Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management



Article

Rescue Light Communication System (RLCS): Enhancing Emergency Signaling in Crisis Situations

Ivo Baćilo[1*]

[1] Zagreb University of Applied Sciences, Croatia; tvz@tvz.hr

[*] Correspondence: ivo.bacilo1@gmail.com.

ABSTRACT

Effective communication during disasters remains a challenge, mainly when traditional Methods become impractical. The Rescue Light Communication System (RLCS) is a new, colour-based signalling method integrated into the Krizor mobile application, aiming to resolve this issue. RLCS utilises an extended RYB colour model, with the addition of white, to visually represent an individual's status during emergencies. By assigning specific meanings to each colour (for example, green for "I am okay." and red for "I have severe injuries."), RLCS offers a straightforward and intuitive method for non-verbal emergency signalling. Although currently in an alpha trial phase, RLCS is designed to work offline and can be adapted for both digital and physical signalling. This paper explains the rationale behind using the extended RYB model, reviews relevant literature on colour perception, emergency communication, and standardisation, and outlines potential applications and future research directions.

KEYWORDS

Communication; disaster risk; emergency response; RLCS; color signalling; mobile application.

1. Introduction

Effective communication in the context of disasters and emergencies is crucial for providing prompt assistance and minimising risks to human life. Conventional methods of communication, such as verbal warnings or radio broadcasts, often become inadequate due to environmental disturbances, infrastructure malfunctions, or cognitive overload during high-pressure situations.

This article introduces the Rescue Light Communication System (RLCS), a systematic visual signalling approach designed to overcome these challenges. Incorporated within the Krizor mobile application – an unofficial tool designed to protect Croatian citizens – RLCS enables individuals to convey their status through a specific array of colour-coded signals. Although not officially endorsed at present, Krizor offers a practical platform for implementing RLCS in emergency scenarios. By leveraging mobile technology and an expanded RYB colour model, RLCS improves the visibility and identification of signals. Additionally, its principles can be applied to physical signalling meth-

Copyright: © 2024 by the authors.

Baćilo, I. (2025). Rescue Light Communication System (RLCS): Enhancing Emergency Signaling in Crisis Situations. *International Journal of Disaster Risk Management*, *7*(1), 55–64.

ods, such as using coloured flags or clothing, ensuring accessibility even in situations where electronic devices are unavailable. Thus, a standardised, adaptable, and inclusive solution for managing disaster risks and responding to emergencies is presented.

2. Scientific background

Effective communication is of utmost priority during crises. Spoken orders and radio transmissions frequently encounter significant challenges, including excessive background noise, damaged infrastructure, and rapidly changing environments (Seeger, Sellnow, & Ulmer, 2003). These challenges have driven research into mobile and digital tools that enable rapid, non-verbal communication. In this context, colour-coded signals can effectively convey critical information when auditory communication is not possible (Fearn-Banks, 2016).

Research in visual ergonomics and cognitive psychology shows that the right combination of colours can enhance the speed and accuracy of recognised signals, even under strenuous conditions. For example, the extended RYB colour model is known for providing greater contrast and easier colour discrimination than conventional RGB or CMYK models, especially in low-visibility situations (Mayo & Kim, 2018; Yuan, Wang, & Li, 2020). This supports the rationale for developing mobile emergency communication systems that prioritise visual signalling devices.

In addition, universally accepted norms, such as ISO 7010 (2011), emphasise the importance of proper colour and symbol design in safety communications for the practical understanding of the messages.

The Rescue Light Communication System (RLCS) was developed to address the communication needs of first responders and organisational staff during disasters and emergencies. It adheres to standards such as ISO 22324 (2015), ISO 3864 (2011), and ANSI Z535 (2017). These standards emphasise the use of specific colours and symbols to ensure clear and precise communication across diverse regions and contexts. RLCS incorporates these standards while introducing modifications for effective disaster communication.

The application of red to indicate severe injuries or urgent assistance in RLCS is consistent with ISO 7010 and ANSI Z535, which use red to signify danger, emergencies, or life-threatening situations. Likewise, green, which RLCS users employ to indicate "I am okay," aligns with the standard application of green for safe conditions and emergency exits. These qualities ensure that RLCS messages are unambiguously comprehensible to users and responders in high-stress situations.

RLCS designates the colour orange for warnings and measures of moderate urgency to illustrate a "threat of danger." Although not explicitly defined in ISO 7010 or ISO 3864, the colour's application aligns with construction zone and hazardous area signage, where it effectively draws attention to potential dangers.

In RLCS, yellow represents minor injuries, aligning with the role of yellow in ISO 7010 and ANSI Z535 while being adapted to meet the requirements of medical prioritisation.

RLCS also uses blue to represent "I need supplies." Even though blue represents mandatory action within the context of ISO 7010 and ANSI Z535, its use in RLCS as a request for resources represents a logical shift from being informative to functional.

The system incorporates white to signal "help is on the way" and purple to indicate "message received." These colours are part of the RYB colour model, chosen for their high perceptual contrast.

Purple, as a secondary colour in the RYB model, provides distinctiveness and visibility. On the other hand, white ensures maximum contrast against dark backgrounds.

By integrating mobile technology with established colour standards, RLCS strikes a balance between innovation and familiarity, making it a versatile tool for disaster communication. This approach not only adheres to internationally recognised guidelines but also addresses the unique challenges of emergency scenarios, where clarity, speed, and adaptability are paramount.

3. Description of the RLCS implementation

The digital implementation of RLCS operates by utilising flashing, alternating colours on a device to convey status information in emergencies. It employs an extended RYB colour model enhanced with white. The colour assignments are as follows:

1. Green – "I am okay."
2. Blue – "I need supplies."
3. Yellow – "I have minor injuries."
4. Orange – "Threat of danger."
5. Red – "I have severe injuries."
6. Purple – "Message received."
7. White – "Help is on the way."

Users can select either a single colour or a combination of two colours to indicate their status. In single-colour mode, the screen alternates between the chosen colour and black, enhancing visibility and reducing the potential for misinterpretation. Dual-colour mode enables the screen to switch between two designated colours, allowing for more detailed signalling while maintaining clarity.

Limiting RLCS to one or two flashing colours aligns with research on the efficiency of visual signalling. Studies have shown that "two-colour alternating signals significantly improve recognition speed and accuracy compared to multi-colour signals" (Kemeny & Panerai, 2003). Additionally, excessive variation in flashing colours can introduce cognitive overload, delaying response times in high-stress environments (ISO 9921:2003; IEC 60073). The IEC 60073 standard further emphasises that "a maximum of two alternating colours should be used in visual alarms to ensure clarity," as additional colours may reduce effectiveness, particularly in peripheral vision.

Figure 1 illustrates the RLCS implementation within the "Krizor" application, displaying simple toggles for selecting the desired colour (s) and an activation button for initiating the signal. Once RLCS is active, the button assumes a deactivation role, as demonstrated in Figure 2.

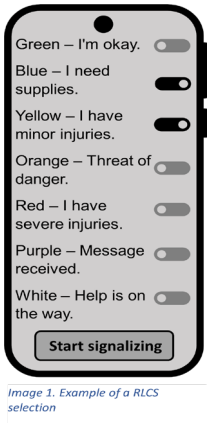


Figure 1. Example of an RLCS digital interface on a mobile device

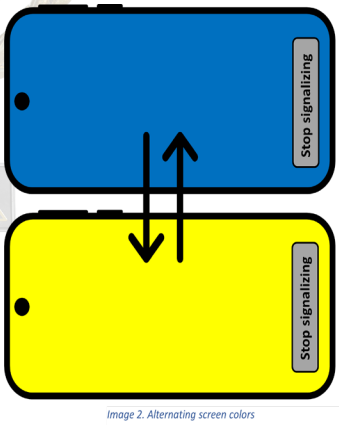


Figure 2. Portrayal of an activated RLCS signalisation on a mobile device

4. Advantages and Potential Applications

RLCS provides several key advantages:

1. Seamless Integration and Accessibility – Designed for widespread mobile use, RLCS is easy to adopt, functions offline, and aligns with multiple ISO standards for emergency communication.
2. Intuitive and Inclusive Design – A simple toggle-based interface ensures quick activation, making it accessible to users in high-stress situations, including individuals with disabilities.

3. Automated Functionality – Once activated, RLCS operates independently, allowing users to focus on survival and response efforts.
4. Efficient Rescue Prioritisation – Clear, standardised visual signals enable emergency responders to assess and prioritise assistance rapidly.
5. Versatile Implementation – Beyond digital displays, RLCS can be adapted for physical applications, such as colour-coded clothing and flags, ensuring usability when electronic devices are unavailable.
6. Optimised Colour Recognition – By employing an extended RYB model, RLCS minimises misinterpretation and enhances visibility, particularly in low-contrast environments.

4.1 Applications in Flood Emergencies

Floods can make verbal communication almost impossible due to high noise levels and physical isolation. RLCS can provide a quick, visual way for individuals to signal their condition, even when water and debris interfere with sound. The advantage of prioritisation becomes apparent in a flooded environment, where there are often multiple groups of people stranded on roofs or similar, and aerial rescue requires lightning-fast triage. Research on flood risk management (Cutter et al., 2003) highlights the need for alternative signalling methods, and RLCS meets this need by offering clear visual cues.

4.2. Applications in Stealth Environments and Urban Terrorism

In situations like urban terrorism or violent conflicts, discretion is vital. Loud or obvious signals can draw unwanted attention. RLCS offers a silent, non-verbal method of communication that can be activated without alerting nearby threats. Studies on crisis communication during terrorism (Coombs, 2007) highlight the importance of secure and quiet communication, and RLCS's visual approach has significant potential to be useful in such events.

4.3 Applications for Individuals with Disabilities

For individuals with disabilities, particularly those who experience difficulties in speaking or hearing, conventional communication methods frequently prove inadequate. The RLCS offers an accessible interface that is independent of verbal communication. This system is customisable, allowing for alterations such as larger icons or simplified tools to accommodate individuals with diverse impairments better. The World Health Organisation (WHO, 2011) emphasises the importance of inclusive emergency systems, and RLCS is well-aligned with these recommendations.

In the context of colour blindness, RLCS mitigates potential challenges by integrating textual descriptions alongside colour-coded signals. Users with colour vision deficiencies can effectively navigate the system by referring to the accompanying text. Additionally, while first responders are unlikely to have colour blindness, training programs should account for this possibility to ensure accurate interpretation of signals. Furthermore, individuals with colour blindness who receive a distress signal can verify its meaning by recording their screen and presenting the footage to someone capable of perceiving colours accurately.

Regarding individuals with other visual impairments, prospective enhancements may include alternative signalling techniques, such as auditory or tactile alerts, to ensure that RLCS remains maximally inclusive. For individuals with severe disabilities, an assisted signalling system could be implemented, allowing a nearby responder to assign an appropriate RLCS signal based on their assessment and the individual's feedback. This method would facilitate rapid triage and resource allocation by rescuers while ensuring that individuals with disabilities remain identifiable for further assistance.

4.4 Applications in Offline Use

In disaster scenarios where digital infrastructure may be compromised, offline applications of RLCS become critical for ensuring effective communication and rescue operations. Although RLCS is primarily designed for digital applications, it can be adapted for use in scenarios where mobile screens or battery power are inaccessible, utilising everyday objects. During daylight hours, individuals in distress may use colour-coded materials, such as shirts, tablecloths, or fabric banners, to signal for help. These items can be positioned in prominent locations, such as rooftops or open fields, or displayed in windows, ensuring optimal visibility from both aerial and ground search teams.

At nighttime, RLCS-based signalling will necessitate an external light source. By illuminating a flashlight, vehicle headlights, or a campfire behind a translucent or semi-transparent coloured object, individuals can project signals to rescuers. This strategy could be particularly beneficial if optical or digital zoom capabilities are available, allowing emergency personnel to identify signals from a distance. However, several challenges may arise with this method:

- Light Source Availability: During extreme disaster situations, access to artificial light may be restricted, diminishing the effectiveness of nighttime signals.
- Colour Accuracy and Recognition: The visible colour of fabric materials can be affected by surrounding lighting conditions, dirt, or wear, potentially leading to misinterpretation of the colour.
- Environmental Interference: Fog, smoke, heavy rain, or physical barriers can further obstruct visibility, particularly at night.
- Standardisation Issues: Since RLCS can be improvised with readily available materials in emergency contexts, precise control over brightness and hue consistency may not always be feasible.
- Nevertheless, RLCS is engineered to prioritise general colour recognition over specific shades, ensuring that the conveyed message remains comprehensible despite variations in materials and lighting conditions. To address these challenges, incorporating offline RLCS methodologies into training for emergency preparedness and related awareness initiatives may improve their implementation. Future research should focus on developing standardised materials, such as reflective sheets or phosphorescent coatings, to enhance the reliability and visibility of offline RLCS signals in diverse environmental conditions.

4. Alpha Trial Status and Future Directions

The alpha trials involved four participants divided into two groups. Both groups utilised the digital RLCS system without prior knowledge of the signals being displayed by the other group. Communication was conducted via radio frequencies, with participants verbally identifying the colours they perceived. Their challenges in recognising colours, as well as the reasons for their confidence in their assessments, were documented at each measured distance.

4.1 Daytime Testing Observations

Initial field assessments conducted during daylight hours uncovered several important observations regarding the practical visibility and functionality of RLCS. One of the main issues identified was the visibility of colours at extended distances. Under sunny conditions, colour differentiation was effective only within a limited range of up to 5 meters. Beyond this distance, even when utilising an additional mobile device for zooming, the clarity of the colour signals significantly decreased, resulting in possible misinterpretations.

Conversely, during cloudy weather, the effective range increased to approximately 7 to 10 meters. Nevertheless, the clarity of the colour signals still diminished with distance, underscoring that RLCS

is most effectively utilised for close-range applications in bright environments while still maintaining greater ranges in less intense sunlight.

These results align with existing studies on visual perception in emergencies, which highlight that environmental lighting conditions significantly impact signal visibility (Yuan, Wang, & Li, 2020). Given these constraints, alternative physical signalling methods, such as textile markers or reflective materials, might be more appropriate for long-range communication in bright conditions. Nonetheless, RLCS demonstrated effectiveness in short-range situations, particularly in environments where verbal communication was impractical due to elevated ambient noise or the necessity for silence. In these instances, rapid, discreet visual signals could still be communicated and comprehended, highlighting RLCS's potential for group coordination in tactical or high-noise settings.

4.2 Nighttime Testing Observations

Nighttime trials of the digital RLCS system were conducted on the bank of the Sava River in Zagreb on March 22nd, 2025, between 20:00 and 22:00, under clear weather conditions.

They demonstrated significantly improved visibility compared to daytime conditions, with colour signals remaining discernible to the naked eye at distances of up to 70 meters. Within this range, both individual colours and multi-colour combinations were distinguishable, confirming the system's effectiveness for short- to mid-range signalling in low-light environments.

Between 70 and 100 meters, some difficulties emerged in differentiating between similar shades, particularly yellow and white, as well as pink and red. However, contextual interpretation played a crucial role in mitigating potential misidentifications. For instance, in a rescue scenario, if a responder encounters an ambiguous signal that could be either pink (meaning a message has been received) or red (indicating urgent assistance is needed), the logical assumption would lean toward red, as communication is just being established. This aligns with research on situational awareness in emergency signalling, which emphasises the role of contextual cues in decision-making under uncertainty (Seeger, Sellnow, & Ulmer, 2003). While stress may impair cognitive processing (Wogalter & Mayhorn, 2005), the RLCS interface includes textual descriptions of colour meanings, which further aid in correct interpretation.

Beyond 100 meters, colour recognition without optical assistance became unreliable, necessitating the use of a smartphone camera or binoculars for accurate identification. Under these conditions, signalling with a single colour at a time proved most effective. Notably, high-contrast colours such as red, green, and blue, as well as yellow, remained the most visible, aligning with findings on colour perception in low-light conditions (Yuan, Wang, & Li, 2020).

At distances exceeding 200 meters, standard unaided visual recognition became impractical. However, given that professional rescue teams and some civilians (e.g., hunters and birdwatchers) commonly utilise binoculars or other optical tools, it is reasonable to assume that RLCS signals could still be identified with appropriate equipment. Further trials with specialised optics could provide more precise data on effective recognition ranges under varying environmental conditions.

These findings suggest that RLCS is highly effective for short to mid-range communication in nighttime scenarios and can still function at longer distances with optical aids. Future work will explore potential enhancements, including increasing screen brightness, optimising contrast ratios, and evaluating the use of reflective materials or auxiliary lighting to extend the operational range of RLCS.

5. Discussion

One major challenge is ensuring that RLCS signals are accurately deciphered and effectively incorporated into current emergency response frameworks. A well-established phenomenon is a variation in colour perception between populations and under stress. According to psychological

research, high levels of stress can influence cognitive processing, which may impact how people perceive and respond to visual stimuli (Wogalter & Mayhorn, 2005).

Furthermore, cultural differences must be considered, even though RLCS adheres to the established colour-coding principles outlined in standards such as ISO 7010 and ANSI Z535. In China, for instance, red is typically connected to joy and good fortune rather than peril or urgency (Huang, 2011).

To address this, the significance of international training workshops and cooperation with organisations such as the Red Cross, the United Nations Office for Disaster Risk Reduction (UNDRR), and the Preparedness and Resilience for Emergency Response (PREPARE) Centre is emphasised to encourage uniform comprehension and adoption of RLCS across various regions. This aligns with the Sendai Framework for Disaster Risk Reduction, which highlights the importance of global cooperation and standardised communication strategies to enhance resilience in disaster-prone areas (UNISDR, 2015).

Additionally, further studies by Cvetković et al. (2021) suggest that the public's perception and understanding of disaster communication tools vary significantly across different demographic groups, underscoring the need for targeted education and awareness campaigns to ensure successful implementation. However, even well-designed systems run the risk of being misinterpreted or underutilised in the absence of such efforts.

Moreover, standardisation in emergency and triage procedures is also necessary for RLCS to be widely adopted. A popular triage protocol, called START (Simple Triage and Rapid Treatment), uses colour coding to categorise victims into various priority levels (Kahn et al., 2009). Similar to the critical and non-critical categories in the START system, RLCS uses red to indicate severe injuries and green to indicate those who are unharmed. Strengthening RLCS's alignment with such standardised practices would further enhance its role in disaster preparedness and response.

In addition to these challenges, environmental and technological constraints present further difficulties. Particularly in direct sunlight, screen glare, brightness limitations, and display quality variations can affect the visibility of RLCS signals (Kim & Koga, 2020). Although backlit screens are helpful at night, visibility may still be affected in low-light levels without external lighting.

Furthermore, Vibhas et al. (2019) highlight that digital emergency tools often face disruptions due to unreliable communication infrastructure during disasters. To ensure RLCS remains effective in such conditions, incorporating physical alternatives – such as printed signal cards, flags, or wearable indicators–can provide redundancy when electronic devices are unavailable.

Similarly, fabric and other physical materials present colour consistency issues for offline RLCS applications, as textures and dyes can alter perception. Due to wear, dirt, or manufacturing variations, improvised materials may exhibit differences in brightness and hue compared to digital displays, which are designed to maintain controlled colour accuracy.

On the other hand, RLCS ensures usability even in imperfect environments by prioritising broad colour recognition over precise shades. This aligns with Cvetković's (2021) conclusion that emergency communication systems need to consider practical limitations to continue functioning effectively in emergencies.

Despite these challenges, RLCS represents a significant advancement in emergency communication. By implementing first responder training, standardisation initiatives, and partnerships with international disaster relief organisations, RLCS has the potential to enhance disaster relief efforts on a global scale significantly.

6. Conclusions

The Rescue Light Communication System (RLCS) offers a practical and standardised approach to addressing challenges in disaster communication. By leveraging a structured colour-based signalling system aligned with established emergency standards, such as ISO 7010, ANSI Z535, and the

START triage system, RLCS enhances the clarity and efficiency of visual emergency communication. Recent testing has demonstrated its effectiveness in nighttime conditions for distances up to 100 meters with the naked eye and beyond with optical aids. At the same time, daytime trials indicate that RLCS is most effective at shorter distances or when combined with physical signalling items.

Future research will focus on refining RLCS's usability under various environmental conditions, integrating it into broader emergency protocols, and exploring potential applications with wearable and dedicated hardware. User feedback from the current mobile implementation within the "Krizor" application on the Google Play Store will continue to inform these improvements, with plans for a dedicated RLCS application in development. Through continued testing, standardisation efforts, and collaboration with disaster response organisations, RLCS has the potential to become a globally recognised emergency communication tool.

Acknowledgements: I would like to thank my team at High Base Systems (Bruno Pušić, Niko Turčinov) for their support in establishing our Android application. I also thank the RLCS testers (Ante Medić, Jure Herceg, and Jure Salacan) and other Krizor early-stage testers, as well as anonymous reviewers of this work, for their valuable feedback.

Conflicts of Interest: The author declares no conflict of interest.

References

1. American National Standards Institute. (2017). *ANSI Z535: Standards for safety colours, signs, symbols, and tags*.
2. Carla S, R. G. (2019). School-Community Collaboration: Disaster Preparedness for Building Resilient Communities. International Journal of Disaster Risk Management, 1(2), 45-59.
3. Coombs, W. T. (2007). *Ongoing crisis communication: Planning, managing, and responding*. Sage Publications.
4. Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly, 84*(2), 242-261.
5. Cvetković, V. (2019). Risk Perception of Building Fires in Belgrade. International Journal of Disaster Risk Management, 1(1), 81-91.
6. Cvetković, V. (2021). Innovative solutions for disaster early warning and alert systems: A literary review. In *Eleven International Scientific Conference "Archibald Reiss Days"* (pp. 1–10). University of Criminal Investigation and Police Studies.
7. Cvetković, V., Radovanović, M., & Milašinović, S. (2021). Disaster risk communication: Attitudes of Serbian citizens. *Sociological Review, 55*(4), 1610-1647.
8. Fearn-Banks, V. (2016). *Crisis communications: A casebook approach*. Routledge.
9. Huang, Q. (2011). A study on the metaphor of "red" in Chinese culture. *American International Journal of Contemporary Research, 1*(3), 99-102.
10. International Electrotechnical Commission. (2001). *IEC 60073: Basic principles for human visual system design*.
11. International Organization for Standardization. (2011). *ISO 22324: Guidelines for color-coded alerts in emergencies*.
12. International Organization for Standardization. (2011). *ISO 3864: Graphical symbols – Safety colours and safety signs – Registered safety signs*.
13. International Organization for Standardization. (2011). *ISO 7010: Graphical symbols – Safety colours and safety signs*.
14. International Organization for Standardization. (2011). *ISO 9921: Ergonomics – Visual display requirements*.
15. Kahn, C. A., Schultz, C. H., Miller, K. T., & Anderson, C. L. (2009). Does START triage work? An outcomes assessment after a disaster. *Annals of Emergency Medicine, 54*(3), 424-430.

16. Kemeny, J. G., & Panerai, F. (2003). Human factors in emergency signage and wayfinding. *Journal of Safety Research, 34*(4), 389-397.
17. Kim, H., & Koga, K. (2020). The impact of display brightness and ambient light on colour perception. *Journal of Vision, 20*(11), 1-11.
18. Mayo, J., & Kim, S. (2018). Advances in visual ergonomics for emergency signage. *Journal of Environmental Design, 12*(3), 120–135.
19. Seeger, M. W., Sellnow, T. L., & Ulmer, R. R. (2003). *Communication and organizational crisis*. Praeger.
20. United Nations Office for Disaster Risk Reduction. (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030*.
21. Vibhas, S., Bismark, A. G., Ruiyi, Z., Anwaar, M. A., & Rajib, S. (2019). Understanding the barriers restraining effective operation of flood early warning systems. *International Journal of Disaster Risk Management, 1*(2), 1-19.
22. Wogalter, M. S., & Mayhorn, C. B. (2005). The future of risk communication: Technology-based warning systems. *Ergonomics, 48*(5), 478-491.
23. World Health Organization. (2011). *World report on disability*. World Health Organization.
24. Yuan, L., Wang, X., & Li, H. (2020). Enhanced color models for low-visibility emergency communication. *Safety Science, 134*, 105–112.

