ESJ Humanities Peer-reviewed

Singing from the Same Hymn Sheet? A Semantic and Convergence Analysis of the Extent to Which ‘Smart’ is Similarly Understood and Applied Across Energy, Transport, and Waste Management Sectors of Urban Planning

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Doi:10.19044/esj.2024.v21n8p120

Submitted: 26 December 2024
Accepted: 25 February 2025
Published: 31 March 2025

Cite As:
OnyangoV., Forghaniallahabadi M. & Gazzola P. (2025). *Singing from the Same Hymn Sheet? A Semantic and Convergence Analysis of the Extent to Which ‘Smart’ is Similarly Understood and Applied Across Energy, Transport, and Waste Management Sectors of Urban Planning*. European Scientific Journal, ESJ, 21 (8), 120. https://doi.org/10.19044/esj.2024.v21n8p120

Abstract

The term ‘smart’ is widely used in urban planning, and it is often linked to the use and adoption of technologies or cost-efficiency measures in support of urban development and management. Whether the term is consistently understood and applied to inform practice across different policy sectors is unclear. This paper explores the understandings and applications of the term ‘smart’ within energy, transport, and waste management sectors of urban planning. A systematic literature review, guided by PRISMA criteria, was conducted, and NVivo-based coding was used to assess convergence. The findings provide a comprehensive profile of the term’s convergent and differential understandings and reflect on the scope for standardized terminology for ‘smart’ in urban planning. The term broadly describes a means of ‘deploying mechanical solutions’ pursuing efficiency and optimization, rather than ‘transformational outcomes’ e.g. sustainability. Thus, meaning and different eco-modernism goals are pursued in each sector, steeped in a language of technology-based paradigm, but hollow in meeting any fundamental transformation of the status quo. We conclude that while the concept of ‘smart’ can be adapted to different socio-economic and regional contexts, it requires a shared theoretical foundation. Future research could explore whether differences in understanding and application may be observed at regional levels.

Keywords: Smart urban planning, Smart transport, Smart energy, Smart waste management, Semantic consistency theory, Convergence theory

Introduction

In urban planning, the term ‘smart’ has been likened to intelligent, efficient, and intentional planning approaches (Bollier, 1998). However, this is often in response to the need to address urban sprawl, climate change, urban degradation, or other multi-faceted socio-economic challenges (ISO-IEC, 2015; Rodriguez-Bolivar, 2015; Townsend, 2013). This likening has been underpinned by the assumption that new technologies can enhance the performance, quality, and delivery of urban services and reduce costs by tackling inefficiencies, carbon emissions, and resource consumption (Nesti, 2020). This is done while also generating longer-term positive effects on the economy through the optimization of city functions (Komninos, 2014; NYC, 2015). ‘Smart’ technologies encompass, for example, the Internet of Things (IoT) and Information and Communications Technologies (ICT) (Ejidike & Mewomo, 2023; Huseien & Shah, 2022), big data analytics (Goulas *et al.*, 2022), Artificial Intelligence (AI) and Machine Learning (Pangbourne *et al.*, 2020), and cloud computing and 5G technology (Mendonça *et al.*, 2022).

Their use in different policy and planning sectors has led to the proliferation of the term ‘smart’ as a suffix applied to different forms of planning and policy intervention and focus, such as ‘smart infrastructure’ (Broo *et al.*, 2022), ‘smart buildings’ (El-Motasem *et al.*, 2021), ‘smart traffic’ (Almalki *et al.*, 2021) and ‘smart transportation’ (Sun *et al.*, 2020), ‘smart mobility’ (Docherty & Shaw, 2019), ‘smart energy’ (Aliero *et al.*, 2022), and ‘smart urban governance’ (Govada *et al.*, 2017). In these contexts, ‘smart’ is used to offer a multi-dimensional perspective that integrates technology, people, and institutions, amplifying the relationship between information communication technologies and the future of cities and of urban planning (Alrashed, 2020; Meng & Zhu, 2024).

However, whether the term is consistently understood and applied to inform practice across different policy sectors is unclear. According to Prestamburgo *et al.* (2019), how ‘smart’ integrates into the anthropic, functional, and physical subsystems of urban systems remain unclear. This is within a context where there is no international consensus on the overall architecture and standards for ‘smart’ in urban planning (Javed *et al.*, 2022; Popescul & Genete, 2016). In this context, Cavada *et al.* (2016) poses a fundamental question for urban planning: beyond the rapidly evolving pragmatic engineering-based attempt to improve the operation of individual urban infrastructure and/or services through technology innovations. Therefore, where is the underpinning theory or understanding of the systems to be connected? If unanswered, the extent to which 'smart' is applied to deliver same or convergent outcomes, e.g., promote environmental protection or sustainability across the various sectors of urban planning, is unknown, unclear, or may not be effectively coordinated and aligned to any overarching goal(s).

The above concern is heightened by studies reporting that the realignment of the environment, the economy and climate change, using smart approaches, remains ineffective (Gazzola *et al.*, 2019; Janicke, 2012; Zaccai, 2012). Furthermore, the consideration and prioritization of the environmental and social nexus is not sufficiently and systematically evidenced within smart urban planning (Ahvenniemi *et al.*, 2017). The problem is that 'smart' technology may be increasingly deployed but *without any commensurate* consideration of how they deliver converging or common outcomes for urban planning, e.g., efficiency, quality services, environmental protection, and sustainability. In such practice, adopting terminologies without shared understanding(s) can frustrate the development of a discipline because communication for effective discourse, policy, practice, and research becomes vulnerable to potential misunderstanding and miscommunication. According to Albino *et al.* (2015), a discipline such as urban planning is an area of defined theorization and practice that must have shared meanings and clear and/or consistent usage of its key concepts and terminologies.

Therefore, against the above backdrop of rapid adoption of 'smart' in various sectors of urban planning, this paper aims to explore whether the term is similarly understood and applied. Following the introduction, the theories of semantics and convergence are explained, as part of setting the context for analyzing and interpreting the findings. This is followed by the methodological approach, outlining the procedures of cases study selection, data collection and analysis. Subsequently, the results and implications are presented focusing on the extent of convergence, regarding the term. The study's conclusions and recommendations are drawn up in the final chapter.

Meaning, Semantics, and Convergence: A Framework for Analysis

In this paper, it is argued that despite the plentiful literature on smart urban planning in various areas of application, the level of fidelity, i.e., the degree of exactness, accuracy, or correctness with which the term is applied or reproduced, remains unexamined in any systematic manner. To address this knowledge gap, analysis based on the meaning of text is required. One appropriate approach to this is anchored in Semantic Consistency Theory, which highlights the need to standardize terminology and guarantee common understandings: to improve communication and minimize uncertainty among experts in a specific field. Consequently, in classical linguistics, this is achieved through analysing syntactic and semantic features connected to general world knowledge (De Beaugrande & Wolfgang, 1996). In this study, it will suffice to focus on the semantic features, such as presuppositions and implications, connected to the usage of the term. The goal is to see if meaning and usage of the term ‘smart’ are working towards a united goal or outcome.

In a multi-disciplinary and multi-sectoral field like urban planning, where various stakeholders are involved, this approach has the advantage of facilitating clear and consistent communication aimed at reducing the potential for confusion (Loshin, 2009, 2011). This results to the improvement of the effectiveness of ‘smart’ urban planning initiatives. However, given that the application of ‘smart’ in different sectors cannot be identical, it will be appropriate to also consider the extent of coherence, i.e., the quality of being logical and consistent, and forming a unified whole in the meaning and use of the term. Convergence can be understood as a process of “becoming,” of moving from different positions towards a “common” point or aim. This is done sometimes with similarities between the different paths emerging within the adopted processes (Inkeles, 1999). Within the social sciences, convergence can be defined as the “increasing similarity over time” (Harris & Moore, 2015), e.g., in terms of meanings, approaches, and goals (Bennet, 1991).

Following Bennet’s (1991) theorisation of convergence, similarities can be manifested in terms of: (a) goals coming together in various instances; (b) content, as in formal policy or discourse; (c) instruments or mechanisms, e.g., smart eco-innovations; (d) the outcomes or impacts of going smart; and (e) style, e.g., in terms of how these ideas are formulated and agreed upon. Therefore, the extent to which these elements are expressed within the use of ‘smart’ in urban planning can be a useful approach to address the extent to which the term ‘smart’ is similarly understood and applied. Coherence will be higher if ‘smart’ initiatives in different sectors are similarly understood and/or applied to achieve or contribute to similar goals. In contrast, coherence is less or lost when ‘smart’ initiatives take separate directions and pursue aims or goals which are dissimilar or incongruent. For the ‘smart’, therefore, to be effectively and efficiently applied in real-world urban systems, it must first be internally coherent in theory. If the meaning of ‘smart’ varies drastically across different contexts, then its application will inherently be fragmented and inconsistent. So, this paper prioritizes understanding whether a shared conceptualization of ‘smart’ exists in smart planning before considering how it manifests across different geographies or socio-economic conditions.

Methodological Approach

In this paper, convergence will be examined following a systematic review of literature based on a selected sample of documents from urban planning. This will be done in two stages. The first one will identify relevant documents from which data will be extracted. The second one will involve data collection and analysis following the manifestations of convergence identified in Bennet (1991) (Figure 1). Thus, this comprises of understandings (meanings and definitions of smart), goals (aims, objectives, and big picture of smart), and applications (deployment, mechanisms of smart), as discerned in the documents from stage one.

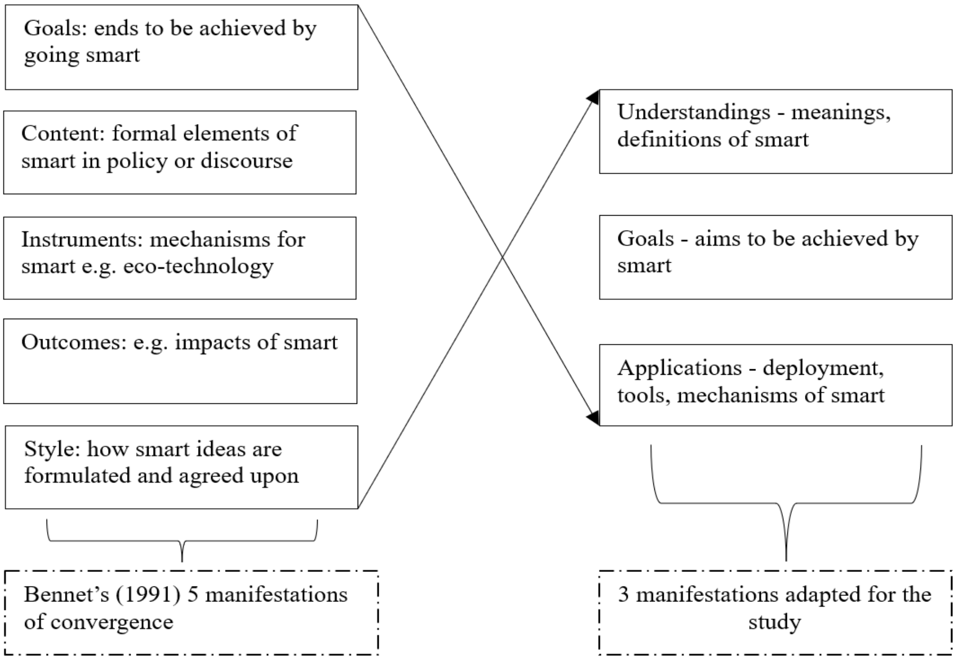

Figure 1. Bennet's (1991) five manifestations of convergence adapted into three

Identifying Relevant Literature for Review

This first stage is aimed at identifying relevant literature for undergoing a systematic review, following the Preferred Reporting Items for Systematic Review (PRISMA) guidelines (Page *et al.*, 2021). The scope of the review was defined via search criteria composed of the keywords (smart transportation, smart energy, and smart waste management), representing case studies from sectors which commonly applied the term within urban planning, policy-making, and urban studies.

In terms of case study selection, we acknowledge that a truly comprehensive understanding of 'smart' urban planning requires examining a broad range of sectors. However, for practicality, we shall examine only the above mentioned three sectors. As these sectors form the backbone of urban systems where ‘smart’ interventions are often applied, they were considered as appropriate sources of data to meet the scope of the study.

As the literature sought was distributed across several sources, Boolean operations were used (“smart” AND “energy” OR “transport” OR “waste management”), as conjunctions to combine key words in Google Scholar, Scopus, and ScienceDirect databases, to identify potentially relevant documents. The targeted literature included peer-reviewed international academic articles, book chapters, and conference proceedings. This returned 131,639 hits. To refine the search, a staged review process (Torraco, 2016) (i.e., title, abstract, body, conclusion) was applied to eliminate irrelevant documents based on several inclusion and exclusion criteria (Appendix 1). Finally, 121 relevant documents were selected for review using NVivo in stage two.

Data Extraction and Coding

Data was extracted from each document via coding using NVivo software (Silver & Lewins, 2014). It has appropriate techniques to systematically analyze textual data (Dhakal, 2022). The codes for convergence were adapted from previous literature on Bennet’s (1991) five manifestations of convergence (Figure 1), thus following a deductive coding approach (Saldana, 2009). The coding was applied as follows:

- Each document from the PRISMA results (sec 3.1) was uploaded into NVivo by sector. It was opened and perused line-by-line.
- Where a statement of definition, meaning or understanding of ‘smart’ was found, it was assigned code M.
- Where a statement of goal(s), i.e., overarching big picture to be achieved by the term ‘smart’ was found, it was assigned code G (see Appendix 2).
- Where a statement of application, i.e., how specific technologies were deployed to deliver ‘smart’ was found, it was assigned code D.

Codes like EG01 or WD05 denote the following information: First letter – sector, e.g., energy, transport, or waste; second letter – dimension of convergence, e.g., meaning, goal, or application; last two digits – identity number). Thus, the code and its text, its frequency, and sector were traceable to the document, generating numerical data for quantitative analysis. The main statements of definitions, goals, and applications were coded at level one. Further supplementary statements, adding more details, were coded at level two. Effort was made to be consistent in applying the coding scheme across all documents. Where the authors disagreed, they engaged in a detailed discussion to arrive at a consensus. The codes and statements were reviewed by the authors to remove repeated or unnecessary text.

Potential methodological limitations in our study are worth highlighting. Firstly, our analysis was based on a specific sample of documents and, therefore, the findings may not fully represent the total diversity of smart urban planning literature. Secondly, our study based on textual analysis could not account for the varied styles of writing in the documents which can distribute the elements of convergence in desperate or several overlapping places. Thirdly, contextual differences in regions, policies, and urban development stages might have influenced the level of convergence or divergence exhibited in our analysis.

While we were aware of these potential limitations, our use of PRISMA hopefully provided a systematic approach to allow the reader to judge the extent to which the findings can be generalizable to their situation. PRISMA reports our complete search strategies for the databases, including any filters and limits used, thus enhancing transparency and repeatability in our work.

Data Analysis

Firstly, NVivo (Release 1.5) cluster analysis function was applied to the codes (M, G, D), clustered by coding similarity, to help find patterns by visualizing the similarity based on Pearson correlation coefficient metric. The similarity was a proxy indicator for convergence, by groups of similar words in common (Lame, 2019). To improve the outcome of a cluster analysis, stop words (e.g., and, the, a, an, also), which convey less meaning were excluded from the similarity analysis. Codes containing texts with a higher degree of similarity based on their occurrence and frequency are shown clustered together. The results took the form of word clouds based on frequency, a summary frequency table, and a dendrogram presenting a hierarchical tree showing how coded items were associated, and could therefore be grouped together, based on their levels of correlation (Miles & Huberman, 1994). In the dendrogram, a horizontal branching diagram shows similar items clustered together on the same branch while different items are further apart: useful for comparing pairs of items. Thus, more convergence is assumed where there is closer proximity in the diagrams, and vice versa.

Secondly, the frequencies of G (goals) and D (applications) codes were analyzed, using Kendall’s tau_b correlation coefficient (2-tailed) on SPSS software (v29 with PROCESS 4.3), to measure the correlation between them: for each sector separately, then all combined. Correlation coefficients were classified as follows: (-1 = most dissimilar, 1 = most similar); Sig. (significance) values: (0.0 to 03.0 low association, 0.31 – 0.6 moderate association, 0.61 – 1 strong association).

Results

Meanings and Understandings

For Smart Energy, a word frequency map and a table summarizing the frequencies from the cluster analysis of the texts, found in the meanings/definitions/understandings (code M), was generated (Figure 2).

Texts used in similar ways	**Count (%)**
Efficiency, enhancement, optimization, demand, reduction, consumption	78 (25%)
Technologies, ICT, grids, distributed infrastructure, networks, operations	62 (19%)
Systems, management, decisions, reliability, real time, data	46 (14%)
Sustainability, resilience, environment, carbon emissions	43 (14%)
Integration, interconnection	32 (10%)
Renewable sources	18 (6%)
Quality of life	14 (4%)
Other less frequent words	25 (8%)
Total	**318 (100%)**

Figure 2. Smart Energy: Cluster analysis of 75 most frequent words from 41 documents. The original table was condensed by collating texts with similar meanings together

The most frequent texts are about systems and efficiency, which is followed by management, technologies, enhancement, optimization, integration, sustainability, and renewable energies. For Smart Transport, the most frequent words are congestion and traffic, followed by mobility, planning, management, enhancement, intelligence, etc. (Figure 3). Relatively, the environment and sustainability do not feature prominently in the word cloud and frequency table.

Texts used in similar ways	Count (%)
Data, systems, real time, advanced technologies, Intelligent, IoT, integration, sensors, autonomous infrastructure, networks	167 (38%)
Traffic, vehicles, congestion, mobility, road safety	105 (24%)
Management, planning, analysis, communication, decision making, control, dynamic monitoring	68 (16%)
Efficiency, effectiveness, enhancement, optimization, reduction, consumption	55 (13%)
Sustainable, environment	13 (3%)
Other less frequent words	28 (6%)
Total	**436 (100%)**

Figure 3. Smart Transportation: Cluster analysis of 75 most frequent words from 40 documents

For smart waste management, the most frequent texts are collection, efficiency, data, and sensors. This is followed by routes, management, optimization, systems, and IoT (Figure 4). Notably, the environment and sustainability do not feature prominently in the word cloud and frequency table.

Texts used in similar ways	Count (%)
System, IoT, sensors, bins, monitoring technologies, information, integration, intelligence	104 (30%)
Efficiency, costs, optimization, improvement, enhancement	68 (19%)
Collection, routes, generation	44 (13%)
Data, real time	41 (12%)
Management, planning, analytics, communication	36 (10%)
Sustainability, consumption, development, environment, emissions	27 (8%)
Other less frequent words	29 (8%)
Total	**349 (100%)**

Figure 4. Smart Waste Management: Cluster analysis of 75 most frequent words from 40 documents

While differences in word frequency in each sector revealed the influence of context in determining how the term is understood and applied (Figures, 2,3,4), from all three sectors, the most common terms are efficiency and data. This is followed by management, optimization, data, IoT, integration, sustainability, and systems (Figure 5). The table provides a comprehensive summary of the key words and ideas associated with the ‘understanding’ of the term ‘smart’ in the three sectors. Overall, it can be concluded that ‘smart’ is about achieving those items in **bold**, via the means in *italics*, and by deploying those in standard font. For outcomes, sustainability and reduced emissions are down in prominence while efficiency is high. In terms of means (applications), integration, intelligence, optimization, management, and planning are predominant terms in the documents.

Texts used in similar ways	**Count (%)**
Systems, IoT, ICT, *integration*, sensors, *intelligence*, infrastructure, networks, monitoring, processes, services	283 (26%)
Management, *optimization*, *enhancement*, planning, decision making, analytics	189 (17%)
Sustainability (development, environment), *renewable sources*, **emissions reductions**	137 (12%)
Real time, data, *information*	136 (12%)
Efficiency, *reduce* (costs, consumption)	134 (12%)
Other less frequent words	200 (18%)
Total	**1097 (100%)**

Figure 5. For All Sectors: Cluster analysis of 75 most frequent words from 121 documents

From the 42 definitions we listed from the 121 documents analyzed, it can be concluded that the discourse defines and understands ‘smart’ as referring to the ‘integration of advanced technologies and data analytics to optimize dynamic decision-making for efficiency, sustainability, and resilience’, or the ‘seamless coordination across various services, infrastructures, and informatics to enhance resource management, reduce environmental impact, and improve citizens' quality of life’.

Association between Goals and Applications

The correlation analysis reveals significant associations between specific goals and applications, indicating underlying patterns of convergence and non-random logic in their usage (Appendices 3–7). This suggests that certain "smart" urban planning aspects tend to be pursued and grouped across sectors.

The correlation between energy efficiency (EG12) and planning and policy integration (EG10) suggests that efforts to enhance energy performance are often aligned with broader urban planning strategies and regulatory frameworks, which means that improving energy efficiency is not pursued in isolation but is typically embedded within policy-driven approaches that guide urban sustainability initiatives. Also, the strong association between reducing emissions (EG01) and renewable energy integration (EG03) indicates that lowering carbon footprints is closely linked to adopting renewable energy sources. Cities that aim to cut emissions often prioritize clean energy solutions, reinforcing the interdependence between these goals.

The connection between urban development (EG05) and energy security (EG06) highlights the need for reliable energy systems to support urban expansion. Ensuring a resilient and secure energy supply as cities grow becomes crucial to maintaining infrastructure, services, and economic activities. However, weaker correlations between energy optimization (EG11), cost-efficiency (EG02), and resilience (EG09) suggest that these factors are not always primary drivers in smart energy planning. While important, they may be considered secondary concerns or addressed separately rather than being integral to broader urban energy strategies. This implies that cost-effectiveness and system optimization might not always be prioritized in large-scale urban sustainability initiatives, where regulatory and environmental considerations tend to dominate decision-making.

The strong associations of cost-efficiency (EG02), planning and policy integration (EG10), and energy efficiency (EG12) with at least seven other goals (see appendix 2) indicate that these objectives are widely interconnected in smart energy planning, which means that strategies to reduce costs, improve energy performance, and align energy policies with urban planning tend to be integrated with multiple other sustainability and development priorities. Their broad connectivity suggests that these goals can play a central role in shaping smart energy strategies, promoting a convergent approach where multiple aspects of energy planning are pursued together rather than in isolation.

However, since cost-efficiency (EG02) is only significantly linked to three other goals and resilience (EG09) is associated with just one other goal suggests that these two aspects are less central in discussions about smart energy, which implies that resilience - ensuring energy systems can withstand disruptions - is not as frequently embedded in broader energy planning efforts, possibly because immediate efficiency and policy-driven priorities take precedence. Also, cost efficiency can be a factor in decision-making but does not appear to be a dominant driver in shaping urban energy strategies.

While planning and policy integration (EG10) and energy efficiency (EG12) have the highest number of associations with other goals, none of these correlations are particularly strong (with coefficients below 0.61). This indicates that while these goals are widely referenced across different aspects of smart energy planning, they do not always drive decision-making with absolute certainty. Instead, their influence may depend on specific urban contexts, policy frameworks, or sustainability agendas, making their integration to some extent flexible rather than universally applied in all planning efforts.

The strong associations among advanced technologies (ED01), energy infrastructure integration (ED03), energy management (ED04), and energy optimization (ED05) suggest that these applications are frequently used together in smart energy planning, which means that when cities or organizations implement advanced technologies, they often simultaneously focus on integrating energy infrastructure, managing energy consumption, and optimizing system performance. Their interconnectedness highlights a coordinated approach where digital innovations and infrastructure upgrades work together to improve energy efficiency and sustainability.

However, simulation and modeling (ED02) are only significantly associated with one other application, indicating that it is used more selectively rather than as a standard tool across multiple applications of smart energy planning, which suggests that while simulations are valuable for testing scenarios and predicting outcomes, they cannot be as widely integrated into practical energy management or infrastructure projects. Planning and policy integration (ED06) is connected to three other applications, meaning it plays a role in shaping energy strategies but is not as universally embedded as core technical applications like infrastructure integration and energy management. This shows that while policies and regulations guide energy planning, they cannot always be directly tied to specific technological implementations, instead functioning as a broader framework within which different applications operate.

Thus, when none of these associations across energy deployments are particularly strong suggests that while these applications are frequently linked, they are not always implemented in tandem. Instead, their relationships may depend on specific project needs, regional policies, or technological advancements, meaning that while there is evidence of convergence, the degree to which these applications are pursued together can vary across different contexts.

The strong association between effective transport planning (TG01) and economic benefits (TG09) suggests that strategic transport planning is directly linked to economic growth, meaning that well-organized transportation systems contribute to cost savings, efficiency, and overall urban prosperity. Their 100% correlation with other transport-related goals indicates that they are fundamental priorities in smart transport strategies.

However, human mobility patterns (TG07) have a weaker correlation, particularly with traffic congestion reduction (TG02), which suggests that while understanding how people move in urban environments is important, it may not always be directly integrated into congestion management efforts. Instead, traffic planning can focus more on infrastructure and traffic flow than mobility behavior.

Unlike the energy sector, transport goals, including traffic safety (TG03), public safety (TG05), improved traffic flow and mobility (TG08), and addressing climate change (TG10), show strong correlations, meaning they are often pursued together, which indicates that smart transport planning tends to integrate safety, efficiency, and sustainability objectives in a coordinated manner, ensuring that improved mobility solutions align with environmental and security concerns.

Smart transport applications TD01, TD02, and TD03 exhibit moderate correlations with at least two other applications. However, while TD01 (Transport data analytics) is moderately correlated with TD02 (Traffic monitoring systems), it is only weakly correlated with TD03 (Predictive traffic management). TD02 and TD03, also, have weak correlations, meaning that while these technologies are sometimes used together, their integration is not always strong or consistent. This suggests that while data-driven transport solutions are increasingly implemented, their level of convergence varies depending on the planning priorities and technological adoption rates in different regions.

Within smart waste management, certain goals are more commonly linked than others. Environmental sustainability (WG02), community engagement (WG04), and quality of life (WG05) are significantly associated with at least two other waste-related goals (50%), indicating that waste management strategies often incorporate sustainability, public participation, and social well-being as interconnected priorities. However, optimized waste collection (WG01) and community engagement (WG03) are only significantly correlated with one other goal (25%), suggesting that they are not as widely integrated into broader waste management strategies, which shows that while waste collection and public participation are important, they cannot always be considered central to long-term sustainability planning.

When the goals and applications (codes G and D) in the energy sector were collated and a cluster analysis undertaken, the generated dendrogram revealed four classifications (color coded and numbered) based on closeness according to Pearson’s correlation coefficient within NVivo. Figure 6 reveals that ED5, ED6, EG01, and EG02 form a cluster (1) of close goals and applications and are closer to cluster (2) containing EG03, 04, 05, and 06. Thus, clusters 1 and 2 are closer together while further apart from clusters 3 and 4, which are closer together than clusters 1 and 2. This revelation confirms that certain goals and applications tend to go together more than others, identifying areas of commonality in the goals and applications of smart. This reveals areas where urban planners and policymakers can prioritize their focus for enhanced strategic and operational synergies within smart planning. Areas of strong clustering can be prioritized for optimization, while areas of low clustering can be investigated, and efforts made to recruit them as leverage.

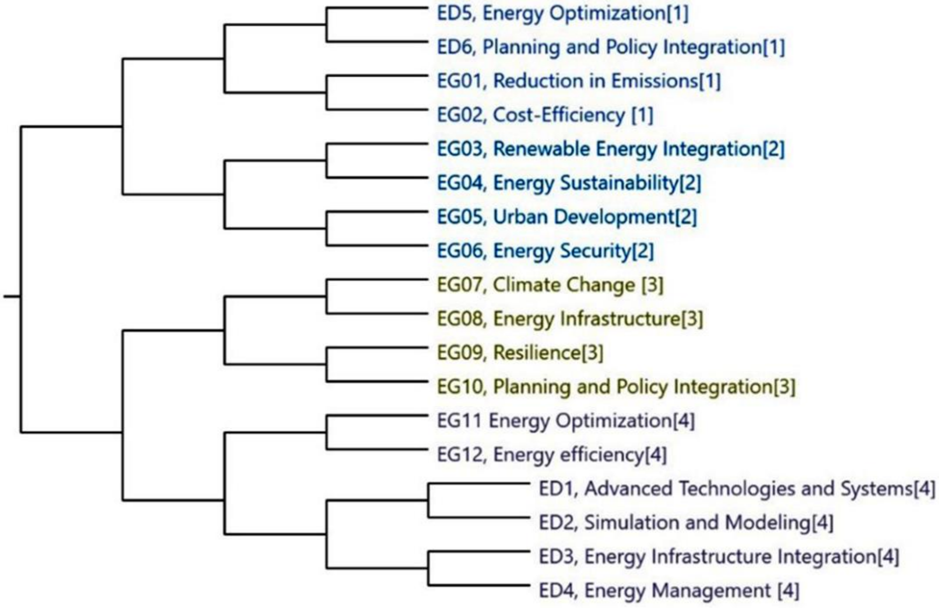

Figure 6. Smart energy goals and applications distributed by code similarity into 4 clusters of close correlation

Items closer together on the horizontal axis share more common themes or keywords, revealing the level of convergence. The number of clusters was set by the researchers.

Furthermore, Figure 6 reveals that the operations (cluster 1) are relatively less closely linked to the goal ‘clusters’ of environmental protection and sustainability (cluster 3), implying the need to consider how to better integrate or align them. This can then better support the literature claiming that the term ‘smart’ can be transformative (Masucci *et al.*, 2020; Zawieska & Pieriegud, 2018) at least in environmental and sustainability outcomes. The clustering of various goals and applications were also observed within smart transport (Figure 7) and smart waste management (Figure 8).

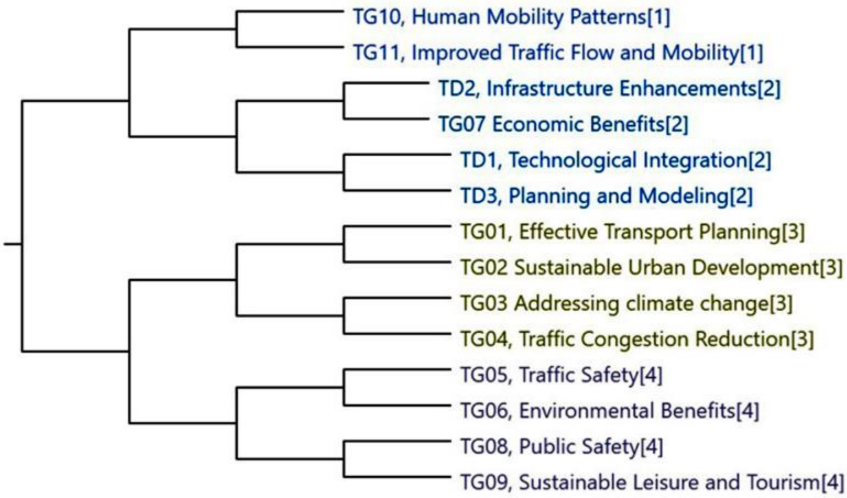

Figure 7. Smart transport goals and applications distributed by code similarity into 4 clusters of close correlation

In Figure 7, the cluster focusing on human mobility patterns and improved traffic flow appears furthest from those of public safety and sustainable leisure, implying that perhaps these could be more closely considered by planners and decision-makers as closer opportunities for synergies.

Figure 8. Smart transport goals and applications distributed by code similarity into 4 clusters of close correlation

Figure 8 reveals 2 main clusters – one of technologies and their network (clusters 1 and 2), and another of key outcomes to be achieved (clusters 3 and 4).

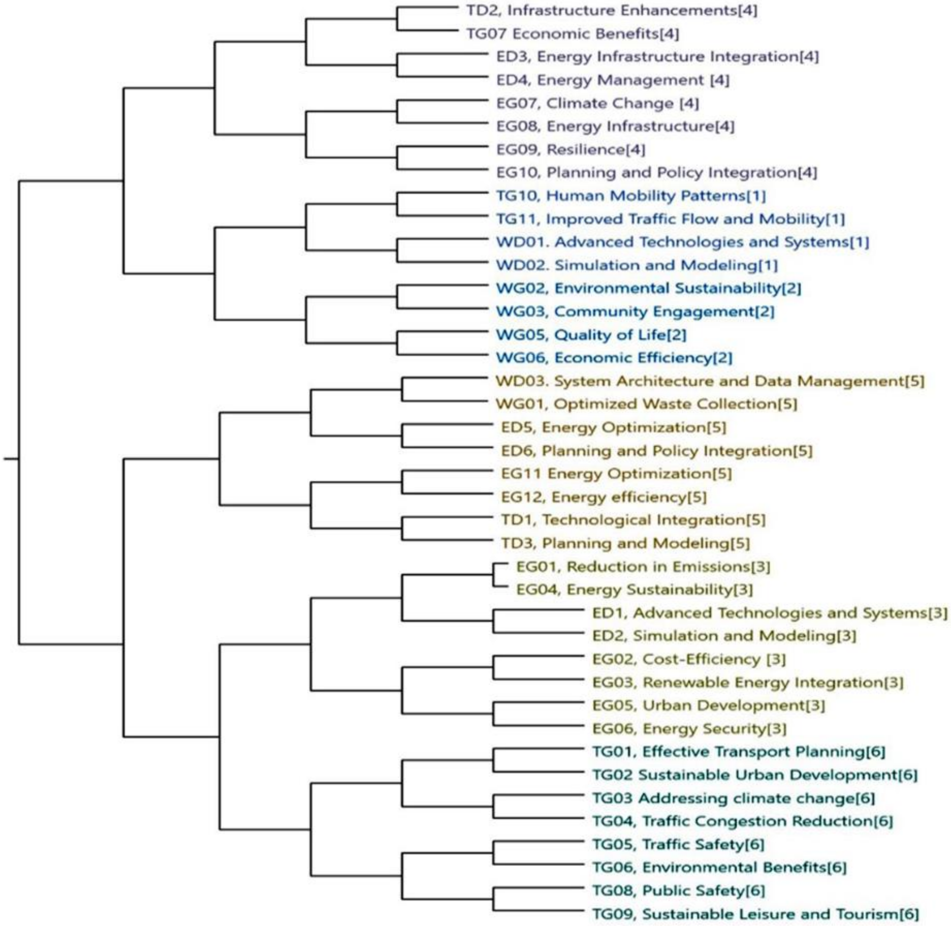

Figure 9. Dendrogram for all sectors' goals and applications, split into 6 clusters

A dendrogram from the collated goals and applications of the 3 sectors generated two main branches – one of 16 items, with transport contributing 4, energy 6, and waste 6; and the other of 24 items, with transport contributing 10, energy 12, and waste only 2. This confirms that sectors have bespoke areas of focus with specific goals and applications that tend to cluster together, which can be useful targets for policymakers (Figure 9).

Summary and Discussion

From the 42 definitions (M codes) of 'smart' in urban planning collated in our study, the words in them reflect the prevailing literature: essentially about linking the use of technologies to several goals like sustainability, resilience, resource management, environmental protection, and citizens' quality of life. Analysis of the application of 'smart' (D codes) revealed that transformative agenda were not prominent: a gap that would require policymakers to further explore how to effectively leverage the term ‘smart’ to bigger outcomes.

A key message is that on the one hand, the current discourse of ‘smart’ in urban planning, frequently uses words like ‘sustainability’ and the ‘environment’ in their definitions and understandings. However, on the other hand, the texts used in the goals and applications of ‘smart’ do not evidence a sense of a common usage of these texts. Instead, what is dominant is a motif of consumerism evidenced in words like ‘data’, ‘efficiency’, and ‘optimization’ – which are more about ease of access to places, goods, and services – perhaps assuming that these will necessarily correlate to environmental protection or sustainability.

‘Smart’, within urban planning, is defined by a discourse largely of deployment of technologies as recognized by others (Cai *et al.*, 2023). However, texts denoting outcomes, e.g., resilience and sustainability, were more visible in the energy sector and not in the transport and waste sectors. Notably, the word ‘clusters’ frequently contained texts describing ‘operations and mechanisms’, e.g., efficiency and optimization. This echoes scholars who define ‘smart’ in urban planning (Allam & Dhunny, 2019; Cui *et al.*, 2023; Soyata *et al.*, 2019) as essentially the integration of advanced technologies and digital innovations into the urban planning process to improve the efficiency, optimization, productivity, and effectiveness of planning activities.

The findings in this paper strongly confirm the Cyber-Physical Systems (CPS) Theory approach, emphasising the seamless integration of physical infrastructure with digital technologies (Andronie *et al.*, 2021; Pacheco & Hariri, 2016). Notably, missing in our word ‘clusters’ were other salient terms in urban planning, such as ‘spatial justice’ (Masucci *et al.*, 2020), which address equity and inclusivity. Overall, a Sustainable Smart Planning Theory approach, connecting the principles of sustainability with smart urban development, ensuring that technological advancements align with long-term environmental, social, and economic goals (Bruzzone *et al.*, 2021; Cai *et al.*, 2023; De Jong *et al.*, 2015) was not strongly evidenced by the clustering or convergence of words in our documents. A similar gap in meaning is raised in Gazzola *et al.* (2019), highlighting the incongruence associated with the terms “going green” and “going smart.” They found that “smart” approaches narrowed their focus on technology, potentially overlooking broader environmental and sustainability objectives and risks.

It was also noticed that smart energy and transport documents exhibited a lower level of convergence of text (Figure 8, Appendix 3 and 4), reflecting the diverse landscape within which ‘smart’ can be applied in those domains (Mosannenzadeh *et al.*, 2017; Zhang *et al.*, 2020). A relatively higher level of textual similarity was registered in smart waste management documents (Figures 8, Appendix 7), reflecting a narrower scope for application compared to the other two sectors. These levels of similarity can underpin the development of a standardized framework to guide smart city initiatives in each sector. A common sectoral understanding can facilitate shared smart city principles for effective urban planning and development (Loshin, 2011; Söderström *et al.*, 2020).

While applying the framework for convergence in our study, it was noted that convergence can be viewed from two different dimensions. One is '*within application*', where in one instance of use, the understanding, goal, and application all converge towards a common purpose or aim. Thus, the concept of smart is mainstreamed and streamlined from goal to application without let-up. Two is '*across applications*', where the smart concept is mainstreamed and streamlined, vertically or horizontally, in several other instances of use, without let-up. This would ensure a common goal of smartness across various coordinated instances of use, e.g., various policies, programs, plans, and projects in energy, transport, and waste management sectors.

While the paper provides deep insights into how the term 'smart' is understood and applied across energy, transport, and waste management, there is an opportunity to broaden the sectoral scope by integrating additional sectors such as smart buildings, water management, and public health. Expanding these areas would provide a more comprehensive understanding of smart urban planning across multiple sectors. Additionally, this study is primarily based on a literature-driven approach, meaning that it does not incorporate practitioner viewpoints or expert insights from urban planning professionals. Since smart urban planning is shaped by both academic discourse and real-world policy implementation, future research should consider including interviews, case studies, or survey data from professionals actively engaged in smart city projects. This would offer a more nuanced, practical perspective on how 'smart' strategies are designed and implemented at different levels. Finally, while this study identifies patterns of convergence and divergence, it does not assess the long-term impact of smart urban planning strategies. Future research could build on this work by applying quantitative validation methods, conducting longitudinal studies, or integrating geospatial data analysis to measure how smart initiatives evolve over time and across regions.

On reflection, the remits of transport, energy, and waste sectors may have unsurprisingly led to more technical understandings being given to the word 'smart'. Nevertheless, the paper shows that there remains a gap in connecting 'smartness' to other big picture 'transformational' goals and outcomes, e.g., sustainability, at least at the level of applications. So far, environmental and sustainability goals are assumed to follow automatically from being 'smart'.

Conclusion and Recommendations

In this paper, we noted that the term ‘smart’ has taken a visible and crucial policy and conceptual role in urban planning, governance, and decision-making, providing targets and forms for urban planning. Consequently, it is influencing how cities function and impact on their environmental friendliness or sustainability. We also noted that multiple interpretations of the term, within variable applications, risks misunderstandings, and misapplication can hinder smoother advancements in urban planning. Guided by semantic consistency theory and convergence theory, this study explored what the term ‘smart’ means between different areas of practice in urban planning, and within that, the extent to which the term is applied to achieve similar ends or outcomes. Subsequently, a systematic review of the literature facilitated by PRISMA was undertaken to identify documents to be analyzed. This was followed by similarity/convergence analysis based on NVivo’s cluster analysis and correlation analysis to ascertain levels of association of pertinent texts used in stating meaning and usage of the term. This was based on data drawn from 121 peer-reviewed international documents on energy, transport, and waste management sectors.

From our analysis, it is concluded that the term ‘smart’ is broadly understood as a means, i.e., a process by which technology and data is integrated into the urban planning processes (e.g., data collection and analytics) and outputs (e.g., digital maps and other representations, or enhanced traffic management or reduced greenhouse gas emissions). Sectors with more areas of application, such as energy, registered less convergence compared to sectors with narrower areas of application, such as waste management. Despite the plurality and intricate interplay of the idea of ‘smart’ in the three sectors, it is essentially about mechanical ‘deployment solutions’, pursuing efficiencies and optimizations, rather than ‘transformational outcomes’. Unless we assume that significant efficiencies and optimization can deliver transformational change.

While several articles have highlighted how smart urban planning is ostensibly contributing to a paradigm shift, our analysis has not uncovered convincing evidence for this. Instead, an eco-modernism steeped in a promising language of technology-based paradigm but hollow in meeting the key challenges, or even fundamentally transforming the status quo, is emerging.

For a multi- and inter-thematic area of application like urban planning, the future dynamic use of the term ‘smart’ calls for research addressing how the term’s understanding and application can underpin more transformational outcomes. This echoes Cavada *et al.* (2016) asking for a theory to underpin the systems to be connected to deliver such a transformation. This can pursue:

1) scale approaches, e.g., whole sector or city level application, 2) deeper integration, e.g., holistically linking several sectors as an organic whole, to 3) radically altering the configurations at qualitative and quantitative levels of ‘smart’ performance. These pursuits will require establishing relevant threshold metrics for classification as ‘smart’. For example: Is an urban system with 10x technology smarter than one with 5x technologies? What if the one with 5x technologies delivers more carbon reductions than the one with 10x? Thus, what framework can help distinguish the various typologies and levels of ‘smartness’?

The concept of convergence in this paper has served to highlight the challenges associated with the terminology ‘smart’, exposing the complexities and ambiguities that arise in its implementation. This matters in a multidisciplinary and interdisciplinary field like urban planning where various stakeholders and differing areas of application are involved, offering several instances for variously interpreting the meaning and use of the term. However, this can be guarded against by facilitating a standardized set of common understandings, goals, and applications to support a shared vocabulary for communication. This can provide policymakers with common terms of reference to inform the formulation of appropriate policy and practice.

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the paper's content.

Funding Statement: The authors did not obtain any funding for this research.

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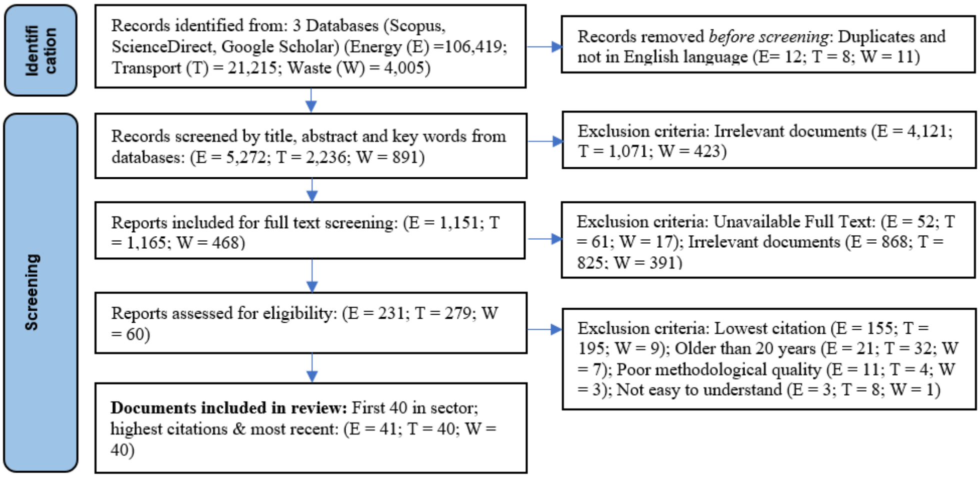
ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Appendix 1: The PRISMA approach ensures that the search for relevant literature to analyze is systematic and transparent (adapted from: Page *et al.*, 2020).



Records identified from: 3 Databases (Scopus, ScienceDirect, Google Scholar) (Energy (E) =106,419; Transport (T) = 21,215; Waste (W) = 4,005)

Records removed *before screening*: Duplicates and not in English language (E= 12; T = 8; W = 11)

Records screened by title, abstract and key words from databases: (E = 5,272; T = 2,236; W = 891)

Exclusion criteria: Irrelevant documents (E = 4,121; T = 1,071; W = 423)

Reports included for full text screening: (E = 1,151; T = 1,165; W = 468)

Exclusion criteria: Unavailable Full Text: (E = 52; T = 61; W = 17); Irrelevant documents (E = 868; T = 825; W = 391)

Reports assessed for eligibility: (E = 231; T = 279; W = 60)

Exclusion criteria: Lowest citation (E = 155; T = 195; W = 9); Older than 20 years (E = 21; T = 32; W = 7); Poor methodological quality (E = 11; T = 4; W = 3); Not easy to understand (E = 3; T = 8; W = 1)

Documents included in review: First 40 in sector; highest citations & most recent: (E = 41; T = 40; W = 40)

Appendix 2. Codes for the 29 main goals in the three sectors. Sub-goals are excluded.

Sector	Code	Goal
Energy	EG01	Reduction in emissions
	EG02	Cost-efficiency
	EG03	Renewable energy integration
	EG04	Energy sustainability
	EG05	Urban development
	EG06	Energy security
	EG07	Climate change
	EG08	Energy infrastructure
	EG09	Resilience
	EG10	Planning and policy integration
	EG11	Energy optimization
	EG12	Energy efficiency
Transport	TG01	Effective transport planning
	TG02	Traffic congestion reduction
	TG03	Traffic safety
	TG04	Environmental benefits
	TG05	Public safety
	TG06	Sustainable leisure and tourism
	TG07	Human mobility patterns
	TG08	Improved traffic flow and mobility
	TG09	Economic benefits
	TG10	Addressing climate change
	TG11	Sustainable urban development
Waste	WG01	Optimized waste collection
	WG02	Environmental sustainability
	WG03	Community engagement
	WG05	Quality of life
	WG06	Economic efficiency

Appendix 3: Correlation between Smart Energy goals (**Correlation is significant at 0.01 level; *Correlation is significant at 0.05 level; n=41).

		EG01	EG02	EG03	EG04	EG05	EG06	EG07	EG08	EG09	EG10	EG11	EG12
EG01	Cor	1.000	.234	.391**	.309*	.517**	.363**	.226	.246*	.195	.447**	.169	.485**
	Sig.	.	.065	<.001	.011	<.001	.003	.057	.045	.109	<.001	.183	<.001
EG02	Cor	.234	1.000	.100	.169	.346**	-.022	.155	.231	.219	.409**	.325*	.162
	Sig.	.065	.	.430	.194	.006	.869	.224	.080	.096	.002	.018	.197
EG03	Cor	.391**	.100	1.000	.195	.227	.561**	.278*	.355**	.205	.268*	.112	.378**
	Sig.	<.001	.430	.	.107	.055	<.001	.020	.004	.094	.032	.378	.001
EG04	Cor	.309*	.169	.195	1.000	.411**	.205	.036	.213	.179	.267*	.366**	.238*
	Sig.	.011	.194	.107	.	<.001	.105	.771	.091	.155	.038	.005	.047
EG05	Cor	.517**	.346**	.227	.411**	1.000	.207	.187	.304*	.221	.431**	.217	.503**
	Sig.	<.001	.006	.055	<.001	.	.092	.115	.013	.071	<.001	.089	<.001
EG06	Cor	.363**	-.022	.561**	.205	.207	1.000	.313*	.304*	.228	.220	.142	.364**
	Sig.	.003	.869	<.001	.105	.092	.	.012	.017	.075	.091	.285	.003
EG07	Cor	.226	.155	.278*	.036	.187	.313*	1.000	.170	.459**	.267*	.000	.302*
	Sig.	.057	.224	.020	.771	.115	.012	.	.169	<.001	.034	1.000	.010
EG08	Cor	.246*	.231	.355**	.213	.304*	.304*	.170	1.000	.144	.392**	.450**	.278*
	Sig.	.045	.080	.004	.091	.013	.017	.169	.	.258	.003	<.001	.022
EG09	Cor	.195	.219	.205	.179	.221	.228	.459**	.144	1.000	.200	.258	.232
	Sig.	.109	.096	.094	.155	.071	.075	<.001	.258	.	.123	.051	.055
EG10	Cor	.447**	.409**	.268*	.267*	.431**	.220	.267*	.392**	.200	1.000	.324*	.406**
	Sig.	<.001	.002	.032	.038	<.001	.091	.034	.003	.123	.	.016	.001
EG11	Cor	.169	.325*	.112	.366**	.217	.142	.000	.450**	.258	.324*	1.000	.181
	Sig.	.183	.018	.378	.005	.089	.285	1.000	<.001	.051	.016	.	.150
EG12	Cor	.485**	.162	.378**	.238*	.503**	.364**	.302*	.278*	.232	.406**	.181	1.000
	Sig.	<.001	.197	.001	.047	<.001	.003	.010	.022	.055	.001	.150	.

Appendix 4: Correlations for applications in smart energy application

		ED01	ED02	ED03	ED04	ED05	ED06
ED 01	Cor	1.000	.167	.500**	.447**	.388**	.542**
	Sig.	.	.158	<.001	<.001	.001	<.001
ED 02	Cor	.167	1.000	.227	.187	.416**	.054
	Sig.	.158	.	.055	.112	<.001	.646
ED 03	Cor	.500**	.227	1.000	.376**	.384**	.422**
	Sig.	<.001	.055	.	.001	.001	<.001
ED 04	Cor	.447**	.187	.376**	1.000	.291*	.357**
	Sig.	<.001	.112	.001	.	.013	.002
ED 05	Cor	.388**	.416**	.384**	.291*	1.000	.133
	Sig.	.001	<.001	.001	.013	.	.261
ED 06	Cor	.542**	.054	.422**	.357**	.133	1.000
	Sig.	<.001	.646	<.001	.002	.261	.

Appendix 5: Correlation between smart transportation goals. (**Correlation is significant at 0.01 level; *Correlation is significant at 0.05 level; n=40).

		TG01	TG02	TG03	TG04	TG05	TG06	TG07	TG08	TG09	TG10	TG11
TG01	Cor	1.000	.359**	.426**	.391**	.444**	.280*	.290*	.470**	.595**	.316*	.530**
	Sig.	.	.003	<.001	.002	<.001	.045	.022	<.001	<.001	.015	<.001
TG02	Cor	.359**	1.000	.266*	.228	.269*	.042	-.059	.489**	.251*	.127	.509**
	Sig.	.003	.	.029	.065	.033	.761	.637	<.001	.041	.322	<.001
TG03	Cor	.426**	.266*	1.000	.200	.602**	.083	.228	.642**	.343**	.249	.405**
	Sig.	<.001	.029	.	.111	<.001	.552	.071	<.001	.006	.055	.001
TG04	Cor	.391**	.228	.200	1.000	.327*	.370**	.101	.362**	.495**	.601**	.419**
	Sig.	.002	.065	.111	.	.012	.009	.430	.004	<.001	<.001	<.001
TG05	Cor	.444**	.269*	.602**	.327*	1.000	.187	.188	.423**	.352**	.297*	.426**
	Sig.	<.001	.033	<.001	.012	.	.194	.150	<.001	.006	.027	.001
TG06	Cor	.280*	.042	.083	.370**	.187	1.000	.210	.189	.398**	.518**	.358*
	Sig.	.045	.761	.552	.009	.194	.	.140	.170	.005	<.001	.011
TG07	Cor	.290*	-.059	.228	.101	.188	.210	1.000	.234	.311*	.234	.202
	Sig.	.022	.637	.071	.430	.150	.140	.	.060	.015	.078	.114
TG08	Cor	.470**	.489**	.642**	.362**	.423**	.189	.234	1.000	.368**	.426**	.567**
	Sig.	<.001	<.001	<.001	.004	<.001	.170	.060	.	.003	<.001	<.001
TG09	Cor	.595**	.251*	.343**	.495**	.352**	.398**	.311*	.368**	1.000	.479**	.633**
	Sig.	<.001	.041	.006	<.001	.006	.005	.015	.003	.	<.001	<.001
TG10	Cor	.316*	.127	.249	.601**	.297*	.518**	.234	.426**	.479**	1.000	.407**
	Sig.	.015	.322	.055	<.001	.027	<.001	.078	<.001	<.001	.	.002
TG11	Cor	.530**	.509**	.405**	.419**	.426**	.358*	.202	.567**	.633**	.407**	1.000
	Sig.	<.001	<.001	.001	<.001	.001	.011	.114	<.001	<.001	.002	.

Appendix 6. Correlations for applications within Smart transportation

		TD01	TD02	TD03	TD04
TD01	Cor	1.000	.650**	.318**	.150
	Sig.	.	<.001	.007	.212
TD02	Cor	.650**	1.000	.287*	.182
	Sig.	<.001	.	.020	.146
TD03	Cor	.318**	.287*	1.000	.168
	Sig.	.007	.020	.	.161
TD04	Cor	.150	.182	.168	1.000
	Sig.	.212	.146	.161	.

Appendix 7. Correlations for goals in smart waste management. (**Correlation is significant at 0.01 level; *Correlation is significant at 0.05 level; n=40)

		WG01	WG02	WG03	WG04	WG05
WG01	Cor	1.000	.227	.003	.090	.590**
	Sig.	.	.065	.981	.477	<.001
WG02	Cor	.227	1.000	.253	.301*	.408**
	Sig.	.065	.	.051	.022	.001
WG03	Cor	.003	.253	1.000	.421**	.174
	Sig.	.981	.051	.	.002	.175
WG04	Cor	.090	.301*	.421**	1.000	.204
	Sig.	.477	.022	.002	.	.117
WG05	Cor	.590**	.408**	.174	.204	1.000
	Sig.	<.001	.001	.175	.117	.