

Article

Smart Technology Impact on Neighborhood Form for a Sustainable Doha

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Abstract: This study focuses on the significance of neighborhoods in a city as the smallest self-sufficient urban units akin to nuclear families in the larger society. Thus, improvements to the neighborhood form can improve livability, maximize walkability, and better the overall life quality of city inhabitants, which, in turn, advance a city's overall environmental and social sustainability profile. The physical form (arrangement) and density of neighborhoods are primarily shaped by land ownership regulations, transportation, and communication means. The development of smart technology, especially in the fields of transportation and communication, has led to the reconsideration of some of sustainable urban form concepts such as neighborhoods. Low-density cities like Doha, Qatar can become both sustainable and livable, creating the basis for a sustainable city. First, this paper presents a critical review of Doha's neighborhoods and advanced transport and communication technologies, in addition to the integration of these technologies with the physical form of neighborhoods. Then, the paper discusses the influences of such technologies on the future sustainability of the city of Doha and its neighborhoods. This investigation is based on a Delphi study to address the characteristics of a neighborhood and to identify two paradigms of 'good' design practice.

Keywords: smart transportation; sustainable neighborhoods; sustainable cities; urban form

1. Introduction

The physical forms and density of neighborhoods have been largely impacted by their land ownership regulations, transportation, and communication methods [1]. Various previous research findings suggest that life quality in neighborhoods can be improved by, for example, planning and developing mixed land use, establishing integrated communities with increased walkability needs and opportunities, promoting a sense of belonging, and encouraging attractive and participatory communities [2,3]. Additionally, the integration of advanced or smart technologies in the field of transportation and communications may lead to the reconsideration of some of the concepts of sustainable urban forms [4], so that neighborhoods in low-density cities like Doha, Qatar can become both sustainable and livable, creating the basis for a sustainable city.

The original plan for the city of Doha, comprising distinct neighborhoods, provided ample outdoor areas for walking and public spaces in which people could socially interact. However, due to the 1990's and 2000's urban sprawl, the current challenge is the resultant low density of the city [5,6]. Communication and mobility advancements have inspired many to speculate on how future technology will change urban spaces and cities. In the case of Doha, the integration of smart transport

and communication technologies is considered a promising mechanism to offer a potential solution for improving quality of life and delivering sustainability.

Section 2 presents a literature review and critical analysis of urban planning theories for sustainable and livable neighborhoods, elaborating on the wider impact of smart technology on urban planning, along with the effectiveness of sustainable mobility in its employment of these smart technologies as the theoretical framework of this study. To further investigate and analyze the future of Doha, a Delphi study was conducted to understand the impact of ‘smart’ transportation systems on the refurbishment of Doha’s existing low-density neighborhoods. On the basis of responses from the members, we have identified and discussed five perceptions for the future sustainability of the city.

The primary research question in this paper is: Considering the existing neighborhoods of Doha, how can smart transportation and communication technologies improve the sustainability and livability of the low-density city?

The study attempts to answer the question through two themes:

- First—The neighborhood physical form:

The physical arrangement of Qatari neighborhoods lacks facets that promote social cohesion and walkability- two key characteristics of sustainability. Many of these facets are defined by mainstream urban planning theories, such as the Neighborhood Unit Movement and New Urbanism.

- Second—Smart technology:

The technology associated with improved transportation and communication can contribute significantly to the neighborhood’s sustainability and livability. However, acceptance of these technologies is subject to social and cultural norms. Currently, the most patent social barrier to alternative transportation modes in Qatar is Qataris’ preference to drive their private cars. So, breaking this link by introducing a socially acceptable alternative, such as self-driving cars, may help overcome this barrier. These hypotheses were presented to the Delphi team for their review and comments.

It has been predicted in some research papers that not owning a private car will contribute to increasing people’s need to walk, thereby increasing the desire to use alternative transportation such as the metro [7] and allowing some of the areas in the urban context used for cars, like streets and parking, to be allocated for other uses, such as linear parks and food production. This means that if this theory succeeds, the city will become more livable and more sustainable.

2. Theoretical Framework

2.1. Sustainable and Livable Neighborhoods

2.1.1. 1929—Clarence A. Perry’s Theory of the ‘Neighborhood’, Its Definition and Characteristics

Clarence A. Perry coined the term ‘neighborhood unit’ in 1929. It was an expression used in the planning of cities that has frequently been referred to in the context of residential development [8]. As outlined by Perry, the principles of good neighborhood design center around the function of its school, and, depending on the population density (10 units per Acre), each unit should provide one school for the population residing in local housing. Each quadrant of the neighborhood should contain small open parks and other recreational spaces, located close to the schools, while shopping districts should be situated at the edge of the neighborhood, preferably at the major street intersections. Instead of passing through residential areas, major arteries and traffic routes should form the boundaries of the neighborhood. The internal streets should be designed using curvilinear and diagonal roads to encourage slower movement of traffic, thereby enabling a safer, quieter environment, while at the same time retaining the residential feel [9].

Perry’s neighborhood unit concept generated the idea of building communities based on this construct, and it duly became the basis for neighborhood planning and design by most international

organizations [8]. The neighborhood also came to be seen as a self-governing unit, by providing services such as education, health, and commerce [10].

2.1.2. Livable Renovation of Existing Neighborhoods

Many studies have suggested that improving the quality of life in urban neighborhoods, for example, by promoting mixed land-use, establishing walking communities, developing a sense of place, and encouraging attractive communities, tends to create a harmoniously built environment for citizens [2,3]. Cho and Rodríguez [11] analyzed the relationship between the location of the neighborhood, its built environment, and walking for various purposes. It was observed that there was a distinct association between the location of the neighborhood and the likelihood of individuals walking, as well as an association between the neighborhood built-environment and walking. The proximity of residential areas to employment centers and the regional transportation system increased the likelihood of walking to and from work and reduced the need to travel to other city centers for work. Walkable neighborhoods are therefore an essential part of urban planning.

2.1.3. New Urbanism

The New Urbanist movement mainly targets low-density American cities to make them walkable communities again [12]. It has two well-known approaches: Traditional Neighborhood Development (TND) and Transit-oriented Development (TOD). Duany, Zyberk and Alminana [13] set out the basic physical attributes needed in a neighborhood space to make it walkable again, as defined by the term 'traditional neighborhood development,' which refers to a post-Modernist urban movement that started in the 1980's in the US. The New Urbanists' objective was to redevelop American neighborhoods before they become car-dependent, aiming to make them safe, walkable, and of mixed use. The new design would have a compact, mixed-use center including places of work along with entertainment, retail, education, health, and civic services. By providing such a mix, they maintained that the neighborhood would become more likely to attract public transportation services and become more affordable for residents in comparison to city centers, while also maintaining a mixture of socioeconomic groups.

In the 1990's, the idea of TOD gained popularity internationally in urban planning development [14]. Central to this approach is the positioning of the transit station as the prominent feature of the town center, surrounded by residential, commercial, recreational, and civic areas. Housing should be a mix of different types to serve the needs of as many socioeconomic groups as possible. The TOD is pedestrian- and bicycle-friendly, and local destinations are connected through a pedestrian-friendly street network, with the local population all living within this 10-min walking radius. Bike-share rental systems and dedicated bike parking should be integrated with the transit stations [15].

2.2. Smart Technology's Impact on Urban Planning

Cities currently face various significant challenges, including improving safety, encouraging healthy social interactions, increasing energy efficiency, improving air quality, and raising the overall quality of life for residents. The urge to address these concerns underlies the momentum to make cities smarter [16].

Technology impacts the way people live and work. Research and innovation in the areas of digitization, robotics, and artificial intelligence are a few advances that have the potential to reshape cities, connect humanity, and boost human capability holistically [17]. Superfast, high-capacity broadband networks are able to monitor and automate operations and applications in utilities [16]. City planners link networking requirements to the planning processes for modernization or beautification efforts in public spaces [18,19].

2.2.1. Sustainable Mobility

Smart technologies can make cities more efficient and transform public transportation systems. Information and communication technologies have given rise to intelligent transportation systems that facilitate the integration of information, communication and transportation technology (ICT) devices

into transport and highway systems [20], from means such as better reporting and monitoring of traffic and public transportation status, to finding alternative ways for transporting people and goods. The advantages of ICT devices are that they help to gather information, report accidents, control information panels and signs (speed signaling, highway dosage), and manage traffic flows (often from centralized control centers) [21].

Buses with green propulsion technologies, such as battery-electric and fuel cells, powered by compressed natural gas and biofuels, can be beneficial for low-density areas where public transport is expensive and generally unattractive and will help reduce negative impacts on the environment [22]. Electric vehicles that are designed and built as autonomous vehicles (AVs) from the outset are likely to emerge in the next decade. Since AVs can move while empty, they can therefore offer door-to-door journeys to match individual needs exactly, without needing parking spaces at either end of the trip [4].

The impact of these new emerging practices and initiatives in relation to mobility and demand management can lead to behavioral changes [23,24]. Singapore is the first city to be fully accessible by public transport; self-driving cars have replaced 30% of its existing vehicles and this number could be further increased to 40% if passengers traveling similar routes at the same time were willing to car share [7].

2.2.2. Communication Technology

Information and communication technology (ICT) is an all-encompassing, all-inclusive marvel of a network that covers the full spectrum of human activity from individual use to economic and political activities. ICT is all the hardware, software, and combined systems thereof that store, guide, deliver, and share information. It is an information and communication network that permeates all aspects of our lives and is extremely versatile and expandable, allowing for the continuous development of solutions for individual or local needs [25]. ICT has readily provided the majority of individuals on earth the opportunity to be part of the network society, a newly defined society that re-identifies peoples and communities as well as the configuration of the cities in which they live. Simultaneously, this virtual network corresponds to the dynamics of users and their physical habitats. ICT connects members of urban communities together and bridges them to other parts of the world. The network has done away with isolation to no return [26].

ICT has also developed a new form of infrastructure that facilitate services to communities. The use of smart grids and smart meters for power and water transmission have reduced waste and increased the transparency and reliability of services. Tele-health/Tele-medicine services connect hospitals to remote facilities for consultation, diagnosis, and medical training. These are examples of how ICT has added priceless features to basic human needs. ICT connects providers of public services closely with consumers, increases safety and security, and optimizes efficiency of resource usage to generally better people's lifestyles by smartening cities [25].

3. Sustainability in the Middle East and Doha

Sustainability in urban planning in the Middle East lies between two schools of thought. The first is associated with a national vision of sustainability, mostly drawn from the United Nations Sustainability Goals. The second school limits the view of sustainability to the condition of the urban built environment [27]. In the view of many researchers, there is a close relationship between sustainability and national visions in the Middle East, as seen from examples in Qatar and the UAE [27,28]. Vision encourages a holistic approach that tackles a comprehensive sustainability profile that includes social, economic, and environmental goals. These national visions were the first motive in the built environment to implement environmentally progressive projects in government or semi-government, aiming at promoting Qatar and the UAE's cities as safe business hubs for investors in the region [5].

In less than ten years, the Greater Doha Area has grown into a metropolitan center that includes the Al Rayyan and Al-Dhayeen municipalities to the east and north of the Doha municipality, respectively. Its rapid growth, which is fueled by the country's exploitation of hydrocarbon resources, has led to an

extensive urban sprawl with a very high dependence on private transportation, especially in recent years, mainly due to the absence of public transportation. Doha has grown into a relatively low-density city where the predominant driver of its urban form stems from deep-set desires for home-ownership of detached villas, which have become the predominant residential neighborhood urban form, with little provision of local neighborhood services [5]. Consequently, this has led to long commutes and resulted in high transportation-related CO₂ emissions, traffic congestion, and air-pollution, amongst several other environmental and social sustainability impacts.

Doha is, in many ways, a 'fractured multicenter city'. Qatar's capital, where 80% of the population resides, lags in many of the 'city livability' indices of international cities. However, Qatari institutions have exerted extensive efforts in the area of sustainability, overall. Namely, extensive infrastructure investments are underway to provide an effective road network, and with the provision of a widespread network of metro lines and a public bus transportation system, congestion will be reduced, and transportation-associated environmental burdens will be alleviated, in the long run (GSDP, 2011). However, it is still not clear whether these measures will be enough to greatly improve the 'livability' of Doha or the overall sustainability of Qatar, at large.

The Ministry of the Municipality and Environment (MME) addresses Doha's urban issues in its document "Qatar National Development Framework 2032" [6] and proposes medium-and long-term solutions. For the medium term, solutions are concerned with the transport regimes of the three municipalities which will be significantly changed by the completion of the metro system. For the long run, set strategies are primarily for creating self-sufficiency opportunities within cities with regard to food, water, energy, and even employment. Luckily, the 2022 World Cup projects have accelerated the completion of Qatar's fundamental infrastructure projects of the medium-term goals set in the Qatar National Development Framework 2032. New cities, stadiums, hospitals, airports, a marine port, and metro lines were all created in a very short period of time. However, this urban development overlapped with a sudden change in the demographic structure, increasing the number of low-income foreign workers to over 50% of the population, while Qataris emigrated from inner Doha to its outskirts [29].

On the other hand, Musheireb Downtown Doha represents a different approach to sustainability in this region. It is a medium-density, mixed-use district that appeals mostly to non-Qatari residents-expatriates. According to the Qatar National Development Framework 2032, there is a very small percentage of Qataris living in the historical city center, mainly because of the compactness of the district. Musheireb is strategically located in the historical city center of Doha [30]. However, as a new, high-end development, the newly constructed district lacks socio-economic diversity, as it only targets residents of mid to high income [31].

4. Materials and Methods

The suggested qualitative method for testing the success of this proposal is the Delphi method. This method is often used in areas such as healthcare services, education, sociology, design, and urbanism [32], and has been proven to create more valid and effective results than qualitative methods. Urban planning is not a science, it is a discipline that is subject to experts' judgments and opinions and has multidisciplinary problems that cannot be validated by causal models. The Delphi method will serve the following objectives:

- Objective 1: To explore and understand the impact of smart transportation on cities' urban planning.
- Objective 2: To emphasize the credibility of a low-density sustainable city with new smart technology.
- Objective 3: To focus on the polycentric development of neighborhoods because it is the most appropriate approach for turning Doha into a sustainable, resilient city.

4.1. The Delphi Method

The Delphi method is based on assembling a group of subject matter experts that will be involved in answering questionnaire initial questions and follow-up questions. The questionnaires are provided to each expert anonymously. Each round of questionnaire content is based on the outcomes of the previous round of questions. The researcher or facilitator breaks the rounds of follow-up questions when at least 70% of the experts agree. The expert might choose to discuss the final outcomes of the experiment after its completion [33,34].

The characteristics of the Delphi method subjects were mentioned in a paper by Yang, Zeng and Zhang [35], and they are as follows: subjective expertise and judgmental inputs; complex, large, causal models that cannot be built or validated; and opinions required from a large group. Anonymity is deemed beneficial.

4.1.1. Delphi Method Background

The first recorded uses of this method are post-World War II, mainly taking place during the Cold War. The RAND Corporation stated that it has been using this method since the early 1950s, mainly to predict the future of weapons and the probability or prevention of war [33].

4.1.2. Conventional Delphi Method and Modified Delphi Method

There are two approaches for the Delphi method: the conventional Delphi method (CDM) and the modified Delphi method (MDM). CDM is an approach in which data for each round of questionnaires is generated from the experts themselves, meaning that data collected from the first round is investigated and then provided to the Delphi group for further comments in the subsequent round [34].

However, in the modified Delphi method (MDM), the source of data in the first round of questionnaires is the existing data, from sources such as face-to-face interviews with experts, literature reviews or surveys. In this way, the experts participating in the modified Delphi method know the specific area on which the study is focused [32].

In the case of this experiment the used method is MDM. The Delphi Group members will be provided with some of the findings about Doha, and literature review about sustainable and livable cities. Key findings from each round will be investigated and provided in the next round to help narrow responses to the most common opinions.

4.1.3. Advantages

The anonymity and confidentiality of responses allows the experts to express their strong opinions freely, as they will not be criticized for their views or for being influenced by the opinions of others. However, anonymity might reduce the seriousness of the responses of experts [34].

4.1.4. Limitations of the Delphi Method

One of the limitations of the method is that it can be prejudiced. If the study is biased, it is often due to the opinions of the researcher or facilitator of the Delphi experiment. Some have argued that a biased outcome might be due to ambiguous or leading questions or to the selection of experts who support the researcher's views [32,34]. One suggested approach is to review the work by a third party, to ensure neutrality.

Another criticism of the Delphi method was made by Sackman in 1975 when he emphasized that this method has limited scientific value [36]. A paper by Yang, Zeng and Zang [35] explained that the Delphi method is used in complex, subjective-input studies in which no cause and effect can be established.

4.2. The Delphi Group Experiment

Identifying apt Delphi members was dictated by the following criteria:

- Academic and/or practical experience:
 - Academic experience: the expert relies on empirical experimentation and application of academic theories.
 - Practical experience: the expert has a role in applying knowledge in professional practice.
 - Some experts may be well-versed in both academic and professional arenas.
- Urban planning and/or technology backgrounds:
 - Physical changes to the neighborhood form
 - “Soft” changes by enabling technology of transportation and communication.
- Significant level of expertise at a regional or international level:
 - Regional experience: the expert is familiar with the local culture and the regional urban planning practices.
 - International experience: the expert has up-to-date understanding of urban-planning, technology, sustainability and smart cities as well as exposure to new trends of sustainability.
- Significant contribution to his/her field.

On the basis of the above criteria, sixteen experts were identified as the most apt members to take part in the study.

4.2.1. Invitation to Participate in the Delphi group

An invitation email was sent to the identified Delphi members that was organized as follows:

- A request of participation in the Delphi study and a briefing of the intended research.
- Attached documents that aimed to provide a background to the Delphi group on the research topic:
 - The urban form of Doha as a low-density, multi-center city continually growing as an urban sprawl [6].
 - Social norms of Qataris and expatriates’ habits and expectations [5].
 - Outlook on changes of Qatar’s demography and urban form [6].
 - A study that illustrates the relationship between population density, sustainability and livability.

4.2.2. The Questionnaire

The initial set of questions consisted of:

- Question 1: “Do you think that it is fundamental to consider the application of sustainability at a local or neighborhood level when delivering resilient sustainable cities?”

Objective: understand the expert’s definition of “sustainability” and the scale(s) at which it can be applied.

Typical sources and bases for defining sustainability:

- The United Nations provides a comprehensive definition of sustainability; however, it is somewhat vague.
- The built environment discipline defines sustainability using measurement tools of green building, such as LEED, BREAM, GSAS and ESTEDAMA, and masterplan rating systems which are rarely implemented. In general, these tools are scoring tools that solely rate environmental sustainability [37] with little or no consideration of the economic and social aspects of sustainability.

The social aspects of sustainability are rarely discussed while tackling urban sustainability because of the difficulty encountered in empirically determining social aspects of sustainability.

- Question 2: “Do you think that the concept of a ‘compact city’ is the only template for creating sustainable cities, or can low-density ‘livable’ cities (often cited as being ‘the most livable’) also achieve sustainability and resilience?”

Objective: Challenge the prevalent view that the only application of sustainability in the built environment is monocentric and high-density cities.

Documents provided to Delphi participants highlighted the correlations between sustainability, quality of life and density.

- Question 3: “Do you think that the application of ‘smart’ or intelligent systems to cities can greatly contribute to making them truly sustainable and resilient, and, if so, how?”

Objective: Assist the participant in connecting the axioms of city form, density and technology. The objective drivers are: urban planners often do not emphasize the importance of the role technology plays in shaping city form and density; advancement in technologies of transportation and communication is closely associated with the City regeneration phenomena; and communication technologies reduce the need for mobility. For example, outsourcing jobs to people in different countries is an obvious outcome of the influence of communication technologies.

4.2.3. Responses to the Invitation Email

Of the sixteen invited participants, four declined, two answered insufficiently, and ten members offered sufficient responses, reflecting cooperation and keenness to take part in the study. The anonymity and confidentiality of responses were maintained throughout the period of the study. The Venn Diagram, Figure 1, identifies the expertise of the Delphi group members as categorized by the criteria in 1 above. The main areas of expertise, urban planning, smart cities and technologies, and both, is depicted by the circles and their intersection. Six members were urban planning experts, two members were smart city and technology experts, and two members were experts in both areas. The shapes refer to the type of job: academic or practical. Square is purely practical experience, Triangle is purely academic, and Star is both academic and practical experience.

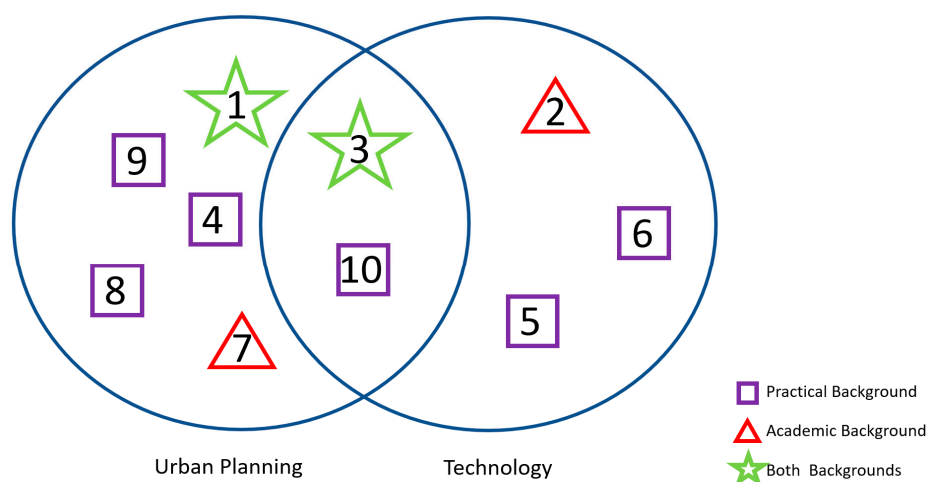


Figure 1. Delphi Members' Experiences and Fields.

A brief background of the approved Delphi members is as follows:

- Participant 1—A professor of architecture and urban planning at a Middle East university. He/she has published many research papers and books on Qatar's urban planning.

- Participant 2—A specialist in intelligent systems that operate in large, nondeterministic, cooperative, survivable, adaptive, or partially known domains.
- Participant 3—A professor directing a research group at an international university that explores how new technologies are changing the way we understand, design, and ultimately live in cities.
- Participant 4—A professional leading consultant of a multi-disciplinary team involved in preparing the Qatar National Development Framework 2032.
- Participant 5—An expert from one of the largest multi-profile business conglomerates specializing in smart solutions and technology with a long list of technology innovations.
- Participant 6—An expert with over 18 years of experience working in the Qatari Ministry of Transport and Communications, leading programs to drive Qatar’s digital transformation toward a smart future.
- Participant 7—An assistant professor at a Middle East university, working on projects examining urban transformation and sustainable development in the Arabian Gulf.
- Participant 8—A chartered quantity surveyor with 30 years of experience working for global cost consultancy companies in various locations around Asia and the Middle East and with extensive experience in ‘green buildings’ in both Qatar and elsewhere.
- Participant 9—An architect responsible for the management and delivery of various large-scale development projects in Doha and a published author with an interest in evidence-based scientific analysis and applied socio-spatial research for urban planning solutions.
- Participant 10—A sustainability and energy professional who has successfully managed and delivered various scales of sustainability projects, including masterplan development in Qatar.

5. Analysis of the Delphi Group’s Responses

The following are the final perceptions from the questionnaire, and follow-ups, of the Delphi Method. The full Delphi Group responses were provided in the Supplementary Materials.

5.1. Perception 1: Polycentric Cities Are the Future Sustainable Cities

Six Delphi members (all the urban planning participants, except for one) supported this approach. The Delphi group confirm some general views about cities’ master plans. First, Compact Cities and those based on New Urbanism are not the same, though they might have some common grounds and might achieve the same results. Compact cities are associated with high densities, while New Urbanism is associated with medium or multi-densities. Second, Compact Cities are often associated with monocentric cities, while New Urbanism is typically multicentric. The core of Compact Cities is high density and the core of New Urbanism is functionality.

All members of the Delphi group with an urban planning background agreed that the compact city has achieved tangible success in the field of environmental sustainability, supported by concrete measures. Participants 2 and 7 stated that the compact city is the only way to implement sustainability in a city. Participant 9 explained that “compact cities are more sustainable socially and economically (people interact more, they meet more often and create healthier communities; and they transact more, business is better, etc.), but not environmentally (more pollution, lots more resources, etc.)” Participant 9 argued that “but then again, one might say that compact cities are less sustainable socially; they alienate people and actually don’t have a sense of community, especially in super dense areas where people just create a routine of work-home and don’t engage much with the rest of the city or there are simply no communities or neighborhoods units to identify with; but at the same time they’re more environmentally friendly, because they might have a highly developed transit system, etc.”

Delphi members argued that the compact city form is definitely one of the forms of sustainable cities, but it is not the only form. Participant 1 stated: “[a]spects of New Urbanism and polycentric planning should also be considered towards creating lovable and livable cities.” Participant 6 said that “strategic objectives, I mean mandates such as introducing high-economic diversity and growth

and/or increase happiness factor and/or reduce travel time, etc.” are important factors, regardless of density.

The form of the city is often not dictated by urban planners, because cities are existing urban centers, not nascent, thus the option of making a city more or less dense is not always available. The applicability of compact or multi-center cities is determined by the historical development of the city. In most cases we do not set up and build a new city from scratch. We try to understand the existing context of a city, develop it and build on it. Participant 8 stated: “This is primarily because in most instances a city already exists and as a planner you would be working within the confines of what is there (wholesale change is usually not possible—except in the case of urban regeneration)”.

The combination of low-density and technology might not only be able to achieve good quality of life, but also enhance self-sufficiency, as stated by Participant 10: “. . . it can also help to decentralize essential services, to offer the flexibility and adaptability so vital to cities. From that perspective, a low-density sustainable city would be more suitable. I think that it would be good to find a balance between a compact city and low-density city where the sustainable city can achieve both resource efficiency and human-oriented value”.

Multi-centered cities are comprised of multiple urban centers and nodes. People may move back and forth between these centers for their jobs and daily needs. Fragmented Cities, such as Buenos Aires, Bangkok [38] and Doha [6], are cities where movement between the many centers is chaotic. The chaotic pattern is associated with the lack of mixed-use, housing types, and socioeconomic groups among the centers, causing the separation of the poor from the rich. If the need of people to commute between the subcenters diminishes, polycentricism strengthens, but if the trips between subcenters increase, fragmentation heightens. Recent studies by the OECD and the World Bank have concluded that the fragmentation-type of multicentered city shows positive correlation with high wages and even more so with the concentration of high-tech industry [38].

The relation between City Regeneration and Polycentricism was brought up by Participant 9 as positively correlated to population size and density. It is often due to the need of businesses and industries to find less congested and more affordable places. Each of these subcenters can provide many of the city’s services, which leads to these subcenters being self-sufficient.

Doha is a multi-center and low-density city. Doha centers, such as Capital or Metropolitan Centers described in the Qatar National Development framework 2032 [6], have many unique characteristics that make them semi-independent. These centers can be linked to surrounding centers through a hierarchical relationship such as that between the district, town, and neighborhood centers. Thus, this complementary relationship is motivated to reduce the need for people to commute long distances for daily needs. In addition, it will solve the issue of social separation.

5.2. Perception 2: City Design Approaches: Top-Down or Bottom-Up?

Two participants (5, 7) believed that a top-down approach would be most appropriate. Six participants (1, 3, 4, 6, 8 and 10) believed that a combination of both top-down and bottom-up approaches was required.

Not all Delphi members mentioned the point about the top-down or bottom-up approach; however, most who have discussed this topic agree that both national or local authority/government, as well as community members, have roles in decision making. Participant 4 stated: “In my experience both as an academic and a place-maker it is vitally important to act at a larger scale in terms of creating a ‘framework’ for sustainable development. It is also critical to consider local, neighborhood scale in terms of the livable functionality of cells within that framework.” This view is established in literature, as authorities largely prefer limiting the bottom-up approach because other forms of community involvement slow down the processes of decision-making and increase authorities’ workload [39]. Participant 4 continues to say that “a bottom-up approach focusing on getting neighborhood-scale planning right is bound to be a key factor in making cities (more) sustainable.”

Most of the smart cities and sustainable cities in the region are organized by the top-down approach, mainly because they are newly constructed. This has been confirmed by Participant 5.

In his book *Smart Cities*, Townsend explains that a bottom-up approach is no longer needed for direct engagement or the expression of an opinion [40]. Technology may overcome the obstacles of the bottom-up approach, such as its implementation being limited to the 'micro level' or 'community level' and the slow rate at which data is often processed [41]. In Qatar, despite the existence of a municipal council, there is no evidence of the involvement of the neighborhood residents in urban planning decisions.

5.3. Perception 3: Inconsistency in the Definition of 'Density'

Feedback from the respondents suggests that the terms 'compact' and 'dense' need to be clearly defined. Three participants (2, 3, 7) affirmed that the 'compact' city is the only feasible form for a sustainable city.

Density and city sustainability and livability are very controversial topics. There is empirical evidence of the positive correlation between environmental sustainability and high-density; on the other hand, there is empirical evidence for the positive correlation between livability and low-density form [42]. Participant 4 stated "Low-density urbanization will score highly on health and some of the social indices of livability. However, density tipping points are evident in relation to a number of other livability factors such as: energy-efficient transportation and mixed-use..." He continues explaining that it is possible to have low-density but conditioned that with "nodes of higher density are endemic to contemporary urbanism." This means that there must be a hierarchical relationship among a group of centers in the city. This view is shared by Participant 9, who stated that "I believe the most sustainable cities have a balanced gradient of dense and lesser dense areas. It's a question of scaling the parameters and densities to achieve an optimum sustainability level that works for the particular city, given its existing conditions." This applies to the case of city regeneration, where new areas of the city become denser and a core for new businesses and support surrounding centers in a hierarchal relation.

City density is cultural and is driven by cultural and historical context; for example, some European cities might be considered low-density compared to some Asian cities [43]. The compact and high-density concept is perceived to be a European romantic view and should not be generalized in world cities without understanding the comprehensive context. Participant 3 says, "Just think of how public transportation is widespread in continental Europe's century-old cities, while it is hardly affordable in many American metropolises, where the phenomenon of sprawl is at its highest." Then Participant 9 stated "Interestingly, cities tend to perform in one or two areas much better than the third. It seems that no cities are achieving a sort of a balanced sustainability across the board." This means that cities can be good or bad based on the key performance indicators used.

Many concepts related to sustainability and urban planning have not been defined, although there is a general understanding of these concepts, low and high density being among them. Urban form density has been defined as "a numerical measure of the concentration of individuals or physical structures within a given geographical unit" [43,44]. However, different methods might be used to measure the same type of density in different countries: for instance, the UK and US have different ways of measuring regional density, although regional density has the same definition in both nations. Finally, 'density' might be taken as a description of spatial density or social density. An urban form might have a low spatial density but is perceived to have high social density. Social density is the way in which people perceive the space, and it might have many influences such as crowding, interaction, layout, building coverage, or other space design elements [44,45].

The Qatar National Development Framework 2032 has defined the concept of density in Qatar. This is very important because there is a general understanding of density, it is not internationally standardized, so high or low density is culturally relative. The document, which shows great influence of the British standards and uses its definitions for the "net density" and "gross density", defined

the gross density for each level of density, so low density is a land with 0–60 persons per hectare, medium is between 60–120 and high is between 200–300. For each type, it mentioned the building forms and appropriate location within the city. Therefore, low-density exists only in suburban areas with detached or semi-detached houses, either single or 2 floors and penthouse, housing compounds, and villas with private open spaces. Medium density is of two types: first, the ones within inner-cities can be found in district and town centers, and second, any significant landmark near a metro station. High-density building form is an apartment building or any housing building with higher dwelling yields. In the case of Doha, the areas of high density are specified by name, and they are areas around the C-ring road, Al-Sadd, the three capital centers precinct, and centers that are linked to the 12 Transit-oriented-Development projects.

5.4. Perception 4: The Integration of Technology into Daily Life

As stated by two participants (2,3), the integration of technology into our daily lives is no longer a choice. Technology implementation is increasingly prevalent, and it surely extends above and beyond the objectives of a smart city.

Participants discussed the concept of technology and its impact on urban planning, from conventional perspectives to popular perspectives. The conventional way was stated by Participant 5: “Technology can improve the efficiency of city systems. In addition, it can improve the safety and security of people. It can improve the environmental, economic and social aspects of a city.” They went on to list conventional functions like smart grid and fire/life safety systems. Other participants discussed technology with respect to “trendiness” and how it associates with the concept of a smart city. “Living Labs (think-tanks), city control rooms, monitoring economic externalities- an impact on behavior,” they listed. Though all these are interesting concepts, they are theoretical rather than practical, because they have no direct impact on the end user, and as a result, no impact on the city form. This is a view that is worth more exploration.

Economic externality is an impact on a third party caused by an action that economists often consider negligible, such as the impact of cars on air-pollution and human health [46]. Participant 4 stated that “technology will be able to reduce per-capita consumption and externalities (waste). They will clearly have a positive effect upon spatially extensive patterns of urbanization and potentially bring them closer to the attributes of, for example, ambient modes of movement achievable under life-work walkable catchments favored by so-called new urbanists.” Meaning: the city can be more efficient in consumption of resources, and as result, can reduce waste and conserve natural resources. Participant 3 stated: “Sustainability makes our cities less dependent on non-renewable sources—and hence more resilient (Self-sufficient)”.

The concept of the internet of things (IoT) is associated with the idea of machine to machine communication with no human interference. Streetscape may start having technologies that use the internet to monitor, report and communicate with a central control room or directly with the other objects throughout a city [47]. This concept may appear farfetched at the current city form. However, there are encouraging signs for the future implementation of IoT in the near future. Countries such as Qatar and the UAE have already begun experimenting with the use of IoT in monitoring and controlling environments [48,49] such as street traffic. Participant 3 stated that “the Internet is more and more entering the spaces we live in, and is becoming the Internet of many Things, allowing us to create a myriad of sensing-and-actuating loops that were not possible before. Applications of intelligent systems are diverse: from energy to waste management, mobility to water distribution and from city planning to citizen engagement.”

The Living Lab (Think-tank) concept is also an interesting one. The media continuously prompts news on think-tanks and living labs in the region. In Qatar, the similar model of “smart city living labs” is developed by the Department of Smart Nation which runs an annual “TASMU” conference exhibiting the status of all ongoing construction and smart-city projects in Qatar [50]. Participant 1’s view is that “Application of smart or intelligent systems can greatly contribute, but that should couple with the

belief in using and operating them and the behavior of people using them. Yet, they should also be conceived at all scales". These advances will impact behavior and influence social norms in addition to impacting the city's physical form [51].

World cities in general cannot fulfil the three fields of sustainability, and often cities tend to be good at two but not the third. Participant 9 stressed that it might be the next approach for sustainability to target technology to fill this gap: "If smart technology is used to influence all three domains for the better, then great. To conclude, recently, at the Pearl where I live, they've introduced an app for delivery of groceries to your home. So, you have a small grocery store making great money, thriving economically, which diversifies the Pearl economy with smaller cheaper establishment. Great. But the smart app that lets you place your order, etc. makes you stay at home, not interact with your community, not move. So socially, it's bad. It also creates the need for drivers who run around emitting CO₂ using unsustainable transportation."

In recent years, cities have implemented many tools and instruments, such as widespread internet availability, the use of data-collecting instruments such as cameras and sensors, informing, reporting and giving feedback through social media, harnessing the increasing capability of computing power and artificial intelligence, and employing new technologies such as 3D printing and robotics [52].

5.5. Perception 5: Integrated Mobility Plan at the Multi-Urban Level (Regional to Neighborhood)

Two participants (4,9) who had experience working with masterplan projects in Qatar supported this perception.

The hierarchy and the integration of city centers were one of the points highlighted in the literature review sent to participants. Sustainability has always been one of the key objectives in Qatar and the UAE's mega projects. Literature shows that this attention to sustainability has been driven by those country's national visions. However, they also believe that the implementation of sustainability measures has not been fully realized, especially in terms of the integration of these projects and their contextual surroundings [31,53]. Uncomprehensive sustainability implementation has resulted in socioeconomic segregation among other shortcomings to city master planning. Participant 4, nonetheless, wrote that [he is] "doubtful whether there is something called 'true' sustainability. At this point if you are able to show that something is more sustainable than something else it is probably good enough," considering that both Qatar and the UAE are developing countries. Participant 8 asserted that: "there is an urgent need to provide linkage between the isolated district centers, which are currently under development. This means that your neighborhood study will become vital because these zones will be the lifeblood of businesses and communities as the current multiple major destinations around Doha begin to struggle with competition amongst themselves." The linkage can be physical by means of transportation, or by introducing more compact mixed-use areas to neighborhoods. Social cohesion is a quality in neighborhoods and is supported by neighborhood characteristics like walkability and mixed use. Walkability might be one quality that is lacking in many of Qatar's neighborhoods, driven by numerous reasons, but mainly as a result of the physical form of neighborhoods. P10 added that "implementation [of mix use areas] at local and neighborhood scale would be ideal to facilitate interaction of people. It is surely a fundamental application of a smart city starting at the smaller community level to later implement it at city-wide level. However, it would be also important to consider how to collate different local/neighborhood level applications and how to implement them in a city level in an agreeable and integrated approach".

It is essential to integrate mobility into urban planning at different levels. The Qatar National Development Framework 2032 classifies the hierarchy of centers in the country's cities into capital, metropolitan, town, and neighborhood. These specifications are based on historical background, current use of the center, and population density. The nature of transportation in these centers can also be classified as: more than one TOD project and metro stations for the capital center; the town center surrounds a metro station; and the neighborhood station will surround a transportation hub that might include a bus service or bike-sharing service. This transportation hub will be the link

between one neighborhood and another [6]. Qatari social norms might prove to be a challenge to transportation-classified urban centers because Qataris do not ride buses or bikes [5]. A more likely change in social norm could begin with car-sharing schemes, peer-to-peer car-sharing (like Uber), and the adoption of renewable, energy-efficient and self-automated vehicles [4].

Car-sharing schemes, self-automated vehicles and other influencing technologies are predicted to have a significant impact on the form of future cities. First, many studies predict that if people start embracing such technologies, they are more likely to use other forms of public transportation, reducing the overall environmental impact of the rising number of private cars [54]. The change in transportation modes will also impact the urban plan of metropolises, as the need for parking spaces will lessen [55,56] and more than one form of transportation will share the same street space [4].

5.6. Perception 6: Qatar

Most of the participants have visited Qatar and other GCC countries and are aware of the regional cultural context, stressing that the future Doha might be less dense than it is today. Participant 8 thought that “right sizing” Qatar for the long term would better the future of sustainability. Participant 8 also stressed that the way cities are designed in this region is in adherence to world expectations and not to the unique measures that satisfy the wants and needs of the local people. Another important view about Qatar came from the smart nations specialist, Participant 6: “if an integrated smart solution is implemented, this would bring about improvements such as reduced traffic congestion, lowered carbon footprint, quicker bureaucratic action time and efficient, resilient crisis management, etc.” Though these views could be true, this view represents the statement of Participant 8 that the approach is generic and should look for a further push beyond the comfort zone of design to deal with the uniqueness of Qatar.

6. Conclusions

Conventionally, there has been an emphasis on the structure of a “compact city” as a sustainable model for urban centers. The model was promoted by increasing the population density in a city’s inner areas and limiting the use of private cars. The expected outcome was to encourage walking, promote the use public transportation, and ultimately increase the efficiency of existing infrastructures. However, more recently, the advent of the “livability” of a city concept aligned closely with low-density rather than high-density cities [57].

In light of the Delphi Group’s answers and their analyses by this research, the following findings clarify associations and probable development strategies at the intersection of technology, city sustainability and urban planning:

- There was a consensus that monocentric cities are not the only sustainable model and that polycentric or multi-centered cities are a preferred model. A multi-centered city form was considered by the Delphi Group to be optimal in pursuing sustainability goals.
- Neighborhoods are the smallest building block of the city and deserve detailed physical planning, especially when considering issues of city livability. The Delphi Group confirmed the proposal that neighborhoods were a good starting point to commence sustainability and livability enhancement.
- Mixed-use and self-sufficient neighborhoods and district centers reduce the need to travel to a central city center or from one center to another, avoiding the phenomena of city fragmentation.
- Technology can provide information, interact with the user, and improve quality of life and sustainable behavior.
- Technology can support the independence of neighborhoods to promote sustainability in terms of energy, waste, transport, etc. and thus imbue a sense of neighborhood belonging, as is the case in the Pearl, Qatar.

- The question posed regarding low-density settlements and whether transport and communications technology are able to impel a low-density city towards sustainability and livability were confirmed by the Delphi Group as an area worthy of further enquiry.
- City planning is no longer just a top-down approach; it could become both top-down and bottom-up.

The next question that follows on from these findings is how they can be applied to Doha in shaping a path to becoming a sustainable city. The starting point, as a recommendation for future research to explore this question further could be through an understanding of the city's developmental history and the underlying drivers and growth context, and an understanding of the Qatar National Development Framework—the document that sets out the proposed development goals.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2071-1050/10/12/4764/s1>, the full Delphi Group responses and the Institutional Review Board (IRB) approval.

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