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Enhancing Climate Resilience in Kenya's Maize Supply Chains through Digital Procurement: A Systematic Review

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Abstract: **Climate change continues to destabilize Kenya's maize supply chain, exacerbating food insecurity through erratic weather patterns, declining yields, and heightened production risks. This paper presents a systematic review of empirical and grey literature to assess the role of digital procurement particularly e-procurement platforms in enhancing resilience, sustainability, and efficiency within the maize supply chain. Guided by PRISMA methodology, 15 studies published between 2010 and 2024 were critically appraised to evaluate the impact of digital tools on cost efficiency, supply chain responsiveness, inventory control, and climate adaptability. Findings indicate that e-procurement technologies improve real-time decision-making, transparency, and coordination among stakeholders. They also promote climate-smart practices through better input targeting, market integration, and reduced post-harvest losses. The paper recommends scaling digital infrastructure, mainstreaming e-procurement across value chains, and enhancing digital literacy. Strengthening regulatory frameworks around interoperability, data protection, and institutional accountability is also essential for building a resilient and inclusive maize supply system capable of withstanding future climate and market shocks.**

Keywords: **digital procurement, e-procurement, maize supply chain, resilience, sustainable agriculture, climate-smart agriculture.**

1. BACKGROUND & LITERATURE REVIEW

Kenya's maize supply chain plays a critical role in national food security and rural livelihoods, with the crop cultivated on over 90% of farms (Agriculture and Food Authority, AFA). However, the sector faces mounting climate-related stressors erratic rainfall, prolonged droughts, and rising temperatures which have adversely affected yields and disrupted supply chain operations (Chikoore & Jury, 2021; Thoithi, Blamey & Reason, 2021). The World Bank Climate Risk Profile (2021) attributes these disruptions to environmental degradation, pest outbreaks, and soil erosion, with smallholder farmers being particularly vulnerable.

To bridge recurrent production shortfalls, Kenya has increasingly turned to imports, sourcing over 277,000 metric tons of maize mainly from Uganda and Tanzania in 2020 (MOA, 2021). However, this reliance introduces additional risks, including foreign exchange volatility and exposure to regional climate and trade policy shocks (Zhai et al., 2021). Broader projections for Sub-Saharan Africa forecast a 5% decline in staple crop production by 2050 under a 1.5°C warming scenario, with a corresponding 21% drop in per capita food availability (IPCC, 2019; KIPPRA, 2019).

Kenya's maize value chain also suffers from systemic inefficiencies such as limited irrigation, poor infrastructure, fragmented extension services, and manual procurement systems. These constraints reduce visibility, increase transaction costs, and limit responsiveness (Gunasekaran et al., 2019; Xu et al., 2024). Digital procurement technologies including e-sourcing platforms, mobile input systems, and real-time inventory tools offer potential solutions by improving transparency, coordination, and climate adaptability (Kamilaris et al., 2019; Saberi et al., 2019; Balcıoğlu et al., 2024).

Over 100 digital tools have been deployed in Kenya's agricultural sector, several integrating procurement functionalities (Bowling et al., 2021). Studies indicate that such tools can enhance market access, input delivery, and supply chain performance particularly when adapted to smallholder contexts (Alabdali et al., 2022; Mogere, 2021; Kagondu, 2023). However, adoption remains uneven due to digital illiteracy, infrastructure gaps, limited rural connectivity, and fragmented institutional support (Compagnucci et al., 2022; Aseka, 2019; Ministry of Agriculture, 2022).

This paper responds to these challenges by systematically reviewing literature on the potential of digital procurement to enhance resilience, sustainability, and efficiency in Kenya's maize supply chains.

2. THEORETICAL REVIEW

The transformation of Kenya's maize supply chain in response to climate-related disruptions and technological innovation can be critically examined through two interrelated theoretical lenses: Diffusion of Innovation (DOI) Theory and Supply Chain Resilience Theory (SCRT). Together, these theories provide a multilayered framework for understanding both the adoption dynamics and system-wide impacts of digital procurement technologies within agricultural contexts.

Diffusion of Innovation (DOI) Theory, originally advanced by Rogers (1962; 2003), explains how new ideas and technologies spread within a social system over time. Adoption is influenced by five key attributes: relative advantage, compatibility, complexity, trialability, and observability. In the context of digital procurement for maize supply chains, DOI offers insight into the micro-level behavioral and institutional factors that affect technology uptake among farmers, suppliers, and procurement officers. For instance, e-procurement systems may offer relative advantages in cost savings and transparency, yet face adoption barriers due to low digital literacy, infrastructural limitations, and resistance to change (Hanelt et al., 2021). DOI thus highlights the need for targeted capacity-building, participatory design, and policy incentives to foster meaningful adoption and sustained use of digital tools.

Complementing this perspective, Supply Chain Resilience Theory (SCRT) emphasizes the ability of supply chains to absorb, adapt to, and recover from disruptions, such as those induced by climate change, trade shocks, or pandemics (Christopher & Peck, 2004). SCRT is particularly relevant at the meso- and macro-levels, providing a system-wide understanding of how digital procurement tools can enhance visibility, coordination, responsiveness, and adaptive capacity across the supply chain. Key mechanisms include real-time data sharing, predictive analytics for demand and climate forecasting, and digital traceability systems that reduce lead times and mitigate post-harvest losses (Ponomarov & Holcomb, 2009; Balcıoğlu et al., 2024).

Operationally, these theories are complementary. DOI addresses the socio-technical processes at the grassroots and organizational levels that determine whether digital procurement innovations are accepted and diffused. In contrast, SCRT focuses on structural and systemic enablers that determine whether such innovations translate into measurable improvements in resilience, sustainability, and efficiency. DOI helps explain the "how" and "why" of adoption behavior, while SCRT addresses the "so what" of adoption; its implications for risk mitigation, performance, and long-term sustainability.

Together, DOI and SCRT offer a robust theoretical foundation for this study. They support the development of a conceptual framework that positions digital procurement as both an innovation diffusion process and a resilience-building strategy within Kenya's maize supply chain. This dual lens enables a holistic assessment of the technological, institutional, and socio-economic drivers that shape digital transformation in agri-food systems under conditions of increasing climate uncertainty.

3. METHODOLOGY

This study adopted a systematic literature review methodology to examine the role of digital procurement in enhancing cost efficiency, sustainability, and resilience in Kenya's maize supply chains. The review was conducted in line with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2009), which emphasize transparency, comprehensiveness, and replicability.

3.1 Search Strategy

A systematic search was undertaken across multiple databases including Scopus, Google Scholar, JSTOR, AGORA, and ScienceDirect to identify peer-reviewed and grey literature relevant to digital procurement and agricultural supply chains in Kenya. The strategy ensured broad coverage of empirical studies, policy reports, and conceptual contributions.

To complement academic sources, grey literature such as policy briefs, government publications, and development agency reports were included. These were obtained from the websites of the World Bank, Alliance for a Green Revolution in Africa (AGRA), Ministry of Agriculture, Livestock, and Fisheries – Kenya, and Dutch Development Finance Company (FMO/DFCD). The inclusion of grey literature aligns with recommended systematic review practices, particularly in sectors where non-academic stakeholders generate valuable insights (Paez, 2017; Godin et al., 2015).

The search employed Boolean logic and keyword combinations such as:

- "Digital procurement" AND "maize supply chain" AND "Kenya"
- "E-procurement" OR "mobile agriculture" AND "resilience" OR "sustainability"
- "ICT in agriculture" AND "Sub-Saharan Africa"

Only studies published between 2010 and 2024 were considered, and the review was limited to English-language sources. Reference lists of key articles were also manually screened to identify additional relevant studies.

3.2 Inclusion and Exclusion Criteria

To ensure the relevance and quality of the studies included in this review, clearly defined inclusion and exclusion criteria were applied in accordance with systematic review best practices (Moher et al., 2009; Higgins et al., 2022).

Inclusion Criteria:

Studies were eligible for inclusion if they met the following conditions:

- Published between 2010 and 2024, to capture contemporary trends in digital technologies and procurement practices;
- Peer-reviewed journal articles, technical reports, and policy briefs that provided empirical or theoretical insights into digital procurement within the context of maize supply chains or broader agricultural systems;
- Focused on Kenya or comparable contexts within Sub-Saharan Africa, where agricultural transformation and digital interventions are a strategic development focus;
- Written in English, given language constraints and the availability of translated regional literature.

Exclusion Criteria:

Studies were excluded based on the following:

- Literature unrelated to agriculture, procurement, or supply chain management, even if it addressed digital technologies;
- Non-empirical articles such as opinion pieces, editorials, or blog-style content that lacked methodological rigor;
- Duplicates, inaccessible full texts, or publications lacking sufficient data for synthesis.

These criteria ensured that the review remained focused, rigorous, and relevant to the study's objective of evaluating the role of digital procurement in building resilient and sustainable agricultural supply chains.

3.3 Study Selection and Quality Appraisal

The process of identifying, screening, and selecting literature for this systematic review is illustrated in **Figure 1**. An initial total of 63 records were identified through database searches and grey literature sources. Following the removal of duplicates, the remaining studies underwent title and abstract screening based on predefined inclusion and exclusion criteria. Ultimately, 15 studies were selected for full-text review and inclusion in the final synthesis.

To ensure objectivity and reduce potential bias, two reviewers independently conducted the screening process. Any disagreements were resolved through discussion and consensus, adhering to established systematic review protocols (Moher et al., 2009; Higgins et al., 2022).

Quality appraisal of the selected studies was carried out using a modified Critical Appraisal Skills Programme (CASP) checklist (CASP, 2018). The evaluation focused on:

- Appropriateness of the study design;

- Transparency and rigor in data collection and analysis;
- Relevance to Kenya's maize supply chain context.

Only studies meeting acceptable thresholds for methodological rigor and contextual relevance were retained for inclusion in the review.

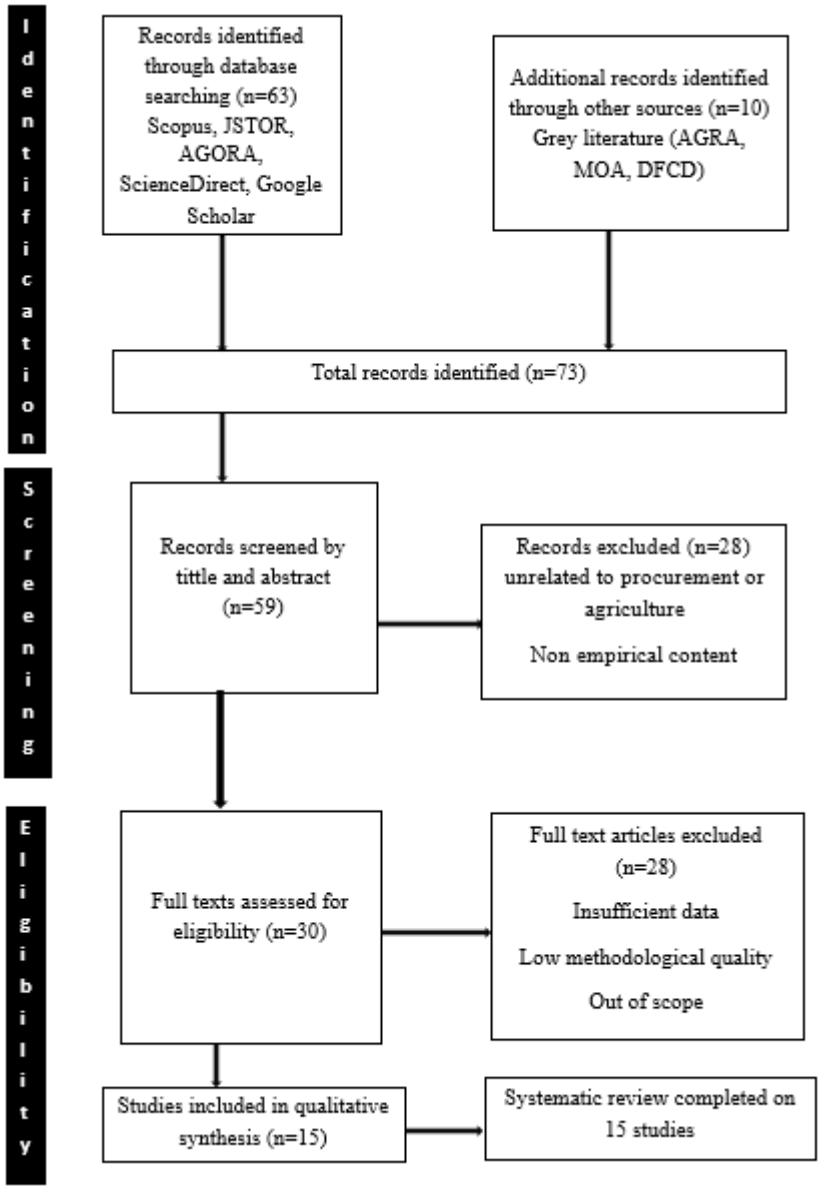

Figure 1: PRISMA Flow Diagram for Study Identification, Screening, and Selection

3.4 Data Extraction and Synthesis

A structured data extraction matrix was developed to capture relevant attributes from each included study. Key variables included:

- Type of digital procurement intervention;
- Technologies employed;
- Outcome indicators such as cost reduction, inventory visibility, or supply chain responsiveness;
- Reported barriers such as digital literacy, infrastructure, or policy gaps.

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The extracted data were subjected to a thematic synthesis following the principles outlined by Thomas and Harden (2008), which allows for the generation of higher-order analytical themes grounded in the included evidence base. The thematic coding process was inductive but guided by an a priori conceptual framework of digital transformation in agri-food systems, which emphasizes the socio-technical and institutional dynamics shaping the adoption of digital innovations in agricultural value chains (Klerkx & Rose, 2020).

Four main themes were identified through the synthesis:

1. Cost Efficiency: Highlighting reduced procurement costs and improved sourcing through digital tools.
2. Inventory Control: Emphasizing enhanced visibility, traceability, and reduction in post-harvest losses.
3. Supply Chain Responsiveness: Capturing benefits such as faster lead times and real-time coordination.
4. Climate Resilience: Encompassing the role of digital platforms in mitigating climate-related risks and enhancing adaptation.

These thematic findings demonstrate the contribution of digital procurement to both the resilience and sustainability of maize supply chains in Kenya and provide insight into scalable strategies for other agricultural contexts within Sub-Saharan Africa.

4. RESULTS AND DISCUSSION

4.1 Overview of Studies Reviewed

This review synthesized findings from 15 peer-reviewed journal articles**,** policy briefs, and technical reports published between 2010 and 2024**.** These studies focused on Kenya's maize supply chain and comparable agricultural contexts in Sub-Saharan Africa. Digital procurement tools examined included e-procurement platforms, mobile-based advisory systems, digital inventory solutions, and e-voucher systems**.** Sources included both academic publications and grey literature from institutional stakeholders, allowing for a comprehensive perspective on technology uptake and performance in agricultural value chains.

4.2 Impact of Digital Procurement on Supply Chain Resilience and Efficiency

Findings strongly indicate that digital procurement technologies improve cost efficiency and procurement responsiveness**,** aligning with DOI Theory's constructs of *relative advantage* and *observability*. Tools such as *Esoko*, *Ujuzi Kilimo*, *Kilimo Salama*, and *DigiFarm* enabled farmers to bypass intermediaries, access real-time market data, and enhance profitability **(**Ogutu et al., 2020; Mensah & Adu, 2018**).** These benefits represent the perceived value that drives adoption under the DOI framework.

In parallel, Gunasekaran et al. (2019) emphasized how digital procurement enhances coordination and visibility, reinforcing SCRT's dimensions of *visibility* and *collaboration* necessary for resilience. The World Bank (2021) reported that Kenya's national e-voucher program powered by the KIAMIS platform registered over 6.5 million farmers and contributed to a 39% increase in maize output and 67% reduction in imports**,** demonstrating systemic benefits across the supply chain.

Additionally, platforms such as *Twiga Foods*, *DigiSoko*, and *EA Foods* improved logistics, reduced spoilage, and streamlined market linkages, which enabled real-time procurement responsiveness and minimized waste **(**DFCD, 2023; AGRA, 2021**).** These outcomes align with SCRT's goals of enhancing recovery and adaptability to operational disruptions.

4.3 Sustainability and Climate Resilience Outcomes

Digital procurement systems contribute not only to economic efficiency but also to environmental sustainability and climate resilience**,** core components of SCRT. Studies show that mobile and digital platforms facilitate precision agriculture, reduce chemical input overuse, and improve post-harvest handling **(**Kiriinya, 2024; Shianda & Phiri, 2015**),** enhancing ecological sustainability.

In Ethiopia, Teshome et al. (2021) documented that farmers who accessed weather forecasts via mobile tools adopted climate-resilient practices. Similarly, the World Bank (2021) noted that integrating weather advisories into Kenya's e-voucher system improved preparedness for climatic variability. These cases demonstrate SCRT's anticipatory and adaptive capabilities through digital channels.

These digital innovations also reflect DOI's trialability and compatibility factors, as farmers adopt solutions that align with local needs and offer demonstrable benefits. Kenya's Climate Smart Agriculture Strategy (2022–2028) explicitly promotes digital procurement for adaptive input delivery, reinforcing the relevance of digital systems in government-led resilience strategies.

4.4 Barriers to Adoption

Despite demonstrable benefits, the adoption of digital procurement technologies across Kenya's maize supply chain remains uneven, particularly among smallholder farmers. Drawing from Compagnucci et al. (2022) and Aseka (2019), the barriers can be categorized into four interrelated domains: technological, institutional, economic, and socio-cultural.

Technological constraints include limited access to smartphones, unreliable internet connectivity, and low digital literacy particularly in rural areas. Compagnucci et al. (2022) highlight that many digital platforms lack user-friendly interfaces or offline functionality, further excluding farmers with limited technological exposure. Similarly, Aseka (2019) notes that poor ICT infrastructure undermines the scalability of digital systems in agricultural procurement.

From an institutional perspective, while tools such as IFMIS have improved transparency in national public procurement systems, their rollout to decentralized agricultural agencies has been minimal (Ministry of Agriculture, 2022). Moreover, the absence of farmer-focused digital procurement policies and a fragmented regulatory environment contribute to what may be termed *regulatory inertia*. Many platforms operate without clear data protection frameworks or standardized procurement procedures, discouraging trust and long-term engagement.

Economic barriers further hinder adoption. Costs associated with internet access, smartphones, and platform fees are prohibitive for many smallholder farmers, particularly women and youth. AGRA (2021) reported that affordability issues remain a key deterrent to digital inclusion in smallholder farming.

The socio-cultural dimension includes limited awareness, language barriers, and deep-seated trust issues regarding digital contracts and transactions. Compagnucci et al. (2022) emphasize that many farmers lack familiarity with digital interfaces and express skepticism about digital marketplaces due to past experiences of non-payment or fraud.

Importantly, the gender digital divide persists as a critical inclusivity challenge. Studies across Sub-Saharan Africa show that women face disproportionate barriers to accessing digital tools due to lower digital literacy, socio-cultural norms, and unequal asset ownership. For instance, GSMA (2020) reported that women in Sub-Saharan Africa are 20% less likely than men to own a smartphone and 28% less likely to use mobile internet. This indicates that gender-responsive digital procurement strategies are essential for equitable adoption.

To advance inclusive adoption of digital procurement, there is a need for: policy coherence across national digital agriculture strategies; public-private partnerships to subsidize digital infrastructure in underserved areas; targeted training programs to close gender and age-related digital skill gaps; and development of user-centric platforms tailored to the needs and constraints of smallholder farmers. Without addressing these multifaceted barriers, the transformative potential of digital procurement for building resilient and sustainable maize supply chains in Kenya and by extension, Sub-Saharan Africa will remain unrealized.

4.5 Summary of Thematic Findings

Outcome Variable	Impact of Digital Procurement	Supporting Sources
Cost Efficiency	Cost Efficiency, Improved Sourcing, Market Integration	Ogutu et al., 2024; Gunasekaran et al., 2019
Price Stability	Greater market transparency, reduced middlemen exploitation	Mensah & Adu, 2018; Tegemeo Institute, 2023, Shianda & Phiri, 2015, Shrestha & Rai, 2017, Owusu, 2019;
Supply Chain Responsiveness	Faster delivery and adaptive procurement practices	Kiriinya, 2024; Pereira & Rodgers, 2018; Hassan et al., 2016; Tegemeo Institute, 2023; Quayson, M et al., (2020)
Inventory Management	Better stock tracking and loss reduction	Shianda & Phiri, 2015; Kagondu, 2023
Climate Resilience	Facilitates climate-smart farming decisions, Policy Effectiveness, Input Access,	Teshome et al., 2021; World Bank, 2021; Tegemeo Institute, 2023; IDsight, 2024;

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5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This systematic review has demonstrated that digital procurement technologies such as e-procurement platforms, mobile marketplaces, e-voucher systems, and digital inventory tools offer transformative potential to address long-standing inefficiencies and vulnerabilities within Kenya's maize supply chain. The findings underscore significant improvements in cost efficiency**,** supply chain responsiveness**,** inventory control**,** and climate resilience**,** especially when these technologies are tailored to smallholder farmer contexts.

The integration of tools like DigiFarm, KIAMIS, Twiga Foods' digital logistics systems, and public e-voucher programs has shown demonstrable benefits in enhancing procurement transparency, reducing post-harvest losses, and improving market access. These technologies align strongly with the principles of Diffusion of Innovation (DOI) theory which emphasizes the importance of perceived relative advantage, trialability, and compatibility in adoption and Supply Chain Resilience Theory (SCRT)**,** which stresses the need for adaptability, visibility, and responsiveness in managing systemic disruptions.

However, the review also highlights critical adoption barriers**,** including digital illiteracy, infrastructural constraints, regulatory fragmentation, affordability challenges, and socio-cultural exclusions; particularly for women and older farmers. These barriers reinforce the importance of policy coherence, inclusive design, and institutional capacity-building to ensure equitable diffusion and sustained impact of digital procurement innovations.

5.2 Recommendations

The following prioritized and theory-informed recommendations aim to enhance the adoption and performance of digital procurement tools in Kenya's maize supply chain, addressing both immediate and long-term needs:

Expand Rural Digital Infrastructure: Investments in mobile broadband, last-mile connectivity, and electricity access are foundational for digital procurement to take root in rural and semi-arid maize-growing regions. These efforts require public-private partnerships between telecom providers, government agencies and development partners. Enhanced infrastructure improves supply chain visibility and responsiveness under volatile climate and market conditions.

Enhance Farmer-Centered Digital Literacy Programs: Implement scalable training programs delivered through extension agents, digital village hubs, and community-based organizations in local languages and using accessible formats such as USSD simulations, and audio-visual modules. These should specifically target women, youth, and older farmers, who are often excluded.

Institutionalize Digital Procurement within Agricultural Parastatals: Mainstream digital procurement platforms across all public procurement processes in agriculture, including institutions such as the National Cereals and Produce Board (NCPB), Agricultural Finance Corporation (AFC), and the Agriculture and Food Authority (AFA). Performance targets should be integrated into public service delivery contracts and staff Key Performance Indicators (KPIs). Institutional anchoring enhances end-to-end supply chain coordination and minimizes inefficiencies in public grain procurement.

Reform Regulatory and Data Governance Frameworks: Revise existing procurement and ICT policies to explicitly accommodate digital procurement tools. Fast-track enforcement of the Data Protection Act (2019) with clear provisions for data ownership, portability, and security in digital agriculture. Regulatory harmonization between the Ministry of ICT and the Ministry of Agriculture is essential.

Align Digital Procurement with National Climate Strategies: Integrate e-procurement into Kenya's Climate Smart Agriculture Strategy (2022–2028), National Adaptation Plan (NAP), and Vision 2030 delivery frameworks. This includes bundling climate services such as weather forecasts and risk alerts within digital input systems and procurement platforms. Such integration strengthens adaptive capacity and scenario planning under prolonged climate disruptions.

Establish a Multi-Stakeholder Monitoring, Evaluation, and Learning (MEL) System: Create a centralized MEL framework led by the Ministry of Agriculture in collaboration with research institutes, civil society, and donors. This should include gender-disaggregated metrics, real-time dashboards, and periodic performance audits of digital procurement systems. Continuous feedback supports iterative innovation and institutional learning, reinforcing system resilience.

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