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Principles of Constructing Lighting Schemes for Multi-Camera Shooting in Confined Spaces

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Abstract

The article examines the development of scientifically grounded principles for constructing lighting schemes for multi-camera shooting in confined spaces. The relevance of this work is determined by the exponential growth of streaming content combined with the expansion of the compact multi-camera systems market, which requires optimization of production processes and reduction of costs while maintaining stable image quality and complying with safety requirements. The study aims to formulate a sequential methodology for designing lighting schemes that takes into account room geometry, camera optical parameters, and thermal characteristics of LED fixtures. The novelty of the work lies in the integration of three stages of space analysis—geometry audit, zone priorities, light corridor—united by a cross-key lighting scheme; a clear procedure for calculating camera fields of view by angle of view; a glare-risk assessment based on Unified Glare Rating; and recommendations for selecting fixtures with high TLCI and CRI values to minimize post-processing. Also, rules have been made for putting power supplies together and for joined ventilation to keep workers safe and make sure the gear stays steady. The main results show that the suggested method allows to cut the number of light fittings by nearly half, provides even exposure across cameras, eliminates overheating and power grid overloads, and makes color tuning easier because it requires shooting a color chart with one set level for CCT. This article will be helpful to lighting engineers, technical directors of television production, and studio designers.

Keywords: *Lighting Schemes, Multi-Camera Shooting, Confined Space, LED Lighting, Cross-Key.*

INTRODUCTION

In recent years, global media consumption has rapidly shifted online, and in May 2025, streaming services for the first time surpassed the combined broadcast and cable segments, accounting for 44.8% of total television viewing. Traditional channels retained just 44.2% (Pabst, 2025). The faster growth of streaming raises the need for dynamic stories that directly increase the need for multi-camera setups, which allow the simultaneous capture of many angles for live editing and interactive functions.

This want gets back to the market: the global multi-camera systems market is pegged at USD 2.47 billion in 2025 and, by forecasts, will reach USD 3.86 billion by 2030 at a compound annual growth rate of 9.34% (Mordor Intelligence, 2025). However, the majority of such projects are implemented not in full-scale studios but in compact premises, including mobile stages, coworking spaces, and converted apartments, where every extra watt of heat and every centimetre of space becomes a critical resource.

It is for this reason that the industry is actively transitioning to energy-efficient LED solutions. The shift to solid-state sources has already proven its economic efficiency: the U.S. Department of Energy recorded annual savings of 1.3 quadrillion BTU in 2018, equivalent to USD 14.7 billion in reduced electricity costs, thanks to the replacement of traditional lamps with LEDs (U.S. Department of Energy, 2020).

Streaming content grows exponentially;, the multi-camera systems market expands;, and compact LED fixtures get adopted widely. These factors make up an urgent science-based principle development task for lighting scheme construction inside confined spaces. Methodology will lower costs of production, increase visual coherence between material from different cameras, and provide stable exposure sans overheating or overloading power grids. That determines relevance regarding this study.

MATERIALS AND METHODOLOGY

The study is based on the analysis of 19 sources, including academic publications, industry reports, manufacturers' technical cases and standards of the EBU and SMPTE. The theoretical foundation comprised works on spatial modelling and optical requirements for multi-camera setups: ProGrade

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Digital describes planning rules for fields of view and adherence to the 180-degree rule (ProGrade Digital, 2023), Ikan demonstrates the importance of identical exposure settings for PoE-controlled PTZ cameras (Ikan, 2025), Viula et al. investigate the impact of glare on visual comfort through the Unified Glare Rating (Viula et al., 2019), and the Technical Centre of the European Broadcasting Union along with Hodgetts substantiate methods for assessing CRI and TLCI for live broadcasts (Technical Centre of the European Broadcasting Union, 1989; Hodgetts, 2013). Energy and thermal characteristics of LEDs were taken from U.S. Department of Energy reports (U.S. Department of Energy, 2018; U.S. Department of Energy, 2020), and specifications of key fixtures are provided in documentation of Aputure and ARRI for RGBWW panels and COB heads (Aputure, 2020; Aputure, 2021; ARRI, 2024).

Comparative analysis of approaches to constructing lighting schemes in confined spaces—identified in industry reports and manufacturers' technical documentation—included descriptions of cross-key techniques and isolated exposure zones (V Renée, 2018), recommendations on the 180-degree rule and management of camera fields of view (ProGrade Digital, 2023; Ikan, 2025), as well as specifications of LED panels and COB heads, their color rendering and thermal characteristics (Aputure, 2020; ARRI, 2024). The comparison of data enabled the identification of optimal schemes for fixture placement in terms of space saving, exposure uniformity, and operational safety, as well as the development of criteria for selecting equipment and accessories for compact studios.

RESULTS AND DISCUSSION

To limit errors in subsequent lighting and camera design stages, the first step is a detailed site audit. A laser rangefinder or photogrammetric LiDAR survey records length, width, height and slopes to the nearest centimetre, after which the data are imported into CAD, enabling construction of an accurate model of power grids and the ceiling and immediate visualization of where a tripod or mount will be closest to a wall, a distance critical for safe operator movement in narrow corridors.

Next, the scene geometry is translated into optical requirements. The horizontal angle of view (AOV) of the camera field of view is used as a calculation parameter. During camera planning, the continuity of the visual axis is maintained: setups are arranged along an imaginary action line, adhering to the 180-degree rule so as not to disrupt the spatial logic of editing (ProGrade Digital, 2023). A practical guideline is that each tripod or PTZ head is assigned its sector; sector overlap is managed by zoom rather than by repositioning cameras, otherwise the risk of light overlap increases. Industry recommendations emphasize that identical sensors and identical exposure settings across cameras reduce balancing time during live switching, especially in the case of PoE-powered PTZ robotic units (Ikan, 2025).

The final audit element is reflection analysis. On glossy surfaces of walls or furniture, the maximum brightness of spots is measured with a candela meter, after which the Unified Glare Rating is calculated; with UGR ≥ 22, for general shots, persistent discomfort occurs, and light is redirected using flags or polarizing filters (Viula et al., 2019). In Figure 1, a floor plan of the room and four fisheye shots from different points are shown, illustrating camera placement and their field-of-view overlaps.

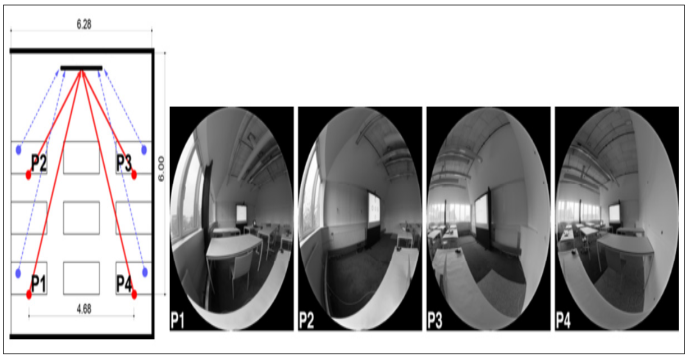

Fig. 1. Plan view of the room and views from the four positions (Viula et al., 2019)

Simultaneously, color rendering is checked: a TLCI index above 85 guarantees that LED panels will not require post-correction, whereas a value of 70–80 will need at least minimal color grading. The gradation scale provided by EBU Tech-i indicates that only the range 80–100 is considered sufficient without correction, which corresponds to the limits established in SMPTE RP 2093 (Hodgetts, 2013).

Such a sequential audit of space, viewing angles, and reflection risks transforms a confined set into a predictable system: by the time the actual lighting scheme is calculated, the team already has numerically justified constraints and margins in terms of light and framing, which will allow avoidance of pre-shoot rearrangements and equipment downtime.

After the geometric survey of the room and calculation of viewing angles, the next step is the placement of sources, and here, the islands of light principle works most reliably. Key fixtures form the primary exposure zones, and their beams intersect such that the same light stream serves as key for the nearest camera and fill for the opposite one. This scheme is known as cross-key: an experiment on a low-budget set demonstrated that two or three panel sources provide full coverage for two opposite angles, reducing the number of fixtures by almost half and freeing up space for operator walkways (V Renée, 2018).

After zoning is marked, priorities are assigned: first, the key light for the primary camera is set, then the fill is synchronously adjusted based on the maximum permissible brightness difference. For standard television broadcasting, SMPTE engineers have, for many years, limited the key-to-fill ratio to 2:1, and this requirement is still monitored on a waveform monitor during a multi-camera live switch (Williams, 2022). In order not to lose skin detail, the maximum illuminance is maintained in the range of 1000–1500 lx, which the EBU uses as its working value when testing camera colour accuracy; in confined studios the lower boundary is sufficient, since modern sensors preserve signal-to-noise ratio at ISO 800 and above (Technical Centre of the European Broadcasting Union, 1989).

The choice of LED fixtures is critical not only for exposure but also for thermal balance. A study by the U.S. Department of Energy showed that solid-state sources consume up to 85% less energy than equivalent incandescent lamps while simultaneously reducing heat output, which directly reduces the load on air-conditioning in small studios (U.S. Department of Energy, 2018). As a result, key panels can be placed closer to actors without the risk of overheating the set or exceeding available power capacity.

For moving subjects, a lighting corridor is established: soft tubes on ceiling booms provide continuous floor illumination; this level guarantees crew safety and frame uniformity when actors move between zones. The corridor is constructed from fixtures with wide diffusers and grids so that the light boundary remains outside camera angles and does not spoil the contrast of key zones. Thus, the sequential scheme zone – priority – corridor combines equipment economy, stable exposure, and movement safety, forming the basis for further precise control of glare and colour consistency.

Key and fill lighting in a small studio is best implemented using slim RGBWW panels such as the Aputure Nova P300c: a single 300-watt panel delivers over 9 000 lx at 1 m, maintains a correlated colour temperature from 2 000 K to 10 000 K and a claimed TLCI of 95 +, and thus allows the same setup to cover daylight, tungsten and effect modes without changing filters (Aputure, 2020). The placement priority is as follows: the panel is first positioned as the key for the primary camera, then its diffused beam is used as fill for the opposite angle, which reduces the number of fixtures and frees the walkways established in the previous zoning stage.

The switch to LED sources provides not only a controllable spectrum but also a tangible resource saving: according to U.S. Department of Energy calculations, widespread use of LED lighting in 2018 already saved 1.3 quadrillion BTU and USD 14.7 billion in electricity costs, and with full implementation of intelligent systems the saving potential increases fourfold (U.S. Department of Energy, 2020). For a confined studio, this gain is expressed in reduced heat output: a 300-watt RGBWW panel emits only a fraction of the heat of an equivalent halogen, thus it can be hung closer to the actor without raising the set temperature or overloading the air-conditioners.

Narrow-angle COB forms Backlight heads with Fresnel optics; a typical example is the ARRI Orbiter, in which the High CRI mode delivers an average TLCI above 95 over a range of 3,200–5,600 K, and the focusing from 15° to 45° allows precise silhouette definition without spilling light onto the walls (ARRI, 2024). Such a fixture is mounted above the camera eyeline, directing the beam tangentially to the subject: the light is sufficient to separate the actor from the background, and the narrow beam hardly interferes with the exposure of adjacent zones.

Accent and decorative sources take on the tasks of spark and practical on-camera lighting. Compact bright lamps Accent B7c, with a power of 7 W, operate from a standard E27 socket, have an internal battery for 70 minutes of full brightness and the same 2 000–10 000 K range as the main panels, therefore they can be dimmed or switched off via DMX without changing the scene's color balance (Aputure, 2021). As shown in Figure 2, with increasing correlated colour temperature (CCT), illuminance in lux and foot-candles at all three distances increases from 2000 K to a peak at 5500–6500 K.

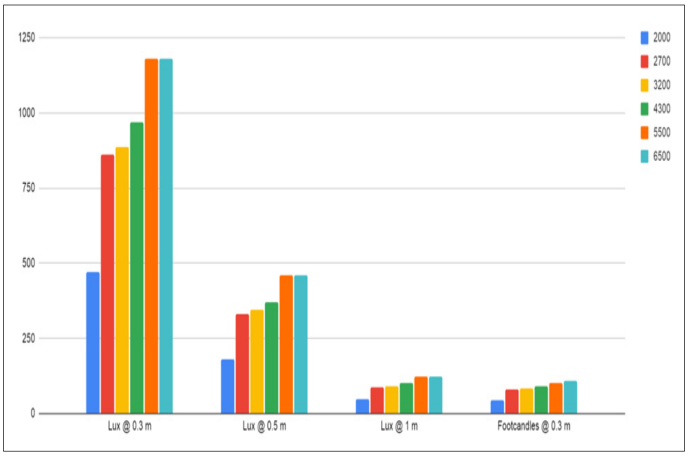

Fig. 2. Relationship between CCT and Illuminance (ARRI, 2024)

To limit spill, accessories are used: fabric or metal honeycomb grids with an angle restriction reduce the beam nearly by half while maintaining a soft light transition. When a sharper cutoff is needed, eight-leaf barn doors CF12 permit blocking side spill thanks to additional sliding leaves and support the installation of scrims, adding another level of control (Aputure, 2023). On soft modifiers such as the Light Dome III, the integrated 40-degree fabric grid performs the same function without requiring a separate frame (Aputure, 2022).

Glare and parasitic reflections are eliminated by combining grids and black fabrics. In scenes where walls or furniture produce unwanted reflections, duvetyne cloths are hung around the perimeter, or flags are set up. The combination of high-precision LED fixtures with high TLCI, narrow-angle backlights, controllable accent lamps, and properly selected accessories creates a flexible and cost-efficient system in which each camera receives stable exposure and operators retain freedom of movement even on the most confined set.

The fixtures have already been distributed by zone and power, yet without strict colour discipline, even perfectly set illuminance levels will not prevent contrast discrepancies between cameras. The first parameter to establish is the target correlated colour temperature. Studio practice for almost twenty years has maintained a daylight reference of 5600 K: it was under this spectrum that the first high-efficiency LED modules were developed, and it is close to the white point of most video walls that are actively used as backgrounds. A TV Tech review emphasizes that studios' switch from old 3200 K halogens to 5600 K LEDs occurred not for aesthetic reasons but because of higher light output and compatibility with display panels (Aleksander, 2024). In practice, working at intermediate values such as 4400 K is permissible. Still, it is vital that all fixtures and all cameras maintain the same CCT with an unaltered Planckian locus throughout the entire shoot.

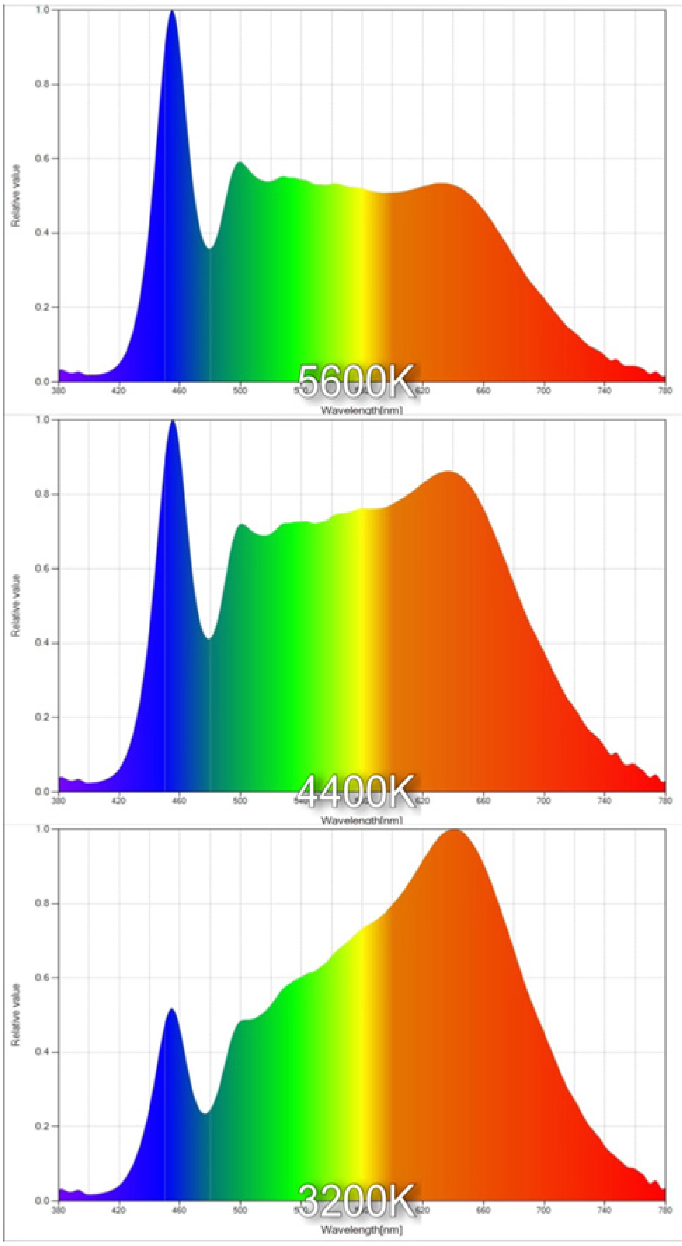

Fig. 3. Spectral Power Distribution from the same full-color LED fixture adjusted to (top to bottom) 5600K Daylight, 4400K Neutral White, and 3200K Incandescent (Aleksander, 2024)

Spectral quality of light is quantitatively described by CRI and TLCI, with the latter index more accurately reflecting how a camera sensor responds to the spectrum. In its TLCI-2012 recommendation, the EBU defines a software model of a standard camera and considers a rating of 85–100 sufficient for live broadcast without subsequent correction (Tomkies, 2016). Manufacturers targeting the broadcast market build in an even larger margin: the Cree LED marketing guide specifies a combined TLCI + CRI threshold of no less than 90, and for critical colours 95 at a daylight CCT of 5700 K (CreeLED, 2022). Accordingly, on set, it is practical to adopt the rule that any primary panel must have CRI ≥ 95 and TLCI ≥ 90, which guarantees delta-E errors on skin below three units, so that live camera matching can be accomplished with a simple white balance without a complex colour corrector.

Even when CCT is consistent and indices are high, cameras of different brands often diverge in their sensor matrices, so each setup begins with neutralization via a colour chart. It is sufficient to shoot the chart under key light, import the frames into a calibration software, and apply the resulting profile to the entire session; this ensures colour repeatability under any exposure change, as discussed in the previous section. The combined adherence to a uniform temperature, strict CRI/TLCI thresholds, and mandatory chart shooting completes the basic calibration cycle, after which all further light control reduces to percentage dimming rather than correcting unexpected hue shifts.

In a confined space, the ceiling becomes the largest reflector, so it is more sensible to build soft light upon it. A matte white surface, illuminated by a narrow beam from an LED panel, functions as a large softbox: the beam angle is chosen so that the bright spot remains outside the frame, and cameras see only the diffused glow. In this scheme, the illuminance falls off gradually, eliminating harsh boundaries and equalizing exposure between the zones previously defined. If the ceiling is painted in a complex shade, a lightweight diffusion fabric may be stretched across a frame to create a neutral reflecting plane without repainting.

Glossy surfaces present a different challenge, since a mirror-like reflector directs the beam straight into the lens and produces unwanted glare. In such cases, a suspended diffusion dome is used, or thin non-gloss films are applied to reduce the reflection coefficient by nearly half. Additional flags around the ceiling perimeter absorb excess spectrum without affecting the overall temperature, as described in the previous section. Combining these measures allows the physical dimensions of the set to remain unchanged while optically neutralizing its shortcomings.

Once lighting zones are defined, the primary limiter becomes the electrical supply. Even with energy-efficient sources, the total load is distributed symmetrically across multiple circuits to prevent voltage drops and false breaker trips. Each circuit is labelled according to fixture location and cumulative power, simplifying diagnostics in case of overload. Separate breakers for key and decorative lights also allow secondary lines to be shut off in an emergency while preserving the main picture and monitoring.

Cables in a narrow studio corridor must follow neat trajectories: flat power buses are run along walls and secured with low-friction textile tape. In contrast, signal cables are routed overhead where the risk of tripping is minimal. Permissible crosstalk between power and data is reduced by using screened twisted-pair, yet physical separation of routes remains the primary defence against impulsive noise.

Thermal management completes the safety picture. Although an LED fixture generates less heat than a halogen, dense rigging can cause localized overheating when panels face the ceiling. This is addressed by combined ventilation: silent axial fans with variable flow are installed under the ceiling, and a through-floor air intake is left open. Temperature is monitored by digital sensors and displayed on a central console where the lighting technician views it alongside dimming parameters. Thus, technical safety is integrated into the same control system that manages exposure, colour, and scene dynamics.

CONCLUSION

Based on this study, the developed sequential methodology for constructing lighting schemes for multi-camera shooting in confined spaces provides a comprehensive solution to the key challenges of organizing compact sets. First, a detailed geometry audit of the room combined with reflection analysis and optical requirements yields numerically justified constraints for camera and fixture placement, reducing the risk of pre-shoot rearrangements and equipment downtime.

Next, applying the zone – priority – corridor principle demonstrates high efficiency: forming primary exposure zones with a cross-key scheme and synchronously adjusting key-to-fill preserves visual coherence between cameras while halving the number of fixtures. A lighting corridor of soft ceiling tubes ensures actor movement safety and uniform illumination during angle changes.

Relying on slim RGBWW panels with high TLCI and CRI, narrow-angle COB heads for backlight and mobile accent lamps achieve robust colour discipline without post-correction: a unified CCT, mandatory chart calibration, and strict colour-index thresholds guarantee minimal delta-E errors in live broadcast. Use of accessories—grids, barn doors, and flags—allows flexible control of glare and parasitic reflections while maintaining compact rigging.

Finally, integrating technical solutions for power management, cable routing, and thermal control transforms small studios into safe and reliable workspaces. Circuit grouping, neat cable layouts, and combined ventilation with digital temperature monitoring prevent overloads and local overheating.

Thus, the proposed principles deliver reduced production costs, stable exposure, colour consistency, and technical-staff safety even in the most confined spaces, confirming their practical significance and readiness for large-scale implementation in modern multi-camera streaming and television projects.

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