2)	0,130	0,090	0,160	0,090	0,160	0,140	0,130	0,140		≥ 0,01
8.	Green (RA1)	0,110	0,415	0,150	0,415	0,150	0,455	0,110	0,455	≥ 0,04	
9.	Green (RA2)	0,110	0,415	0,170	0,415	0,170	0,500	0,110	0,500		≥ 0,03
10.	Dark green	0,190	0,580	0,190	0,520	0,230	0,580	0,230	0,520	0,01 ≤ *ß* ≤ 0,07	
11.	Brown	0,455	0,397	0,523	0,429	0,479	0,373	0,558	0,394	0,03 ≤ *ß* ≤ 0,09	
12.	Grey	0,305	0,315	0,335	0,345	0,325	0,355	0,295	0,325	0,12 ≤ *ß* ≤ 0,18	

The chromaticity limits specified in Table 4 (corresponding to Table 2 from SR EN 12899-1) can ensure a more uniform appearance and consistency in the colour of new signs which are installed at different times than the limits specified in Table 3. Colours conforming to the limits of Table 4 can also be expected to take longer to deteriorate beyond the limits of Table 3 (note excerpt from SR EN 12899-1).

Since luminance factor *β* corresponds to CIEY, the limits specified in Table 3 and Table 4 can be easily converted from CIExyY to CIELAB via CIEXYZ using the appropriate formulas specified by CIE 15 publication [10]. The visual representation of the resulted CIELAB computations is better suited for regular GA user understanding and interpretation (Fig. 6).

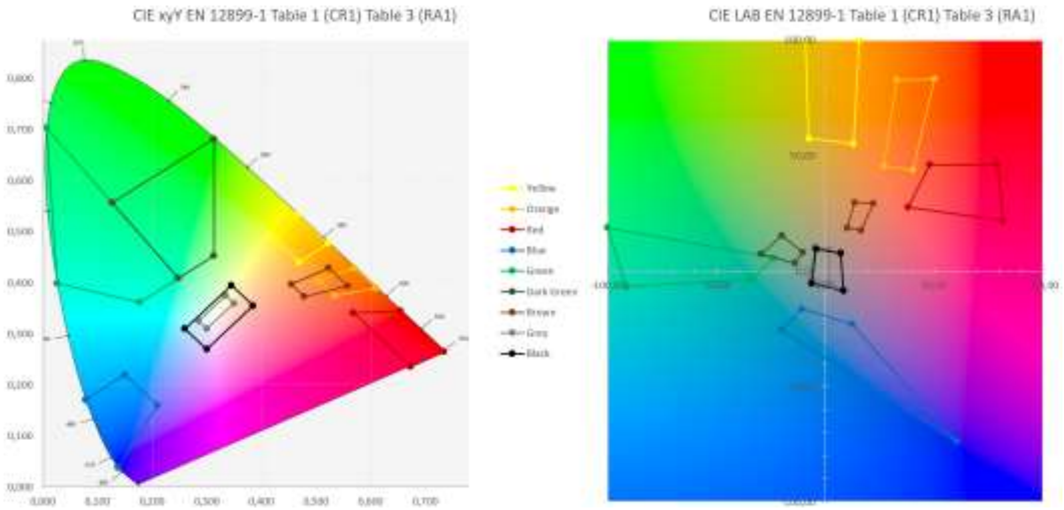

Fig. 6. CIExyY and CIELAB colour limits for Class CR1 and R_A Class RA1

The colour limit for Black is specified in the standard only for non-retroreflective and transilluminated/externally illuminated traffic sign types (as defined in Table 16 and Table 18 from SR EN 12899-1), but it is also applicable for the retroreflective ones (Table 5). The reason in this case is defined by its secondary purpose to cover the retroreflective substrate to the extent that the retroreflection is actually cut out in those areas, otherwise the black area would be rather perceived as grey during the night.

Table 5. Black daylight chromaticity and luminance factors

No.	*Colour*	*1*		*2*		*3*		*4*		*Luminance factor β*
1.		x	y	x	y	x	y	x	y	
2.	Black	0,385	0,355	0,300	0,270	0,260	0,310	0,345	0,395	≤ 0,03

4.2. Colour measurement and viewing condition

The reference standard specifies 45/0 viewing conditions that corresponds to 45°:0° or 0°:45° geometry that is also used by ISO 13655 [11] compliant measurement devices employed by GA for measurement applications. To provide consistency with GA P1 viewing condition, defined in ISO 3664 [12], calculated tristimulus values in GA are based on CIE D50 illuminant and the CIE 1931 standard colorimetric observer (often referred to as the 2° standard observer), but the reference standard specifies CIE D65 illuminant.

To fulfil this application requirements, a non-standard approach shall be used, where the calculation of tristimulus values for reflecting samples is based on CIE D65 illuminant and the CIE 1931 2° standard observer, while the spectral reflectance is measured using an ISO 13655 compliant measurement device. This shall also be extended towards colour management, where a “happy hack” may be employed to use CIE D65 instead of the standard CIE D50 default ICC tristimulus values. The recommended measurement condition for spectral reflectance should be M1 and a compliant white backing should be used behind the sample during measurement.

This situation is becoming more common in GA due to trans-industrial applications, where the standards and references are specified outside GA framework, requiring adaptability and consistency (Fig. 7). The implementation of colour management part will become much easier by using iccMAX [13] new ICC colour management system that goes beyond D50 colorimetry.

Fig. 7. Examples of other trans-industrial GA applications matching (pharma pills, textiles)

Another topic of interest is the aperture size to be used for the measurement of traffic sign face colours. As shown in Fig. 4, the micro prismatic materials appearance is non-isotropic and the resulting measurement will be affected depending on the used aperture size. By analogy to the screen ruling factor considered when selecting the instrument sampling aperture to reduce uncertainty of the single measurement, it is highly recommended to use appropriate large aperture size (e.g., 8 mm) that facilitate better measurement consistency. Scanning instruments that facilitate a virtual averaging are also providing such means.

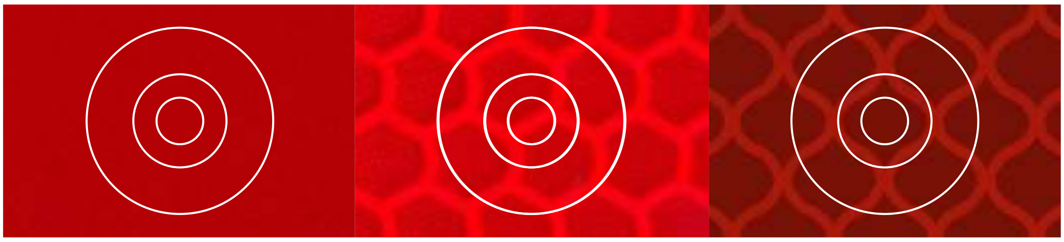

Fig. 8. 2 mm, 4 mm and 8 mm apertures material appearance/colour measurement relation

On the other hand, the structure of the micro prismatic materials is part of its appearance and when positioning inside the gridlines (Fig. 8, right), a small aperture size (e.g., 2 mm) will facilitate a colour only measurement for the purpose of colour process control. Since there are no clear guidelines or studies on the topic, for the purpose of digital printing traffic sign application process control, any aperture size can be used, but it is recommended to use a small aperture size for the metrology of colour reference/reproduction matching method as described in chapter 4.3 and chapter 5.

4.3. Colour references

Randomly choosing a set of coordinates inside any of the reference standard specified colour limits does not look like a sound method, but it may work as well when narrowed down to the intersection of the intended printing condition colour gamut exterior borderline and specified colour limits (Fig. 9). However, this approach has various limitations and it may require too many trial and error redo steps between colour reference adjustment and actual reproduction conformity.

As already mentioned, GA reproduction mechanisms work better when the reference exists either as spectral data in a digital or cloud library or in physical form facilitating the measurement acquisition. For this application, the latter case is supported by the coloured traffic signs materials supplied by the same manufacturers of the white material that is used as the printing substrate for the digital printing application.

Each such model and colour of material can be measured using a small aperture measurement device (e.g., 2 mm) as indicated in chapter 4.2 and the results recorded in a meaningful manner inside a colour database for future use.

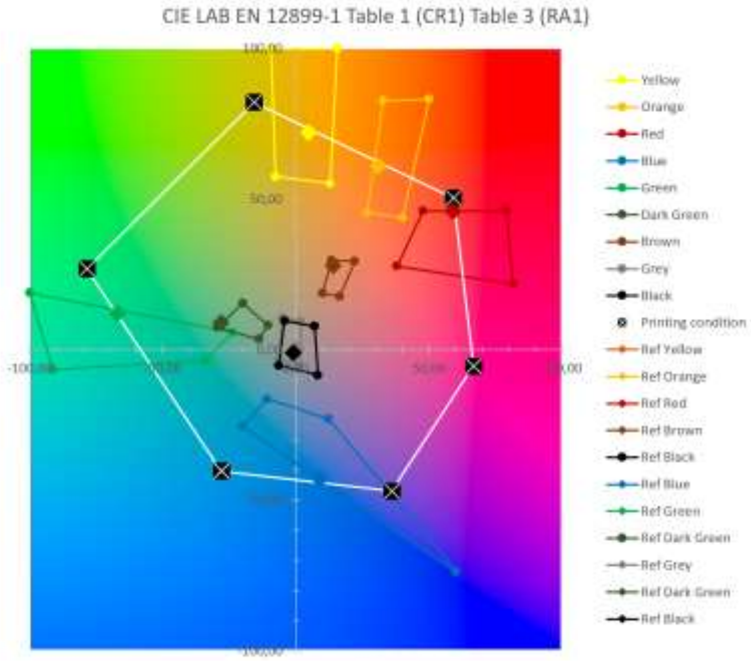

Fig. 9. CIELAB colour limits intersected with intended printing condition

Considering the actual parameters of the printing combination used (e.g., substrate, colorant, printing system), a master colour standard may not be always reproducible. When the production is spread over various combinations, the solution is to reduce production variation based upon matching an adjusted colour standard that is reproducible while still passing the QA criteria. The concept is similar to the one used by PantoneLive cloud-based architecture (Fig. 10). To achieve such a goal, a further modelling of the obtained data is necessary.

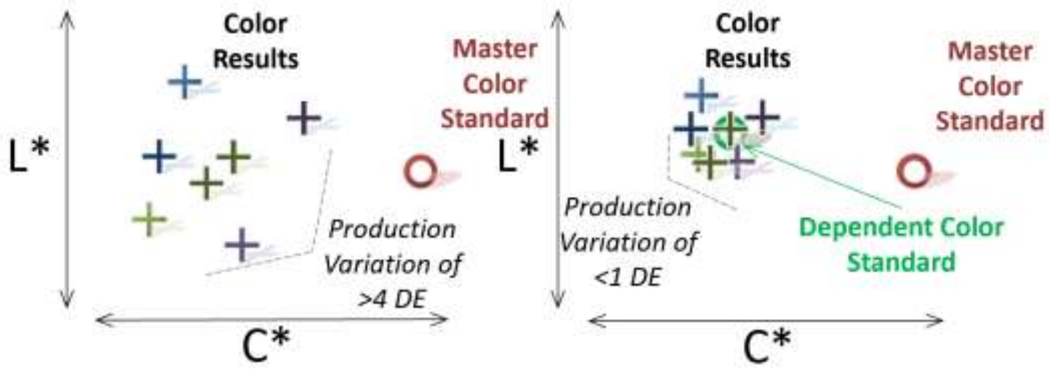

Fig. 10. PantoneLive master and dependent colour standards dependency concept

Furthermore, using CxF/X [14], the newly created colour references can be passed upwards and downwards the process stream allowing the same data to be used as required at any step of the process without the need of remeasurement or additional input.

5. Study case for use case B

To facilitate the proof of concept for use case B, the following combinations were selected for producing the printed part of the traffic signs application:

- printing systems: HP Latex 800W (latex), OCE Colorado 1650 (UV gel);
- printing materials: Orafol ORALITE 5510 (RA1, embedded glass beads), Orafol ORALITE 6710 (RA1, air backed microprisms).

Sample kits of the two retroreflective materials containing all the colours were measured using a combination of X-Rite eXact spectrophotometer with a 2 mm aperture and Color iQC software application as indicated in chapter 4.2 & 4.3. Color iQC is a configurable, job-based software system that allows users to work on a job using process and material templates that contain pre-defined standards, tolerances, and settings being ideal for this application to create the colours database, but also for the QA protocol later in the process with the help of a dedicated Safety Wear OCX module. The obtain data was tweaked and consolidated to reflect an achievable colour reproduction based on the colour gamut of the used printing combinations and the traffic signs colour references library was saved as a CxF/X file to be incorporated as necessary into the workflow based on CIE D65 illuminant and the 2° standard observer colorimetry: print production workflow spot colours library, graphic design application for traffic signs design and print ready file preparation, ICC colour profile optimization and QA protocol for SR EN 12899-1 chromaticity limits and the luminance factor β validation.

To fully characterize the printing combinations, a printed characterization chart for each was measured using X-Rite i1iSis 2 XL A3/Tabloid automated spectrophotometer, establishing the relation between CMYK digital input values and the corresponding measured spectral values. From each obtained characterization data set, an ICC colour profile was generated using X-Rite i1Profiler software application, where profile generation settings were adjusted to reflect the CIE D65 standard illuminant "happy hack" for colorimetric values and the maximum smoothness was used to compensate for non-isotropic structure of the measured materials. An optimization iteration was added into the colour management workflow by using the previously defined traffic signs colour references CxF/X library to further increase the colour matching between the used colour references and the actual reproduction output. As a result, each ICC colour profile quantified a CIELAB D65 colour gamut description for each printing combination optimized to reproduce traffic signs colour references as accurately as possible, being limited only by its size and shape.

Table 6. Tested combinations results (*C15 – OCE Colorado 1650, L800W – HP Latex 800W, AA – Certified digital printing combination, O5510 – Orafol ORALITE 5510, O6710 – Orafol ORALITE 6710)

No.	*Combination**	*Chromaticity*		*Luminance factor*	*ΔE*$_{00}$ (from modelled reference)*	*SR EN12899-1 Table 1(CR1) Table 3 (RA1)*
1.		x	y	*ß*		
2.	C15-O5510-Red	0,612	0,343	0,104	0,07	Passed
3.	C15-O6710-Red	0,607	0,340	0,098	1,62	Passed
4.	L800W-O5510-Red	0,600	0,328	0,086	5,58	Passed
5.	AA-O6710-Red	0,629	0,336	0,086	2,92	Passed
6.	C15-O5510-Blue	0,169	0,150	0,037	4,46	Passed
7.	C15-O6710-Blue	0,166	0,138	0,044	4,78	Passed
8.	L800W-O5510-Blue	0,161	0,105	0,022	11,48	Passed
9.	AA-O6710-Blue	0,146	0,130	0,039	0,69	Passed
10.	C15-O5510-Green	0,169	0,460	0,093	0,51	Passed
11.	C15-O6710-Green	0,159	0,447	0,074	3,40	Passed
12.	L800W-O5510-Green	0,178	0,523	0,081	3,94	Failed
13.	AA-O6710-Green	0,136	0,430	0,067	5,33	Passed
14.	C15-O5510-Brown	0,491	0,400	0,050	0,03	Passed
15.	C15-O6710-Brown	0,479	0,397	0,047	1,49	Passed
16.	AA-O6710-Brown	0,502	0,379	0,046	4,34	Passed

Several traffic signs designs were printed using the choose combination and the colours were measured using the same X-Rite eXact spectrophotometer with a 2 mm aperture and Color iQC software application with Safety Wear OCX module to test SR EN 12899-1 chromaticity limits and the luminance factor *β* conformity (Table 6). For comparison, an external certified digital printing combination using one of the test substrates was included to check the validity of the metrological protocol and the method.

Conclusions

Conclusion (1).

The presented traffic signs colour workflow proves that for use case B, any printer would certainly benefit from this framework allowing him to quickly integrate the traffic signs printing application into the existing process.

Conclusion (2).

Not all printing combinations may be suitable for traffic signs digital printing application even if it is only for temporary signage. Depending on the reference colour reference table choose for conformity testing, it may pass or fail while in some cases it may simply be outside the combination colour gamut reproducibility. Further testing of additional printing combinations on both RA1 and RA2 retroreflective substrates is required to improve the modelling of the dependent colour references. Also, only chromaticity/luminance conformity was evaluated, retroreflectivity being outside the scope of the typical GA workflow. Further work on the topic could include R_A testing of digital printed materials, lamination finishing chromaticity/luminance/R_A testing and the addition of RA2 class materials-based printing combinations.

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Notations and/or **Abbreviations**

GA – graphic arts, alternate term for graphic technology

R_A – coefficient of retroreflection

CIE – Commission internationale de l'éclairage (French), the International Commission on Illumination

CIE D50/D65 – CIE standard illuminants

CIELAB – CIEL*a*b* 1976 colour space

CIExyY, CIEXYZ – CIE xyY and CIE XYZ 1931 colour spaces

P1 – Standard ISO 3664 viewing condition using CIE illuminant D50

M1 – Standard ISO 13655 measurement condition using CIE illuminant D50 spectral power distribution of the measurement source at the sample plane

ICC – the International Color Consortium was established in 1993 for the purpose of creating, promoting and encouraging the standardization and evolution of an open, vendor-neutral, cross-platform color management system architecture and components

CxF/X – the standardized colour data exchange format

QA – quality assurance

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