Conceptualizing the Contextual Dynamics of Carbonization in Beijing: A Multilevel Perspective

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Abstract: **Beijing has pursued a linear direction of urban practices following the global north and suffered from a highly toxic air quality level. This paper aims at synthesizing the main logics leading us to the similar path of massive consumption and lock-in structuration—air pollution in the city. It underlines the limited capacity of different stakeholders to leapfrog the carbon-intensive urban development path. The study takes a panorama view by adopting multilevel perspective (MLP) and applies 15 dimensions of the MLP framework on six primary sources of carbon emission in Beijing. A methodic literature review guided by theoretical coding is undertaken. It combines the multidisciplinary strands into a coherent framework. The study classifies different study domains, stakeholders, and their limits at three levels—niche, regime, and landscape. It provides a baseline for urban stakeholders to conceptualize the diverse configuration of toxic air and potential requirements for reconfiguring the air infrastructure of Beijing.**

Keywords: **urban planning; transformative science; sustainable consumption; sustainability transitions**

I. INTRODUCTION

A deep-rooted knowledge of complex urban structures is crucial for steering the environmental innovation and sustainability transitions [1,2]. There appears to be a certain repetition of air quality issues in mega-cities of emerging economies, following to the global north—Los Angles and Mexico City, decades ago [3]. The reason might be either "leapfrogging" [4] is not practically desirable, or some concrete socio-technical rationales have led cities to follow up the carbon-intensive linear path. Similarly, Beijing—the capital of the Peoples' Republic of China, has faced multiple red alerts due to highly toxic air that led the city chocking off schools, factories and other outdoor activities—locked-in [5]. The annual mean of $PM_{2.5}$ concentration has reached up to 100μg m-3—almost two-fold higher than the latest air quality standards in China, and six-fold higher than the United States [6]. A recent study [7]informs that 64 to 72% of $PM_{2.5}$ is locally generated, while regional transport is responsible for 28 to 36%. Among local source apportionment (64-72%), motor vehicles share 31.1%, coal combustion 22.4%, industrial production 18.1%, fugitive dust 14.3% and other miscellaneous sources accounted for 14.1% $PM_{2.5}$ in Beijing[7].

Given the scenario, urban stakeholders require a broader picture of the contextual dynamics governing the carbonization process [8,9]. Although a considerable amount of studies has conducted a sector-wise decomposition analysis of the driving forces involved in the lock-in mechanisms yet acoherent framework to conceptualize the "pathways"—the interplay of multilevel non-linear processes, which formed the involuntary socio-economic cost of the ambient air degradation is still missing [10–18]. This paper goes one step ahead to the previous studies and synthesizes the contextual "needs"—socio-spatial logics driving the carbon-intensive prosumer activities—the sociology of prosumption[19–22]. Thus, the study aims at zooming the socio-spatial facts of carbonization for supporting the agenda of Sustainability Transitions Research Network (STRN)and low-carbon transitions in Beijing [2,11,23,24].

Sustainability transitions are on the core agenda of many theories and perspectives. For example, structuration theory strives to conceptualize the complex configuration of social practices at the mainstream level by paying attention to the multifaceted interplay of social structure and agency [25]. New urbanists focus on sustainable urban design for establishing a carbon neutral urban form by directing more attention to the spatial arrangements of cities [26]. Social practice theorists are equally interested in conceptualizing the configuration of societal practices through choice editing and purposeful socio-spatial transitions [22,27]. Sustainability transitions are also in the heart of socio-ecological systems, which discuss the potential formation of societal interaction with the environment [28]. These theories are relatively mature and opted by many scholars for reconfiguring the urban practices. Unlikely, this study adopts a different lens by adapting the multi-level perspective [29,30].

MLP framework provides three analytical levels to conceptualize the socio-technical transitions—niche, regime, and landscape [24,31]. The framework offers core components to consider for visualizing the interplay of non-linear evolutionary processes for environmental innovation and societal transitions [32]. The theory explains niches as the center of radical innovations, regimes as the established paths, rules and practices, and landscape as the exogenous context—the powerful configuration socio-technical systems at the mainstream level [29]. The framework has received a constructive criticism which contributed in shining the choices and styles adopted by the framework [30]. The framework is useful to conceptualize the pragmatic issues of transforming consumption from niches to the socio-technical regime and landscape changes for low-carbon transitions[24,32–34].

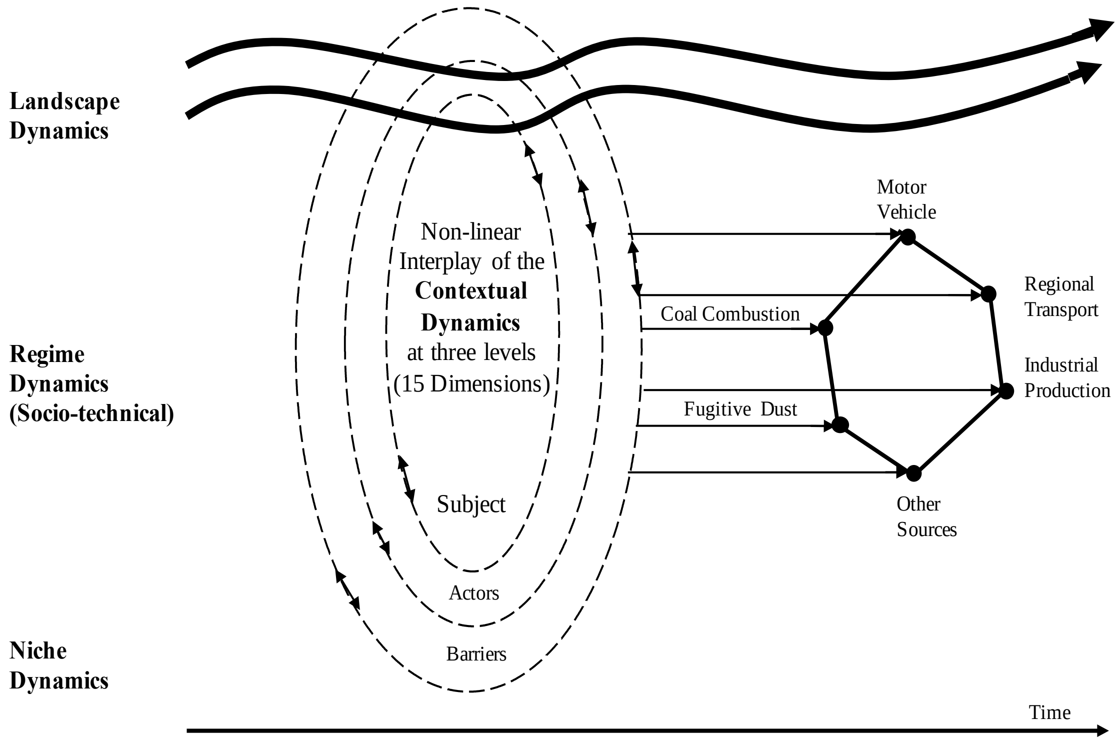

Figure 1. MLP framework for sustainability transitions (adapted from Geels, 2002, 2012)

This study applies 15 dimensions of the MLP framework on "six primary sources" of $PM_{2.5}$ emission in Beijing [7]. The study considers these six primary sources as "regimes" of carbon emission[30]. These "six regime components" are categorically reviewed by "15 dimensions" of the MLP framework. The study combines the contextual dynamics of each emission source at three levels—niche, regime, and landscape. The framework offers a systematic orientation to the backdrop logics leading to the carbon-intensive linear path. Thus, it provides a baseline for further research, policy, and reshaping practices to improve the air infrastructure of Beijing.

There are five further sections in this paper. Section 2 outlines the research method adopted in this study. Section 3 provides results and discusses—key aspects of the lock-in structuration. Finally, section 4 provides concluding remarks and leading agenda for further research.

II. METHODS

A *methodic literature review*[35,36]embracing a collection of subjective analysis—content, descriptive, as well as thematic scrutiny [37–39] is undertaken to identify the key aspects of the carbonization process. The corpus is sorted out by searching keywords in Google, Scopus, and Web of Science. The search included key terms such as consumption, carbon emission, and air pollution in Beijing. The searching of key terms then included the potentially associated factors such as energy consumption, transportation, industrial production, environmental degradation in the city. The scrutiny of research articles is based on the quality of indexing and abstracting, mostly within the area of social sciences, and excluding highly divergent areas in the scope of natural sciences. Within social sciences, the scrutiny of research articles is based on reviewing the titles first, then abstracts, and later the backward analysis, such as references. This paper has retained the most appropriate articles offering a deep conceptualization of the key aspects involved in the carbonization process in Beijing.

Guided by MLP framework [30,33,40,41], and theoretical coding method, 15 dimensions were retained to conceptualize the carbon-intensive linear path at three levels 1) niche dynamics (ND), 2) regime dynamics (RD), and 3) landscape dynamics (LD). The category of each level (ND, RD, LD) is then divided into different sub-domains (ND 1-3, RD 1-6, LD 1-6). To conceptualize the multidisciplinary strands of each regime (six sources of carbon emission), the window of each source is categorically viewed by multi-dimensional lenses (15 components) of MLP framework. Finally, a synthesis of each sub-component is presented in a conceptual framework (Table 5, 6, 7) to understand the contextual dynamics of carbonization—key logics of lock-in structuration in Beijing. With particular reference to each level, the conceptual framework is provided at the end of each section (niche, regime, and landscape). The scheme of arrangements is useful for further research, planning, and an operational mechanism to reshape the air quality of Beijing. The purpose is thus to conceptualize a variety of dynamics that conditioned the air quality issues (configuration) and support the agenda of sustainability transition by reconfiguring urban practices in Beijing.

III. RESULTS AND DISCUSSION—THE INTERPLAY OF THE KEY CARBONIZATION FACTORS

To conceptualize the multilevel structuration process, this section starts from niche dimensions to regime and landscape dynamics of carbonization in Beijing. Table 1-3 describes the multilevel components suggested by MLP framework, and table 4 provides direction to the panorama view of each component with 15 multi-dimensional lenses of the given framework. Each component is then illustrated with different stakeholders, and their limits to bypass the linear direction of consumption path in Beijing.

Table 1. Niche Dynamics (ND)

ND.1	R&D Laboratories	ND.3	Small Markets with Special Users' Demand
ND.2	Subsidized demonstration projects		

Table 2. Regime Dynamics (RD)

RD.1	Market	RD.4	Policy
RD.2	Technology	RD.5	Cultural Discourses
RD.3	Industry	RD.6	Scientific Contribution

Table 3. Landscape Dynamics (LD)

LD.1	Political Ideology	LD.4	Demographic Trends
LD.2	Spatial Structure	LD.5	Media Landscape
LD.3	Macro-Economic Trends	LD.6	Societal Values, Beliefs, Concerns

Table 4. Multi-level Contextual Dynamics of Carbon Emission

Reference	**Year**	**Sector**	**ND**			**RD**						**LD**					
			1	2	3	1	2	3	4	5	6	1	2	3	4	5	6
[42]	2016	General	•	•	•	•	•	•	•		•			•			
[43]	2016	General			•		•		•		•		•				•
[7]	2016	General	•					•	•		•	•		•	•		
[18]	2016	General		•	•					•		•					•
[44]	2015	General	•	•	•			•	•			•		•			•
[45]	2015	General		•		•		•	•		•	•		•			•
[46]	2013	General		•		•	•	•	•		•		•	•	•		
[15]	2013	General				•	•	•	•					•	•		
[47]	2016	General					•		•				•	•	•		
[48]	2003	General				•			•	•		•			•		•
[36]	2016	General	•			•			•	•	•	•					
[49]	2016	General	•			•					•						•
[50]	2015	General	•			•	•		•		•						
[51]	2017	Transport		•			•		•		•		•	•	•		
[12]	2017	Transport	•	•	•			•	•					•	•		
[16]	2015	Transport	•			•	•		•			•	•	•	•		
[13]	2015	Transport							•	•					•	•	•
[52]	2015	Transport							•				•	•	•		
[53]	2014	Transport							•				•	•	•	•	
[33]	2012	Transport	•				•		•		•						

[47]	2016	Energy		•			•						•		•		•
[17]	2016	Energy				•	•	•						•			
[16]	2015	Energy	•	•			•				•			•	•		
[54]	2017	Energy	•					•	•					•	•		
[55]	2016	Energy		•										•	•		
[47]	2016	Energy		•						•			•				
[56]	2016	Energy		•			•		•					•			•
[57]	2017	Industry		•	•		•	•	•								
[58]	2015	Industry	•	•	•	•				•		•				•	•
[59]	2015	Industry	•	•	•	•			•	•				•			•
[60]	2015	Industry			•				•	•			•			•	•
[61]	2016	Industry					•			•							•
[62]	2016	Industry			•				•	•				•			•
[63]	2015	Industry								•				•		•	•
[64]	2014	Industry				•				•		•					•
[65]	2013	Industry		•	•	•			•	•							•
[66]	2016	Industry	•	•	•		•	•	•				•		•		
[67]	2016	Industry		•				•	•		•		•	•			•
[17]	2015	Industry	•		•		•	•				•		•			
[14]	2016	Dust		•			•		•				•	•			
[68]	2016	Dust			•						•		•			•	
[6]	2016	Dust			•				•		•		•				

3.1. Niche Dynamics

This part provides three components of niche dynamics. It helps to conceptualize the contextual forces on the way to novelties that generate people's special demands from entrepreneurs, spinoffs, and start-ups [30]. The brief idea of each component with related stakeholders and their limits is provided at the end of this section (Table 5).

3.1.1. (NC.1) R&D Laboratories

Studies [42,61] have recorded biased attention paid on the development of material aspects (LD2), and limited work is done on the technological innovation (RD2), and behavioral aspects of peoples' lifestyles (RD5). Beijing had been focusing more on production and less on energy-efficient technologies. The agenda of technological innovations in energy structure is not obvious until the "Eleventh and Twelfth Five-Year Plan," which created a huge space for the current air-infrastructure of Beijing [16]. Therefore, a big chunk of private and state-owned transport system, and industry is dependent on the use of oil-burning vehicles and carbon-intensive industrial artifacts, which could otherwise reduce at least 30% material use by product service system (PSS) [59,69]. The gap has limited not only the agency for replacing the energy structure in a short run but also the acceptability of efficient and advanced technologies in the current era. For example, although the choice horizon has been expanded with the availability of electric cars yet insufficient car charging stations have limited the inhibitory role of the advanced energy structure in transport sector [70].

3.1.2. (NC.2) Demonstration Projects

The availability of an inadequate subsidiary projects for innovative business models (RD1), cleaner production technologies, and green consumption campaigns have long been limited local entrepreneurs and scholars to realize their capacities to minimize carbon emissions [42,61]. The majority of landmark endeavors for low-carbon transitions did not make a significant difference due to limited demonstration projects from the government, and ineffective monitoring and evaluation schemes [15,71]. The environmental measurement of product lifecycle and supply chains is rarely checked [55,57]. The validity of innovative mechanisms is hardly tested by the first-hand experience in consumer markets, which is crucial for promoting cleaner products at the regime level, and the area did not receive significant attention [65]. The role of non-governmental organization's (NGOs) in educating consumers for collaborative consumption and green choices in the consumer markets has not been significant [72]. Consequently, the environment-pro market endeavors are rarely reflected in consumer choices[73].

3.1.3. (NC.3) Users' Demands

Networking issue—there is limited organization among individual niche actors, groups and inter-group networks, which can potentially help in uplifting the users' special demand for green choices at regime and landscape level [74,75]. The self-efficacy reinforced by peer-group pressure is the most important aspect missing at an individual's level [76]. Whereas, resources and dynamic inter-group processes (support from the regime and landscape) are crucial for transformative social learning at group level [18]. These collectives and participatory development processes for green development are seldom part of mainstream efforts to support community participation, transformation, and sustainable growth [77]. Therefore, the choice direction of trade corporations and consumers is not that aligned with the landscape priorities to transform consumption at niche level for reshaping the air infrastructure of Beijing[78,79].

Table 5. Conceptual Framework of Lock-in Structuration at Nich Level

Component	Stakeholders	Key Factors of Lock-in structuration	Reference
ND.1 R&D Laboratories	Scientist, Research Institutions	Unequa lattention to material and life style aspects; Insufficient infrastructure to support novelties; made in China not create in China.	[42] [16] [61]
	Entrepreneurs	Inefficient utilization of products, which could reduce material use by 30% through PSS	[59] [69]
NC.2 Demonstration Projects	Financial Institutions	Limited incentives for cleaner production and green products. Green choices are more expensive than carbon-intensive products	[42] [65]
	Community Organizers	Very limited opportunities for collectives— goods and services sharing mechanism among collectives	[74] [77]
	Supply Chain Managers	No environmental measurement of supply chains and product lifecycle	[55] [57]
	Non-Gov. Organizations	Very limited awareness campaigns for green products and environmental issues	[58] [72]
NC.3 Users' Demand	Small markets Consumers	Open markets with limited check and balance for promoting green user's demand as per other products	[74] [77]
	Celebrities, Community Leaders	Influential people show up with luxurious lifestyles that triggers positional consumption	[78,79]

3.2. Regime Dynamics

The grammar of existing consumption practices and CO_2 emission—regimes exist with the interplay of various social groups at different levels [29,30]. It includes market trends, compatible technologies, industries, government policies, culture and scientific inquiries. Whereas, regime actors include policymakers, users, engineers, societal groups, capital banks, government bodies, etc. These actors enable the functioning of niche innovations at the regime level. This part informs the key logics of lock-in structuration at regime level. The brief idea of each regime with related stakeholders and their limits is given at the end of this section (Table 6).

3.2.1. (RD.1) Markets

The city administration has long been adopted a benign stance for restricting traders and manufacturing companies for utilizing cleaner energy in the manufacturing process and maximize the use of final products in markets [49]. On the other hand, casual use of electricity in commercial markets increases the carbon footprints between 3-8% [80]. These market mechanisms and limited subsidized projects (ND2) to encourage investment in innovative business models (ND1), jointly spaced for the current dilemma. These investments are crucial for the advancement of technological transformation in energy-intensive industries, and to encourage market stakeholders for cleaner production and consumption [17]. Although market-related regulations (RD4) like carbon pricing are crucial, yet a recent study [81] concludes the advertisement of green products—behavioral aspects could help more than that of carbon pricing policy to promote green products in markets [16]. Thus, ineffective market mechanisms have spaced for the unwanted outcomes of current prosumer trajectories and carbon emission in Beijing [82].

3.2.2. (RD.2) Technology

Technology and inefficient fuel consumption—motorization, and inefficient plant production technologies are the leading source of CO_2 emission in Beijing [55,66,83]. Although the scale of coal consumption has dropped from 64.36% in 1995 to 35.49% in 2012, yet the fundamental structure of coal-dominant energy structure is yet to be adapted [16]. The fuel consumption in the transport sector has increased from 1.38 Mt in 1990 to 12.04 Mt in 2014 [12]. The volume of automobiles has dramatically risen from 1.04 million in 2000 to 4.94 million in 2012 with 5.16 Mt to 19.5 Mt CO_2 emissions during the same period respectively [13]. The statistics of passenger-related carbon emission rose up to 60% from 9.38 Mt in 2003 to 15 Mt in 2012 [13,51]. In industries (RD4), coal-based propylene production technology generates more primary energy demand (PED) and emits more emissions as compared to petroleum-based propylene routes [84].

3.2.3. (RD.3) Industry

Currently, 70% of total energy is being used in the industrial sector. Metal manufacturing such as iron, steel, and aluminumare the primary sources of CO_2 emission in industries in Beijing [66,85]. A significant amount of CO_2 emissions comes from smelting the metal mining, production of metal products and electronic equipment due to using the traditional form of low-technology and energy-intensive materials (RD2) [17]. Among significant sources of local CO2 emissions, the sole contribution of coal combustion is 22.4%, whereas the cumulative effect of burning fossil fuels is estimated as 88% in 2013 [7]. In all sectors of life, 90% of energy consumption comes from burning fossil fuels such as coal and oil. Whereas, coal combustion itself produces 68% of total energy for household and industrial use [17,47]. Another analysis [86] has uncovered the exercises of inefficient production technology (RD2) in the Chinese herbal industry produces massive biomass waste, which could decrease 1.72 million tons of carbon emissions with efficient plant technology yearly.

3.2.4. (RD.4) Policy

A recent study [13] highlights loopholes in the transport pricing policies such as vehicle purchasing tax, congestion, and fuel tax. For public transportation, a low-fare policy during non-peak hours is missing. Nevertheless, strict policy measures are prevailing for private car holders yet, the number of private cars is still far beyond the capacity of the city to accommodate[51]. In industrial policy matters, an analysis [87] compares the impact of "carbon emission allowances" and "tax adjustments" on CO_2 emission. The study finds that both policies are less helpful in reducing carbon emissions as firms tend to modify their clinker trade strategy [42]. Similarly, [88] investigates the effects of green credit policy on reducing carbon emissions from five industrial sectors including paper, cement, chemical, iron, and steel. They found the investment in these industrial sectors is beneficial; however, the impact in decreasing CO_2 is limited due to general industrial output structures. Furthermore, [89] finds the contribution of market regulations in reducing environmental pollution is not ideal. In markets, corporations are not feared of their bad reputation by selling carbon-intensive goods [44]. In the housing sector, maximum living space is not restricted that results in more carbon cost for each square feet covered area in Beijing[53].

3.2.5. (RD.5) Culture

The city is host to traditional and contemporary Chinese culture with its unique infrastructure explicit in numerous conventional housing, temples, government buildings, academic institutions, industries and parks, which attracts people in the urban center [46]. The visitors like to experience the consumption patterns of the Chinese culture, and people consider it as a leisure-time activity [90]. The figure of internet users reached up to 420 million in 2013, and special shopping days like Black Friday and Cyber Monday [91], the people of Beijing like to celebrate 11/11—an shopping festival for singles' in China [92]. The increasing trend of material culture and conspicuous consumption has increased the level of carbon footprints from young adult consumers in China [93]. The lifestyle of celebrities has influenced on young adults to consume more. Hence, eating unseasonal food has increased the carbon emissions in urban areas. People not only like to eat unseasonal items but also do not care for littering and waste which causes fugitive dust in the city.

3.2.6. (RD.6) Scientific Analysis

Beijing has recently made the availability of air pollution data [94], which has long been invisible for scientific inquiries. Moreover, there is no visible mechanism for making use of existing scientific knowledge to improve the environmental measurements of supply chains and products' lifecycle. The direction of scientific inquiries seemed more focused on the material aspects of the city and limited on sustainability science approach. Therefore, a holistic approach considering lifestyle diseases as well—conspicuous consumption, social practices, and calculations for life-cycle environmental impacts is missing[95]. It requires new ways of knowledge production on central issues of carbonization in Beijing. One example of a new scientific framework can be taken from a pragmatist approach from systems to a reflexive science [96].

Table 6. Conceptual Framework of Lock-in Structuration at Regime Level

Component	Stakeholders	Key Factorsof Lock-in Structuration	Reference
RC.1 Markets	Consumers	Soft regulations, casual use of electric in markets, limited subsidies on innovative eco-products and consumer demand	[17] [49]
	Marketplaces	Reckless use of electricity, ineffective carbon trade policy, lack of comprehensive regulations	[80] [81]
RC.2 Technology	Car Manufacturers	A huge manufacturing and production of oil consuming cars, slow acceptance of eco-cars	[12] [13] [16]
	Households and Industrialists	Coal-based propylene production technology in industries. Limited use of CCS technology and heat energy collection system	[83] [84]

RC.3 Industry	Traders	90% of total energy comes from burning fossil fuels and carbon-intensive manufacturing of metal products	[17] [66,85]
	Line controllers	Irresponsible use of energy, engine bock waste, and clinker mix in production	[86] [7]
RC.4 Policy	Transport administration	Unavailability of low-fare policy during non-peak traveling hours. No restriction on car ownership	[13] [51]
	Banks, Financial institutions	Misuse of carbon emission allowances and tax adjustments, green credit policy without fear of bad reputation	[42] [87] [88]
RC.5 Culture	Families, peergroups	A traditional city with consumption as a leisure-time activity. Festivals like 11/11, positional consumption, and popularity of unseasonal food and waste	[46] [90]
RC. 6 Scientific Analysis	Researchers for urban studies	Unavailability of scientific data to researchers and limited work on behavioral aspects of carbon emissions in the city	[94] [96]

3.3. Landscape Dynamics

The exogenous context including political ideology, spatial structure, macroeconomic trends, demographic trends, media landscape and broad societal concerns [29,97] is worth mentioning for shaping consumption practices and carbonization in Beijing. Here, the study frames key logics of lock-in structuration at the landscape level. The brief idea of each component with related stakeholders and their limits is provided at the end of this section (Table 7).

3.3.1. (LD.1) Political Ideology

In 1949, the socialist ideology with Chinese characteristics kick-started transforming Beijing into a new regime of overall progress[46,48,98]. Many state-owned enterprises were initiated to exclusively focus on city's industrial advancement, which managed to uplift thousands of lives with improved living standards. These early experiences worked as trickle-down effect on future strategies, which reflected in the first five-year national plan (1953 to 1957) with a particular focus on industrial development. The pace of manufacturing growth was so fast that agriculture production could not keep pace with the need for a modernized industry. The coal production had reached up to 131 million tons with 98% increase from 1952 to 1957 [46]. Such a carbon-intensive economic foundation has compromised the ability of the current generation to grow up in clean air—efficiency myopia [44]. Although, Beijing's political insights for ecological civilization are apparent to the commitment with Paris accord recently [99]. However, a giant nature of historical developments—commercial hubs, residential areas, expansion of roads, and massive flow of transportation on unsustainable trajectories have limited the structural ability of current stakeholders for reconfiguring consumption practices in Beijing.

3.3.2. (LD.2) Spatial Structure

The core government institutions, historical sites, shopping areas and business offices are located right in the heart of Beijing—around the second ring road. Whereas, substantial residential areas are built around the fourth and fifth ring road lodging 200-300 thousand residents in each region [46]. Such a mono-centric urban formation (LC2) generates a massive flow of work-related trips from suburban areas to the inner-city. The average intensity of CO_2 emission from daily trips to the city center is 1.44kg per person per day. The most extensive amount of carbon is emitted from outer districts of Haidan and Chaoyang (located at the fourth ring road or far) accounted for more than 1.5 kg with 20 km long traveling to city center per person per day [53]. A close eye on the second and third ring road's neighborhoods[52] informs the average amount of work-related trips is more likely to be longer (9.0 km) and emit more CO_2 emission (0.8 kg) as compared to non-work trips (4.3km/0.4kg). Congestion becomes especially worse for entry-exit points of the third and fourth ring road that restricts vehicle speed 20-40 km/h to 20-35 km/h escalating pollution during peak morning and evening hours respectively [46].

3.3.3. (LD.3) Macro-Economic Trends

Several scholars have confirmed a positive correlation between the income level and private motor vehicles. In Beijing, the average income of people rose up to 3 times from 10,300 Yuan (Chinese currency) in 2000 to 36,500 Yuan in 2012 (LC3), while the number of private cars increased six times during the same period with the cumulative effect of 14.24 Mt CO2 emission [13,100]. In 2014, 4.37 million out of 5.59 million total vehicles were private (78.17%)[12]. In 2012, around 585,500 vehicles were purchased for personal use and private cars emitted 85% of total transport-related CO2 emission[13]. In 2001, China joined the World Trade Organization (WTO), and since then the exogenous factors like international economic development and globalization of the economy (LC5, LC1) have potentially contributed in raising Beijing's Gross Domestic Product (GDP). In Beijing, GDP increased five times within a decade from 2000 to 2010 [17]. Beijing is an attractive destination for job opportunities and higher income levels that attract a sizable chunk of people for better socio-economic status (LC6).

3.3.4. (LD.4) Demographic Trends

Beijing's current population is well above the planned value of 18 million in 2020, and the official figure of permanent residents of Beijing reached 21.14 million with an aggregated effect of 165.4% CO_2 emission in 2013 [46]. Household cooking is responsible for 17.7% of total household emission from energy consumption [47], and cooking fume, livestock breeding, maintenance of vehicles, and building painting/coatings, etc. are contributing 14.1% of total $PM_{2.5}$ in Beijing [7]. It is estimated that the number of motor vehicles will rise to one in every 2.5 people moving to the city [70]. Such a large population size is one of the leading causes for the substantial increase of household consumption, industrial production, auto-mobility and transport related carbon emission [12,101,102]. Although the pace of population growth is dropping from 2.9% in 2011 to 0.9% in 2015 [12] yet the per capita rise in income is potentially giving an edge to increased consumption and CO_2 emission in Beijing [100].

3.3.5. (LD.5) Media

Since 1949 to 2001, the commercialization of media took decades to gain significance in opinion-making[103]. The gap, therefore, has a critical role in slowing down the process of realizing the environmental issues and optimizing public behavior with the ecological condition of the city. The element of confidentiality—limited publication of macro-level surveys, has restricted the agency of researchers to contribute to reshaping the consumption practices and environmental issues [53]. Otherwise, scholarly publications could have had helped in a better way for reshaping lifestyles and minimizing carbon emissions in Beijing [104]. There are limited community awareness campaigns for environmental issues from the non-governmental organizations (NGOs), which restricts the public knowledge for the causes and consequences of CO_2 emission [105]. Hence, the publication of success stories for the adaptation of peoples' lifestyles for low-carbon transitions through articles, newspapers, websites, celebrities, and magazines, rarely focused on transforming energy structures, adverse effects of CO_2 emission, and social change [60].

3.3.6. (LD.6) Social

The power of social forces for conspicuous or positional consumption for the sake of status and prestige is driving energy demand, industrial production, reckless consumerism, and air pollution [61]. Energy consumption is also socially motivated by peoples' beliefs for lifestyle standards in Beijing [106]. A recent study [70] identifies that very amount of people are aware of the environmental issues in response to their consumption in Beijing. Without any exception, social relations are materially motivated in Chinese societies. Therefore, individual needs are not only driven by simple needs for food, clothing, shelter or transportation but also by position, respect, and status. Car use, brand consciousness, and luxurious lifestyles are promoted by celebrities and have increasingly become the part of status the symbol that restricts the ability of social intersected people to make wise choices—green consumption. Thus, lack of alternative lifestyles for self-worth, community acceptance, and appreciation is missing [107].

Table 7. Conceptual Framework of Lock-in Structuration at Landscape Level

Component	**Stakeholders**	**Key Factors of Lock-in Structuration**	Reference
LC.1 Political	Leadership	Efficiency myopia—carbon-intensive industrial development; planning-implementation gap; built-up infrastructure	[44] [46] [99]
LC.2 SpatialStructure	Young job-holders	Job-housings patial mismatch, mono-centric urban structure generates more emission due to work-related trips to city center	[46] [53] [52]
LC.3 Macroeconomic Trends	Government	Repute building after joining WTO; increasing per-capita GDP, and Lifestyle variables due to income growth.	[12] [13] [17]
LC.4 Demographic Trends	Public	Unplanned increase in population and household energy consumption due to limited education and work opportunities in rural areas	[46] [47] [70]
LC.5 Media	Television Channels	Time part in commercializing media and limited publication of macro-level data	[103] [104]
LC.6 Social	Community, Groups	Lack of alternative lifestyles respected at mainstream level	[106] [107]

V. CONCLUSIONS

This study adapts the multilevel perspective and applies 15 dimensions of the MLP framework on six primary sources of $PM_{2.5}$ in Beijing. The study had a snapshot of the contextual dynamics contributed in the lock-in structuration at each level in the past. Niche dynamics have found unbalanced attention paid on the material aspects of the city, and limited work is done on the behavioral aspects of energy consumption and sustainability interventions until the eleventh and twelfth five-year plans. The small niches did not receive proper attention from regime and landscape components for pushing sustainable consumers' choice through subsidizing green products. The small markets for promoting users' special demand for green consumption are seldom part of landscape efforts for the environmental sustainability in Beijing. Consumption has become a leisure time activity. Celebrities show up with carbon-intensive luxurious lifestyles, which promotes increased consumption among others. Regime dynamics have highlighted that marketplaces could reduce 3 to 8% carbon emission with proper policymaking. Inefficient use of advanced technologies, coal combustion, and carbon-intensive use of materials in industries, especially steel and cement have long been contributed to deteriorating the air quality in Beijing. Landscape dynamics show lower socio-economic grounds of common people as the primary logic where leadership had long been having a restricted ability to quit coal combustion in a short run. Population growth, a monocentric form of spatial arrangements, the per-capita growth of income, and job-housing spatial mismatch are grounds for the massive push to regimes of transportation, coal combustion, industrial production, and fugitive dust that aggregately increased 165.4% CO_2 emission in a decade in 2013[46].

Finally, the study validates that climate change is a social issue [108], and that the multi-dimensional aspects of niches, regimes, and landscape, as referred by the MLP framework, have played an interactive and incremental role in carbonizing Beijing. The study suggests to exploring more dimensions of inter-connected networks for decarbonizing practices and reshaping the air infrastructure of Beijing city.

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