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Smart Cities:Catalyzing Circularity in Supply Chains

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Abstract—**Amidst the sprawling literature on sustainability, this paper delves into the green potential of digital technologies. It specifically explores how Smart Cities, powered by smarter industries, can act as catalysts for sustainable practices across individual and supply chain levels. This journey towards ecological production and distribution is paved with greener supply networks, culminating in the ambitious vision of Circular Supply Chains (CSCs).**

The paper proposes a user-centric vision of Smart Cities, displaying their instrumental role in achieving a Circular Economy (CE).

Moreover, it introduces CSCs as the ideal solution for fostering green practices within production networks, emphasizing the indispensable role of Smart Cities in ensuring smooth circularity within the chain.

Keywords—component; Smart cities, Circular economy, Green supply chains, Circular supply chains, Sustainability

Introduction

Driven by the urgent need for both generational well-being and economic longevity, all UN member states embraced the 2030 Agenda for Sustainable Development in 2015 (United Nations, 2020). These Sustainable Development Goals (SDGs) build upon previous aspirations while prioritizing environmental considerations, making sustainability a pillar of modern policy.

This paper delves into environmentally sustainable practices, exploring how smart technologies can empower a greener future. Smart growth, defined as the context specific integration of urban infrastructure and services through complex information systems (Harrison and Donnelly, 2011), paves the way for Smart Cities, a dominant force in recent city planning discussions (Silva et al., 2018).

While the connection between Smart Cities and sustainability has been explored (Bvatvagan, 2011; Cugurullo, 2018), much potential remains untapped. This paper bridges this gap, specifically focusing on how integrating Smart Cities into supply networks can create greener practices. We argue that Smart Cities are crucial for achieving environmentally sustainable production chains.

The surge in research on Sustainable and Green Supply Chains (Khan et al., 2020a) and the rise of Circular Supply Chains (Farooque et al., 2019) highlight the growing momentum towards environmentally conscious production systems.

Notably, circular thinking promises a complete eco-transformation, exceeding the partial outcomes of traditional green supply management practices..

I. INTRODUCTION TO SMART CITIES

A. What is a smart city?

Imagine a vibrant urban network, woven from intertwined threads of technology, citizen engagement, and environmental consciousness. This is the essence of a Smart City, a dynamic ecosystem where citizens co-create a sustainable future.

Not a cookie-cutter model, but a living tapestry: Each Smart City's unique fabric is woven from its distinct "urban DNA" – morphology, demographics, economics, culture, and social interactions.

The Smart City, a glimpse into the future of urban life, rises from the needs of its citizens and finds solutions in a tapestry of technology, services, and applications. While every city is a unique blend of morphology, demographics, and culture, we can define a Smart City as an evolving landscape where:

- Information Communication Technologies (ICT) weave intelligent tools into the fabric of governance and management, enhancing efficiency and enriching the lives of residents.
- Real-time data becomes a catalyst for creativity, optimizing both tangible resources like infrastructure and intangible ones like knowledge and human capital.
- Citizen awareness blossoms through educational campaigns and interactive platforms, fostering responsible behavior and active participation.

- Public-private partnerships connect and empower diverse stakeholders, transforming individual expertise into collective progress.
- Adaptability reigns supreme, as the Smart City continuously evolves to meet the changing needs of its people and environment, ensuring a sustainable future for generations to come.

At its core, the Smart City concept thrives on the interconnectedness of its physical, digital, social, and economic infrastructure. This fusion unlocks the city's collective intelligence, paving the way for sustainable economic growth and enhanced quality of life for its citizens (Harrison et al., 2010; Silva et al., 2018). But "smart" doesn't solely equate to digital; the true heartbeat of a Smart City lies in its empowered citizens. When residents actively participate and leverage technology for social innovation, the city transcends mere bricks and mortar, becoming a vibrant ecosystem where economic, social, and environmental well-being flourish in unison (Silva et al., 2018).

B. Smart cities and sustainability

Forget the glitter of mere "smart" cities – the future sings a grander symphony with the rise of Sustainable Smart Cities. These are not upgrades, but transformative compositions where progress and environmental responsibility entwine, harmonizing economic growth, social equity, and planetary health.

Beyond the flash of gadgets, their magic lies in a deeper orchestration, woven with threads of sustainable development.

Environment, infrastructure, operations, and human services – all brought into graceful accord by resource efficiency, the conductor of this eco-conscious ensemble.

Carbon neutrality and reduced pollution become guiding melodies, while cycling lanes and verdant spaces take center stage. Technology, no longer a flashy soloist, transforms into the lifeblood systems of efficient resource management, with sensors like vigilant instruments monitoring air, optimizing flows, and empowering citizens to co-conduct their eco-friendly communities.

These Sustainable Smart Cities are living laboratories, where technology is not just an accessory, but a crucial partner in composing a future both prosperous and equitable, a future that sings in harmony with our planet.

C. Needs and users

The complexity of modern metropolises, characterized by infrastructural stress, economic dissonance, and environmental threats, necessitates a paradigm shift in urban development.

The "Smart City" concept holds promise, but its efficacy hinges on transitioning from technology-centric solutions to a collaborative tapestry woven with the diverse voices of residents, businesses, and experts. This necessitates a symphony of co-created smart solutions addressing city-specific challenges, from adaptive traffic control and shared resource management to vibrant green spaces. Only through such a community-driven approach can we bridge the chasm between urban vibrancy and ecological responsibility, fostering resilient, sustainable, and equitable cities for generations to come.

D. Categorizing human needs

Moving beyond grand infrastructure projects, truly human-centric Smart Cities must delve into the desires of their inhabitants. Here, Abraham Maslow's 1954 hierarchy of needs offers a powerful lens. His tiered pyramid portrays human needs as a springboard from basic physiological (food, shelter) to the higher reaches of self-actualization. Each level, from safety and security to belonging and esteem, represents a fundamental human yearning.

This model, while influential, has faced critiques. Some question its linearity, arguing for a more complex interplay of needs. Others highlight potential shortcomings in universality, particularly across diverse populations (Cullen & Gotell, 2002).

Despite these nuances, Maslow's framework shines as a blueprint for understanding individual needs within Smart City design.

By embracing the multifaceted nature of human motivation, we can craft systems and technologies that nourish not just basic necessities but also the deeper yearnings for connection, social engagement, and personal growth.

Imagine smart systems fostering vibrant communities, cultivating a sense of belonging, and empowering individuals to flourish, brick by fulfilling brick.

E. Smart Users

The actors who contribute to and ultimately befit from a smarter urban environment are: the city’s population, local businesses, and the Public Administration. These are the so-called “Smart Users”.

1) People: Empowering Citizens for a Better Smart City

Smart Cities only truly illuminate when their light reflects off the faces of their inhabitants. This means moving beyond grand infrastructure projects and into the lives of citizens. Forget broad demographics – focus on the vibrant tapestry of individuals weaving the city's fabric.

Data, like a threadwork guide, reveals the diverse needs of residents, non-residents, families, and solo explorers. From children to elders, single households to bustling families, each group dances to a distinct rhythm. Accessibility for individuals with disabilities, tech literacy for older generations, and support for foreign citizens – these are threads woven into the very fabric of progress. This is a way to ensure that everyone can join the symphony of progress, not just watch from the sidelines. However, empowerment goes beyond access; it demands ownership. Equipping citizens with the skills to shape their city's evolution fosters a sense of responsibility and adaptation. Smart systems will not just manage traffic; they will be managed by the community, ensuring everyone dances to the rhythm of a brighter future.

2) Companies and Economic Activities: A Boon for Business in Smart Cities

The rise of Smart Cities unlocks a treasure trove of opportunities for businesses. New enabling technologies foster innovation and fuel the creation of technological hubs and industrial districts. Local entrepreneurs stand to

gain from dedicated funding programs, facilitating the development of public services and leveraging the power of innovative M2M (Machine-to-Machine) software.
Identifying the target sectors for these initiatives relies on the ATECO economic activities analysis, the national version of the European Nace Rev. 2 classification system. This categorization, outlined in the Official Journal of December 20, 2006, guides the allocation of resources and ensures alignment with broader European economic frameworks.

3) Public Administration: Steering the Course Towards Sustainable Cities

Sustainable cities require agile policies that navigate environmental, economic, and social currents. Public Administration, the local captain, leverages its deep knowledge to craft policies that resonate with the community. This journey demands a full crew – residents, businesses, and NGOs – collaborating to enrich the voyage. Even within government, strong inter-institutional cooperation builds a sturdy hull for effective action. Thus, the Public Administration transforms from administrator to champion, steering cities towards a brighter future where all citizens share the bounty.

F. Smart cities in a circular economy

Smart Cities play a key role inside Circular Economies (CEs). This section introduces the CE philosophy and illustrates its applicability in- side the city with the support of a case study. The case of waste man-agement inside cities shows how smart solutions can be key to realise circularity inside the city.

G. The circular economy philosophy

Inspired by nature's circular dance, Smart Cities can embrace the Circular Economy (CE) - a regenerative model closing the loop on resource use and waste. Escaping the "take-make-waste" linear trap, CE champions reuse, recycling, and extended product lifecycles, minimizing environmental impact and fostering economic and social sustainability. Smart technologies like Big Data, asset tagging, and robust connectivity become the catalysts, illuminating material flows and empowering resource management decisions across the industrial lifecycle. By implementing product-service closed loops and leveraging new digital applications, Smart Cities can minimize waste, maximize product lifespans, and create a thriving hub for resource density and CE practices.
This shift, fueled by local government policies and advancements in geo-spatial technologies, paves the way for a brighter future where cities and nature dance in harmony.

H. From linear to circular supply chains: the role of smart cities

Our current supply chains, fueling progress, leave an ugly, polluting trail. However, fear not, the Circular Supply Chain (CSC) rises as a shining beacon.
This bold new approach rewinds the production tape, closing the loop and squeezing waste out of existence. Smart tech is the magic wand - IoT sensors watch the flow, AI whispers resource recovery secrets, and blockchain builds trust with its digital handshake.
Embracing circularity is not a stroll in the park, challenges lurk, but so do opportunities.

I. Supply chains and the environment

The call for greener supply chains isn't new, but a growing chorus of voices urges its practical implementation across all facets – economic, social, and environmental (Moktadir et al., 2016). Minimizing resource depletion and maximizing longevity is the heart of eco-conscious practices, and it resonates deeply with our supply chains, the alchemists turning raw materials into products (Pero et al., 2017; Saddikuti et al., 2020).
This green quest blossoms into the concept of Green Supply Chains (GSCs) Eltayeb et al. (2011) paint a vivid picture *"GSCs extend beyond traditional models by actively minimizing a product's environmental footprint throughout its entire lifecycle. From eco-design and resource-saving measures to reducing harmful materials and prioritizing recycling and reuse, GSCs offer a roadmap to a greener future, one production cycle at a time"*
The green revolution in supply chains is not a mere spotlight on one stage; it is a full-blown infiltration from start to finish (Chin et al., 2015). This eco-invasion takes countless forms, each strategically chosen for maximum impact:

- Eco-design: Products enter the world with the environment as their birthright, minimizing their footprint for life (Graedel & Allenby, 2008).
- Green purchasing: Procurement becomes an eco-detective, sniffing out items with reusability, recyclability, and a clean material pedigree.
- Supplier synergy: Environmental performance becomes a team sport, driving joint projects for greener products and innovative solutions.
- Customer collaboration: From consumers to creators, the green journey expands, co-creating sustainable products and pushing eco-innovation's boundaries.
- Reverse logistics: Products, instead of retiring young, get a second act - reused, recycled, and reborn with a fresh purpose (Eltayeb et al., 2011).

Forget the tired melodies of "one-size-fits-all" greening – sustainable supply chains demand a harmonious symphony of diverse voices. Consumers, governments, and even the global community must rise as conductors, guiding the flow of goods in a new, eco-conscious rhythm.
But every harmonious orchestra faces obstacles. Communication gaps and coordination issues clog the flow (Villena & Gioia, 2020). Lower-tier suppliers, lacking knowledge or resources, become unintentional roadblocks. Supply leaders battle uninformed customers, leadership apathy, cost burdens, and a host of other eco-ignorance and regulatory hurdles.

J. Thinking green: form linear to circular supply chains

The promise of Green Supply Chains (GSCs) shimmers just out of reach, held back by a web of challenges. Piecemeal greening efforts, while occasionally successful like in SAARC (Khan et al., 2020b), ultimately flounder due to limited scope and dependence on individual company goals.

Forget patching up the leaky "take-make-waste" model – it's time to redefine GSCs from the ground up. Our current linear chains, guzzling resources and spewing waste, are built for environmental harm. They are like rusty pipes, sucking resources upstream and dumping products downstream, leaving trails of destruction in their wake (Beamon, 1999; Eltayeb et al., 2011). What we need is a closed loop, a circular waltz where materials dance through production and consumption, reborn for new life cycles.

Imagine a vibrant network, not a rigid chain. Companies, workers, and information flow seamlessly – a symphony of players guided by a shared vision: Supply Chain Orientation (SCO). Mentzer et al. (2001) offer the analogy: each entity a musician, playing their part in delivering value from source to customer. This shared score, this SCO, ensures harmony. Without it, the symphony descends into discord (Martínez et al., 2016).

Supply Chain Management (SCM) becomes the sheet music, the specific strategies and functions that keep the performance running smoothly (Mentzer et al., 2001).

It's the roadmap guiding sourcing, production, and delivery. But without SCO, the map is useless. A well-aligned orchestra, with both a shared vision (SCO) and skilled execution (SCM), creates a truly sustainable flow – a Green Supply Chain reborn.

K. Circular Supply Chain

Forget a green veneer – building true Green Supply Chains (GSCs) demands a complete "green reorientation," injecting circularity into every step from cradle to customer. Closed loops? Think closed ecosystems, where resources dance a perpetual waltz, reborn and renewed.

These GSCs aren't just about bringing products back – they embrace circularity throughout. Imagine products designed for disassembly and rebirth, whispering, "I'm not trash, I'm new beginnings!" Waste fuels green energy, and materials flow not in a linear chain, but a closed ecosystem. It's nature's recycling system woven into business.

This eco-alchemy boasts two magical tricks:

- Restorative: Engines given a second life, plastic reborn as benches. Products become "technical nutrients," reborn through repair, refurbishing, and recycling. Waste closes the loop within the industrial ecosystem, transformed into valuable resources.
- Regenerative: Food scraps enriching soil, clothes decomposing to nourish new life. Materials return to the earth as "biological nutrients," enriching the biosphere. It is closing the loop with nature, replenishing the very source of our resources.

Nevertheless, this green tango is not easy. GSCs are intricate tapestries, demanding a complete reorientation of existing chains – a complex dance compared to rigid, top-down approaches.

The key takeaway? Green Supply Chains are not just a green coat of paint; they are a fundamental shift in perspective, a reorientation of the entire economic ecosystem based on circularity. This eco-revolution holds the key to a sustainable future, but it demands commitment, innovation, and a willingness to embrace the intricate beauty of closing the loop, both within and beyond our supply chains.

II. RESULTS AND DISCUSSION

The green turn is not as distant as it seems – smart technologies are the missing link, ready to propel us towards sustainable supply chains.

Forget one-way streets – think circular dance floors where resources waltz through production and back again, fueled by data and digital innovation.

Imagine consumers no longer passive spectators, but conductors in this green symphony. Smart cities empower them with information, from a product's origin to its potential afterlife. Data-driven platforms (Accenture, 2020) become crystal-clear windows, enabling informed choices that guide the entire chain. This feedback loop doesn't stop there – smart cities, like living databases, feed retailers and managers with insights into consumer needs and preferences.

This intel, paired with optimized city logistics, creates a dynamic network for efficient resource gathering and dispatch. Smart waste management systems become seamless arteries, where both valuable materials and discarded items flow back into the system for regeneration.

In essence, smart cities become the nerve centers of these circular chains, managing the green ballet according to the circular economy's blueprint.

But the magic goes beyond cities – Industry 4.0 weaves its digital spell across the entire chain. Data analytics and big data play starring roles, deciphering the stories of products and guiding them towards reuse or rejuvenation (Kristoffersen et al., 2020).

Imagine existing linear systems infused with this smart touch, materials and goods dancing in perfect harmony, responding to demand with laser-like precision (Luthra and Mangla, 2018).

This smooth green symphony requires everyone in tune. Consumers, cities, and all stakeholders must join the chorus. When everyone embraces Industry 4.0, the supply chain sings a sustainable tune, where resources get endless encores.

These smart technologies are the missing link, looping the chain and transforming linear thinking into circular reality.

From information-empowered consumers to optimized "smart industries," they pave the way for a future where supply chains become closed loops of reuse and regeneration. This green revolution isn't a distant dream – it's just a digital click away.

III. CONCLUSION:

This paper elevates Smart Cities to the mantle of sustainability superheroes, wielding their unique powers to green product supply networks. We've seen how their user-centric approach fosters ecological responsibility, and explored their essential role in the circular economy In addition to revealing their ultimate weapon: unlocking the true potential of green supply chains through a circular lens. Embracing "smart" environmental solutions becomes a treasure hunt for a sustainable future.

Imagine Smart Cities as thriving eco-hubs, fueling a cascade of green initiatives. They cultivate urban oases, empower citizens as eco-warriors, and even seamlessly reintegrate consumers into circular supply chains like missing puzzle pieces. This deep dive exposes their crucial role in achieving circularity, particularly through innovative waste management systems. We ultimately move beyond outdated Green Supply Chain models, championing circular thinking as the ultimate weapon for a sustainable future.

But unleashing this large-scale green transformation requires two essential ingredients: smart technologies and, above all, Smart Cities. These digital catalysts act as the rocket fuel propelling us towards a greener tomorrow. This paper paves the way for a groundbreaking convergence: Smart Cities and Circular Supply Chains, united under the banner of environmental innovation. It's a new paradigm, connecting economic domains through the magic of circularity.

While this initial exploration lays the groundwork, we acknowledge it's just the beginning. Future research needs to delve deeper in two key areas:

- Demystifying the practical roles Smart Cities can play in real-world circular supply chain networks.
- Refining the implementation steps through targeted research questions and initiatives, transforming theory into tangible action.

As more studies that are comprehensive emerge, they will form the foundation for systematic research. This, in turn, will deliver valuable standards to guide policymaking and propel us towards a greener future, brick by smart brick. Together, we can build Smart Cities that are true guardians of environmental sustainability.

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