KARTEPE SUMMIT
24-27 MARCH 2022

RESILIENT CITIES KARTEPE SUMMIT 2022

Editors

Prof. Dr. Oğuzhan Urhan
Dr. Ali Yeşildal

KOCAELİ
METROPOLITAN
MUNICIPALITY
THAT IS WORKING

November, 2022, KOCAELİ
KARTEPE SUMMIT 2022
RESILIENT CITIES AND TRANSFORMATION OF THE CITY
RESILIENT CITIES KARTEPE SUMMIT 2022

ISBN No: 978-605-72931-2-1
E-ISBN No: 978-625-398-150-1

Kocaeli Büyükşehir Belediye Başkanlığı
Karabaş Mah. Salim Dervişoğlu Cad. No:80 41040 İzmit / Kocaeli
Tel: 00902623181000
www.kocaeli.bel.tr

Publishing Owner

Assoc. Prof. Dr. Tahir Büyükakın
Mayor of Kocaeli Metropolitan Municipality

General Coordinator

Balamir Gündoğdu

Editing Committee

Prof. Dr. Hamza Ateş
Prof. Dr. Ayşegül Mengi
Prof. Dr. Oğuzhan Urhan
Prof. Dr. Nihal Bektaş
Murat Lehimler
Sadık Uysal
Dr. Ali Yeşildal
Raşit Fidan
Hayriye Sözer
Muzaffer Sabur
Uğur Işık

Design

Nobel Akademik Yayıncılık

Printing and Binding

Meteksan Matbaacılık ve Teknik Sanayi Tic. Anonim Şirketi / Sertifika No.: 46519 Beytepe Köy Yolu No.: 3 06800 Bilkent-Çankaya/ANKARA

Project Implementation

Kocaeli Metropolitan Municipality, Department of Culture and Social Affairs Publications - 56

FOREWORD

KARTEPE SUMMIT IN THE FOURTH YEAR

Assoc. Prof. Dr. Tahir BÜYÜKAKIN
Mayor of The Kocaeli Metropolitan Municipality
President of Marmara Municipalities Union

It is a pleasure for us that the Kartepe Summit has reached a level in which the findings and solutions are created in relation to global issues also related to Turkiye, just as we aimed in 2017 when we decided to carry out the Kartepe Summit. The pleasure is not resulted only from creating a project reflecting successful and competitive features of Kocaeli with its historical dynamics in every field including culture, art and sport recently in local government organizations but also from enabling to meet experts, authorities, policy-makers from hundreds of universities, think-tank organizations and international organizations from almost all over the world. At this point, the Kartepe Summit has evolved as a unique meeting to integrate theory and practice.

Main theme of the fourth Kartepe Summit is "Resilient Cities", and it is quite meaningful. Because Kocaeli has experienced a catastrophe in 1999 regarding the resilience of city. Therefore, the modern Kocaeli city of today has been built on that catastrophic experience. The earthquake is an example of the destruction that a risk might result in local level has been added in the history of our city. However, Kocaeli will continue its important mission to remark the destructions that the global risks might cause in local. Kocaeli will continue to emphasize the idea in the Kartepe Summit that the strongest important pillar is science and international cooperation against the risks endangering inhabitability in our world in physical, social and mental fields.

Kocaeli Metropolitan Municipality tries its best to bring out innovative solutions with all of its resources, human resources in every level against global and local issues by establishing strong cooperation with universities, non-governmental organizations, and stakeholder organizations in a scientific approach. Because, science is the main foundation to accomplish tremendous responsibility of metropolitan municipality services in terms of strengthening the capacity of both organization and human capital.

Resilient city is an aim that can be achieved by carrying out the list of mission thoroughly, in which the life and property safety of the inhabitants in the city is prioritized. Kartepe Summit is quite valuable to accomplish this aim.

Hundreds of scientists from various universities in the world have come together in the fourth Kartepe Summit and contributed in a literature that can be used in our city and other cities in the world, just as we have experienced previous years. The studies presented in the Summit will help all parties including policy-makers and city top executives initially.

I express my gratitude to all participants of Kartepe Summit IV who reflect the dynamics of our City and Municipality, and present their qualified contributions in scientific methods.

GENERAL COORDINATOR

Balamir GÜNDOĞDU

Kocaeli Metropolitan Municipality Secretary General

ORGANIZING COMMITTEE

Prof. Dr. Hamza ATEŞ

Istanbul Medeniyet University

Prof. Dr. Ayşegül MENGİ

Ankara University

Prof. Dr. Oğuzhan URHAN

Kocaeli University

Prof. Dr. Nihal BEKTAŞ

Gebze Technical University

Murat LEHİMLER

Istanbul Topkapı University, Migration Policies Research and Application Center

Sadık UYSAL

Kocaeli Metropolitan Municipality Deputy Secretary General

Dr. Ali YEŞİLDAL

President of Center for Urban Policies and Studies

Raşit FİDAN

Kocaeli Metropolitan Municipality Head of Cultural and Social Affairs Department

Hayriye SÖZER

Kocaeli Metropolitan Municipality Culture,Art and Conservatory Branch Manager

KARTEPE SUMMIT

24-27 MARCH 2022

SCIENCE BOARD

CONTENTS

INTRODUCTION

Prof. Dr. Oğuzhan URHAN

Urbanization has continued at an increasing rate all over the world in the last century. When we come to the 2000s, the number of people living in cities has exceeded the number of people living in rural areas. When the graph produced with the data compiled by the World Bank's UN Population Division in Figure 1 is examined, especially as of the 1980s, it is obvious that the rate of urbanization was accelerated. From the same graph, it is seen that the number of people living in cities is higher than those in rural areas in 2007, and as of 2020, the number of people living in rural areas is approximately 3.4 billion, while the number of people living in cities is 28% more (4.35 billion).

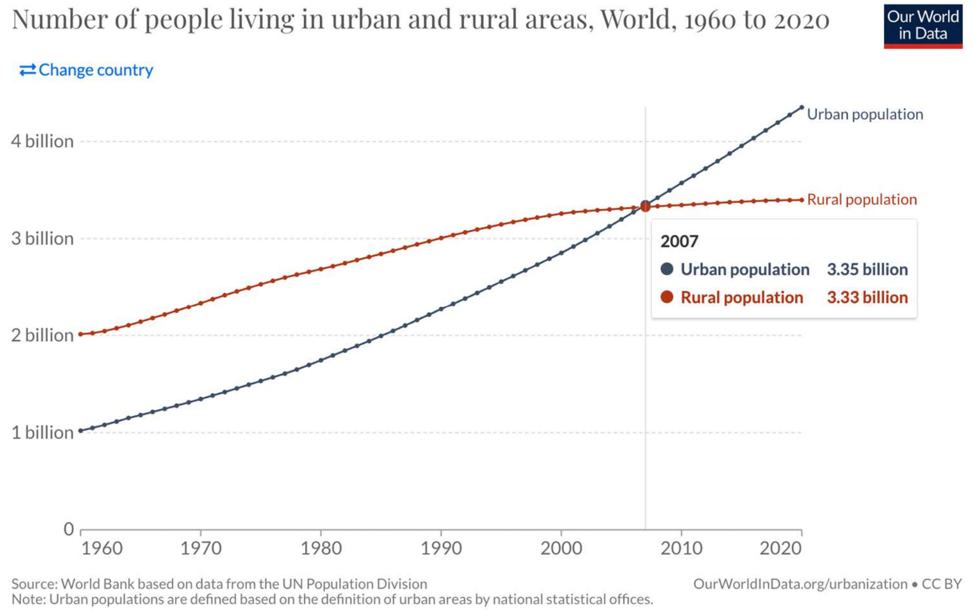


Figure 1. Change of urban and rural population in the world between 1960 and 2020

When these data are evaluated in terms of countries located in different geographies such as Brazil, the United States of America, Turkey, South Africa, China, Vietnam, and India (see Figure 2), it is clearly seen that the urbanization process of Turkey and China accelerated after the 1980s, whereas in countries such as Vietnam and India, the rate of urbanization is well below the world average.

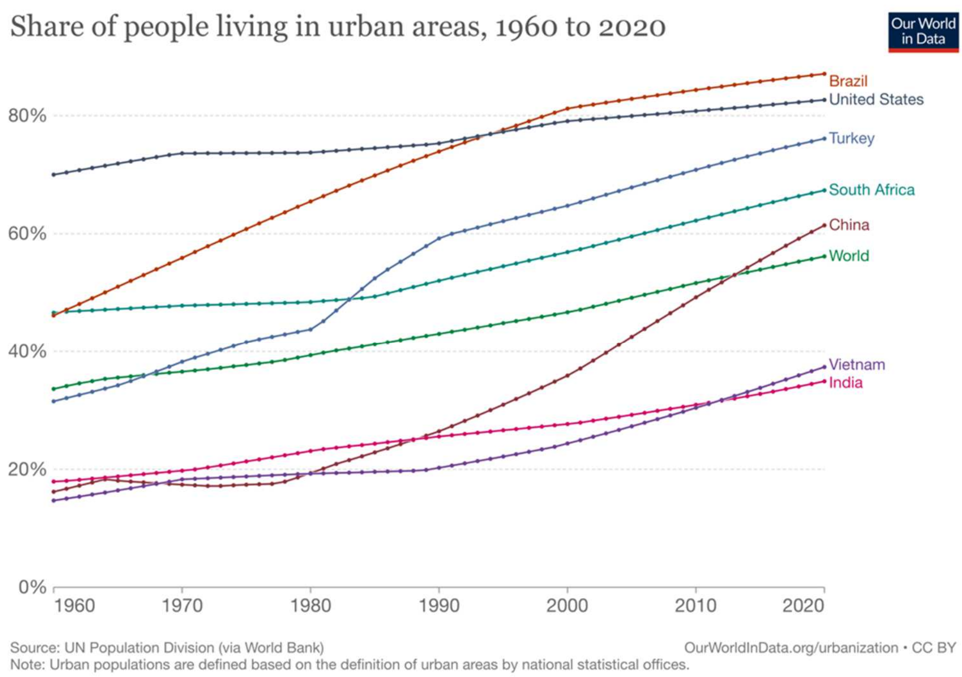


Figure 2. Change of urban and rural population in different countries between 1960 and 2020

The rapid increase in the number of people living in cities, which is clearly seen in Figure 1 and Figure 2, has brought many problems with it. In cities that grew irregularly and unplanned fashion, numerous difficulties were experienced in many areas, especially in infrastructure, education, and health services.

In addition to these difficulties, as a result of this process, cities have also faced some additional threats. Among these, the increase in consumption brought about by urbanization and expectations in urban life, floods, fires, and similar natural disasters that can be considered because of global warming which occurs with uncontrolled industrialization can be counted. It is clear that the impact of disasters such as earthquakes, floods and epidemics will be greater in densely populated cities. Therefore, while urbanization creates new threats, it also brings with its negativities such as increasing the impact of existing threats. At this point, it has come to the fore that cities need to be robust and resilient to such disasters and problems.

In the most fundamental sense, a city's resilience aims to eliminate all kinds of important problems and threats that the city may encounter before they occur if possible. Resilience cities also aim to ensure that an inevitable problem and threat has the least impact on city life and residents. In this respect, urban resilience emerges as a goal that can only be achieved with the effective contribution of many stakeholders, including central and local government, academia, private institutions, and NGOs.

Urban resilience emerges as an interdisciplinary field that requires the collaboration of very different disciplines. Although the subject is related to many engineering fields, social fields have the potential to contribute to the resilience of the city in terms of its human aspect. For example, only for the natural disasters aspect of the subject has the potential to produce solutions in many fields from civil engineering to geology and geophysics engineering, from urban and regional planning to architecture, from environmental engineering to electronics and computer engineering. When the socio-economic aspect of the subject is considered, many fields such as sociology, psychology, economy, finance, political science, public administration become an important and inseparable part of the issue.

The widespread and effective use of data is another important matter in the realization of the resilient city concept. The collection of data concerning the city with various sensors in different modalities with the concept of the Internet of Things (IoT), and their analysis in real-time with data analytics and artificial intelligence-based techniques stand out as important tools for predicting possible threats to the city and eliminating problems once they occur. In this respect, it can be said that the smart city concept actually forms a basis for creating a resilient city.

This book has been compiled by the academic papers presented in English at the 4th Kartepe Summit held in Kocaeli on 24-27 March 2022 with the theme of "Resilient Cities". The chapters in this book contain studies from different engineering and social fields due to the nature of the subject within the framework described above. In this context, we are pleased to present to you selected articles that describe perspectives on the solution of different urban problems and examine their contribution to building resilient cities.

Chapter 1

THE INTERACTION BETWEEN MODERNITY AND TRADITION IN THE ISLAMIC CITIES: LARGE-SCALE TRANSFORMATION PROJECTS FROM THE ARAB WORLD

Khaled Tadmori*

INTRODUCTION

The interaction between modenity and tradition has yet to find its appropriate articulation, as neither extremist positions nor false compromises can get to grips with the problems involved. One current attitude is predicated on the violent verbal refusal of Westernization and all its technical achievements. Another, less hypocritical attitude relies on the somewhat naive assumption that Western concepts can be appropriated as such and that they will somehow amalgamate with traditional values. Both eshew the inherent cultural antagonisms, which tend to uncrease in violence if left to erupt at a later stage.

What is needed instead is a viable reconciliation between Islam as a cultural paradigm and modern civilization as an ideology of progressive technical development. To be successful, any such attempt must first uncover the intents, driving forces and hidden preconceptions of each position. While modern sciences exercised considerable ingenuity in putting traditional cultures and their achievements into a "historic" perspective, they were strangely unaware of the conventions conditioning their own perception.

No real dialogue between the two world views can be established unless this change of paradigms, with all its implications, is clarified and evaluated in the light

* Architect - Restorer - Urban Planner, The Lebanese University / Faculty of Fine Arts & Architecture, Member of the City Council of Tripoli / President of Cultural Heritage Sub-Committee, Tripoli / Lebanon, archiled@hotmail.com

of overriding cultural objectives. The following conceptual analysis endeavour to touch upon such issues, in the full knowledge that the very nature of the problems addressed precludes easy and immediate solutions. Before answers can be envisaged, the right questions have to be posed, without being inhibited by the constraints of modern prejudices.

1. THE PROBLEM OF THE MODERN MOVEMENT

One of the major shortcomings of the Modern Movement was its disdain for the social, cultural and physical context, especialy in its rejection of historically grown urban structures. Whether in Europe or in the Third World, the indiscriminate implementation of its town planning principles always resulted in the partial or complete destruction of traditional urban form. In some cases, important monuments were kept, but they were stripped of their urban context. Wholesale demolition prevailed over conservation, repair and careful renewal. Since the Modern Movement saw architecture as being completely detached from its cultural and social matrix, it did not consider the dangers of the simultaneous disintegration of the underlying social network which had been instrumental in producing, nurturing and maintaining the growth and the evolution of historic cities.

In many Third World countries the Modern Movement continues to serve as an unquestioned sign of progress, no matter how illusory or inappropriate the underlying concept of development may be. To Western observers who are witnessing the collapse of the modern utopia, it must seem puzzling that obsolete Western ideologies should exert such an influence in areas which can muster a strong cultural background of their own. This is even more surprising, considering that a new generation of Western architects is now showing a growing interest in the timeless values of vernacular architecture, sometimes to the point of acknowledging them as a resource for reforming current Western planning methods. Yet many decisions-makers in Muslim countries still take for granted the "superiority" of the foreign paradigm and neglect to question both the validity of the imported principles and the alleged obsolescence of their own traditional urban heritage.

During recent years, large-scale development projects have been exported to many Arab countries, where they were implemented as complete "packages" without recognizing the fact that the physical forms of these projects have grown out of an alien ideological matrix and imply different codes of behavior and different environmental conditions. Basic facilities in terms of housing, transportation, schools or public buildings were not re-assessed in the light of the traditional patterns and local customs, but simply identified with the physical structures these needs and facilities have assumed in the West. Many imported structures, from high-rise buildings to over-dimensioned transportation schemes, may not have been chosen for their supposed functional advantages but merely for the prestige these icons of modernity seemed to convey. Yet much of the new hardware is far from being functionally and culturally appropriate, and a closer analysis may often reveal that its side-effects, which had not been reckoned with, outweigh the anticipated positive factors. As a result of such development processes, many traditional urban structures have been left to decay or were deliberately wiped out, while modern Western-style development has spread at a rapid pace. Since most imported schemes no longer reflect surviving traditional customs and values, they deprive the inhabitants of a consistent, meaningful architectural setting and interrupt the intimate interaction between man and his built environment, the very source of cultural identity.

1.1. Different Concepts of Development

Development could only be understood in terms of a new type of "progress", leading in a direct line of ascent towards eternal bliss for mankind. The firm belief in the absolute success of a self-induced linear development eventually assumed the status of an ecclesiastical dogma, as it were, the fallacy of which resided in the very fact that realities of a higher order were ignored. Most traditional cultures, regardless of their religious orientation, were much more realistic in this respect, as they accepted the given cyclical development of life, death and transformation that operated in nature, in man and in whole civilization. Moreover, they were able to accommodate the darker components of life, whereas modern civilization, precisely by attempting to suppress them, is an easy prey for the powers of evil.

Today, the illusory character of this single-minded type of progress and the eventual collapse of the ideology of linear development has become only too obvious: it is sufficient to mention the ever-increasing environmental problems of modern civilization, which have their origins in the false conception of man being independent from the overriding laws of creation. The devastating exploitation of nature as a dead raw material, including the rapid depletion of natural resources accumulated over millions of years, has been a direct consequence of this attitude.

Inevitably, the present tendency to cope with the emerging environmental problems by further intensification of technological means will only aggravate the situation, as long as the basic attitude is not revised.

1.2. Different Concepts of Planning

The contrast between the socially integrated cybernetics of traditional cities on one hand and the bureaucratically controlled planning processes of modern cities on the other hand transpires in the visual appearance of respective urban structures. The first mode has produced a distinct type of "organic" order, where the variety of individual components by no means precludes, but indeed sustains and enhances the overall unity of urban form. The second mode oscillates between a sterile uniformity, and sheer chaos, without ever being able to attain a lively urban form which could reflect the collective creativity of the society. In the present transitional period of urban development, skillful compromises are called for, as planning cannot be totally dismissed, but needs to engage internal social control mechanisms and responsibilities, instead of imposing rigid constraints derived from alien cultural models.

1.3. Different Concepts of Land Use

Looking at the conditions of contemporary Muslim cities, one can easily see how the functionalist concepts of modern planning, combined with a penchant for dubious replicas of modern Western architecture, have led to a progressive disintegration of the urban fabric. In the residential areas, the stratification of society according to economic and functional criteria works against the survival or the formation of coherent, self-sufficient urban quarters. In the central business districts, the new separation between "sacred" and "profane" realms have evident spatial consequences. New mosques are often designed in complete isolation from the physical and social urban context, and their potential for acting as focal points of aggregated community facilities and other public spaces is ignored. A strange fact when one considers that in the West a new generation of urban planners is deploying considerable efforts to regenerate downtown areas as active meeting places and to bring back to them some of the lost urban density and richness which is still so appealing in the surviving medieval centers of European cities. Historic Islamic cities provide even more striking evidence of the desired interaction between all domains of public life, and there is no reason why the principle of integrated community centers should not be applicable under present conditions.

1.4. Different Concepts of Circulation

Modern planning interventions in historic Muslim cities tend to disregard the traditional urban system and to emulate the Western approach, cutting axial road systems into the organically grown city and dividing the formerly coherent fabric into isolated blocks. Such operations brutally disrupt the cellular order of the traditional fabric and expose the introverted precincts of secluded residential areas to the immediate impact of functions and activities from which they were carefully screened off. Apart from the physical destruction, this also affects the function of the social rituals linked to the spatial qualities and visual codes of the traditional environment. Occasionally, large new roads and squares are not only advocated on the grounds of traffic improvement, but on the pretence on enhancing important monuments such as mosques and sanctuaries. However, nothing could be more erroneous in terms of traditional Islamic architecture than separating individual public buildings from their urban matrix and exposing them as if they were isolated architectural sculptures.

New traffic schemes are often planned with the intention of upgrading the old city and preserving its viability. It is true that the historic districts, in order to survive, need infrastructure improvements, as well as the injection of new economic forces, which require improved accessibility. Such interventions, however, must rely on an intimate knowledge of the cellular structure of the historic fabric and its inner meaning; they can only be successful if they proceed with the necessary subtlety and take into account the induced reactions and side effects. Unfortunately, what happens most of the time is closer to careless carnage than to conscientious surgery, as witnessed by countless historic Islamic cities from North Africa to India, which have become victims of such fatal cures.

1.5. Different Concepts of Urban Form

The two most reliable indicators of good urban form are the degree of integration of individual architectural components and, corollary to that, the successful interaction between buildings and open spaces within the overall built environment. A closer look at the characteristics of pre-industrial cities be it in Europe or in the Arab world, confirms the importance of a differentiated treatment of open space for the genesis of lively urban textures.

The formation of the urban structure of most traditional Muslim cities is not subject to the purely quantitative division of large space into smaller fragments but based on an incremental or "organic" aggregation process, originating in the definition of socially relevant micro-spaces which are connected into larger units. The enclosure of voids by correlated solids, repeated in countless variations, is the generating principle of urban form. Open spaces and pedestrian movement systems are integrated into the various components of the urban structure from the very beginning, which prevents the disruption of built form by the circulation network and excludes the emergence of anonymous wasteland within the urban system. Structures are not conceived as abstract graphic forms, but as the stall of a bazaar, all architectural envelopes are tailored to the needs of human beings, granting them protection and identity. Due to the interdependence between actors, activities and space definition, every place has its specific significance within the semiotic system of the town. The questions of how to sustain such urban form qualities, how to translate and integrate then into a contemporary design language and, most importantly, how to achieve the conditions which enable their implementation are far from being resolved, but pose a challenging task to architects in the Muslim world.

1.6. Different Concepts of Architectural Form

The Modern Movement tended to design buildings in a vacuum and to produce isolated blocks floating in an abstract urban space emptied of all its essential qualities. Individual buildings do not contribute to a meaningful definition of public open space, as related to corresponding community activities.

Traditional Muslim architecture used to work on different premises altogether: buildings were not conceived as detached "objects" but as living architectural shells, shaped according to the internal needs of distinct social micro-units and responding to the enclosed activities. Each individual enclosure incorporated the necessary amount of open space and the required access system within its respective boundaries. It therefore constituted an integral and virtually autonomous entity with its own resource of air, light and open space, independent of the street space. Yet close linkages with other buildings ensured the integration of single units into larger clusters, producing a cohesive urban environment. The layout which most perfectly matched the ambiguous requirements of autonomy and integration was the introverted courtyard house. With many local variations, it became instrumental in producing the dense and totally interwoven urban fabric which is so typical of most historic Arab cities.

Conventional modern building technologies almost invariably fail to provide the type of built environment which could match the sophisticated visual reference system of traditional Muslim architecture. Their shortcomings become apparent once new buildings are inserted into the historic structures of Arab cities. Since the design criteria, starting with access, street orientation, contextual factors, etc., are fundamentally different, the replacement of traditional courtyard houses with modern blocks inevitably leads to disruption and the progressive destruction of the traditional urban fabric. Apart from the typological incompatibilities, modern Western architecture also shows a lack of consideration for local building technologies, due to its bias towards heavy industrial means of environmental control. It thus tends to exclude cheap and easily available local materials in favor of costly, mostly imported industrial products, which in turn demand highly sophisticated and expensive building and maintenance technologies. This makes little sense in countries which have a long tradition of inexpensive and environmentally appropriate construction techniques, not to speak of millions of capable and willing hands who still know how to build their own houses. New models of built forms and of direct interaction with the traditional modes of buildings need to be established in order to sustain and take advantage of the traditional know-how.

2. TOWARDS RECONCILING TRADITION AND MODERNITY

The above conceptual analysis was intended to clarify in schematic terms the basic philosophical contradictions between what could be defined as, on the one hand, the "traditional approach" and, on the other hand, the "modern approach" to the planning and design of the built environment. It must be acknowledged that this distinction is not necessarily identical with an opposition between "Muslim" and "Western" concepts. Yet while these labels are admittedly simplistic, they can hardly be avoided if we are to analyze the reasons underlying the current breakdown in the management of the built environment in most Muslim countries and in the developing world at large. Be this as it may, the ultimate objectives of such an analysis cannot be to deepen the rift between East and West or past and present, or to anathematize specific contemporary attitudes and approaches. What is urgently needed is a thoughtful and creative bridging of the gap, but this can only be achieved if the existing divide is candidly acknowledged and not ignored or camouflaged.

Today's political discourse in the Islamic world is still tainted by the dogmatic and unproductive controversy between "modernists" and "fundamentalists". The cultural domain, having access to spiritual resources and to the power of creative imagination, may offer the best chance to overcome such sterile dichotomies. For the shadow-boxing between extreme but equally limited ideologies can only result in obscuring the real issue, which is how the present clash between different civilizations, mentalities and ways of behaving can be replaced by a more constructive interaction, drawing on all available potentials and strengths. It will hardly be possible to achieve this without on the one hand distilling the essential values from the local traditions and on the other hand scrutinizing Western technologies and architectural concepts with regard to their underlying ideologies and social implications.

Any attempt to achieve a new synthesis would have to adapt and transform foreign concepts and tools to meet the specific needs of contemporary Muslim societies under changed outer conditions, thereby sustaining cultural continuity in creative ways. It would, furthermore, have to demonstrate how the abuses and mistakes of a single-minded industrial development, as implied in modern Western civilization, can be avoided under different and possibly more propitious circumstance, and above all, it would have to explore the innovate potential of traditional structures and the underlying social processes. Fundamental issues of this magnitude need to be nurtured through patient dialogue, based on clear perspectives, shared values and the strong participation of involved local groups.

To be viable, the desired reconciliation between tradition and modernity can hardly be constructed at the theoretical level of the previous conceptual analysis, although ideological implications clearly have an impact on social and economic change. Thus synthetic approaches need to be worked out at the level of concrete situations. The rehabilitation of historic Muslim cities, including the introduction of adapted new building structures, can play a pioneering role in this reconciliation process. As a laboratory of practised cultural continuity, it could set examples which would have much wider application, even in modern parts of the city and particulary in the areas of housing, neighbourhood centres, university compounds and recreational spaces. Admittedly, this would not cause the current duality of urban vocabularies to disappear, but it would offer the society new opportunities and choices and, above all, it would remove the stigma of "backwardness" from the historic districts, which through their centality and enviromental qualities are potentially valuable resdential areas. Brought back into the mainstream of the development discourse, a renewed local building tradition may then emerge which would offer valuable alternatives to the current worldwide confusion of architectural idioms.

3. LARGE-SCALE URBAN TRANSFORMATION PROJECTS FROM THE ARAB WORLD

3.1. Reconstructing the City Center of Beirut After War

Beirut city center has evolved around a site continuously inhabited for over 5,000 years. While respecting this past, its reconstruction and development is creating a modern district, spreading over 191 hectares (472 acres) of land, one-third on reclaimed land. Beirut city center was traditionally the focus of activity in a major regional capital, including: banking, business and commerce, government and parliament, education and culture, leisure. The city center also contained charming residential neighbourhoods and a modern hotel district.

Capitalizing on these assets, the new city center provides a functional and attractive environment. Businesses are drawn by the quality infrastructure, buildings and property management. A new clientele joins former residents in occupying restored or modern residential space. Even outside business hours, shopping facilities, leisure and cultural activities keep the city center bustling with residents, daily visitors and tourists.

Under the patronage of the assassinated late Prime Minister Rafic Hariri, a private joint-stock company, Solidere, has been entrusted with the implementation of the project. Solidere is vested with a challenging and historical mission. Restoring life to this vital part of the country, traditionally a meeting place for all and the focus of economic and cultural activity has an important political and symbolic dimension. Delivering the tangible benefits of comprehensive planning, Beirut's downtown has re-emerged as a prime, active district, at the same time historic core, attractive touristic site, business-cum-institutional center, residential quarter and social arena, the focus of the city's renewed aspirations. Central to the project was the laying of a complete infrastructure and utility network, together with the constitution or reconstitution of the public domain. New and renovated facilities accommodate a variety of activities. They benefit from quality services, and enjoy landscaped open space and an exciting waterfront. This ambitious city-making venture, both in post-war reconstruction, inner city regeneration and waterfront development, has received international acclaim as a model of sustainable urban development.

Master Plan

A formulated, detailed coordinated and phased action plan for the traditional city center and its modern extension on the waterfront, the master plan:

- Subdivides Beirut city center into ten sectors, each with its own character.
- Involves the recovery of the public domain, with the installation of a complete modern infrastructure.
- Provides an urban design framework for new construction and for the restoration of preserved and historic buildings.
- Reflects the site topography and natural features.
- Protects views of the sea and mountains.
- Creates public spaces including gardens, squares, belvederes, promenades and trails.
- Unearths layers of the city center's history.
- Preserves surviving buildings and townscape features.
- Re-establishes the fabric and neighborhood structures.
- Ensures the harmonious integration of old and new, combining tradition with innovation, control with creativity in architectural expression.
- Offers a flexible, market-oriented development framework, encouraging the emergence of a sustainable environment.
- Accommodates a broad mix of land uses ranging from business and institutional to residential, cultural and recreational facilities.
- Creates a vibrant, 24-hour active downtown.
- Creates poles of attraction for city center renewal.

Sustainable Architecture and Green Technology Projects

Since its inception, Solidere has placed a premium on architectural quality for its own developments and insisted on a high level of design for other developments within its territorial borders. Controversially, Solidere has drafted lists of architects that developers must choose from for projects on specific, high-profile plots of land.

Jean Nouvel is working on the luxury Landmark project to be built on Riad Al-Solh Square; Stephen Holl on the Beirut Marina, Michael Graves on the Dib and Town Towers, Rafael Moneo on the souks project, Arata Isozaki on Beirut Gardens, Giancarlo De Carlo on Beirut Village, Herzog and De Meuron on Beirut Terraces, Graham Morrison on District//S, Rassem Badran on Al-Wadi Grand Residence, and Vladimir Djurovic on Samir Kassir Square. Elsewhere, Zaha Hadid is reportedly designing the headquarters of the Al-Mawarid Bank, Christian de Portzamparc is on board as the chief architect on Beirut Gate, and Norman Foster is said to be at the top of the wish list for Phoenician Village. All three have won the Pritzker Prize, the architectural equivalent of a Nobel.

The idea that architecture (or an architect) can bring added value to real-estate projects is catching on for developers working outside the BCD, particularly in such neighborhoods as Gemaizeh, Clemenceau, Sursock and Abdel Wahab al-Inglizi, where land prices are soaring and numerous high-ticket residential buildings are going up based on plans by well-known local and international architects.

Sustainable Green Architecture by International Architects

Beirut Village (by Giancarlo De Carlo)

Beirut Village is the first residential project combining tradition and innovation, a typical Lebanese village at the heart of Beirut city. It is conveniently located at Wadi Abou Jamil area, in an elegant and pleasing residential environment dominated by an aristocratic and bourgeois spirit. The project's floor space covers 27,274 square meters on an 8,530 square meters plot. With a view facing the 2,500 square meters Alliance Garden, two residential resorts are set around several private pools and gardens. Beirut Village epitomizes a harmonious style with autonomous architectural features endowing each apartment with a unique and personalized character.

Among the criteria that lead the design choices in order to maintain certain coherence between buildings are:

1- compactness of the volumes, not allowing for any withdrawals from the street line;

2- an explicit reference to the volumes, windows and mouldings of the urban residential building dating back to the first decades of the 20th century;

3- a stylistic heritage referred to the "palazzo" type showing the central hall on the main façades through the window type.

It was understood that singling out some common principles would have led the city center to maintain a high level of decorum and compactness, and at the same time to strengthen its urban identity even on the new blocks.

The right mix between tradition and innovation has been the backbone of the process of design for the two blocks. The flexibility in use, the high adaptability to the context, the spatial eloquence, the richness of the architectural vocabulary, the intensity of the aesthetic expression was the strongholds of a project with multiple goals. Multiplicity is one of the main qualities of the city of Beirut helping to define its identity.

Beirut Terraces (by Herzog and De Meuron)

The proposed building concept, structure, and appearance are conceived by both awareness and respect for the city, as well as self-confident optimism that it shares with contemporary Beirut. The project is founded on five principles: layers and terraces, inside and outside, vegetation, views and privacy, light and identity. The result is a vertically layered building expressed by diverse sizes of slabs which create both openness and privacy and enable flexible living between in- and outside. Fine detailing and a focus on the concerted orchestration of decent materials make for an efficient and luxurious building. Conscious of energy use, the environmental engineering coupled with the integration of vegetation into the architecture, enhance the quality of living while also lending to the building's sustainability.

The moderate climate of Beirut is certainly one of the city's biggest assets; it makes outdoor life not only an additional, but an integral part of Beirut's urban life. Capitalizing on this asset and cultivating apartments that foster such specificities is one of the key design principles. Each apartment's indoor and outdoor spaces merge, and in this way the terraces become integral to everyday living. The proposal for the vegetation blends in with the concept of the existing master plan. The idea of a green boulevard that connects the residential high rise to its surroundings is taken up by the design and continued vertically both inside and outside of the building. The main entry, an airy high space is equipped with water ponds, plants and outlooks that open up the views to the sea in the north and the green boulevard to the east. The complement between architecture and suspended nature enlivens the spacious lobby around the central core and continues up to the balconies and terraces throughout the entire building. The entry sequence thus develops a consistent transition between the open, public landscape and private, green residences.

Being almost on the shoreline of Beirut, the sea-views are precious qualities of the project. Throughout the building's terraces plantings create vegetated screens, which simultaneously provide shade, but, more importantly, guarantee the necessary level of privacy between the individual apartment's terraces. Additionally, the building's vegetation frames views and generates pleasant microclimates by tempering their immediate environment and providing an active breathing part of the architecture.

District//S (by Graham Morrison)

Described as "an architectural exercise in restraint", District //S - a city in the heart of the city - aims to transform one of Beirut's most sought-after locations into a cultured urban space that draws inspiration from Mediterranean living.

The plans feature 22 buildings including 104 low-rise apartments, 4 townhouses, 8 penthouses and a cultural center. District//S is strategically located between the active Gemmayzeh area, Saifi Village and Beirut's downtown, bringing modern thinking to an existing, traditional urban environment, infusing contemporary architecture with traditional touches and features: A celebration of the inner strength of Beirut as a city.

District//S seeks to infuse modern living with the more traditional ideals of balanced communities, where the residential, commercial and recreational spaces merge effortlessly and in an organic manner. Its contemporary architecture is the result of an extensive study into Mediterranean communities and urban lifestyles. It also puts an emphasis on the kind of cultural spaces that would ultimately define its personality. Additionally, and through its green spaces, courtyards and piazzas, the project would create an inviting, open and breathing environment that aims to represent a refreshing departure from stuffy and crowded developments.

Al-Wadi Grand Residence (by Rassem Badran)

At the city center western periphery, Wadi Abou Jamil commands superb geographic and natural qualities. It is within walking distance from the new waterfront, hotel district and Beirut Souks. A gentle topography cascading towards the seashore and a cluster of stone buildings with terracotta-tiled pitched roofs define it as a Levantine hill town.

Together with nearby Zokak Al-Blatt, it has preserved buildings from the 1930-1950s, turn-of-the-twentieth-century centrally planned Lebanese houses, and Beirut's only surviving synagogue. Residences enjoy high ceilings, generous verandahs, loggias and private gardens. In some cases, fine woodwork, wrought iron, marble floors and decorative false ceilings are further evidence of their former splendor. Heritage mansions are restored to house private art and antiques collections, converted into boutique hotels, or grouped as town houses.

Solidere has initiated the design and implementation of clustered developments in Wadi Abou Jamil and Zokak Al-Blatt, involving infill construction together with restoration. Solidere has sold nine of these clusters together with their concepts which define the future urban and architectural character of the neighborhoods. Among these: Beirut Village 1 and Beirut Village 2, Wadi Gardens, The Courtyard, Med Invest, Stow Wadi, DBA 1, DBA 2 and DBA 3. Clusters designed and developed by other developers include The Pavilions and Périmètre Rue de France.

In Wadi Abou Jamil Housing project designed by Rasem Badran, the physical sequencing and environmental factors are both important factors in the establishment of pedestrian and vehicular pathways. Intersections received special attention because they offer the best opportunity for orientation and place-making in addition to forecasting the future development of the surrounding urban network.

The architect is sensitive to the continuity and mix of successive architectural styles in Beirut. Construction is generally planned around an internal garden courtyard. Badran draw inspiration from the traditional central hall model and enhance it by using more articulate forms and modern features. The apartments, with their private gardens and their interiors of grand standing, offer exclusive residential accommodation combining luxury, tradition, modernity and privacy.

Beirut Gardens (by Arata Isozaki)

Beirut Gardens building overlooks the Martyrs' Square, a public space of great national and historical value, now opened to the sea as the capital's prime public space. This residential complex offers from the other side, a superb view of the Archeology Park within the "Garden of Forgiveness" whose origins stem from the ancient ages, Hellenistic and the Roman, that are all set in an environment of landscaped areas and public open space, and planned future "Site Museum".

Beirut Gardens consists of four basement levels, which are in a natural soil excavation, a ground floor, and eleven upper floor levels constituting the super structure. Active retail of tourist – related will be used at ground floor level and a first floor, whereas the remaining upper floors will be world – class residential apartments. The residents including all family members will also enjoy upscale living with quick and easy access to the relaxing and luxurious sundeck including swimming pools and gymnasium hall.

3.2. The Arabian Gulf: Architecture and Art to Reshape the National Identity

Qatar and the United Arab Emirates; an audacious experiment: two small oil-rich countries in the Middle East are using architecture and art to reshape their national identities virtually overnight, and in the process to redeem the tarnished image of Arabs abroad while showing the way toward a modern society within the boundaries of Islam.

Here, on a barren island on the outskirts of Abu Dhabi, workers have dug the foundations for three colossal museums: an $800 million Frank Gehry designed branch of the Guggenheim 12 times the size of its New York flagship; a half-billion-dollar outpost of the Louvre by Jean Nouvel; and a showcase for national history by Foster & Partners, the design for which was unveiled on Thursday. And plans are moving ahead for yet another museum, about maritime history, to be designed by Tadao Ando.

Nearly 200 miles across the Arabian Gulf, Doha the capital of Qatar, has been mapping out its own extravagant cultural vision. A Museum of Islamic Art, a bone-white I. M. Pei designed temple, opened in 2008 and dazzled the international museum establishment. National Museum of Qatar, Nicknamed the "desert rose", is a masterpiece designed by Jean Nouvel. It is a symbol of the desert because it's an architecture created by time and the desert itself, explained Jean Nouvel at the museum's inauguration: "Nobody knows what the inside of a desert rose looks like, and we created a typology of intersections that makes you question what is inside it".

To a critic traveling through the Gulf region, the speed at which museums are being built in Abu Dhabi conjured culture-flavored versions of the overwrought real estate spectacles that famously shaped its fellow Emirate, Dubai. By contrast, Doha's vision seemed a more calculated attempt to find a balance between modernization and Islam.

But in both cases leaders also see their construction sprees as part of sweeping efforts to retool their societies for a post-Sept. 2011, post-oil world. Their goal is not only to build a more positive image of the Middle East at a time when anti-Islamic sentiment continues to build across Europe and the United States, but also to create a kind of latter-day Silk Road, one on which their countries are powerful cultural and economic hinges between the West and rising powers like India and China. They are betting that they can do this without alienating significant parts of the Arab world, which may see in these undertakings the same kind of Western-oriented cosmopolitanism that flourished in places like Cairo and Tehran not so long ago, and that helped fuel the rise of militant fundamentalism.

An earlier wave of Western consultants - businessmen, foreign service types, engineers and architects poured into the Middle East in the 1950s and '60s, selling a cold war brand of modernity that would uplift Arab societies, in particular by fostering a thriving middle class. In practice the changes often simply reinforced divisions between a privileged elite - modern, educated, in tune with the West - and a struggling underclass, something that was not a small factor in the rise of fundamentalist violence.

No one would claim that a country as small and rich as the United Arab Emirates has the same combustible mix of social problems as, say, Egypt or Iran, but there are obvious echoes when you consider whom these cultural megaprojects will probably serve.

3.3. Abu Dhabi: Building a New Narrative

A little over a half-century ago Abu Dhabi was a Bedouin village with no literary or scientific traditions to speak of, no urban history. Its few thousand inhabitants, mostly poor and illiterate, was surviving largely on animal herding, fishing and pearl diving.

After oil production began here in the 1960s, Sheik Zayed bin Sultan al-Nahayan, who founded the country by bringing several emirates together under Abu Dhabi's leadership in the early 1970s, made deals with Western oil companies that financed the area's first paved roads, hospitals and schools. The emirates became a kind of Switzerland of the Middle East, a haven of calm and prosperity surrounded by big, aggressive neighbors, Iran and Iraq to the north and Saudi Arabia to the west.

But by the time Sheik Zayed's descendants began coming to power in the 1990s, that low-key approach felt out of date. Globalism was the catchword of the moment, and the construction boom in neighboring Dubai was demonstrating, despite its later bust, how completely a city could transform itself in just a few years.

As important, reliance on economic ties with the West began to seem imprudent after Sept. 11, as Western governments scrutinized all sorts of Arab financial dealings with increasing intensity, and even travel to the West became a sometimes degrading experience for Arabs.

In 2005 Sheikh Zayed's son and heir, Sheik Khalifa bin Zayed al-Nahayan, approached Thomas Krens, who was the director of the Solomon R. Guggenheim Foundation in New York, with the idea of creating a new branch of the Guggenheim Museum — a Middle Eastern version of what Krens and Gehry had accomplished a decade earlier in Bilbao, Spain. But the sheik's ambitions were never so small: within a few years the proposed site of the project, Saadiyat Island, a 10-square-mile development zone just north of Abu Dhabi's urban center, was being planned as a miniature city built around culture and leisure, with some of the most recognizable names from the creative world.

Abu Dhabi's blockbuster deal with the Louvre was signed in 2007; another deal, with the British Museum, to design exhibitions for Foster & Partners' Zayed National Museum, was signed two years later. The maritime museum by Tadao Ando and a performing arts center by Zaha Hadid are lately being planned. These cultural megaprojects will be joined by a campus of New York University on Saadiyat Island's southern shore and, in a location to be determined, a four-million-square-foot development for media companies and film studios meant partly to provide job training and opportunities for young Emiratis.

Of all the projects, the Louvre outpost seems the most natural fit with Abu Dhabi's globalist aspirations. On top of a generous construction budget, the government is paying France $1.3 billion, mainly to establish an art-borrowing agreement that will ensure that it gets the pick of the Louvre's encyclopedic collections, as well as art from several other museums. The range and depth of those collections will allow the Louvre Abu Dhabi, which is being marketed as a “universal museum,” to show off the cultural achievements of civilizations from every corner of the world.

And Nouvel's design for this museum -a maze of gallery buildings and canals, all covered by a huge stainless-steel dome- is a wonderfully romantic evocation of a Middle East at ease with technology. Sunlight will penetrate its perforated skin, creating hundreds of beams that recall the interiors of great mosques, or even the filtering of light through the tree canopies in an oasis. Tucked under the dome, the galleries and their watery setting refer to Venice, Nouvel has said, of the fertile cultural crosscurrents that once existed between East and West.

Globalism or Colonialism?

While the Louvre will be able to draw on thousands of years of shifting cultural influences, the Guggenheim Abu Dhabi, which is focused on 1965 to the present, a period culturally dominated by the West, reveals the problems that arise when the political message you are trying to send collides with historical reality.

Krens envisioned a "global museum" that nonetheless seemed to acknowledge the primacy of Western contemporary art. The museum -from the outside, a chaotic pileup of translucent cones and gigantic children's building blocks- was organized around a cluster of first-floor galleries representing key movements in Europe and the United States. Islamic collections would be housed two floors above, while warehouse like galleries would radiate out from the core, each devoted to a different region, the Far East, India, Africa. The plan's Western bent didn't fly for the clients, or for Richard Armstrong, who replaced Krens as the director of the Guggenheim Foundation in 2008.

The Guggenheim Abu Dhabi has a team of three curators working in New York to build a collection with a budget of up to $600 million, more than 200 times the annual acquisitions budget of the Guggenheim in Manhattan.

Similar issues arose with the plan for the Zayed National Museum, the institution that most directly speaks to the country's identity. The museum was intended to explore the United Arab Emirates' relatively sparse historical record through the life of Sheik Zayed, a man known for his humility, who died in 2004. Yet after Norman Foster presented his initial design proposal, in 2007, he was told that the country's leadership wanted something grander, even though there was still no clear idea of what, exactly, would go inside.

Foster was sent back to the drawing board, and a team of curators from the British Museum worked out an exhibition program. The new design features an enormous landscaped mound capped by five featherlike wind towers -the tallest one rising 300 feet- an attempt to evoke falconry, a favorite pastime of Arab royals.

That the collections of both the Guggenheim and the National Museum are being planned in the West raises a larger issue: while the money for all these developments comes from Emirati oil, the projects themselves are being shaped almost exclusively by foreigners. Abu Dhabi has become a revolving door of museum directors, architects, curators and other high-level consultants, and the hectic pace at which their plans are being pushed through has contributed to a sense among some here that what is being touted as a society-wide embrace of global culture will end up being just another example of cultural colonialism.

Although, the plan and the architecture appear intelligent, restrained and distinctive. Many developments in the Gulf have caught the eye, from the breath-taking 160-storey Burj Dubai to Abu Dhabi's cultural behemoth, Saadiyat Island, eco-city Masdar and Qatar's own vast Pearl Island complex but the "Heart of Doha" looks the most mature and serious of all.

It is a rare approach in a region where the default mode is to start from scratch. There is always the possibility with a commercially biased scheme, such as this, that it may tilt towards the banality of the international, but such efforts are being taken to root the architecture in context, climate and culture that, if there is one scheme in the region to keep an eye on, this is it.

REFERENCES

I. Part:

Aboussouan, Camille, L'Architecture Libanaise du XVème au XIXème Siècle, Les Cahiers de l'Est, Beirut, 1956

Butler, Howard C, Ancient Arcitecture in Syria, Leyden, 1907.

Davie, Michael F, La Maison Beyrouthine aux Trois Arcs: Une Architecture Bourgeoise du Levant, Alba, Beirut, 2003.

Day, Alfred E, Geology of Lebanon, American Press, Beirut, 1930.

Kalayan, Haroutune, L'Habitation au Liban, Première Partie, Beirut. 1966.

Chevalier, D., L'Espace Social de la Ville Arabe, Paris, 1979

Germen, Aydin, Islamic Architecture and Urbanism, Dammam, 1983

Hakim, S.B., Arab-İslamic Cities Builiding and Planning Principles, London, 1986

Khalaf, Samir, Constested Space and The Forging of New Culturel İdentities, Prestel, London, 1998

Salam, Assem, The Role of Goverment in Shaping the Built Environment, Prestel, London, 1998

Serageldin, İsmail; el-Sadek, S., The Arab City İts Character and İslamic Cultural Heritage, Riyad, 1982

www. akdn.com, Web Site, Agha Khan Award for Architecture

II. & III. Part:

Ben Hamouche, M.,The Changing Morphology Of The Gulf Cities In The Age of Globalisation: The Case of Bahrain. Habitat International , 28, 521–540, 2004

A. Al-Naim, M., Identity In Transitional Context: Open-Ended Local Architecture In Saudi Arabia. International Journal Of Architectural Research , 2 (2), 125-146. 2008

Abu Dhabi Urban Planning Council, Abu Dhabi Mosque Development Regulations. Retrieved 10 29, 2013, From Abu Dhabi Urban Planning Council: Www.Upc.Gov.Ae/Media/ 148986/ Appendix3-Vernacular-Study.Pdf, (2012, 12 17).

Al-Zubaidi, M. S. , The Sustainability Potential Of Traditional Architecture In The Arab World-With Reference To Domestic Buildings In The Uae. (Doctoral Dissertation), University Of Huddersfield, 2007

Cantacuzino, S. (Ed.), Architecture In Continuity: Building In The Islamic World Today. New York: Aperture, 1985

Capon, D. S. , Categories In Architectural Theory And Design: Derivation And Precedent. Design Studies , 4 (2), 215-226, 1983

Eben Saleh, M. A. , The Architectural Form And Landscape As A Harmonic Entity In The Vernacular Settlements Of Southwestern Saudi Arabia. Habitat International , 24, 455-473, 2000

El Amrousi, M., & Shakour, S. , Sustainable Architecture In Rapidly Developing Gulf Cities: A Search For Identity. Atiner Conference Paper Series (Pp. 5-16). Athens: Athens Institute For Education And Research, 2013

Grichting, A. , Scales Of Flows: Qatar And The Urban Legacies of Mega Events. International Journal Of Architectural Research , 7 (2), 173-191, 2013 **Kultermann, U. ,** Contemporary Architecture In The Arab States: Renaissance of A Region. New York: Mcgraw-Hill, 1999

Samar Damluji, S. , The Architecture of The United Arab Emirates. Rg1 4qs, Uk: Garnet Publishing, 2006

Sozer, H., J. Clark, R., & Elnimeiri, M. , Applying Traditional Architectural Rules For Energy Efficiency And Lateral Structural Stiffness To An 80 Story Tower. Energy , 36, 4761-4768, 2011

Wikipedia. (N.D.). United Arab Emirates, Retrieved 11 10, 2013, From Wikipedia: Http://En.Wikipedia.Org/Wiki/United_Arab_Emirates

Wilson, M. , Vertical Landscraping, A Big Regionalism For Dubai. International Journal of Urban And Regional Research, 34 (4), 925-940, 2010

Chapter 2

PERSPECTIVES ON WAVE POWER PLANT USE IN CITY ENERGY SUPPLY

Alisgandar Salamov* - Sabir Asadov** - Ogtay Salamov***

INTRODUCTION

The rapid growth of science, technology, engineering, and medicine began to have a favorable effect on people's living conditions at the turn of the nineteenth century, and life expectancy began to rise. Thus, if the world's total population was 1 billion people at the beginning of 1800, it had doubled to 2 billion people in 130 years.[1] In the near future, the majority of people's lives will be linked to cities and urban life. In light of current population growth trends, it is clear that the global population will reach 8,54 billion by mid-2030 and 9,73 billion by 2050.

Looking at the current situation, it is apparent that cities are home to more than half of the world's population, or 54 percent, and that this number will rise to 66 percent by 2050 .[2] [3]

The rapid growth of the world's population is causing small cities to expand, large cities to become denser, and a significant increase in difficulties as a result. As a result, there is a rise in unemployment and poverty, a worsening urban environment, a considerable increase in traffic congestion, and issues with energy and heat supply.

* Azerbaijan Technical University; alisgandarsalamov@gmail.com
** Baku State University; sasadov@hotmail.com
*** Institute of Radiation Problems, Azerbaijan National Academy of Sciences; oktay_dae@mail.ru
1 https://www.worldometers.info/world-population/?content_title=Why+You%27re+Losing+Proposals&content_format=ebook&offer_by_author=Jami+Oetting
2 https://www.prb.org/wp-content/uploads/2018/08/2018_World-Population-data-sheet.pdf
3 https://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html

At the moment, one of the main factors affecting people's well-being, particularly their healthy lifestyle in large cities, is the rapidly deteriorating environmental situation as well as their inability to meet their electricity and thermal energy needs without interruption in some cases.

Cities account for roughly 70-80 percent of energy demand and pollution by various types of thermal gases discharged into the Earth's atmosphere (CO_2, CH_4, N_2O, NO_x, hydrofluorocarbons, perfluorocarbons, as well as non-methane volatile organic compounds), despite occupying only about 2-3 percent of the total land area of the world's cities.[4] [5] In densely populated cities, this manifests itself in a variety of ailments, including a reduction in life expectancy, human losses, reduced ability to work, economic losses, and other issues. Thermal power plants (TPPs), which operate on the combustion of mobile sources (different modes of transportation) and conventional fuels (fossil fuels), account for the majority of gaseous emissions into the atmosphere.

From this perspective, the development of new technologies in the production and delivery of environmentally friendly energy, as well as the use of smart systems, are key to making the lives of people in major cities safer and healthier. As it is known, the use of conventional fuels is currently the most important factor in energy generation, with the collection, processing, and conversion processes having a negative impact on the planet's ecological situation. Gas, liquid, and solid waste released during the operation of conventional fuels, heat supply centers, and many other large industrial companies in large cities or suburbs, on the other hand, have a significant severe impact on these cities' ecology. As a result, for urban energy supply, ecologically friendly and renewable energy sources (RES) should be favored. As you know, clean and RES sources include solar, wind, geothermal, hydropower, tidal power, wave energy. Consumers can be supplied with energy more consistently and uninterruptedly thanks to the complex (hybrid) utilization of such energy sources. In cities, whatever options and types of RES are more successful relies on the relief structure of the geographical area where they are located, climatic circumstances, and the facility's ability to operate safely. Wind power plants, for example, are particularly effective both in terms of providing

[4] O.M.Salamov, Q.M.Atamoğlanova. Azərbaycanda atmosferin müxtəlif mənbələrdən atılan zərərli qazlarla çirklənməsinin ekoloji qiymətləndirilməsi. AzTU-nin "Elmi Əsərlər" toplusu, 2018, №2, s.111-119

[5] Z. Liu, C. He, Y. Zhou, J. Wu. How much of the world's land has been urbanized, really? A hierarchical framework for avoiding confusion. "Lanscape Ecology", 2014, №29, s.1-9

consumers with uninterrupted electricity and in terms of the environment in cities with large wind potential. At the same time, greenhouse gases and other hazardous chemicals are not released into the atmosphere. In any case, while deploying RES in cities or suburbs, it's critical to consider and mitigate the potential negative effects on the environment, flora, and fauna. In this regard, the use of clean and RES is one of the most critical issues in sustainable urban projects.

1. ANALYSIS OF THE USE OF WAVE ENERGY.

Wave energy has a lot of potential for people who live on the coasts of seas and oceans, especially those who live on huge areas. Thus, the yearly wave energy of the oceans and seas is predicted to be $8{\cdot}10^6$ TW·hours, which is 100 times more than the annual output of all hydropower plants now in operation.[6] As we know, wave energy converters (WEC) with various architectures and operational principles have been installed and proven to transform wave energy into electricity.[7] In comparison to other types of RES, however, wave energy is not yet widely used. The key reason for this is that, despite the creation of numerous projects, a more technically and economically advanced WEC has yet to be developed. As a result, a number of technical issues await researchers and engineers conducting research in the relevant field in order to create a perfect WEC. If more efficient WEC are developed that have low installation and maintenance costs, they will be able to harness the energy of not only the oceans, but also seas with lesser wave potential than the oceans. The Caspian Sea, for example, has no direct link to the seas and has a low wave potential in comparison to the oceans. However, the wave energy of such seas can also be used efficiently. To accomplish this, a well-designed WEC with a high efficiency and the ability to gradually convert the energy of weak waves into electricity with greater efficiency is required. As a result, the majority of the electrical needs of all Caspian settlements may be supplied, including Khachmaz in the north and Astara in the south, as well as cities, towns, and villages on the Absheron Peninsula, such as Baku and Sumgait. This can be seen more clearly on the map below (Figure 1).

---

6 Koteswararaoa B, Ravib D, Appalarajuc P. Wave Power Conversion Systems for Power Generation. 2nd National Conference on Developments, Advances and Trends in Engineering Science. International Journal of Modern Engineering Research (IJMER)

7 IRENA. Wave energy technology. Brief 4. June 2014

Figure 1. Map of the Republic of Azerbaijan

As shown in Figure 1, as Azerbaijan is surrounded by a huge region of the Caspian Sea, the use of wave energy and the construction of a well-designed, more advanced thermal power plant are extremely important in our country and some work is being done in this direction by local researchers.

The Caspian Sea differs from other seas due to a number of characteristics (natural geographical conditions, diversity of climate zones, features of the hydrometeorological regime, etc.). The location of the sea over a large area, of course, causes hydrometeorological parameters to change over time and space.

2. ANALYSIS OF EXISTING WIND REGIMES IN THE ABSHERON PENINSULA.

The Caspian Sea, particularly its water area in Azerbaijan (Absheron Peninsula, Oil Rocks, Gunashli oilfield, Baku archipelago, and so on), is known for its alternative energy potential (solar radiation, wind flow, waves, tides, etc.). The wind regimes in those areas were first examined in order to determine the Caspian Sea's wave energy resources in Azerbaijani waters. Because wind is the cause of waves in the open sea and oceans, knowing the cadastral characteristics of the average monthly, average annual, and instantaneous values of the wind generating these waves, the quantity of energy that the wind may generate at different times of the year, and the characteristics of the wind flower in each chosen location (prices as a percentage of different winds observed during the year) is important to measure wave energy. Taking this into account, average monthly and average annual wind speeds and directions observed in different months of the year in the waters of Azerbaijan of the Caspian Sea, the duration of different winds, changes in its strength according to the seasons, as well as wave heights were studied, and wind-wave energy and wave power were calculated based on wind speed and wave heights.

Depending on the air flow over the Caspian Sea, there are 6 main types of winds according to their directions: the first type (I) - North-West (NW) and North-Northern-West (NNW); second type (II) - North (N) and North-Northern-East (NNE); third type (III) - Northern-East (NE) and East-Northern-East (ENE); fourth type (IV) - Southern-East (SE); fifth type (V) -Southern-East and related (SE and related); sixth type (VI) - vortex cyclonic, weak and unstable. In this case, the latter type is conventionally denoted as (VIa).[8]

It is clear from the seasonal recurrence schedules of wind types moving over the Caspian Sea that the recurrence of winds belonging to types I, II and VI (weak and unstable) (directions) is observed mainly in summer. Recurrence of III, V and VI (vortex cyclonic) types occurs in winter, and recurrence of IV types of winds occurs in summer.

Analysis of the average annual recurrence of wind types by direction indicates that the average annual recurrence of winds with type I, IV and VIa directions is about 20% (Figure 2). The Absheron archipelago region is characterized by hurricane winds from the north-west, which create higher and greater energy waves at sea. This makes the installation of WPP on the northern side of the Absheron Peninsula highly effective (see Figure 1-map). In this regard, the city of Sumgayit and the surrounding areas are of exceptional importance.

---

8 Гидрометеорология и гидрохимия морей. Т 6. Каспий-ское море. Вып. 1. Гидрометеорологические условия. Санкт-Петербург. Гидрометиздат. 1992. 360 с.

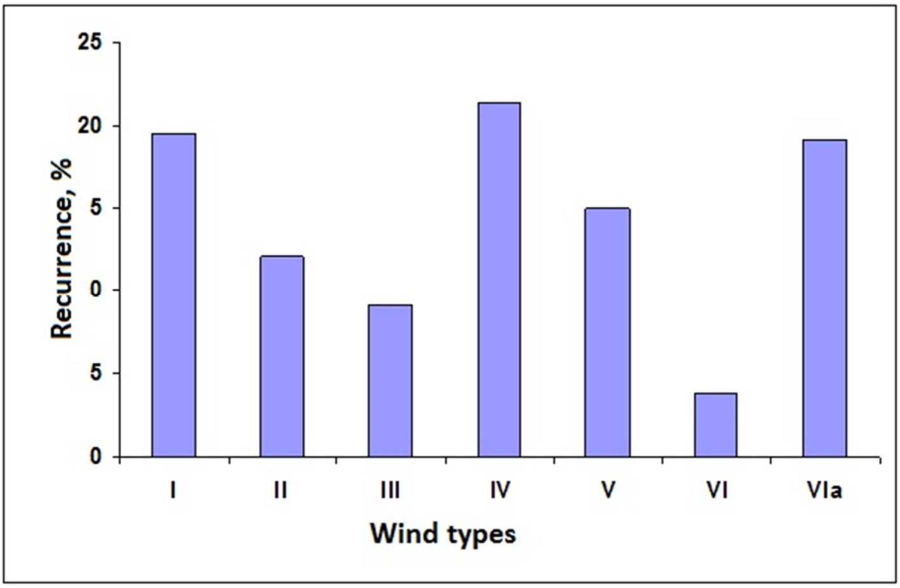


Figure 2. Average annual recurrence of wind types (recurrence %) [9]

From the seasonal and annual analysis of various medium-speed winds, we see that the recurrence of winds with an average speed of 5-9 m/sec prevails in all seasons (especially in autumn -58%). The most recurrence of winds with an average speed of 10 m/sec and more occurs in the winter season, and the most recurrence of winds with an average speed of less than 5 m/s occurs in the summer season. The annual recurrence of winds with an average speed of 10 m/sec and more is 29%, and the annual recurrence of winds of 5-9 m/sec and less than 5 m/sec is 52% and 19%, respectively (Figure 3).

[9] M.M. Quliyev, Y.E. Əhmədov, S.B. Əsədov. Xəzər dənizinin Azərbaycan sektorunda dalğa enerjisinin qiymətləndirilməsi Azərbaycan Neft Təsərrüfatı jurnalı, № 2, 2014, s. 43-46

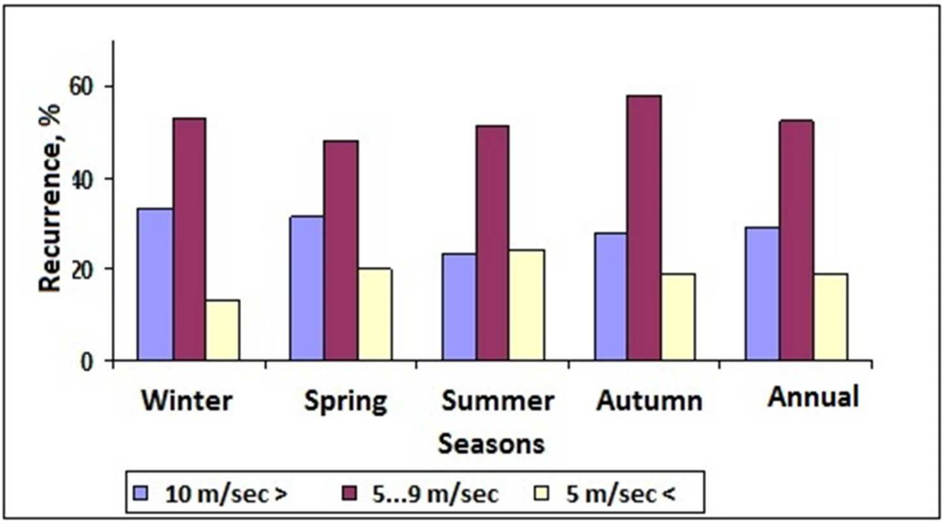


Figure 3. Recurrence of different fast winds by seasons [9]

We have also studied the maximum seasonal duration of wind types moving over the Caspian Sea. The results obtained are illustrated in Figure 4.

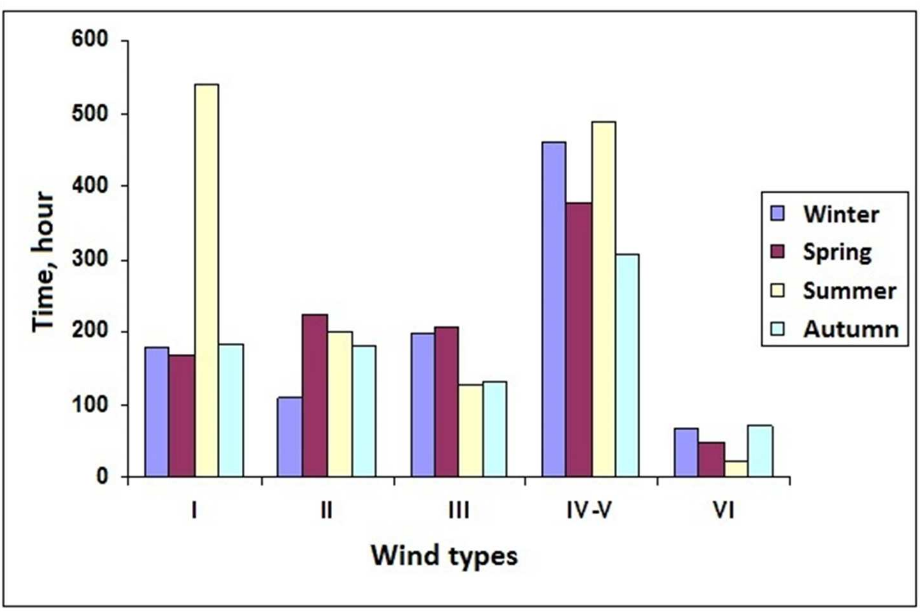


Figure 4. Maximum duration of wind types by seasons [9]

If we compare the average seasonal duration of different types of winds, we can see that winds with I and IV-V direction types prevail. The maximum duration of uninterrupted duration of winds of type II direction occurs in summer, which is equal to 540 hours (Figure 4). The duration of winds of V direction type is high in almost all seasons. In summer, the maximum duration of winds in this direction reaches 490 hours. The maximum duration of winds of II and III direction types is in the spring and is 222 and 204 hours, respectively. The winds of the VI direction type, which are mainly observed in the autumn season, have the lowest duration and last only 72 hours. It can be concluded that in order for WPP to work efficiently, it is necessary to place them in the coastal strip of the Caspian Sea, where winds of I, II, IV and V direction types are received, which have a longer duration of uninterrupted duration. Thus, since the Absheron Peninsula enters the Caspian Sea in a transverse direction (West-East), the installation of WPP, which operates due to winds of I and II direction types on the northern side of the peninsula and on the south side, due to winds of IV and V direction types promises great prospects.

As a result of multi-year observations on wind-wave regimes in the Caspian Sea Oil Rocks waters, the average wind values for different months, as well as the maximum limits of instantaneous wind values were determined.[10] The results indicate that the maximum value of the instantaneous wind speed is 34 m/sec in winter, which is observed especially in February and March. In other seasons, the maximum value of instantaneous wind speed varies in the range of 20-28 m/sec. The average annual wind speed varies in the range of 5,4-7,3 m/sec. Taking this into account, it can be concluded that the installation of WPP on all sides of the islands in the Caspian Sea, such as Oil Rocks, Pirallahi, etc., can be quite effective. However, even in this case, the main priority should be given to winds of I, II, IV and V types, which are more frequent during the year.

During the observation period, many data on the height of waves in the Caspian Sea were averaged over months and years, and their average, absolute maximum and minimum values were determined. It was found that the average height of the wave varied by months in the range of 0,90-1,62 m, and the absolute maximum and minimum values in the range of 5,5-9,6 m and 0-0,1 m, respectively.

[10] F.Q.Həsənov, S.B.Əsədov. Xəzər dənizinin neft-qaz hasil edilən akvatoriyalarında hidrometeoroloji parametrlərin tədqiqi. Azərbaycan Neft Təsərrüfatı jurnalı, № 2, 2015 s. 39-43

The average annual height of the wave varies in the range of 1,18-1,40 m. Absolute maximum and minimum values of waves calculated for years vary in the range of 4,18-5,65 and 0,14-0,23 m, respectively. The analysis of the absolute maximum values of the wave height indicates that the highest waves were observed in October (9,6 m), January and March (8,4 m), February and May (8,0 m) in different years. During the observations, the maximum wave heights were recorded during the NNW with a maximum value of 22-28 m/sec and the NW wind with a maximum wind speed of 28-34 m/sec.

The instantaneous wind speed over the Caspian Sea, especially in the Azerbaijan waters, can reach 46 m/sec, which occurs once every 100 years. Such winds create large energy waves in the sea with a height of 10-11 m. However, the higher the height and energy of the waves, the higher their destructive power. This can result in the failure of the WPP structures installed at sea or on shore. Such cases are especially typical for onshore WPP. So that, when the waves move from the sea or ocean to the shore, their height and energy increase exponentially, depending on the distance, and become destructive. For this reason, the uninterrupted life of the WPP installed in many countries around the world does not last long. Therefore, in the future, wave energy assessment and more progressive in terms of meeting the energy needs of the population and equipment living in urban and suburban areas, as well as islands and platforms in seaside areas, entertainment, dining, fountains etc. for children and adults in the seaside resort and the establishment of WPP is very important.

The energy, strength, and wind energy of two-dimensional waves were calculated based on formulas known from classical theory [9].

For a case where the instantaneous wind speed is 10 m/sec and the wave height is 1,5 m, the wind and wave energy are 613 and 2756 W/m^2, respectively. For comparison, in this case, the energy of the wave exceeds the energy of the wind by ~ 4,5 times. Depending on the development of the wave, its average height is 2-3 m and more.

In the Caspian Sea, especially in the Absheron archipelago, wind and wave energy and wave strength were calculated according to the characteristics of strong winds and wave heights (Table 1).

Table 1. Wind and wave parameters in the waters of the Absheron archipelago and values of their relative energies [9]

Wind		Wave		Wind energy, W·hours/m²	Wave energy, W·hours/m²	Wave power, kW/m
Direction	Speed, m/sec	Direction	Height, m			
NW	20,6	N	4,5	5354	24806	24,8
NNW	20	N	4,2	4900	21609	21,6
N	28	N	4,1	13445	20592	20,6
N	22	N	5	6522	30625	30,6
NNW, N	20	N	4,5	4900	24806	24,8
N	40	N	10	39200	122500	122,5
N	24	N	8,2	8440	82369	82,4
NNW	28	N	8,5	13445	88506	88,5
N	20	N	4	4900	19600	19,6
NW	20	N	7	4900	60025	60,0

At a wave height of more than 10 m, the power per unit wavelength (1 m) reaches 122,5 kW. At a wind speed of 40 m/sec, the wave power is 122,5 kW per meter and 122,5 MW per kilometer. In order to better evaluate the results given in Table 1 and to determine the possibility of more efficient use of wave energy in the direction of winds in the Caspian Sea, the ratios of wave and wind energies for different instantaneous winds and waves of different heights were determined using this table. The results are given in Table 2.

Table 2. The ratios of energies generated by winds of different directions and speeds and waves of different heights ($k = E_d/E_k$) [9]

The direction of the wind	NW	NNW	N	N	NNW, N
Wind speed	20,6	20	28	22	20
The height of the wave	4,5	4,2	4,1	5,0	4,5
Energy ratio (E_d/E_k)	4,633	4,410	1,531	4,693	5,062
The direction of the wind	N	N	NNW	N	NW
Wind speed	40	24	28	20	20
The height of the wave	10,0	8,2	8,5	4,0	7,0
Energy ratio (E_d/E_k)	3,125	9,760	6,597	4,000	12,250

As can be seen from Table 2, the most efficient use of wave energy in the Azerbaijan waters of the Caspian Sea can be achieved during north-west winds. In this case, although the instantaneous wind speed is not as great as in the other cases mentioned in Table 1 and Table 2, the height and, of course, the energy of the waves are large enough. Therefore, the ratio of wave and wind energies for this case reaches a maximum ($k = E_d/E_k = 12{,}25$). Other cases, which are considered to be relatively favorable, are obtained during winds in the direction of N (II direction type) and NNW (I direction type). In this case, despite the fact that the instantaneous speed of the north winds is 24 m/sec, sufficiently high and large energy waves are formed for this case, for this reason, the ratio of wave and wind energies is higher ($k = 9{,}76$) than in the other case (NNW winds with an instantaneous speed of 28 m/sec). However, with the exception of the third column in Table 3 (in case of north wind with instantaneous speed of 28 m/sec, the height of the wave is 4,1 m), the use of wave energy in the Azerbaijan waters of the Caspian Sea may be highly effective in all other cases. The differences between the results shown in Table 2 are mainly related to wind speed. Thus, as mentioned earlier, such differences arise because the wind energy depends on the cubic speed of the wind and the wave energy on the square of the wave height.

Thus, it can be seen that the use of wave energy to provide consumers with electricity and heat in all areas of the Azerbaijan sector of the Caspian Sea, especially in the Absheron Peninsula and a number of large islands in the Caspian Sea, promises great prospects.

As for the lack of use of wave energy, the main thing is that the wave mode is intermittent. This, in turn, is related to the wind regimes given in Figure 2, Figure 3, and Figure 4. Nevertheless, waves in the Caspian Sea at a height of 1,0-1,5 m are observed in most months of the year. In order to overcome this shortcoming, it is possible to use WPP in a complex (hybrid) way with other types of power plants. For example, both wind power plants with accumulative systems and Solar power plants installed at sea or on the coast can be used for this purpose, and the second case is more relevant.

As for the environmental aspect of the use of wave energy, it is enough to say that the energy generated by a 10 m^2 surface wave (h10 m, 1 m wide wave) per hour can save 15,1 kg of conventional fuel. If we take into account that the width of the wave-receiving parts of the WEC can be up to 20 m, then it turns out that the amount of conventional fuel saved by such a WPP per hour is equal to 302 kg of coal. If we add this to the annual energy production of WPP, we get a very large figure, which, in turn, the large amount of heat-emitting gases (CO_2, CH_4, N_2O, NO_x, hydrofluorine and perfluorocarbons, as well as non-methane volatile organic compounds) from the TPP operating with conventional fuels means the prevention of emissions into the atmosphere, reducing the amount of carbon emissions.

At present, a number of projects are being implemented in countries with access to the sea and oceans, along with active research in the use of wave energy. It should be noted that if we take into account that a large part of the borders of the brotherly country Turkey is covered by the sea, it is clear that there are ample opportunities for the use of wave energy.

Thus, the use of wave energy in countries and cities with access to the sea can both meet a significant part of consumer demand for electricity and significantly reduce the negative impact on the environment, which plays an important role in providing sustainable energy and health in urban areas.

Chapter 3

COVID-19 AND DEVELOPING COUNTRIES: A STORY FROM PAKISTAN

Ayesha Hanif* - Muhammad Zeeshan Hanif**

1. BACKDROP

In the first quarter of 2020, the world found itself caught in the shackles of a novel virus of COVID-19 (coronavirus pandemic) which has had proved to be a black swan in the history of the world. The outbreak of the disease occurred in the city of China called Wuhan and gradually travelled all across the globe. World Health Organization (WHO) defines COVID-19 as an infectious disease caused by the SARS-CoV-2 virus. WHO realized the calamity COVID-19 going to bring and declared a "public health emergency of international concern" on 30 January 2020. Within a short period, the positive COVID-19 cases grew exponentially all over the world; as a result, the WHO declared COVID-19 a "pandemic" on March 11, 2020. After a few more months, the number of confirmed and death cases were rapidly grown globally. As of February 4, 2022, WHO reported 383,509,779 confirmed cases in 216 countries with 5,693,824. Most common symptoms of this virus are fever, cough, tiredness and loss of taste and smell whereas less common symptoms are sore throat, headache, aches and pains, diarrhoea, a rash on skin or discolouration of fingers or toes, and red or irritated eyes. Serious symptoms on which medical attention to be immediately sought include difficulty breathing or shortness of breath, loss of speech or mobility or confusion and chest pain. It usually takes 10-

* Assistant Professor at Institute of Administrative Sciences, University of the Punjab, Email: ayeshahahnif.ias@pu.edu.pk

** Lecturer at Institute of Administrative Sciences, University of the Punjab, Email: zeeshan.ias@pu.edu.pk

14 days for symptoms to become visible in the patient and people with mild symptoms are advised to, administer the disease, and manage at home. Currently the world is facing the fifth wave of COVID-19 and the variant is “OMICRON”.

WHO has prescribed various precautionary measures and preventions like hand washing, using sanitizer, staying at a one-meter distance from other person and wearing fully fitted mask, covering the mouth and nose when sneezing or coughing in many others.

All the countries followed these precautionary measures along with local guidance. Both developed and developing world formulated their own strategies to combat and control the spread of COVID-19. Closure of academic institutions, suspension of international as well as local flights, adjusting timings of markets and offices and various others are the strategies opted by different countries at different points in time.

This deadly virus also affected Pakistan and the government of Pakistan opted for various strategies to fight against it. In the lines below, situation the Pakistan facing and the administrative and precautionary measures taken by the government of Pakistan in response to it are mentioned.

Situation in Pakistan (Statistics)

The very first case of COVID-19 in Pakistan was reported on February 26, 2020. The ongoing fifth wave of OMICRON in Pakistan and so far on February 4, 2022, number of positive cases are 6,377 with the positivity ratio of 9.94%.

Total number of deaths so far on February 4, 2022 in Pakistan due to Covid-19 are **29,330,** confirmed cases are **1,436,413** and recovered cases are **1,304,980.**

In the upcoming pages, statistical illustration of COVID-19 about pertinent information is provided

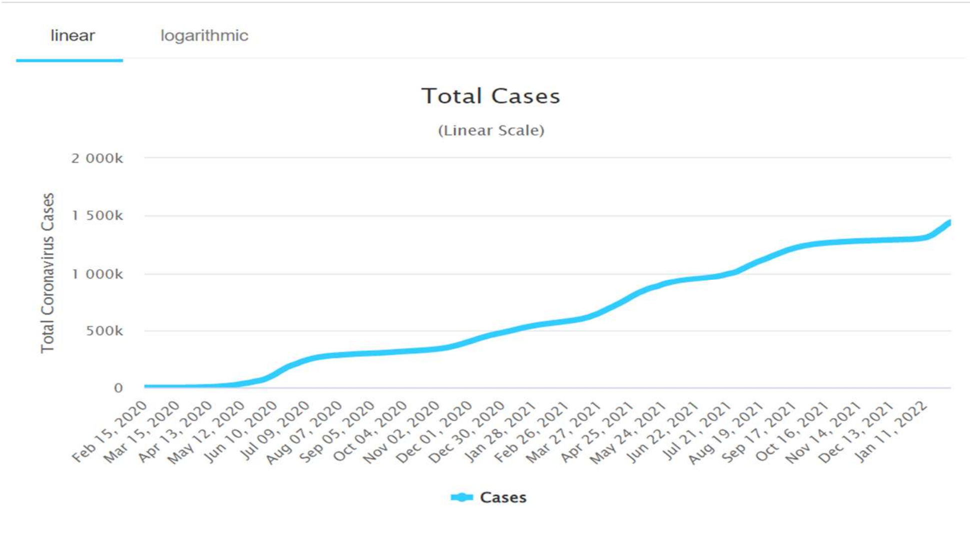


Figure 1: Total cases reported in Pakistan as of January 11, 2022

Source: Statistics on the website of worldometers containing worldwide statistics on COVID-19

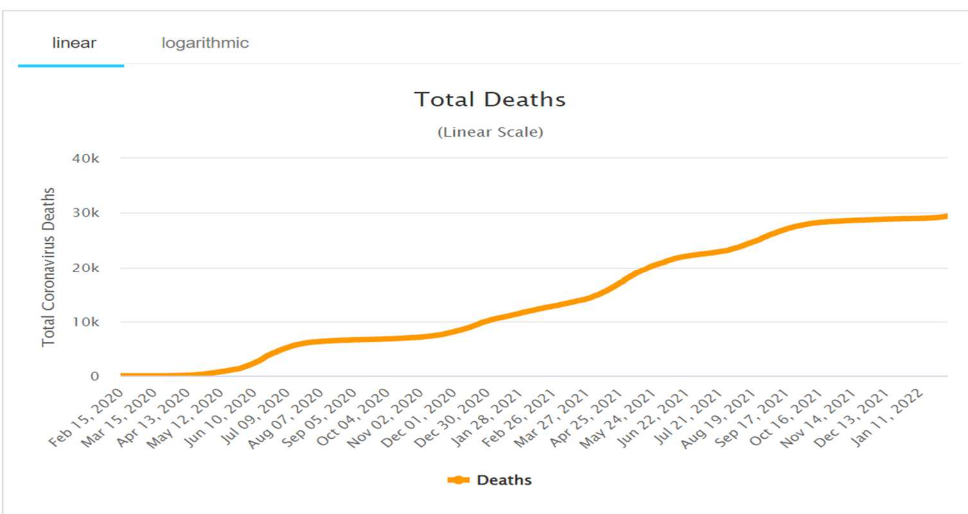


Figure 2: Total deaths reported in Pakistan as of January 11, 2022

Source: Statistics on the website of worldometers containing worldwide statistics on COVID-19

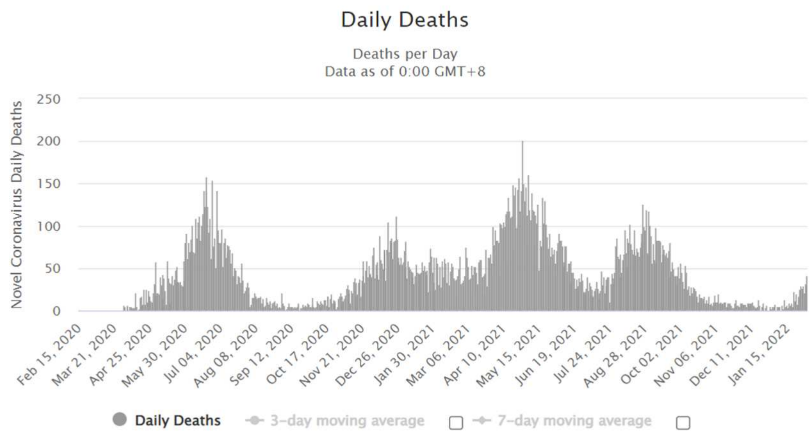


Figure 3: Daily deaths reported in Pakistan as of January 15, 2022

Source: Statistics on the website of worldometers containing worldwide statistics on COVID-19

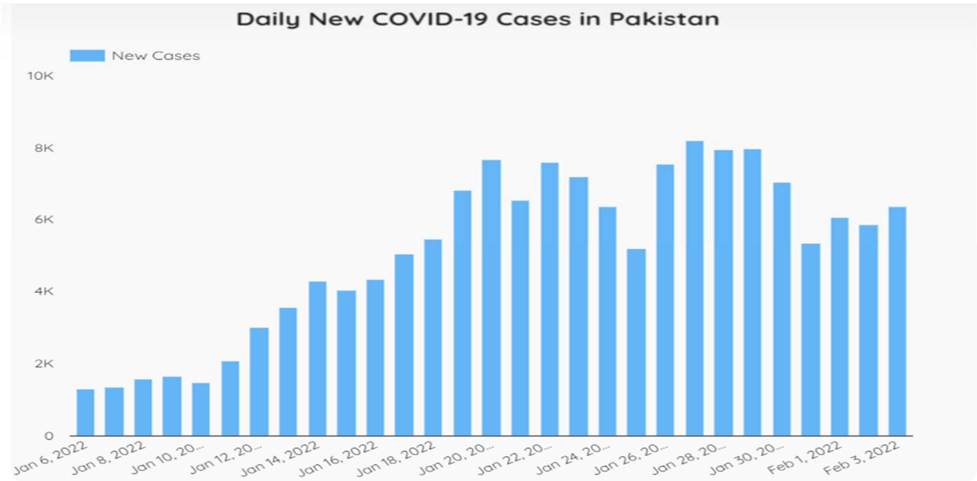


Figure 4: Daily new COVID-19 cases reported in Pakistan as of February 3, 2022

Source: Statistical information on the website of Government of Pakistan

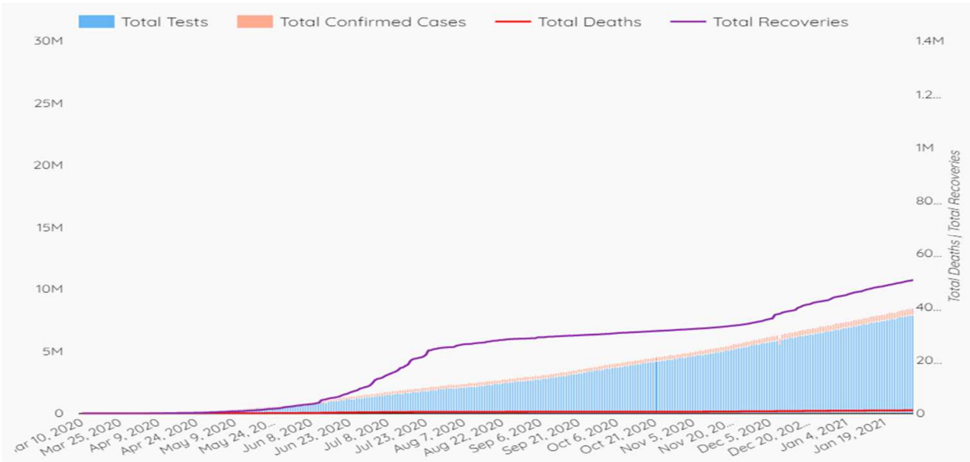


Figure 5: Total tests, total confirmed cases, total deaths and total recoveries reported in Pakistan as of February 3, 2022

Source: Statistical information on the website of Government of Pakistan

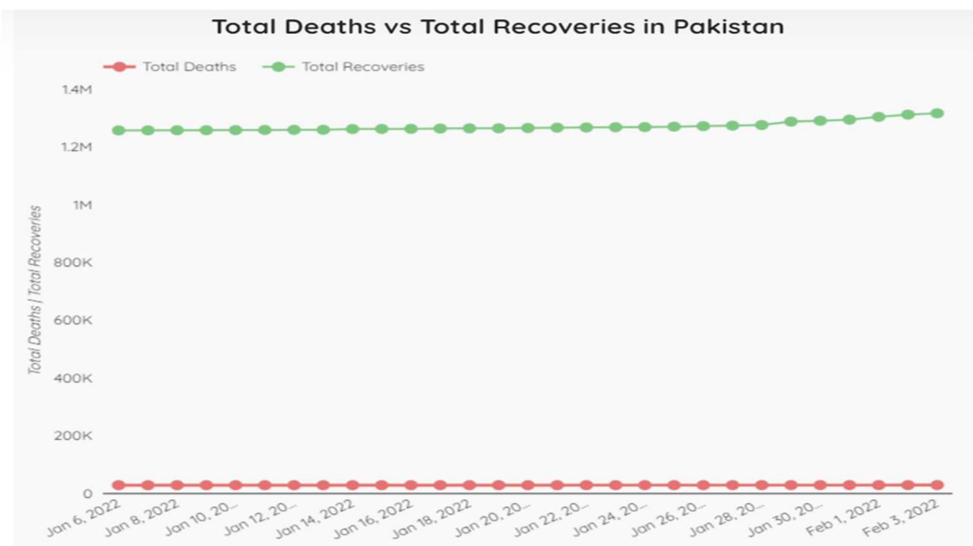


Figure 6: Total deaths and total recoveries reported in Pakistan as of February 3, 2022

Source: Statistical information on the website of Government of Pakistan

2. IMPACT ON PAKISTAN'S ECONOMY

Government of Pakistan imposed lockdown as soon as the single case of COVID-19 emerged and because of this initial lockdown in March 2020, the Pakistan stock market lost on average 1500 points daily. Billions of rupees invested in different shares were reduced by one third and in some case half of the value. Overall economic growth in Pakistan contracted to (-) 0.47% in 2019-20 when it already had weak economic growth of just 1.9 percent in the prior year. The COVID-19 further compounded long-standing challenges, especially in the industrial and services sector. Manufacturing sector, especially the exporters faced difficulties due to the decline in the demand for imports from Pakistan and other developing countries. Numerous consignments of the textile sector were stranded on sea and returned because, in wake of the pandemic, no state wanted to bring them inside the country unless everything was back to normal. Exporters also faced with problems in working capital management. Moreover, small businesses, especially freelance entrepreneurs, have struggled as supply chains dried up, leaving them without products or essential materials. The pandemic crisis severely affected the services sector like hotels, restaurants, wedding halls and marquees, which has the biggest share in the economy. Due to the closure of service sector, wholesale and retail trade as well as transport sector also effected. Additionally the platform economy workers like those providing transportation (Uber and Careem), delivery of items (Bykea) and domestic work services (Mauqa, Ghar Par) faced employment problems amid lockdown. These workers are considered as independent contractors, hence there is no employment responsibilities towards these workers by the state and these white collars workers cannot be part of any social protection program like Ehsaas. Border closures and lockdown disrupted agriculture value chain. Healthcare system of Pakistan was also under so much burden as the healthcare facilities could not suffice the population needs as on average one bed is available for 1680 people. Initially the testing services for COVID-19 were very low though gradually improved. Provision of health services to non COVID-19 illness like routine immunization or mother and child health care, reproductive health care system and newborns was a major concern and by the lockdown and border closures, which disrupted supply chains, stock shortages of essential vaccines and resultant disruption of immunization services have affected immunization of children. Burden is primarily borne by women who are mostly health care professionals as well as looking after their domestic responsibilities[1].

Micro, small, and medium sized enterprises (MSMEs) in the pandemic had been facing issues like financial (67.93%), supply chain disruption (47.83%), decrease in demand (44.02%), reduction in sales and profit (38.04%, 41.85% respectively) and decline in 60% sales, three-fourths of firms and over two-thirds of participating enterprises were expecting a decline in profits by more than 60% during 2020. In addition, those firms that have very low cash reserves are vulnerable and may not survive during the ongoing outbreak of COVID-19[2].

Pakistan Bureau of Statistics has conducted a special survey for evaluating impact of COVID-19 on wellbeing of people to provide representative results at national/provincial level to inform government about the effects of pandemic on employment, food security and general wellbeing of the population for informed decision-making.

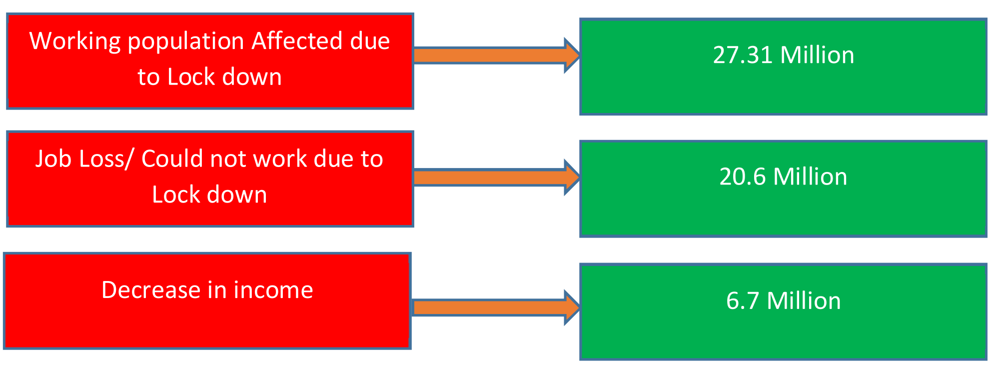


Figure 7: Situation Analysis of Affected Working Population

Source: Pakistan Bureau of Statistics

1 Economic Survey of Pakistan, 2019-2020.

2 Mohsin Shafi, Junrong Liu, and Wenju Ren, "Impact of COVID-19 Pandemic on Micro, Small and Medium Sized Enterprises operating in Pakistan," *Research in Globalization* 2(2020): 1

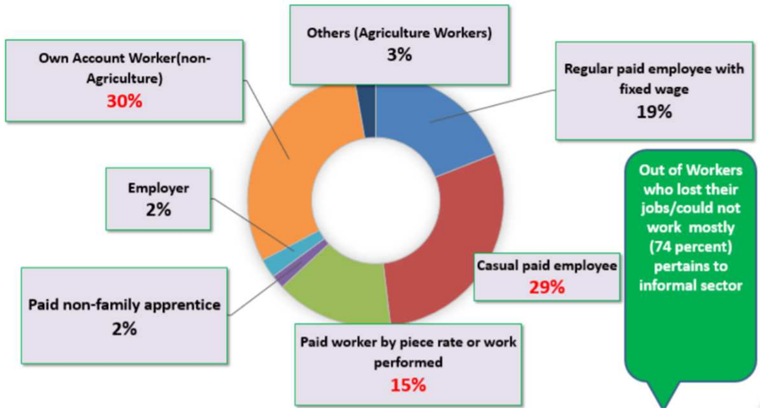


Figure 8: Distribution of effected workers by job status

Source: Pakistan Bureau of Statistics

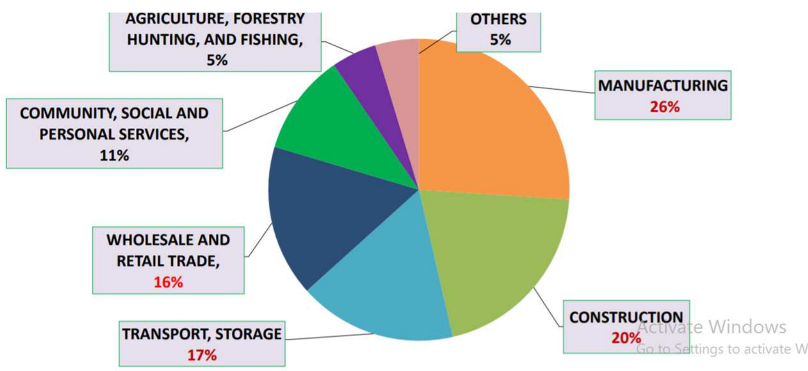


Figure 9: Distribution of affected working population-by industry (%)

Source: Pakistan Bureau of Statistics

Results of the survey showed that half of the households reduced their non-food expenditures, whereas almost half also reduced the non-food expenses. Moreover, significant number of households sold their property or used their savings whereas one-third households reported borrowing from their relatives and friends. Ehsaas has increased the scope of Kafaalat program, however the findings show that 33 percent of the households i.e. approximately 17.07 million households received assistance during the COVID-19 period. Out of which, 19 percent received assistance from government, while private sector assistance reported as 18 percent. The share of NGOs is 2 percent. Nonetheless, out of 33 percent, 5.5 percent households had received assistance from both government and private sector.

3. ADMINISTRATIVE AND PREVENTIVE RESPONSE TO THE PANDEMIC BY THE GOVERNMENT OF PAKISTAN

3.1. Formation of the National Command and Operation Center (NCOC) and Evidence based Policy Making

The immediate administrative response by the Government of Pakistan was setting up of clearinghouse mechanism of data and science related to COVID-19. NCOC was responsible for close monitoring, issuing guidelines and giving statistical information on daily basis about the confirmed cases suffering of COVID-19, death rate, positivity ratio etc. and that also total as well as province wise. NCOC is a pluralistic mechanism combining federal government, four provincial governments, regional governments and representation of Pakistan Army. In the light of data and evidence shared and close monitoring by NCOC and informed decision making takes place by the government like smart lockdown, online education, closure of business or/and changes in the timings and days of commercial activities and other measures to deal with the pandemic.

Three tasks define the functioning of NCOC; first, using robust data and technology to draw insights from it. Second, clear and effective public messaging and behavioral change communications. Third, ensuring coherent and cohesive governance to ensure consistency and predictability in the national response. The NCOC is essentially the nerve center through which real time data about Covid-19 has flowed. Every day, the four provinces and the federal government come together to examine the data, and the insights and trends that it reflects, to identify what measures need to be taken.

3.2. Smart Lockdown

After discovering COVID-19 positive cases, an immediate complete lockdown was imposed nationwide which prolonged until September. During the time of complete lockdown, there was an online mode of education, national and international flights were suspended, intercity travel was made non-operational, academic institutions were closed and the government institutions were made operational on selective basis like days per week and staff ratio. When economy and more specifically, the livelihood of people got in danger then the government decided to introduce a novel idea of "smart lockdown". Smart lockdown means closing or slowing down particular commercial, academic, and/or transport activities in provinces/cities/areas depending on the rate of spread of infection with a view to contain local COVID-19 by breaking the transmission cycle. The logic of government behind the smart lockdown is that citywide lockdowns, though administratively convenient, are economically/ socio-economically unsustainable and therefore not practicable and this approach can differentiate within a city depending upon the intensity of disease spread. Smart lockdowns therefore offer a balanced approach to limit the spread under the circumstances without at the expense of livelihood of economically vulnerable classes. It is pertinent to mention here that NCOC issues the guidelines for smart lockdown, which become available on its website and the district government is responsible for the implementation of the guidelines. People in Pakistan do not want complete lockdown based on the economic reasons, trade disruptions, increasing unemployment and poverty, so smart lockdown becomes an option. Wearing of gloves and masks; work from home including online classes; two-week work schedule in all big firms with penalties if become source of spread of disease or not following SOPs; opening of local shopping centres on specific days with limited timings and each shop allowing the specific number of people that can enter and ensuring social distance; allowing only for take away and delivery are a few salient features of smart lockdown. Smart lockdown has always been adopted in addition to all the epidemiological measures, including hygiene, physical distancing and testing, tracing and isolating the infected.

It is strongly suggested that government and police in collaboration with civil society and assistance of electronic surveillance can develop monitoring mechanisms with the continuous review of smart lockdown strategy according to the contingency[3].

3.3. Education

The education all around the globe has suffered the most in the existential COVID-19 war. The havoc on education wreaked by COVID-19 gets gigantic when the state is developing like Pakistan. Government's policy on education under COVID-19 has been dependent on the recommendations put forth by NCOC. Mostly throughout the period of severe COVID-19, the education was online/digital and staggered if at all shifted from virtual to physical mode. Federal government also launched the

3 Durr-e-Nayab, and Nadeem ul Haque, "Opting for a Smart Lockdown in Pakistan", *PIDE COVID-19 BULLETIN* 17 (2020).

channel of "Teleschool" to offer digital learning content to the students of school. The content on the teleschool is provided free of cost by major Edtech partners including Sabaq Foundation, Taleemabad, The Citizens Foundation (TCF), Punjab IT Board (PITB), Allama Iqbal Open University, and Knowledge Platform for the duration of this crisis, the policy highlights. This policy on education realized after the government built national consensus and coordination through the platform of Inter-provincial Education Ministers' Conference and took decisions after consultations. The policy enunciated the National Guideline issued by government for safe reopening of educational institutes after every episode of intermittent lockdown.

3.4. Vaccination in Pakistan

In Pakistan the process of vaccination started in 2021 and initially the vaccination imported from other countries primarily China was administered among the population according to age groups and above age the priority was given to frontline health workers. From "Our World in Data" as of February 3, 2022, 38% population is fully vaccinated and the process of booster doses is currently going on.

3.5. Social Aids by the Government

The policy on economy under COVID-19 aims at mitigating the adverse effects on the economy, Prime Minister, Imran Khan announced on March 24, 2020 a fiscal/economic stimulus package of Rs1130 billion to support the economy and protect the weak segments of the population in particular the daily wagers and the poor laborers. Prime Minister, Imran Khan has been very cognizant of the risk of poverty and hunger especially among the daily wagers and laborers, the policy enunciated that smart lockdown has been successful in mitigating the effects of recession and unemployment in Pakistan by allowing limited business, commercial and economic activities. Other measures to manage the impact of COVID-19 on economy highlighted in the policy include maintaining low interest rate to stimulate GDP growth and employment; cash transfer to poor women through Kafaalat programme and launch a poverty alleviation programme via micro-loans. PM Khan and the government created three categories of subsidy that have helped individuals and businesses deal with the crisis. One, the Benaizr Income Support Programme (BISP) Ehsaas Emergency Cash programme of a one-time Rs12, 000 cash grant for over 16 million households. Two, the electricity and utilities bill subsidies for small and medium sized businesses. Three, substantially lower interest rates. These measures have been instrumental in fending off the worst of the economic impact of Covid-19.

There are many other strategies also to combat and contain the pandemic, which are enlisted on the website of NCOC. They are explained in the following lines

3.5.1. SOPs Violation Reporting

NCOC launched a WhatsApp number for the reporting of COVID related violations of SOPs by the public, like non wearing of mask, non-adherence to social distancing, overcrowding at public places.

3.5.2. Resource Management System (RMS)

NCOC conceived a well-structured IT based national framework for credible health resource mapping. RMS was rolled out on 31 May 20 and currently contains data of about 4000 COVID/ non-COVID hospitals of the entire country. The system facilitates decision making in terms of establishment of correct need assessment and capacity enhancement. It also reinforces the usage of another app "Pak Negheban" which provides its users, location based guidance to nearest COVID treating hospitals.

3.5.3. Pak Neghayban App

This app provides real-time visibility of hospitals based on location and color-coded status as per availability of beds/ vents. Pak Neheyban app is being used by various emergency response organizations.

3.5.4. Integrated Disease Information Management System (IDIMS)

Integrated Disease Information Management System (IDIMS) developed by National Emergency Operation Centre (NEOC) forms the national repository for all COVID related data. IDIMS connects all the provinces to facilitate exchange of data among them. This helps in identifying the disease occurrence and probability of smart lockdown.

3.5.5. Education Institutes Monitoring System (EIMS)

NCOC in collaboration with other stakeholders from NITB designed for the first time the database containing data of more than 275,000 educational institutions across the country. EIMS has a comprehensive and updated statistics of educational institutions at national level. SITREP and SOP compliance data regarding COVID-19 is being updated by provinces on daily basis for necessary decision making at provincial and national level.

3.5.6. National Helpline& WhatsApp Chatbot for Healthcare Workers

National helpline& WhatsApp Chatbot has been disseminated in June 2020 for healthcare workers to register complaints with concerned government authorities. In addition to the national helpline, which is accessible to all, healthcare workers can punch their complaint as a text message on a allotted specified WhatsApp Chatbot number. Helpline is linked with NCOC and will be handled by a complaint management team of NHSR&C. Complaints will be forwarded to relevant focal point at federal and provincial levels for actions who will contact and update healthcare workers.

3.5.7. COVID-19 Telehealth Portal

Doctors in Pakistan can volunteer their time for a free consultation with patients. Pakistanis can fill out a Corona screening questionnaire on WhatsApp and may opt to speak to a doctor.

3.5.8. Launching of Helpline

In February, 2020, Special Assistant to the Prime Minister, Health, launched the "Sehat Tahaffuz" helpline 1166 to provide health-related information services to the people. Through the Helpline citizens will be able to obtain immediate assistance to their queries and concerns related to Polio and routine immunization services.

3.5.9. Isolation Hospital & Infectious Treatment Centre (IHITC)

Imran Khan in July 2020 inaugurated Islamabad Isolation Hospital & Infectious Treatment Centre (IHITC) for medical assistance of patients suffering from viral diseases. State of the art IHITC was constructed in record 40 days has five different wards and 250 beds with maximum facilities to diagnose and treat the infectious diseases. IHITC is fully functional and treatment of COVID-19 patients is being carried out.

3.5.10. Community Mobilization

Fight against existential war of COVID-19 demands a synergetic response from all segments of society. NCOC made arrangement with RSPs (active in 66 x Districts) to collaborate with District Administrations in undertaking activities including awareness campaign, assistance in trace & quarantine, disinfection of public places, data collection, hospital duties of volunteers, ration collection & distribution, utility store inspection and price control & hoarding. These unprecedented efforts have proved to be helpful.

3.5.11. Prime Minister's Relief Fund

Prime Minister's COVID-19 Pandemic Relief Fund-2020 has been set up to fight this pandemic. Prime Minister requested everyone to donate towards this fund, which has been spent to take care of all those who are economically crushed by the lockdown

3.5.12. We Care

Ministry of National Health Services, Regulations and Coordination (MNHSRC) launched a national campaign named "We CARE", aimed at protecting and supporting our frontline health workers in the context of Covid-19. 'WE CARE' aims at providing adequate personal protective equipment (PPE) to the health workers, orienting them on using various PPE items as per international standards, and creating an overall psycho-social environment of care and support. 'WE CARE' also aims to sensitize the public, including patients and visitors at healthcare facilities, to supports frontline healthcare workers by following preventive behaviors to not only reduce the risk of infection to themselves but also reduce the work burden on and health risks for the health providers.

3.5.13. Tiger Force and Yaran e Watan

Ex-Prime Minister Imran Khan launched Corona Relief Tiger Force to help and support government. The relief force volunteers will distribute food to the poor and create awareness about Covid-19 in areas under lockdown. Citizens can volunteer for the force through the PM Office portal by filling out a digital form. Yaran e Watan is a public-private partnership of MNHSRC and the Ministry of Overseas Pakistanis and Human Resource Development (MOPHRD) with support from Pakistani health organizations.

4. IN A NUTSHELL....

From public administration point of view, the governance strategies opted by the Government of Pakistan can be summed up and better understood from theoretical standings.

The joining of hands of government of Pakistan with the private and third sector shows *collaborative governance* has been the main mechanism for controlling COVID-19. *Welfare* policies like launching of Ehsaas program and provision of financial assistance has been a daunting step amid given economic crisis. Reliance of nerve center organization on real time data indicates *evidence based policymaking* to handle COVID-19 and in the similar vein access of citizens to the government whether to file complaint regarding SOP violation, health advice or voluntary inclusion in tiger force manifests *New Public Governance (NPG)*.

5. CONCLUSION AND SUGGESTIONS

Worldwide organizations like World Bank acknowledged Pakistan for efficiently handling and combating the spread of COVID-19. The novel policy of smart lockdown received acknowledgement from world for containing the virus without at the expense of livelihoods of people. The *Economist* (2021) in its world's normalcy index ranked Pakistan among the best performing countries for handling the coronavirus pandemic. The WHO (2020) not only hailed rather also declared Pakistan as an example for the world to learn to deal with the pandemic.

After reviewing, experiencing and observing the episode of COVID-19 in Pakistan including strategies by the government to combat it, following recommendations are suggested especially when the fifth wave of COVID-19, OMICRON is hitting the country:

- The establishment of NCOC and its efficient performance proved this organization as the nerve center, but lack of coherence and consensus among provincial governments has also been there on some issues. There has been difference of opinion on the strategies of complete lockdown, smart lockdown or no lockdown at all; online or face to face education and much more. In light of this evidence, establishing organizations in all provinces like Provincial Command and Operation Center (PCOC) can be an option, as provincial autonomy is an important clause after18th Amendment which empowers the provinces to take administrative measures on their own. Moreover, to avoid any political vengeance or violation of national interest over personal interest, PCOCs in all four provinces may have representation form federal government or made accountable to central body, some independent institution or some watchdog.
- Other actors in society like civil society and religious entities also need to play their due role. Government of Pakistan has been very efficient in the tackling of COVID-19 by dodging the bullet and blunting the feared effects of COVID-19 as compared to its neighboring countries. Economy and education (in the context of Pakistan) are the biggest challenges in the wake of pandemic and strong technical and programmatic oversight, engagement of civic society and intervention of religious scholars as nonpharmachological intervention compliance are required[4].
- There can be various policy recommendations to ease the burden on MSMEs. Included in them like protection of employees and information accuracy, boosting economy, income and employment support for MSMEs, planning, building resilience capability and positive social relations.

---

[4] Zulfiqar A Bhutta,Faisal Sultan, Aamer Ikram, Adil Haider, Assad Hafeez, and Muhammad Islam, “Balancing Science and Policy in Pakistan's COVID-19 Response,” *Eastern Mediterranean Journal* 27 (2021): 8.

- The basic challenge faced by policy makers in underdeveloped is the utilization of meager resources to achieve interconnected goals for managing health recovery, economic crises, and creating environmental sustainability. The interconnected nature of COVID-19 crises demands an integrated approach and coordination among all stakeholders to handle the pandemic and alignment of the policies with the challenges[5].
- There are few policy options to handle COVID-19; every party must have a functional policy-planning wing, formation of parliamentary committees to discuss and draft policy on COVID-19 after several brainstorming sessions, role political parties may play in public messaging and behavioral change at grassroots level[6].

5 Fariha Sohil, Muhammad Umair Sohail, and Javid Shabbir, "COVID-19 in Pakistan: Challenges and Priorities," *Cogent Medicine* 8(2021): 1.

6 Fahd Hussain, "Policy Issues Relating to COVID-19," *Discussion Paper (2020)*

KARTEPE SUMMIT

24-27 MARCH 2022

Chapter 4

SOCIOECONOMIC IMPACT ASSESSMENT OF COVID-19 AND ECONOMIC STIMULUS PACKAGE ON LOW-INCOME HOUSEHOLD IN PAKISTAN

Javarıa Nasir* - Aneela Ashraf**

1. INTRODUCTION

The global population increase creates serious socioeconomic challenges regarding sustainable development. The advent of technology is creating some creation of manmade capital that increase the provision of goods and services and increase the productivity of resources. While billions live in luxury, more than a tenth of the world's population now lives in absolute poverty[1]. Poverty is caused by political and economic inequality, not by a scarcity of global resources. The poorest people are nearly invariably the most vulnerable to pandemics, environmental degradation, climate change, and resource competition[2]. Global population is rising drastically that affect the human resource distribution and public equity in short term and long term. The covid-19 outbreak creates millions of deaths in last two years throughout the globe. When people lack economic security and are unable to rely on their government or a social safety net, they frequently have children to ensure that they will be cared for when they grow up. According to World Bank estimates, 9.2 percent of the world's population, or 689 million people, live in extreme poverty on 1.90 dollar or less per day. The international poverty line is currently 1.90 dollar

* University of Agriculture Faisalabad, javarianasir@yahoo.com; javaria.nasir@uaf.edu.pk

** University of Agriculture Faisalabad, aneelaashraf1995@gmail.com

1 Chen, Zhong, and Yishu Liu. "Economic Development Ideas of Regional Convergence Industry Based on Artificial Intelligence Multimedia Background." *Mobile Information Systems* 2021 (2021).

2 Petrov, Kamen. "Methodological problems before regional development in the conditions of post COVID-19 governance." *Journal of Geography, Politics and Society* 11, no. 3 (2021): 41-48.

per day. Originally, the worldwide poverty threshold was established at about 1 dollar per day. Organizations can establish which people are regarded to be in absolute poverty when purchasing power parity and all items consumed are taken into account in the computation of the line. Around 4 billion people lack access to critical health care, according to the "World Health Organization" and the "World Bank"[3].

The Effect on Pakistan's Poverty Rate COVID-19 was epidemic in the first quarter of 2020, then became pandemic in the second quarter, and scientists predict that this terrible infection will soon become endemic in the "Global community". COVID-19 has a particularly negative impact on low-income areas and impoverished individuals, among other things[4]. This pathogen is disproportionately affecting the poor in all countries where cases are concentrated, and it is more likely to go undetected or under-detected, according to experts. Experts are urging international organizations and developed countries to lend support to low-income countries, whose healthcare systems are weak and rely on international assistance to combat the virus [5][6][7][8].

Economic stimulus package was announced by Pakistan government and it includes the launch of Pakistan's Ehsas Emergency Cash Program, which provides PKR 12,000 (USD 75) to each eligible family whose livelihood has been severely impacted by COVID-19; (ii) a relief package for unemployed industrial workers; and (iii) deferring payment of gas and electricity bills for three months. (iii) subsidized daily household consumption products for the poorest of the poor through Utility Stores; (iv) payment of energy bills for up to three months for those utilizing 5 kilowatts (commercial customers) or 70 kilowatts (industrial users) of electricity;(vii)

---

3 Liu, Weiyong, Q. I. Zhang, Junbo Chen, Rong Xiang, Huijuan Song, Sainan Shu, Ling Chen et al. "Detection of Covid-19 in children in early January 2020 in Wuhan, China." *New England Journal of Medicine* 382, no. 14 (2020): 1370-1371.

4 Lakner, Christoph, Daniel Gerszon Mahler, Mario Negre, and Espen Beer Prydz. "How much does reducing inequality matter for global poverty?." (2020).

5 Zhebit, Alexander. "Human Rights in a Pandemic." *Outlines of global transformations: politics, economics, law* 13, no. 5 (2020): 219-252.

6 Khan, Atta Ullah, Abdul Saboor, Ikram Ali, Wasim Shahid Malik, and Khalid Mahmood. "Urbanization of multidimensional poverty: empirical evidences from Pakistan." *Quality & quantity* 50, no. 1 (2016): 439-469.

7 Fazal, Owais, and Peter J. Hotez. "NTDs in the age of urbanization, climate change, and conflict: Karachi, Pakistan as a case study." *PLoS Neglected Tropical Diseases* 14, no. 11 (2020): e0008791.

8 Islam, SM Didar-Ul, Md Bodrud-Doza, Rafid Mahmud Khan, Md Abidul Haque, and Mohammed A. Mamun. "Exploring COVID-19 stress and its factors in Bangladesh: a perception-based study." *Heliyon* 6, no. 7 (2020): e04399.

increasing the wheat procurement price to PKR1400 per 40 kg's to offer additional income to farmers, and (v) an incentive package for the construction industry; (vi) eliminating import charges on food products to maintain food security in the nation, and (viii) providing funding for the purchase of required medical equipment and logistical improvements. 14.8 million Households, as of September 14, 2020. After biometric identification with NADRA's (National Database and Registration Authority) database, which preserves the digital identity of 122 million individuals, 88 million people have earned PKR178.5 billion (US1.1 billion) through transparent delivery of this program.

This research is, therefore, an attempt to analyze lower income households' responses towards COVID-19. The research is expected to provide richer insights of the socioeconomic impacts of COVID-19 on the livelihood of lower-income households and how the resource-poor households respond to these financial risks along with the effectiveness of economic stimulus package in Pakistan.

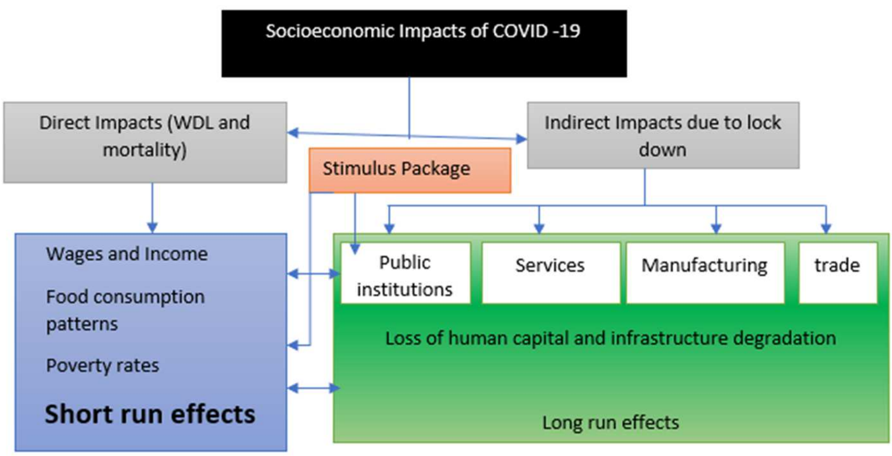


Figure 1: The socioeconomic impact assessment of COVID-19 on households

Source: World Bank, 2021

2. METHODOLOGY

The study was conducted in Faisalabad that is the largest industrial city of Pakistan. The research sites and sampled respondents were chosen using a multistage survey method. During the initial period district Faisalabad is purposively elected. In the second stage a stratified random sampling is used to select two union councils one each from rural and urban locations. In the third stage of the sampling procedure two villages were randomly selected from the selected union councils. After the selection of two villages in each union council, 300 sampled respondents, 150 each from rural and urban locations were randomly selected in the last stage of the sampling process and information be composed commencing the sampled awake. Following the selection of the sample size, data was collected from the sampled respondents via a structured questionnaire and face-to-face meetings. While collecting the required data, all ethical considerations were kept in mind, and the respondent's prior consent was sought before collecting the data. Data on respondents' socio-economic attributes including age, education, employment status, family size, income etc., respondents' perceptions of the financial risk' sources, their attitude towards and their responses to cope with the financial crises were collected through questionnaire.

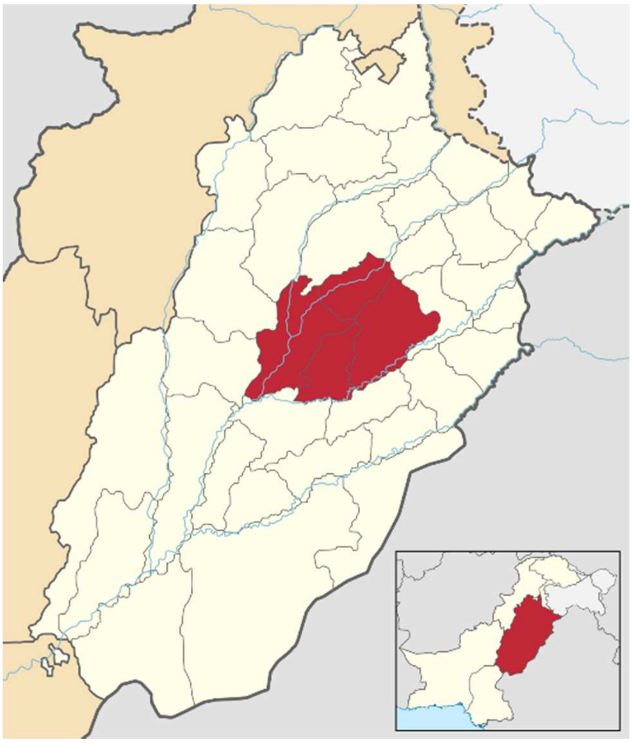


Figure 2: Map of Punjab, Pakistan

Source: https://en.wikipedia.org/wiki/Faisalabad_Division

Principal components, which are the linear functions of the measurements, are suggested for this purpose[9]. Principal component analysis is a statistical procedure that allow you to summarize the information content in large data tables by mean of smaller set of summary indices that can be more easily visualized and analyzed, PCA is a very flexible tool and allow analysis of datasets that may contain, for example, multicollinearity, missing value, categorical data and imprecise measurements. The goal is to extract the information from the data and to express information as a set of summary indices called principal component [10].

3. RESULTS AND DISCUSSION

The research was conducted to identify the impact of COVID-19 on the livelihood of lower income household. The government announces the stimulus package for poor household. This study aims at finding the impact of covid on lower income household and also tries to capture the compensation amount impacts on households. The socioeconomic description of respondents is enlisted in table 1.

Table 1. Socioeconomic profile of respondent

Socioeconomic Indicator	Mean	Standard Deviation
Age of Household head (years)	42.67	10.64
Total number of earners	1.20	0.50
Education (Year of schooling)	6.06	4.68
Monthly Income (Rupees)	19483.33	3802.8
Family Size (Number)	6.2	2.08

Source: Author's own calculations based on survey data

Data described that 8 percent of sampled urban respondents were engaged in government job as a primary source of income. About 24 percent had the private source of in-come and 66 percent respondents involved in labor activities and 2 percent respondents had their own business. While in rural area who were involved in government job 0 and 13 percent respondents had the private source of

[9] Islam, SM Didar-Ul, Md Bodrud-Doza, Rafid Mahmud Khan, Md Abidul Haque, and Mohammed A. Mamun. "Exploring COVID-19 stress and its factors in Bangladesh: a perception-based study." *Heliyon* 6, no. 7 (2020): e04399.

[10] Geniş, Bahadır, Nermin Gürhan, Medine Koç, Çiğdem Geniş, Burak Şirin, O. C. Çırakoğlu, and Behcet Coşar. "Development of perception and attitude scales related with COVID-19 pandemia." *Pearson journal of social sciences-humanities* 5, no. 7 (2020): 306-328.

income and 3 percent respondents had their own business and 84 percent sampled respondents involved in labor activities. About 80 percent household have no house ownership and living on rented houses [11].

Table 2: Mean Comparison of socioeconomic profile of households before and after covid

Socioeconomic Indicator	Mean differences	t-value	Significance
Income	-4063.33	-7.280	0.000
Food expenditure	1111.33	8.185	0.000
Health expenditure	398.000	9.726	0.000
Education expenditure	- 135.333	2.274	0.024
Changes in savings	-198.666	5.203	0.000
Transportation Expense	-128.66	-4.159	0.000

Source: Author's own calculations based on survey data

The socioeconomic indicators like income, expenditures (food health, education, transportation) and saving affected significantly due to covid and lockdown in poor communities. The data described that income decrease significantly due to covid and lockdown as most of the respondents were from daily labor. The saving also declined substantially due to covid. The education expenses decrease due to covid significantly. While the 2 death cases were also reported from sample survey but most of respondents reported the death cases in their surroundings.

The rural household's perception about covid-19 was much lower than the urban households whereas impacts on employment status was reported from all. About 24.0 percent respondent had no employment issue 76.0 respondent is unemployed due to COVID-19. However, in rural areas 26.7percent respondent had no unemployment issue 73.3 percent were unemployed due to COVID-19. Overall, 25.3percent respondent had no unemployment issues 74.7percent respondent were unemployed due to COVID-19. The sample comprised on lower income group and majority of sample work as labor that drastically affected due to pandemic. Majority of respondents claims that their monthly income was reduced due to lockdown.

[11] Ali, A., Ahmed, M., & Hassan, N. (2021). Socioeconomic impact of COVID-19 pandemic: Evidence from rural mountain community in Pakistan. *Journal of Public Affairs*, *21*(4), e2355.

Table 3: Perception of households regarding covid-19

Indicators for perception of households regarding covid-19	Mean	Standard Deviation	Min	Max
Health effects of Covid-19 are severe	4.21	0.88	1	5
The impacts of covid on income are severe	4.15	0.68	1	5
Vaccination as important preventive measure	4.14	0.84	1	5
Adoption of mask/ gloves	4.13	0.88	1	5
Adoption of Social distancing	3.97	0.59	1	5
Covid-19 is detrimental	3.96	0.92	1	5
Positive COVID-19 cases observed	3.92	0.97	1	5
Precautionary measure is better than vaccination?	3.61	1.17	1	5
Do you face any anxiety/depression	3.55	1.22	1	5
COVID-19 affect your work	3.50	0.91	1	5
Humor about covid-19 is true	3.10	0.99	1	5
Government stimulus package is effective	3.02	1.18	1	5
Covid-`19 is still exist	2.17	2.03	1	5
COVID-19 affect education, life amenities	2.02	0.62	1	5

Source: Author's own calculations based on survey data

The objective of PCA is to find common factors, called principal components, in the form of linear combination of the constraint under study and to rank them according to their importance. Table 5 shows the Eigenvalue of the components. There are four components whose eigenvalue is greater than one and they account for 77 percent of the total variance.it is worth that only factor that have eigenvalue greater than one are retained. The plot of the eigenvalues shows that only four factors are above the one eigenvalue and the rest are show in Figure 3.

Table 4: Bartlett test of Sphericity (BTS) and Kaiser-Meyer-Olkin (KMO)

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.635
Bartlett's Test of Sphericity	Approx. Chi-Square	309.665
	Df	91
	Sig.	.000

Source: Author's own calculations based on survey data

In order to confirm the appropriateness of PCA, Bartlett test of Sphericity (BTS) and Kaiser-Meyer-Olkin (KMO) were employed in this study. The table 4.42 shows that the value of BTS at 309.665 and its level of significance, which indicate that data were appropriate for PCA. The value of KMO 0.635, indicating that there are enough items for each other. We have selected a total of 14 relevant variables for our analysis.

Table 5: Rotated component matrix

Factors	Component	Component		
		1	2	3
Socioeconomic Impacts	Health effects of Covid-19 are severe	0.789		
	The impacts of covid on income are severe	0.697		
	COVID-19 affect your work	0.611		
	COVID-19 affect education, life amenities	0.423		
Precautionary measures	Adoption of mask/ gloves		0.694	
	Adoption of Social distancing		0.614	
	Covid-19 is detrimental		0.432	
	Vaccination as important preventive measure		0.315	
	Precautionary measure is better than vaccination		0.301	
Institutional factors	Positive COVID-19 cases observed in community			0.78
	Do you face any anxiety/depression			0.578
	Humor about covid-19 is true			0.432
	Government stimulus package is effective			0.315
	Covid-19 is still existed			0.215

Source: Author's own calculations based on survey data

The perception of household about covid is linked with socioeconomic impact of covid and respondents had insight about covid and its impacts. Due to access towards mass media internet and TV the respondents also reported the adoption of the precautionary measures. The respondents were not highly educated but they have awareness about impacts, precautionary measures and institutional factors especially Ehsas program.

4. CONCLUSION AND POLICY RECOMMENDATIONS

This research aimed at finding the perception of lower income households about covid-19 and its socioeconomic implications. The perception about pandemic and its se-verity is understandable by majority and they drastically affected by the lockdown due to covid. The income and consumption patterns were completely changed in poor households but they managed and survived due to economic stimulus package and community charity services. The impacts or covid-19 are evident on income, consumption and saving in Pakistan lower income households. Likewise, the beneficiary's income and consumptions are significantly higher than non-beneficiaries of economic package. This research only utilizes the perception and impacts but the action plan and adaptive efforts could be analyzed that helped these marginal communities to better survive during covid-19. Based on the research findings the following recommendations are suggested for public policy.

KARTEPE SUMMIT

24-27 MARCH 2022

Chapter 5

ENHANCING DATA QUALITY OF FINE-GRAIN MEASUREMENTS IN NANOPARTICLES HYPERLOCAL AIR QUALITY STATIONS TO MEASURE THE IMPACT OF CLIMATE CHANGE AND URBAN HEALTH

Eduardo Illueca Fernández* - Iris Cuevas Martínez** -
Jesualdo Tomás Fernández Breis - Antonio Jesús Jara Valera

INTRODUCTION

Air quality monitoring is a key challenge in digital transformation for the next years. In 2015, an estimated 4.2 million people died prematurely due to PM2.5 exposure putting it in the top five mortality risk factors worldwide[1], making it one of the significant, current public health problems, and highlighting the need to generate innovation in this field from the ICT sector. For this reason, the *Directive 2008/50/EC of the European Parliament and of the Council on air quality and cleaner air for Europe* establishes a list of pollutants and permitted limits to ensure the health of citizens, which public administrations must be obliged to comply with, including aerosols and particulate matter because of their health impact.

Therefore, the need for high-resolution monitoring with a larger number of sampling points is essential. The use of and research on so-called IoT hyperlocal sensors - that can provide real or near-real-time data and provide meaningful

---

* Correspondent Authors: Eduardo Illueca, email: eduardo@hopu.org, Department of Informatics and Systems, University of Murcia, Murcia (Spain)

** HOP Ubiquitous S.L (HOPU Smart Cities), Luis Bunuel 6, Ceutí 30562 Murcia (Spain) www.hopu.org

1 Aaron J. Cohen et al., «Estimates and 25-Year Trends of the Global Burden of Disease Attributable to Ambient Air Pollution: An Analysis of Data from the Global Burden of Diseases Study 2015», *The Lancet* 389, n.º 10082 (2017): 1907-18, https://doi.org/10.1016/S0140-6736(17)30505-6

measurements at a local scale[2] - has increased in recent years. These devices are optical particle counters based on the assumption that the number of particles is proportional to the light scattering. It has been shown that such sensors can have an acceptable linear response in the laboratory. However, there are deviations under real conditions due to particle size, chemical composition, and relative humidity[3], which implies a lower quality of measurements in comparison with the reference technique. The use of high-resolution networks is essential to implement measures in *Smart Cities,* such as LEZ - zones with limitations in the number of vehicles circulating inside[4].

In this sense, a lot of work has been performed in the evaluation, calibration and improvement of IoT sensors, due to the fact that many of these sensors are sold to the public with minimal testing and validation[5]. These assessments are performed by comparing the data of the sensor with a reference instrument. This test can be performed in two different ways in the function of the conditions. We define a *laboratory evaluation* as to when the evaluation is performed in controlled laboratory conditions and using particles of known chemical composition[6]. On the other hand, a *field evaluation* is performed with real ambient particles[7].

Currently, research on hyperlocal PM sensors focuses on two aspects: i) interpreting their signal through calibration or modelling and ii) modifying them for more accurate use[8]. In this sense, machine learning has gained relevance in recent years, since it allows for generating models that enable real-time calibration of IoT devices by using training data obtained by reference equipment. It has been

2 Kira Sadighi et al., «Intra-Urban Spatial Variability of Surface Ozone in Riverside, CA: Viability and Validation of Low-Cost Sensors», *Atmospheric Measurement Techniques* 11, n.º 3 (2018): 1777-92, https://doi.org/10.5194/amt-11-1777-2018.

3 Yang Wang et al., «Laboratory Evaluation and Calibration of Three Low-Cost Particle Sensors for Particulate Matter Measurement», *Aerosol Science and Technology* 49, n.º 11 2015): 1063-1077, https://doi.org/10.1080/02786826.2015.1100710.

4 Veronika Fensterer et al., «Evaluation of the Impact of Low Emission Zone and Heavy Traffic Ban in Munich (Germany) on the Reduction of PM10 in Ambient Air», *International Journal of Environmental Research and Public Health* 11, n.º 5 (2014): 5094-5112, https://doi.org/10.3390/ijerph110505094.

5 Alastair Lewis and Peter Edwards, «Validate Personal Air-Pollution Sensors», *Nature* 535, n.º 7610 (2016): 29-31, https://doi.org/10.1038/535029a.

6 Sinan Sousan et al., «Laboratory Evaluation of Low-Cost Optical Particle Counters for Environmental and Occupational Exposures», *Sensors* 21, n.º 12 (2021): 4146, https://doi.org/10.3390/s21124146.

7 Brandon Feenstra et al., «Performance Evaluation of Twelve Low-Cost PM2.5 Sensors at an Ambient Air Monitoring Site», *Atmospheric Environment* 216 (2019): 116946, https://doi.org/10.1016/j.atmosenv.2019.116946.

8 Jiayu Li et al., «Evaluation of Nine Low-Cost-Sensor-Based Particulate Matter Monitors», *Aerosol and Air Quality Research* 20, n.º 2 (2020): 254-270, https://doi.org/10.4209/aaqr.2018.12.0485.

demonstrated that these models can significantly improve the behaviour of these sensors[9] with gases. Therefore, our hypothesis is that the use of machine learning models will improve the signalling of hyperlocal sensors.

This work tested seven different hyperlocal IoT for particulate matter covering the PM10, PM2.5 and PM1 fractions. Then, two sensors were selected - Alphasense OPC-N3 and Winsen ZH03B - to be improved with artificial intelligence and test our hypothesis, all in *field conditions*. The rest of the paper is structured as follows: the *State of the Art* reviews related work performed in PM hyperlocal IoT sensors evaluation and *machine learning* models. Then, in *Theoretical and Mathematical Fundamentals* the basis of the algorithms and models are explained. *Material and Methods explains the* methodology applied in this work. The section *Results* present the performance of the sensors and models, which is analysed in the *Discussion*. Finally, *Conclusions and Future Work* assets the key points of the paper and the next steps of the research.

1. STATE OF THE ART

Hyperlocal IoT sensors are devices that measure air quality using traditional techniques but with the ability to generate a huge amount of data in real time or quasi-real time. There exists a large variety of devices to measure gases - using electrochemical sensors - and aerosols through light scattering[10]. This state of the art focuses on aerosol's devices based on the *understanding of the signal* and the *improvement of the signal*. Related to the first point, numerous studies have been conducted to evaluate low-cost sensors with different medium - and high-cost - reference techniques. The first problem that usually shows these sensors is scale bias. For example, in this study, Speck sensors for PM2.5 were used and found to overestimate the concentration by 200% in indoor and 500% in outdoor conditions, compared to the GRIMM Reference Dust Monitor[11]. On the other hand, the Plantower PMS1003 sensor has a bias of +46% when measuring PM10[12]. Another

---

9 Naomi Zimmerman et al., «A Machine Learning Calibration Model Using Random Forests to Improve Sensor Performance for Lower-Cost Air Quality Monitoring», *Atmospheric Measurement Techniques* 11, n.º 1 (2018): 291-313, https://doi.org/10.5194/amt-11-291-2018.

10 Aakash C. Rai et al., «End-User Perspective of Low-Cost Sensors for Outdoor Air Pollution Monitoring», *Science of The Total Environment* 607-608 (2017): 691-705, https://doi.org/10.1016/j.scitotenv.2017.06.266.

11 Nadezda Zikova, Philip K. Hopke, y Andrea R. Ferro, «Evaluation of New Low-Cost Particle Monitors for PM2.5 Concentrations Measurements», *Journal of Aerosol Science* 105 (2017): 24-34, https://doi.org/10.1016/j.jaerosci.2016.11.010.

12 Rohan Jayaratne et al., «The Influence of Humidity on the Performance of a Low-Cost Air Particle Mass Sensor and the Effect of Atmospheric Fog», *Atmospheric Measurement Techniques* 11, n.º 8 (2018): 4883-90, https://doi.org/10.5194/amt-11-4883-2018.

key aspect is the spatial variability of the devices, which stands for the difference between measures taken in different locations. To study this effect, the performance of this Plantower PMS1003 when measuring PM2.5 has also been evaluated in different cities around the world[13], obtaining significant differences in the performance of the sensor depending on its geographical location (R^2 values ranging from 0.44 to 0.91). Finally, a study highlights the importance of intra sensor comparisons in the evaluation of twelve sensors for the PM2.5 fraction[14]. OPC-N2 is a sensor evaluated in this study, and whose R^2 values were between 0.38 and 0.67.

Regarding the *improvement of the signal*, the development of *machine learning* models improves the results based on the accuracy and correlation present in the state of the art. Different model designs have been used to calibrate IoT devices, with important results for CO, NO_2 and O_3[15]. For particle matter, two-stage algorithms have also been employed for 236 hours and different traditional algorithms such as support vector machine, nearest neighbour, random forest, or Extreme Gradient Boosting, obtaining $R^2 = 0.78$ with this last model. On the other hand, more statistical models have been used, such as Gaussian mixture regression, obtaining an $R^2 = 0.88$[16]. However, these models need to be fed with high-quality data, so a prior data mining process is essential. One of the key problems linked to low sensor data – especially PM data – is the noise. To overcome this, some studies promote the implementation of a weighted moving average filter to the raw data[17].

The effect of humidity in IoT sensors was reported coupled with particle size and chemical composition[18]. In contrast with those last two factors – which are really difficult to study and require expensive instrumentation -, extensive research has studied the error related to humidity to calculate the correction factor related to this parameter[19]. The results show a significant improvement of sensor

---

13 Xiaoting Liu et al., «Low-Cost Sensors as an Alternative for Long-Term Air Quality Monitoring», *Environmental Research* 185 (2020): 109438, https://doi.org/10.1016/j.envres.2020.109438.

14 Feenstra et al, 2019, 116946.

15 Zimmerman et al, 2018, 291-313

16 Byoung Gook Loh y Gi Heung Choi, «Calibration of Portable Particulate Matter–Monitoring Device Using Web Query and Machine Learning», *Safety and Health at Work* 10, n.º 4 (2019): 452-460, https://doi.org/10.1016/j.shaw.2019.08.002.

17 Hyuntae Cho y Yunju Baek, «Practical Particulate Matter Sensing and Accurate Calibration System Using Low-Cost Commercial Sensors», *Sensors* 21, n.º 18 (2021): 6162, https://doi.org/10.3390/s21186162.

18 Wang et al, 2015, 1063-1077

19 Leigh R. Crilley et al., «Evaluation of a Low-Cost Optical Particle Counter (Alphasense OPC-N2) for Ambient Air Monitoring», *Atmospheric Measurement Techniques* 11, n.º 2 (2018): 709-20, https://doi.org/10.5194/amt-11-709-2018.

performance and retention of fundamental information related to particle composition. Thus, a particle size distribution-based correction algorithm was developed to correct the influence of RH on sensor measurements. The correction algorithm's application assumed a physically reasonable correction factor, with the overestimation of PM measurements reduced from a factor of ~5 before correction to 1.05 after correction[20]. The main drawback of this study is that this correction factor is highly dependent on chemical composition, and it is difficult to extrapolate these results to other locations or explain the seasonal intrinsically variation associated with particulate matter chemical composition.

2. THEORETICAL AND MATHEMATICAL FUNDAMENTALS

Commercially available low-cost particle sensors are based on optical scattering (Figure 1). A flow of air is generated employing a fan or convection due to a heating element. The airflow is in the y-direction in Figure 1. Particles in the airflow travel through a beam of light, propagating in the z-direction, and scatter light in all directions. The amount of scattered light detected in a particular direction ϕ depends on the particle properties (size, shape, absorption, refractive index), wavelength, and polarisation. In general terms, high intensity means a large particle and vice versa. The particle size is determined based on the measured intensity[21]. Thus, these devices are known as optical particle counters because they calculate the diameter of the particle and classify it into one bin, a size range in which all particles with a diameter within this size range are contained.

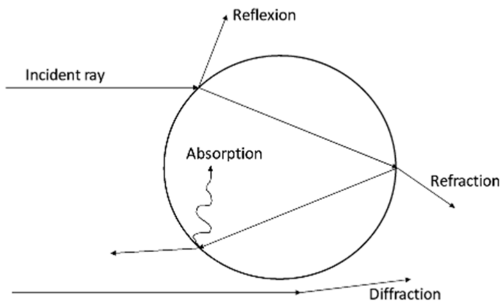


Figure 1. Phenomena induced by the interaction of a single particle with a light beam[22]

[20] Andrea Di Antonio et al., «Developing a Relative Humidity Correction for Low-Cost Sensors Measuring Ambient Particulate Matter», *Sensors* 18, n.º 9 (septiembre de 2018): 2790, https://doi.org/10.3390/s18092790.

[21] Peter Görner et al., «Workplace Aerosol Mass Concentration Measurement Using Optical Particle Counters», *Journal of Environmental Monitoring* 14, n.º 2 (2 de febrero de 2012): 420-28, https://doi.org/10.1039/C1EM10558B.

2.1. Bins and Transformation To Mass Concentration

Particule matter regulations are expressed in terms of mass per volume, whereas optical scattering sensors count particles, and classify these based on size. This implies that mass concentration should be calculated and the total mass for a set of particles can computed by the formula shown in (1), where n is the number of particles, r is the radius of each particle and ρ is the density of each particle.

$$m = \sum_{i=0}^{n} \frac{4}{3} \pi r^2 \rho. \quad (1)$$

It is easy to note that particle mass scales with particle size to the power three, so small errors in particle classification led to large errors in calculated mass. Moreover, the density of the particles is an important parameter in converting size to mass, which is generally unknown. Typically, the unit contains a microcontroller with a calibration algorithm, but calibration constants may not relate to the actual situation. For example, an outdoor sensor near heavy traffic will mainly see black soot particles, while a sensor installed indoors in a construction site in a building will mainly see bright particles with higher density. The calibration factors for these situations will be very different, and this should be considered. Thus, it is easy to conclude that it is important to work with raw data and particle number concentration[22]. The problem arises when working with this data because bin's ranges differ from one device to another so that they are not comparable with each other. For this purpose, the boundaries of the bins must be standardized to have the same bin's limits when comparing devices. For this purpose, we will suppose that we have two optical particle counters. Each bin of the first device is expressed as a linear combination of different bins of the second device (2). The algorithm[23] is based on determining the value of the coefficients c_i, which is between 0 and 1. When both boundaries are within the same bin, c_i=1. In addition, this algorithm is essential when implementing the proposed algorithm for correcting the humidity since this is based on adjusting the bins limits, as will be seen in the next subsection.

$$B = c_0 b_0 + c_1 b_1 + \ldots + c_{n-1} b_{n-1} + c_n b_n. \quad (2)$$

---

[22] Li et al, 2020, 254-270.

[23] Di Antonio et al, 2019, 2790

2.2. Humidity Correction Algorithm

A major challenge in this paper is the definition of a specific humidity correction algorithm to complement the calibration. This algorithm is executed before the calibration, as it modifies the limits of the bin's intervals depending on the unit. Therefore, for each measurement, new bins will be defined which will be used to calculate the mass concentration and particle number values. Therefore, standardization of the bins is essential. The algorithm is based on implicit knowledge and is an adaptation of the algorithm used in this article[24]. The starting assumption is that an increase in humidity implies an increase in the hygroscopic radius of the particle. To quantify this effect, a hygroscopic growth factor, g, is defined in (3), where D is the diameter of the particle in wet conditions (Wet) and in normal or dry conditions (Dry). This growth factor is a function of relative humidity, RH.

$$g(RH) = D_{Wet}\frac{(RH)}{D_{Dry}}. \tag{3}$$

Using the theory that Köhler proposed (Köhler, 1936) the above quotient can be expressed as a function of a single parameter, RH, which in turn is the only one on which g depends, as shown in (4).

$$g(RH) = \left(1 + \kappa D_{Wet}\frac{(RH)}{D_{Dry}}\right)^{\frac{1}{3}}. \tag{4}$$

In this equation, κ is a parameter describing the degree of hygroscopicity of a particle, which is a function of the chemical composition of the particle[25]. The value of κ for a mixture of organic and inorganic compounds in polluted environments (MIXPO), such as urban environments, is κMIXPO = 0.62[26]. However, there is no information on the efflorescence point of this mixture. This implies that it is not possible to determine the RH value at which the particles are no longer absorbing water. On the contrary, the efflorescence point of ammonium sulfate is known to

---

24 Di Antonio et al, 2019, 2790

25 Paul Zieger et al., «Effects of Relative Humidity on Aerosol Light Scattering: Results from Different European Sites», *Atmospheric Chemistry and Physics* 13, n.º 21 (2013): 10609-31, https://doi.org/10.5194/acp-13-10609-2013.

26 Birgitta Svenningsson et al., «Hygroscopic Growth and Critical Supersaturations for Mixed Aerosol Particles of Inorganic and Organic Compounds of Atmospheric Relevance», *Atmospheric Chemistry and Physics* 6, n.º 7 (2006): 1937-52, https://doi.org/10.5194/acp-6-1937-2006.

be at RH = 35%[27]. Considering the small difference in the hygroscopicity of the two compounds and the information on the efflorescence point, it is assumed that the particulate matter is composed only of ammonium sulfate (κ = 0.61). Once the correction factor has been calculated, the values of the bin boundaries are recalculated by clearing Dwet from (5).

$$D_{Dry} = D_{Wet} \frac{(RH)}{\left(1+\kappa D_{Wet}\frac{(RH)}{D_{Dry}}\right)^{\frac{1}{3}}}. \quad (5)$$

3. MATERIALS AND METHODS

3.1. Laboratory Devices

The equipment used in the laboratory are the devices used as a reference to evaluate the performance of the sensors and to generate the training dataset for the machine learning algorithms. Regarding particles measurement, according to the Directive 2008/50/EC of the European Parliament and the Council of 21 May 2008 on ambient air quality and cleaner air for Europe, the reference method for PM measurement is the gravimetric measurement method, described in standard UNE-EN 12341:2015. However, this legislation allows other equipment to be used as a reference if it proves to correlate well with this method. In this study, we have used the GRIMM 11-D OPC (Optical Particle Counter) device, tested and validated in air quality stations to be used as a substitute for manual gravimetry as indicated in the UNE-EN 12341:2015 standard. It is a portable instrument calibrated according to ISO 21501-1 to measure dust in the air and its particle size distribution in 31 bins, in a range between 0.250-40 μm. In addition, we compared the GRIMM measurements with a wide range of hyperlocal IoT PM sensors, that includes Nova SDS011, Winsen ZH03B, Honeywell HPMA115S0-004, Plantower PMS3003, Plantower PMS5003, Plantower PMS7003 and Alphasense OPC-N3. The measured values are output as a mass concentration with the unit μg/m3.

[27] Yong Liu et al., «Hygroscopic Behavior of Substrate-Deposited Particles Studied by micro-FT-IR Spectroscopy and Complementary Methods of Particle Analysis», *Analytical Chemistry* 80, n.º 3 (2008): 633-42, https://doi.org/10.1021/ac701638r.

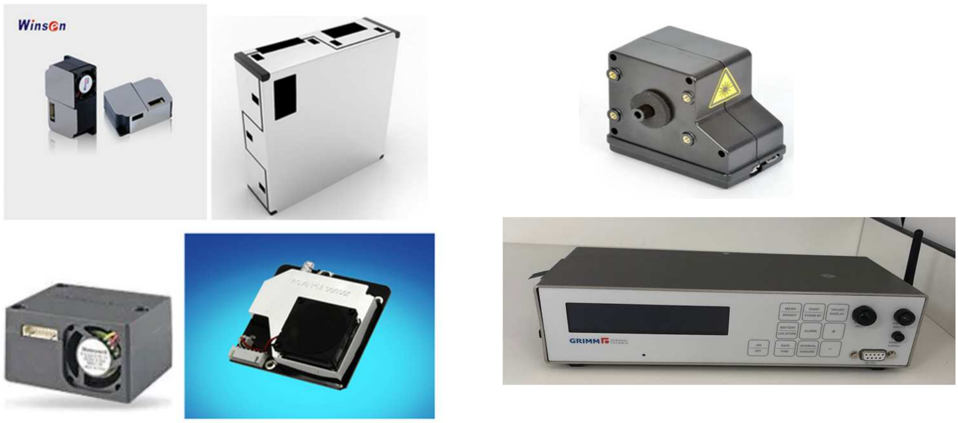


Figure 2. Devices used in Laboratory

3.2. Generation OF Machine Learning Models

The calibration was performed using *Machine Learning* models based on empirical knowledge and not on implicit knowledge of a given discipline. To achieve this a dataset with 43.000 observations was generated, which included the signal of each sensor for PM10, PM2.5 and PM1, mapped with the corresponding observation with the GRIMM 11-D. All the sensors and devices were in the same ambient conditions and sampling times. The evaluation of the system was performed against the reference observations of on 1 min averaged real data. Metrics to quantitatively compare the different devices to the reference monitor concentrations included the Pearson Coefficient, the mean absolute error MAE, and the Coefficient of Determination R^2. The models tested in this paper were *Multiple Linear Regression, Support Vector Machine* and *Random Forest*[28].

3.3. Software and Libraries

Regarding software, all the developments and solutions were implemented in Python 3. Table 1 shows a detailed list of the Python packages used. The core packages for our work are *numpy*, pandas and json in order to work with arrays, data frames and JSON files. Then, all the machine learning models were generated with the scikit-learn package. These models are stored using the *joblib* package. In

28 Trevor Hastie, Robert Tibshirani, y Jerome Friedman, *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*, Springer Series in Statistics (2009)

concrete, the RandomForestRegressor implementation has been used. Statistical analysis was performed using *scipy* and *statistics*. Finally, *matplotlib* was used to visualise the data and results, and other libraries such as os, *shutil*, *getpass*, etc., were applied to work with the servers.

Table I. Python packages used in this study

Name	Use	Reference
numpy	Scientific computing with python	https://numpy.org/
pandas	Data analysis and dataframe manipulatin	https://pandas.pydata.org/
scikit-learn	Machine learning in python	https://scikit-learn.org/
scipy	Mathematics and statistics	https://www.scipy.org/
joblib	Running models as pipeline jobs	https://joblib.readthedocs.io/
bentoml	Machine learning services	https://www.bentoml.ai/
matplotlib	Data visualitation	https://matplotlib.org/

4. RESULTS

4.1. Selection of Sensors

We have tested the different sensors against GRIMM 11-D devices to select the most appropriate one - from 15 March of 2021 to 15 April of 2022. The selection metric was the Pearson Coefficient *r*, calculated for each sensor and fraction. These results are represented in Figure 4, where the three fractions analysed are represented on the X-axis and the different sensors on the Y-axis. The best results were usually obtained for the smaller fractions (PM1 and PM2.5). In contrast, the results for PM10 showed a lower correlation with GRIMM 11-D, and, therefore, worse performance in general. In detail, for PM1 the Plantower sensors (r = 0.73, r = 0.83 and r = 0.86 for PMS3003, PMS5003 and PMS7003, respectively), Winsen ZH03B (r = 0.88) and OPC-N3 (r = 0.74) obtained quite good results. For PM2.5, the best results were obtained for Winsen ZH03B (r = 0.75) and Plantower PMS7003 (r = 0.74). For Nova SDS011 and Honeywell HPMA115S0-004, a value of r = 0.73 was obtained. OPC-N3 sensor showed a value of r = 0.63 for this fraction. Finally, PM10 showed the lowest values, with the best performance for Honeywell HPMA115S0-004 (r = 0.46) and the Nova SDS011 (r = 0.48). For the Alphasense OPC-N3, r = 0.31, r = 0.63 and r = 0.74 for PM10, PM2.5 and PM1.

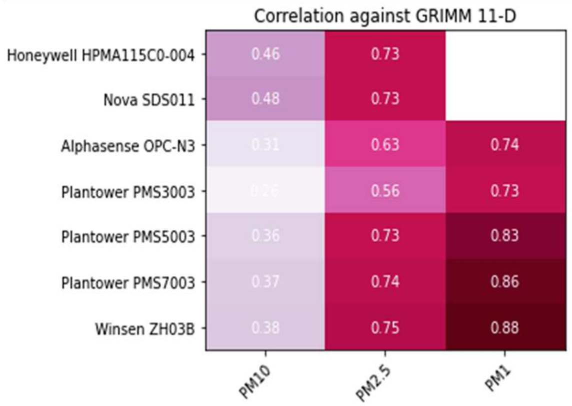


Figure 3. Heatmap showing the Pearson Coefficient. Reference: GRIMM 11-D Optical Particle Counter.

In addition, a more exhaustive analysis based on Linear Regression Models was performed. The approach generates a calibration model for each sensor and computes the slope (m). This value is representative of the offset of the measurement. A slope of 1 means that the sensor's measurements exactly match the reference. The results are shown in Figure 5, where the log(m) is computed to guarantee an easy interpretation, so negative values match with a measurement underestimation and positive values with an overestimation. It is important to note that the Honeywell HPMA115S0-004 is highly underestimated - in order of magnitude. Also, this effect is important for Alphasense OPC-N3 for PM1 and PM2.5 and Nova SDS011. There are not any sensors that overestimate the values in a significant way.

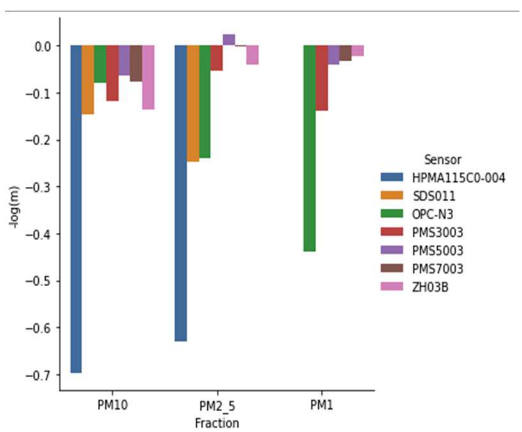


Figure 4. Minus logarithmic value of the slope of each calibration model.

4.2. Machine Learning Models

Using the same datasets, the Alphasense OPC-N3 sensor and Winsen ZH03B were selected to be improved by *machine learning* models. Honeywell HPMA115S0-004 was discarded because of the high offset and Nova SDS due to the lack of ability to measure the PM1 fraction - especially important in nanoparticles. Finally, the sensors of Plantower have also been discarded due to the lower price in comparison with Winsen ZH03B, which has similar performance but it is more reliable in terms of maintenance and durability of the device. The results are plotted in Figure 6, where a clear trend can be observed. For the models, the best results were achieved by *Support Vector Machine*, but they were really similar to *Random Forest*. On the other hand, *Multiple Linear Regression* had lower performance. The results were better for the smallest fractions.

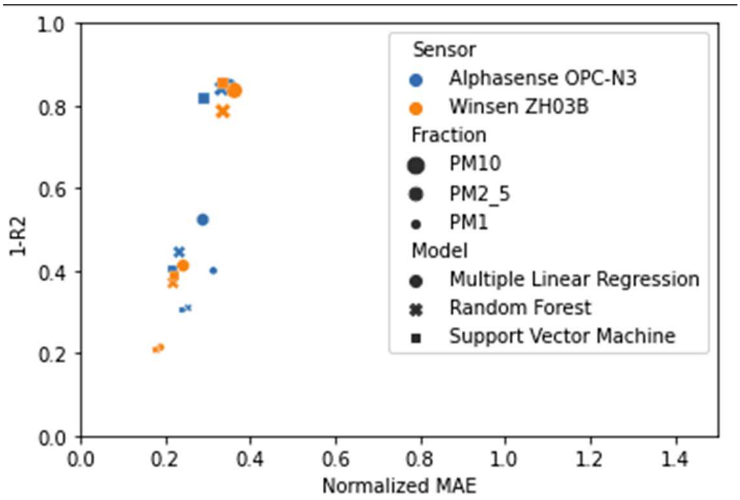


Figure 5. Performance of the different models. Better models are closer to (0,0).

These results are summarized in *Table II*, including the values when we applied the humidity correction algorithm using the *bin* data. Note that this approach was only applied for the Alphasense due to the lack of bin reporting in the Winsen ZH03B sensor. In terms of R^2, the application of this algorithm did not suggest an improvement, but it provided a considerable reduction of the MAE in some cases.

Table II. Result of the Machine Learning Models

Fraction	Multiple Linear Regression	Support Vector Machine	Random Forest
PM1 ZH03B	$R^2 = 0.79$	$R^2 = 0.79$	$R^2 = 0.79$
PM1 ZH03B	MAE $= 2.33$	MAE $= 2.16$	MAE $= 2.21$
PM2.5 ZH03B	$R^2 = 0.59$	$R^2 = 0.61$	$R^2 = 0.63$
PM2.5 ZH03B	MAE $= 4.28$	MAE $= 3.90$	MAE $= 3.86$
PM10 ZH03B	$R^2 = 0.16$	$R^2 = 0.15$	$R^2 = 0.21$
PM10 ZH03B	MAE $= 9.59$	MAE $= 8.82$	MAE $= 8.87$
PM1 OPC	$R^2 = 0.60$	$R^2 = 0.70$	$R^2 = 0.70$
PM1 OPC	MAE $= 3.84$	MAE $= 2.93$	MAE $= 3.11$
PM2.5 OPC	$R^2 = 0.47$	$R^2 = 0.60$	$R^2 = 0.56$
PM2.5 OPC	MAE $= 5.04$	MAE $= 3.77$	MAE $= 4.06$
PM10 OPC	$R^2 = 0.15$	$R^2 = 0.18$	$R^2 = 0.16$
PM10 OPC	MAE $= 9.11$	MAE $= 7.58$	MAE $= 8.63$
PM1 OPC (RH)	-	$R^2 = 0.68$	$R^2 = 0.80$
PM1 OPC (RH)		MAE $= 2.91$	MAE $= 2.13$
PM2.5 OPC (RH)	-	$R^2 = 0.57$	$R^2 = 0.72$
PM2.5 OPC (RH)		MAE $= 4.36$	MAE $= 3.07$
PM10 OPC (RH)	-	$R^2 = 0.18$	$R^2 = 0.28$
PM10 OPC (RH)		MAE $= 8.84$	MAE $= 6.91$

In contrast, the correlations calculated through the Pearson test improves in a significant way when we apply the correction humidity algorithm to PM2.5 and PM1, with quite good results. In this sense, we pass of r = 0.51 to 0.73 for PM2.5 and of r = 0.60 to 0.89 for PM1 in a validation dataset that is independent from the training and test dataset - to simulate real conditions. This last result is plotted in Figure 6.

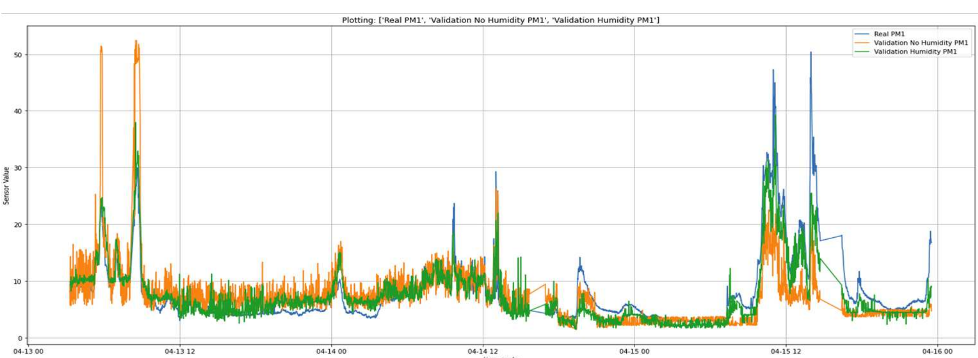


Figure 6. Comparison of PM1 signals in independent data validation. In blue the reference signal, in orange *Random Forest*, and in green *Random Forest* with *Humidity* correction.

5. DISCUSSION

One of the main findings that can be deduced from the statistical and systematic evaluation of the different sensors in the first analysis was the important increment of the error values and a decrease in correlation against GRIMM 11-D in the PM10 fraction. Moreover, this effect was progressive as the best results were obtained for PM1, followed by the PM2.5 fraction and lastly, the PM10 fraction. Therefore, it is logical to think that this error is associated with the physical fundamentals underlying the technology that suppose a high uncertainty in the measurement of large particles. Particle size had a critical effect on measurements because the transformation to mass concentration was indirectly calculated according to Section 3.1. Once determined the diameter of a particle, its mass was calculated using the density formula, as $= d * v$, where m is the mass, d represents the density and v references the volume of the particle. The volume was obtained from the radius as $v = \frac{4}{3}\pi r^3$. This implies that the larger the diameter, the greater the mass increases with a cubic factor.

Another important issue is the fact that Alphasense OPC-N3 sensors showed similar results in comparison with the Winsen ZH03B sensor, which is less expensive. The price of Alphasense OPC-N3 sensors is around ten times higher in comparison with the rest of sensors tested in this study. Therefore, it was expected to obtain the best results. In contrast, the experimental results showed that the correlations were worse in this case. There are some reasons that can cause this paradoxical effect: i) the FIRMWARE configuration of Alphasense OPC-N3 is complex in comparison to the rest of the devices, so it was not optimised at maximum. The sensor is reading raw data, and a low-cost sensor may perform processing of the signal - moving averages, rounding of decimals, etc. that should be configured via FIRMWARE in OPC-N3; ii) the sensor operates in discontinuous mode, reading data every 30 s and resting 30. Low-cost sensors do not offer this option; iii) this sensor can measure bins higher than the PM10 fraction, which could be a source of noise. It is necessary to perform an exhaustive study of this sensor to explore all the possibilities for all these reasons.

Regarding *machine learning*, we can conclude that the artificial intelligence models and the drying system considerably improved the correlation concerning the base sensor. In addition, these results were comparable to those obtained in the state of the art. For the study performed for the PM2.5 fraction, our highest value of R^2

was similar to the ones obtained in other studies for Alphasense – 0.72 vs 0.67[29]. In addition, the values with the machine learning models were lower than those obtained in other studies in terms of R^2 [30], for the PM2.5 fraction - 0.72 vs 0.88, indicating that an approach based on *deep learning* should be explored. In contrast, our work presented significant improvements in relation to the state of the art: i) Our devices have been designed for all the fractions, and not only for the PM2.5 fraction, obtaining promising results for PM1 and ii) our solutions have been tested in a *field* scenario using real particles. About humidity correction, it reduced the overestimation of PM1 - Figure 7- and a reduction of the error, as shown in previous work[31]. Thus, this correction humidity approach is feasible and can be complemented with *hardware* improvements in the IoT devices - such as humidity filters that we are working on - in order to obtain better results for PM10 and develop an IoT device that can monitor the performance in a Low Emission Zone based on the sensor OPC-N3.

CONCLUSIONS

This article describes the results obtained in a pilot project carried out in Madrid, which aims to develop a system for measuring particulate matter in low-emission areas. The proposed prototype combines innovative hardware solutions - a two-column drying system - and machine learning and artificial intelligence models based on the humidity correction algorithms available in the literature. The results were quite promising for PM2.5 and PM1, obtaining a correlation of 0.72 and 0.89 for in the best scenario, working our solution in a real scenario, with all parameters affecting the device in a real environment, so we propose for next work that continuous monitoring of nanoparticles is possible in the context of a low-emission area. The ability to generate and query this data in real-time allows cities to monitor violations and extreme events and make decisions quickly. This facilitates the efficient management and promotes clean and healthy areas by new European legislation. The proposed prototype successfully meets these needs and emerges as a product that meets the city's needs.

However, some points for improvement need to be worked on and investigated in-depth in future projects. The first of these is the optimisation of all the capabilities

[29] Feenstra et al, 2019, 116946.
[30] Loh et al, 2019, 452-460
[31] Di Antonio et al, 2019, 2790

of the Alphasense OPC-N3 sensor to get the maximum performance out of it. In addition, further research is needed on the role of the underlying measurement technology. Therefore, we propose to generate a dataset that includes reference data from different devices - OPC, TEOM, beta attenuation, etc. - to obtain a representative dataset. Thus, it is possible to obtain a more accurate model that works better with gravimetric approaches. The best strategy to perform this task is to install devices in different air quality stations and guarantee the selected stations. Finally, the last issue proposed is an extension of the artificial intelligence service to calculate more indicators. In this sense, an analysis of primary and secondary aerosols could be interesting and overcome the state of art of particulate matter monitoring. This could be achieved by integrating Chemistry Transport Models and satellite measurements, such as Copernicus.

ACKNOWLEDGMENTS

This work has been supported by the fellowship 21300/FPI/19 founded by Fundación Séneca and co-founded by HOP Ubiquitous S.L. Región de Murcia (Spain). For this, we would especially like to thank these two institutions for their support, which has made this work possible. In addition, the work is also founded by CO_2 Marketplace from EIT Digital and ODALA from CEF.

BIBLIOGRAPHY

1. Cho, Hyuntae, and Yunju Baek. "Practical Particulate Matter Sensing and Accurate Calibration System Using Low-Cost Commercial Sensors." *Sensors* 21, no. 18 (2021): 6162. https://doi.org/10.3390/s21186162.
2. Cohen, Aaron J, Michael Brauer, Richard Burnett, H Ross Anderson, Joseph Frostad, Kara Estep, Kalpana Balakrishnan, et al. "Estimates and 25-Year Trends of the Global Burden of Disease Attributable to Ambient Air Pollution: An Analysis of Data from the Global Burden of Diseases Study 2015." *The Lancet* 389, no. 10082 (2017): 1907–18. https://doi.org/10.1016/ s0140-6736(17)30505-6.
3. Colvile, R.N, E.J Hutchinson, J.S Mindell, and R.F Warren. "The Transport Sector as a Source of Air Pollution." *Atmospheric Environment* 35, no. 9 (January 1, 2001): 1537–65. https://doi.org/10.1016/s1352-2310(00)00551-3.
4. Crilley, Leigh R., Marvin Shaw, Ryan Pound, Louisa J. Kramer, Robin Price, Stuart Young, Alastair C. Lewis, and Francis D. Pope. "Evaluation of a Low-Cost Optical Particle Counter (Alphasense OPC-N2) for Ambient Air Monitoring." *Atmospheric Measurement Techniques* 11, no. 2 (2018): 709–20. https://doi.org/10.5194/amt-11-709-2018.

5. Di Antonio, Andrea, Olalekan A. M. Popoola, Bin Ouyang, John Saffell, and Roderic L. Jones. "Developing a Relative Humidity Correction for Low-Cost Sensors Measuring Ambient Particulate Matter." MDPI. Multidisciplinary Digital Publishing Institute, August 24, 2018. https://doi.org/10.3390/s18092790.
6. Feenstra, Brandon, Vasileios Papapostolou, Sina Hasheminassab, Hang Zhang, Berj Der Boghossian, David Cocker, and Andrea Polidori. "Performance Evaluation of Twelve Low-Cost PM2.5 Sensors at an Ambient Air Monitoring Site." *Atmospheric Environment* 216 (2019): 116946. https://doi.org/10.1016/j.atmosenv.2019.116946.
7. Fensterer, Veronika, Helmut Küchenhoff, Verena Maier, Heinz-Erich Wichmann, Susanne Breitner, Annette Peters, Jianwei Gu, and Josef Cyrys. "Evaluation of the Impact of Low Emission Zone and Heavy Traffic Ban in Munich (Germany) on the Reduction of PM10 in Ambient Air." *International Journal of Environmental Research and Public Health* 11, no. 5 (2014): 5094–5112. https://doi.org/10.3390/ijerph110505094.
8. Fuzzi, S., U. Baltensperger, K. Carslaw, S. Decesari, H. Denier van der Gon, M. C. Facchini, D. Fowler, et al. "Particulate Matter, Air Quality and Climate: Lessons Learned and Future Needs." *Atmospheric Chemistry and Physics* 15, no. 14 (2015): 8217–99. https://doi.org/ 10.5194/acp-15-8217-2015.
9. Görner, Peter, Xavier Simon, Denis Bémer, and Göran Lidén. "Workplace Aerosol Mass Concentration Measurement Using Optical Particle Counters." *J. Environ. Monit.* 14, no. 2 (2012): 420–28. https://doi.org/10.1039/c1em10558b.
10. Hastie, Trevor, Jerome Friedman, and Robert Tisbshirani. *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*. New York: Springer, 2017.
11. Jayaratne, Rohan, Xiaoting Liu, Phong Thai, Matthew Dunbabin, and Lidia Morawska. "The Influence of Humidity on the Performance of a Low-Cost Air Particle Mass Sensor and the Effect of Atmospheric Fog." *Atmospheric Measurement Techniques* 11, no. 8 (2018): 4883–90. https://doi.org/10.5194/amt-11-4883-2018.
12. Köhler, Hilding. "The Nucleus in and the Growth of Hygroscopic Droplets." *Trans. Faraday Soc.* 32 (1936): 1152–61. https://doi.org/10.1039/tf9363201152.
13. Lewis, Alastair, and Peter Edwards. "Validate Personal Air-Pollution Sensors." *Nature* 535, no. 7610 (2016): 29–31. https://doi.org/10.1038/535029a.
14. Li, Jiayu, Simar K. Mattewal, Sameer Patel, and Pratim Biswas. "Evaluation of Nine Low-Cost-Sensor-Based Particulate Matter Monitors." *Aerosol and Air Quality Research* 20, no. 2 (2020): 254–70. https://doi.org/10.4209/aaqr.2018.12.0485.
15. Liu, Xiaoting, Rohan Jayaratne, Phong Thai, Tara Kuhn, Isak Zing, Bryce Christensen, Riki Lamont, et al. "Low-Cost Sensors as an Alternative for Long-Term Air Quality Monitoring." *Environmental Research* 185 (2020): 109438. https://doi.org/10.1016/ j.envres.2020.109438.
16. Liu, Yong, Zhiwei Yang, Yury Desyaterik, Paul L. Gassman, Hai Wang, and Alexander Laskin. "Hygroscopic Behavior of Substrate-Deposited Particles Studied by Micro-Ft-Ir Spectroscopy and Complementary Methods of Particle Analysis." *Analytical Chemistry* 80, no. 3 (2008): 633–42. https://doi.org/10.1021/ac701638r.

17. Loh, Byoung Gook, and Gi Heung Choi. "Calibration of Portable Particulate Matter–Monitoring Device Using Web Query and Machine Learning." *Safety and Health at Work* 10, no. 4 (2019): 452–60. https://doi.org/10.1016/j.shaw.2019.08.002.
18. Rai, Aakash C., Prashant Kumar, Francesco Pilla, Andreas N. Skouloudis, Silvana Di Sabatino, Carlo Ratti, Ansar Yasar, and David Rickerby. "End-User Perspective of Low-Cost Sensors for Outdoor Air Pollution Monitoring." *Science of The Total Environment* 607-608 (2017): 691–705. https://doi.org/10.1016/j.scitotenv.2017.06.266.
19. Sadighi, Kira, Evan Coffey, Andrea Polidori, Brandon Feenstra, Qin Lv, Daven K. Henze, and Michael Hannigan. "Intra-Urban Spatial Variability of Surface Ozone in Riverside, CA: Viability and Validation of Low-Cost Sensors." *Atmospheric Measurement Techniques* 11, no. 3 (2018): 1777–92. https://doi.org/10.5194/amt-11-1777-2018.
20. Sousan, Sinan, Swastika Regmi, and Yoo Min Park. "Laboratory Evaluation of Low-Cost Optical Particle Counters for Environmental and Occupational Exposures." *Sensors* 21, no. 12 (2021): 4146. https://doi.org/10.3390/s21124146.
21. Svenningsson, Birgitta., Jenny Rissler, Erik Swietlicki, Mihaela Mircea, M. Bilde, Maria Cristina Facchini, Steffano Decesari, et al. "Hygroscopic Growth and Critical Supersaturations for Mixed Aerosol Particles of Inorganic and Organic Compounds of Atmospheric Relevance." *Atmospheric Chemistry and Physics* 6, no. 7 (2006): 1937–52. https://doi.org/10.5194/acp-6-1937-2006.
22. Wang, Yang, Jiayu Li, He Jing, Qiang Zhang, Jingkun Jiang, and Pratim Biswas. "Laboratory Evaluation and Calibration of Three Low-Cost Particle Sensors for Particulate Matter Measurement." *Aerosol Science and Technology* 49, no. 11 (2015): 1063–77. https://doi.org/10.1080/02786826.2015.1100710.
23. Zieger, Paul., Rahel Fierz-Schmidhauser, Ernest Weingartner, and Urs Baltensperger. "Effects of Relative Humidity on Aerosol Light Scattering: Results from Different European Sites." *Atmospheric Chemistry and Physics* 13, no. 21 (2013): 10609–31. https://doi.org/10.5194/ acp-13-10609-2013.
24. Zikova, Nadezda, Philip K. Hopke, and Andrea R. Ferro. "Evaluation of New Low-Cost Particle Monitors for PM2.5 Concentrations Measurements." *Journal of Aerosol Science* 105 (2017): 24–34. https://doi.org/10.1016/j.jaerosci.2016.11.010.
25. Zimmerman, Naomi, Albert A. Presto, Sriniwasa P. Kumar, Jason Gu, Aliaksei Hauryliuk, Ellis S. Robinson, and Allen L. Robinson. "A Machine Learning Calibration Model Using Random Forests to Improve Sensor Performance for Lower-Cost Air Quality Monitoring." *Atmospheric Measurement Techniques* 11, no. 1 (2018): 291–313. https://doi.org/10.5194/amt-11-291-2018.

Chapter 6

THE IMPACT OF URBANIZATION ON THE QUALITY OF NATURAL RESOURCES AND FOOD SECURITY

Mahreen Alam* - Muhammad Ashfaq**

INTRODUCTION

Rapid population growth is not only a threat to food security but rising urbanisation has a substantial impact on natural resources. The global population will be increased to 9 billion people by 2050 [1]. Food security refers to the availability of a significant quantities of good-quality food to maintain nutritional well-being [2]. Many developing countries are quickly urbanizing, and extreme poverty is common phenomena in these areas. Urbanization take place in two ways. First, rural population move toward urban areas. Second, cities emerge in places where crops were previously produced. The urban population in Asian countries will increase from 55 percent to 68 percent by the 2050 [3]. Urbanization is the process of removing trees and transforming land to construct modern infrastructure [4]. Groundwater recharge decreases as urbanisation increases. Groundwater level is sinking at a pace of 1.38 meters per year [5].

* mahreenalam07@gmail.com

** ashfq9@hotmail.com, Institute of Agricultural and Resources Economics, University of Agriculture Faisalabad

1 Liu, Xian, Yueyue Xu, Bernie A. Engel, Shikun Sun, Xining Zhao, Pute Wu, and Yubao Wang. 2021 "The impact of urbanization and aging on food security in developing countries: The view from Northwest China." *Journal of Cleaner Production* 292: 126067.

2 Sekaran, Udayakumar, Liming Lai, David Ussiri, Sandeep Kumar, and Sharon Clay. 2021. "Role of integrated crop-livestock systems in improving agriculture production and addressing food security–A review." *Journal of Agriculture and Food Research* 5: 100190.

3 Kookana, Rai S., Pay Drechsel, Priyanka Jamwal, and Joanne Vanderzalm. 2020. "Urbanisation and emerging economies: Issues and potential solutions for water and food security." *Science of the Total Environment* 732: 139057.

4 Ahmad, Waqas, Javed Iqbal, Muhammad J. Nasir, Burhan Ahmad, Muhammad T. Khan, Shahid N. Khan, and Syed Adnan. 2021. "Impact of land use/land cover changes on water quality and human health in district Peshawar Pakistan." *Scientific Reports* 11, no. 1: 1-14.

5 ul Haq, Faraz, Usman A. Naeem, Hamza F. Gabriel, Noor M. Khan, Ijaz Ahmad, Habib Ur Rehman, and Muhammad A. Zafar. 2021. "Impact of Urbanization on Groundwater Levels in Rawalpindi City, Pakistan." *Pure and Applied Geophysics* 178, no. 2: 491-500.

The water demands of the crops are not being met by a mix of surface water and rainfall. As a result, a large amount of groundwater is required to provide 40 to 60 percent of irrigation needs in Pakistan [6]. The country has 1.2 million operational private tube wells. The total groundwater extraction in Pakistan is around 60 billion cubic meters [7]. The water crisis is not just about scarcity; the quality of groundwater is also a severe threat to human survival [8]. Decreased availability of good quality water resources leads to use poor quality irrigation water for agricultural production [9]. Intensive use of groundwater in agriculture is no doubt raising agricultural productivity, but it is also reducing remaining resources of water [10] [11]. Rapid groundwater extraction is resulting in salinity as well as sea water intrusion in coastal areas [12]. Water quality is also deteriorating from disproportionate fertilizer use in agriculture. Absence of proper waste management system and excessive industrial and domestic garbage dumping is threating the groundwater resources [13].

The bulk of the world's population relies on groundwater for drinking and other reasons [14]. In dry and semiarid areas, when precipitation and runoff are limited, groundwater is an important resource [15]. Contaminated groundwater exposes

---

6 Muzammil, Muhammad, Azlan Zahid, and Lutz Breuer. 2020. "Water resources management strategies for irrigated agriculture in the Indus Basin of Pakistan." *Water* 12, no. 5: 1429.

7 Qureshi, Asad S. 2020. "Groundwater governance in Pakistan: From colossal development to neglected management." *Water* 12, no. 11: 3017.

8 Sleet, Phoebe. 2019 "Water resources in Pakistan: scarce, polluted and poorly governed. 2019. " *Independent Strategic Analysis of Australia's Global Interest. Nedlands* 2:1-5.

9 Alam, Mahreen, Muhammad Ashfaq, Sarfraz Hassan, and Asghar Ali. 2021. "The Analysis of Groundwater Quality and the Impact of Remedial Measures Adopted by the Wheat Growers: Using Endogenous Switching Regression Model Approach." *Journal of Economic Impact* 3, no. 3: 144-151.

10 Bhattarai, Nishan, Adrienne Pollack, David B. Lobell, Ram Fishman, Balwinder Singh, Aaditya Dar, and Meha Jain. 2021."The impact of groundwater depletion on agricultural production in India." *Environmental Research Letters* 16, no. 8: 085003.

11 Figureau, Anne-Gaelle., M. Montginoul, and Jean-Daniel Rinaudo. 2015. "Policy instruments for decentralized management of agricultural groundwater abstraction: a participatory evaluation." *Ecological Economics* 119: 147-157.

12 Basharat, Muhammad, and Maham Basharat. 2019. "Developing Sukh-Beas as a potential recharge site during wet years for Bari Doab." *Applied Water Science* 9, no. 7: 1-15.

13 Shoemaker, Cory M., Gary N. Ervin, and Evelyn W. DiOrio. 2017. "Interplay of water quality and vegetation in restored wetland plant assemblages from an agricultural landscape." *Ecological Engineering* 108: 255-262.

14 Chen, Feifei, Leihua Yao, Gang Mei, Yinsheng Shang, Fansheng Xiong, and Zhenbin Ding. 2021. "Groundwater Quality and Potential Human Health Risk Assessment for Drinking and Irrigation Purposes: A Case Study in the Semiarid Region of North China" *Water* 13, no. 6: 783. https://doi.org/10.3390/w13060783.

15 Nsabimana, Abel, Peiyue Li, Song He, Xiaodong He, S. M. K. Alam, and Misbah Fida. 2021. "Health risk of the shallow groundwater and its suitability for drinking purpose in Tongchuan, China." *Water* 13, no. 22: 3256.

humans to dangerous materials, putting their health at risk [16]. Dietary quality has an impact on food security [17]. As a result of deteriorating groundwater quality, people are becoming food insecure [18].

Wheat plays an important role in achiving food security. Wheat is top cereal crop in the region and it is cultivated on a large scale. It contains important nutrients which are necessary for living organisms to function. In Pakistan, it contributes 9.2 percent in value addition and 1.8 per cent to gross domestic production. Wheat crop reported increase of 8.1 percent in production in the year 2020. The land under wheat cultivation is increased by 1.7 percent over the last year. The increase area under cultivated is key cause of higher production [19]. With irrigation water salinity increased by 1 gramme per litre to 5 gramme per litre, water efficiency decreased linearly [20]. Drinking water is also extracted from the ground. The quality of poor groundwater affects not only human health but also the health and productivity of dairy animals [21]. Animal supplies are also in high demand. Increased livestock output will be critical in ensuring long-term food security in most urbanised regions [22]. There are several studies that assess groundwater quality in Pakistan, but there are few that assess the impact of urbanisation on groundwater quality in Pakistan.

1. MATERIAL AND METHODS

1.1. Area of the stud

Agriculture is particularly significant in the Sahiwal District. The District covers an area of 3201 km2 and has a population of approximately 7.3 million people. With an average rainfall of 177 mm. The weather is hot. Wheat is a major crop and every

---

[16] Karunanidhi, D., T. Subramani, Priyadarsi D. Roy, and Hui Li. 2021. "Impact of groundwater contamination on human health." *Environmental Geochemistry and Health* 43, no. 2: 643-647.

[17] World Health Organization. 2020. "*The state of food security and nutrition in the world 2020": transforming food systems for affordable healthy diets* 2020. Food & Agriculture Org., 2020.

[18] Janjua, Shahmir, Ishtiaq Hassan, Shoaib Muhammad, Saira Ahmed, and Afzal Ahmed. 2021. "Water management in Pakistan's Indus Basin: challenges and opportunities." *Water Policy* 23, no. 6: 1329-1343.

[19] Government of Pakistan. Economic survey of Pakistan. 2021. Government of Pakistan, Finance division, Economic Advisor's wing, Islamanad. Pakistan.

[20] Dawooda, Faizan, Malik M. Akhtarb, and Muhsan Ehsanc. 2021. "Evaluating urbanization impact on stressed aquifer of Quetta Valley, Pakistan". Desalination and Water Treatment 222, doi: 10.5004/dwt.2021.27068. 103-113.

[21] Kumar, Sumant, Manish Kumar, Veerendra K. Chandola, Vinod Kumar, Ravi K. Saini, Neeraj Pant, Nikul Kumari *et al*. 2021. "Groundwater Quality Issues and Challenges for Drinking and Irrigation Uses in Central Ganga Basin Dominated with Rice-Wheat Cropping System." *Water* 13, no. 17: 2344.

[22] Hatab, Assem Abu, Maria E. R. Cavinato, and Carl J. Lagerkvist. 2019. "Urbanization, livestock systems and food security in developing countries: A systematic review of the literature." *Food Security* 11, no. 2: 279-299.

farmer is growing it [23]. Groundwater quality is varying in the district from good to saline. The quality of groundwater is positively related to the distance from the main city. Farming is the principal occuption in the study area. Due to abased groundwater quality farm output is declining.

1.2. Data Collection

Data were collected from 300 respondents, using stratified random sampling technique. Three locations were identified, location-I was identified with up to 10.0 km distance from the main city, location-II was 10.1-20.0 km away and Location-III with 20.1-30.0 km away from the main city. Data were collected from 100 respondents from each location.

1.3. Groundwater analysis

Groundwater samples were tested for electric conductivity (Ec µS/cm), Total dissolve salt (TDS ppm) and pH using Ec meter during the survay.

1.4. Production Function Analysis

The Cobb-Douglas production functions are often used in agriculture to estimate the relationship between inputs and outputs. Using the production function technique, many researchers have assessed crop losses owing to salinity [24]. Some researchers used different production functions for different level of salinity to highlight the impact of salinity [25].

1.5. Data envolpment Analysis (DEA)

It is a non-parametric approach for measuring relationships using mathematical techniques [26]. The DEA evaluates the performance of peer entities referred to as decision-making units (DMUs). When inputs and outputs cannot be enhanced without any change in the other inputs and outputs, the DMUs are considered fully

---

[23] Khalid, Umer B., Pomi Shahbaz, Shamsheer ul Haq, and Sikandar Javeed. 2017. "Economic Analysis of Integrated Farming Systems on Farm Income. A case Study of Sahiwal District, Punjab, Pakistan." *International Journal of Management and Economics* 3, no. 11: 1434-1444.

[24] Hassan, G. Z., and F. R. Hassan. 2017. "Sustainable use of groundwater for irrigated agriculture: A case study of Punjab, Pakistan." *European Water* 57: 475-480.

[25] Jha, Pramod, S. K. Srivastava, and S. K. Dubey. 2012. "Effect of water quality on yield and water use efficiency of irrigated wheat crop." *Indian journal of soil conservation* 40, no. 3: 236-239.

[26] Yilmaz, Hasan, Fekadu Gelaw, and Stijn Speelman. 2020. "Analysis of technical efficiency in milk production: a cross-sectional study on Turkish dairy farming." *Revista Brasileira de Zootecnia* 49. 1-10.

efficient [27]. Data Envelopment Analysis (DEA) is frequently used to assess technical and economic efficiency in virtually every aspect of life [28]. It is used to assess performance by determining the relative efficiency of decision-making units [29 30].

Maximize: $$T_0 = \frac{\sum_{i=0}^{r} w_i Y_i}{\sum_{j=0}^{t} Z_j X_i}$$

Subject to:

$$\frac{\sum_{i=0}^{r} W_i Y_{im}}{\sum_{j=0}^{t} Z_j X_i} \leq 1 \quad m = 1,2,\ldots, n$$

$W_i \geq 0$; $i = 1,2,\ldots, r$

$Z_j \geq 0$; $j = 1,2,\ldots, t$

Where:

Here Y_i is Output of wheat, X_i are possible Inputs W_i are weights for the output, Z_j isw eight for the input, N is number of DMUs, r is number of inputs and t is number of outputs.

1.6. Tobit regression analysis

The Tobit model deals with a continuous dependent variable that is constrained in nature. The Tobit regressions are suitable for modelling, in which the dependent variable is bounded between two values. The value of the dependent variable cannot move away from those boundaries. If the dependent variable is bounded between zero and one, it cannot take values less than zero and greater than one [31]. In such a case, the explanatory variables become non-linear, and variance tends to decrease as the mean of the variable gets closer to one of the boundaries [32].

---

27 Pan, Zhiwei, Decai Tang, Haojia Kong, and Junxia He. 2022. "An Analysis of Agricultural Production Efficiency of Yangtze River Economic Belt Based on a Three-Stage DEA Malmquist Model." *International Journal of Environmental Research and Public Health* 19, no. 2: 958.

28 Mwalupaso, Gershom Endelani, Shangao Wang, Sanzidur Rahman, Essiagnon J. Alavo, and Xu Tian. 2019. "Agricultural informatization and technical efficiency in maize production in Zambia." *Sustainability* 11, no. 8: 2451.

29 Gelaw, Fekadu, and Bezabih Emana. 2004. "Analysis of technical efficiency of wheat production: a study in Machakel Woreda, Ethiopia." *An M. Sc Thesis Presented at Alemaya University* 7 no 2:1-15.

30 Musa, H. Ahmed, Lemma Z, and Endrias G. 2015. "Measuring technical, economic and allocative efficiency of maize production in subsistence farming: Evidence from the Central Rift Valley of Ethiopia." *Applied Studies in Agribusiness and Commerce* 9, no. 3: 63-73.

31 Odah, Meshal H., Bahr K. Mohammed, and Ali S. M. Bager. 2018. "Tobit Regression Model to Determine the Dividend Yield in Iraq." *LUMEN Proceedings* 3: 347-354.

32 Yu, Hongshen, Yundi Dai, and Lihong Zhao. 2021. "Evaluation and Study on influencing factors of agricultural products logistics efficiency based on DEA-Tobit model--from panel data from 2010 to 2019." In *Journal of Physics: Conference Series* 1941 no 1:012070.

$$\text{Yi} = \begin{cases} Y_i^* & : if\ Y_i^* > 0 \\ 0 & : if\ Y_i^* \leq 0 \end{cases}$$

Yi is technical efficiency of inputs to produce output that takes positive values only if a farmer applied the inputs.

2. RESULTS AND DISCUSSIONS

The Ec level of groundwater has the greatest impact on agricultural yield. It acts as a baseline for measuring water quality [33]. Results show that the Ec value declined as the distance from the main city increased as shown in Figure 1. The maximum Ec value near the city was 2865 µS/cm and minimum value was 349 µS/cm. Urbanization is contributing to increase the salinity in the groundwater resources.

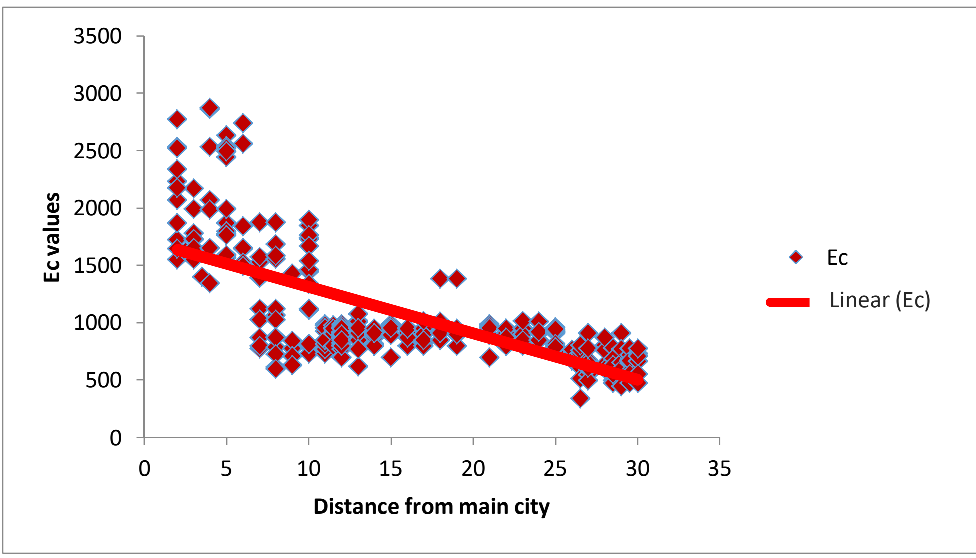


Figure 1: Relationship between EC value and distance from the city

Source: Author's own calculation

Most of the crops can tolerate a wide pH range. It is not very harmful for crop but it effects the performance of livestock. The pH also improves when move away from the main city as shown in Fidure 2.

33 Arshad, Muhammad, and Aamir Shakoor. 2017. "Irrigation water quality." *Pakistan Journal of Agricultural Research* 31, no. 2: 102-123.

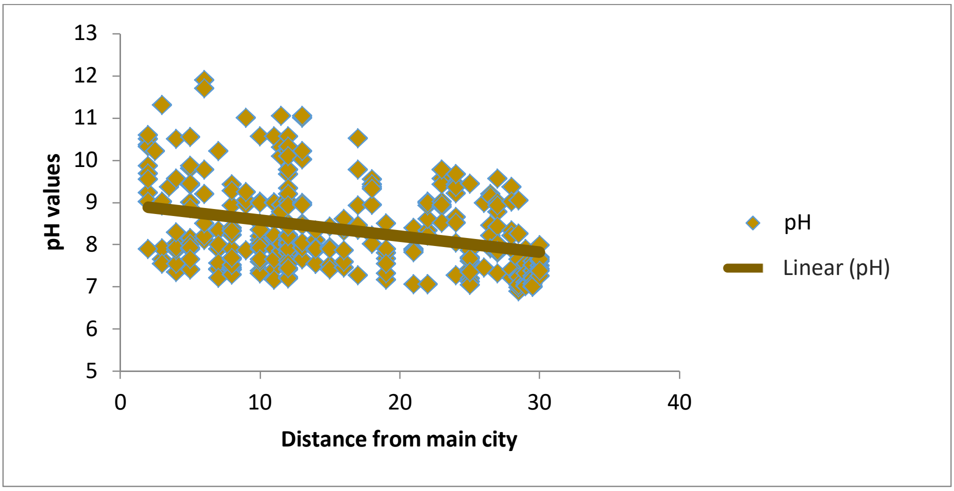


Figure 2: Relationship between pH value and distance from the city

Source: Author's own calculation

The TDS also showed th epostive relationship with distance from the main city as shown in Figure 3. The rising population leads to higher urbanization that leades to higher industries and food processing. These all factors contribute to increas the total salt in under ground water resources.

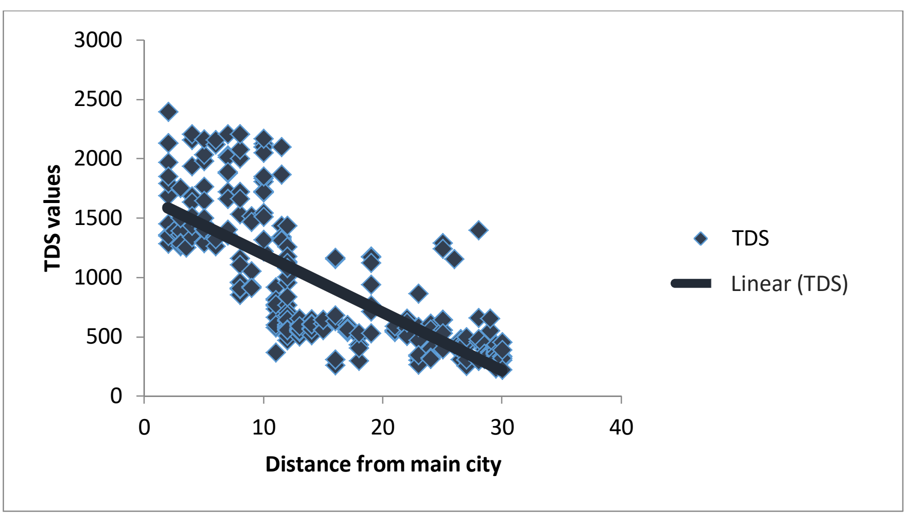


Figure 3: Relationship between TDS value and distance from the city

Source: Author's own calculation

The wheat crop is critical to sustaining food security in the country. Every person in Pakistan consumes it on a daily basis. Wheat is a moderately salt-tolerant crop with large salinity tolerance genotypic differences. It is one of the most important crops for meeting people's daily protein and calorie needs. Wheat yield is sgnificantly low in salt-affected areas in Pakistan [34]. In the study area the avergae yield on each location is shown in Figure 4. There exist postive relationship between Distance from city and wheat yield.

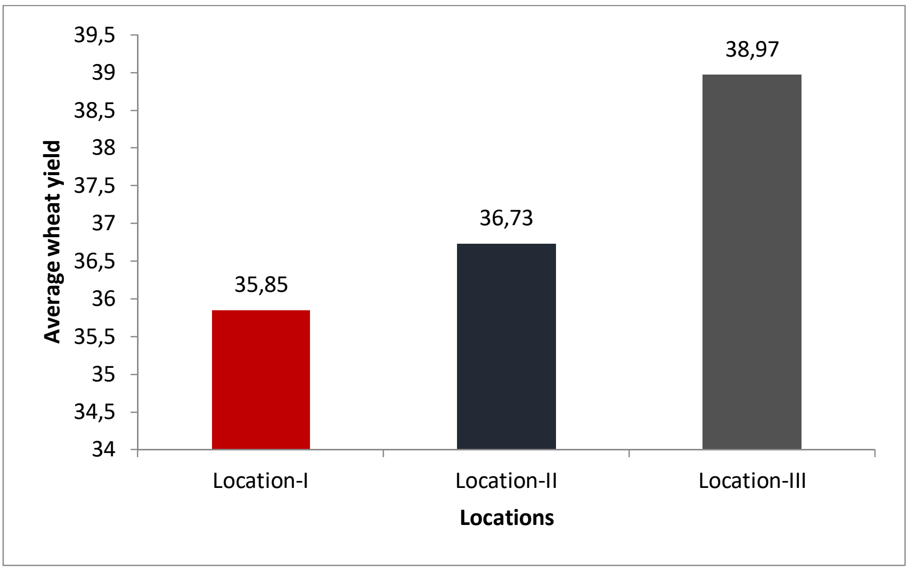


Figure 4: Average wheat yield on three locations

Source: Author's own calculation

Important input variables for wheat crops include tillage number, seed quantity, fertiliser application numbers, irrigation numbers, and labour numbers. The result of production function showed that the the coefficient values and relationship become better as the distance increased from the urban areas.

With poor groundwater quality the other inputs also reduce their capability. The estimated coefficients for tillage, irrigation, fertilizer, were significant at less

[34] Abbas, Ghulam, Muhammad Saqib, Qaisir Rafique, M. Atiq ur Rehman, Javaid Akhtar, M. Anwar ul Haq, and M. Nasim. 2013. "Effect of salinity on grain yield and grain quality of wheat (Triticum aestivum L.)." *Pak J Bot* 50 (2013): 185-189.

than 5 percent of probability level, at location-I. Tillage has positive significant impact at all three locations. Irrigation showing negative relationship with wheat production at location-I because groundwater quality was poor so it induces negative impact on wheat crop, so more use of poor groundwater negatively affect the wheat yield. At location-II and III irrigation showed positive impact, and the impact is significant at location-III. Fertilizer is also showing negative relationship at location-I while location-II and III the relationship is positive and significant.

Table 1: Cobb-Douglas Production Function Estimates for Wheat crop

Variables	**Location-I**	**Location-II**	**Location-III**
Constant	8.241 (0.004)*	11.765 (0.073)**	13.508 (0.021)*
Tillage	.195 (0.005)*	.096 (0.162)	.128 (.047)*
Irrigation	-.247 (0.049)*	.101 (0.219)	.065 (0.036)*
Fertilizer	-.128 (0.043)*	.193 (0.000)*	.177 (0.000)*
Seed quantity	.061 (0.731)	.442 (0.060)**	.296 (0.217)
Labour	.243 (0.182)	.156 (0.011)*	.063 (0.286)
R^2	0.49	0.51	0.60

Source: Author's own calculation. Note: Dependent variable: wheat yield, Significance value is given in parentheses. * Significant at 5% level. ** Significant at 10%.

The technical efficiency of inputs was calculated by using DEA analysis. The efficiency of all the inputs improves with improved irrigation water quality. The relationship between the technical efficiency of wheat and distance from the main city is depicted in Figure 5.

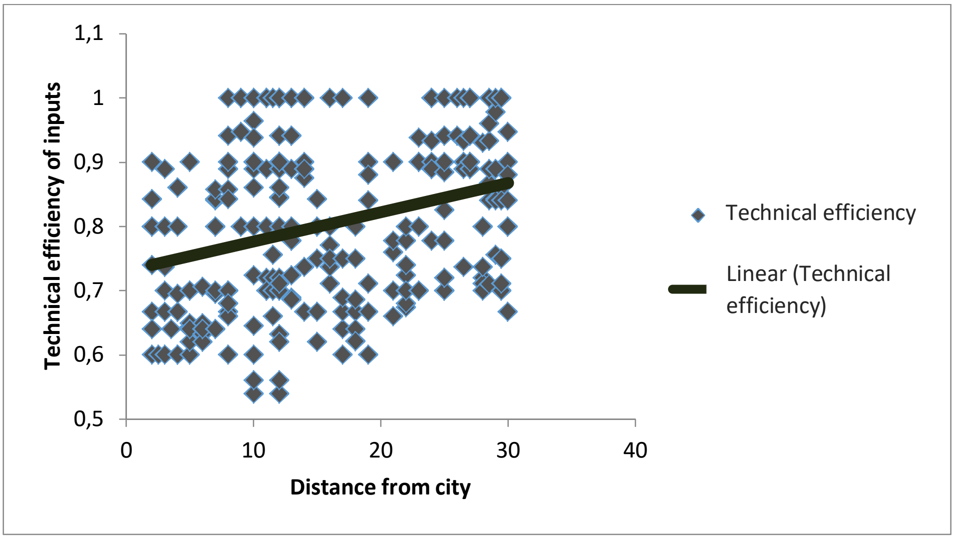


Figure 5: Relationship between Technical efficiency and distance from city

Source: Author's own calculation

The technical efficiency of inputs can be affected by varicious factors. Tobit model was applied to highlight the impact of urbanization on technical efficiency of input used for wheat production. The results showed that education, experience, family size and tube-well ownership have positive significant impact on efficiency of wheat crop. Distance from market, showed negative relation with efficiency. Tobit model results with efficiency of wheat are shown in Table 2.

Table 2: Tobit model results for Wheat

Variables	**Coefficient**	**Std. Error**	**Significance**
Constant	0.6892	0.0341	0.000
Education	0.0038	0.0019	0.042
Experience	0.0010	0.0007	0.193
Family size	-0.0007	0.0021	0.717
Family worker	0.0149	0.0071	0.044
Distanc from city	0.0023	0.0015	0.049
Farm machinary	0.963	0.169	0.000

Source: Author's own calculation

3. CONCLUSIONS AND RECOMMENDATIONS

The destruction of natural resources is largely due to growing urbanization. The fundamental reason for rapid urbanisation is to meet the needs of an increasing population. Shalter is not the only requirment of growing population. Food, clothing, medication, and a variety of other items are required for human survival. To accommodate these requirments humanbeings, industries are expanding as well. When all of these factors are combined, the quality of groundwater compromised. Poor groundwater quality reduces the food security because it is largely used for drinking and irrigation purposes. In Punjab, groundwater plays a critical role in irrigation. The poor quality of groundwater is lowering wheat yields, posing a threat to the rising population's food security. The groundwater quality and wheat yield improve as the distance from main city increased.

The study recommended that:

- The amount of land used for residential purposes should be reduced.
- In Pakistan, it is common to have a large houses. High rise buldings should be introduced.
- The size of the population in a specfic area should be identified.
- Reducing urbanization growth is necessary to improve the groundwater quality and preserve food security in the country.
- The waste managment system should be very strong that avoide leaching the hazrdaus elements into groundwater.

KARTEPE SUMMIT

24-27 MARCH 2022

Chapter 7

POTENTIAL ROLES OF ICT IN SUPPORTING CIRCULAR ECONOMY TRANSITION: STORIES FROM INDONESIAN MOBILE APPS

Rendy Bayu Aditya*

INTRODUCTION

Trash is a global issue. Mismanagement of human garbage has caused significant environmental deterioration—for example, the existence of a gigantic plastic garbage patch in the Pacific Ocean. The size of the plastic garbage patch is modelled around 1.6 million km2 with an estimated weight of at least 79 thousand tonnes.[1] For comparison, this size is approximately three times larger than France and twice larger than Turkey.

In terms of contributors, some Southeast Asia countries are responsible as they contribute significantly to marine plastic pollution. A study released a list of the top 20 global marine plastic emitters and placed China in the first rank, followed by 5 South-East Asian countries, which are Indonesia (2), Philippines (2), Vietnam (3), Thailand (6), Malaysia (8).[2]

Furthermore, this part will focus more on Indonesia to illustrate the case study context for this paper. As mentioned previously, Indonesia ranks second for its contribution to global marine plastic pollution. This occurs due to insufficient integrated waste management from the source, transportation, and recycling

* Bartlett School of Planning, University College London, Architecture and Planning Department, Universitas Gadjah Mada, adityarb@ugm.ac.id

1 L. Lebreton et al., "Evidence That the Great Pacific Garbage Patch Is Rapidly Accumulating Plastic," *Scientific Reports* 8, no. 1 (2018): 1–15, https://doi.org/10.1038/s41598-018-22939-w.

2 Jenna Jambeck et al., "Plastic Waste Inputs from Land into the Ocean," *Marine Pollution* 347, no. 6223 (2015): 768–71, https://science.sciencemag.org/CONTENT/347/6223/768.abstract.

provided by municipalities for people living in urban and rural areas.[3] With that condition, trash generated by households or enterprises is usually managed unsustainably, such as burning or dumping them in rivers or idle lands.

To achieve more sustainable solid waste management, various initiatives have been developed by parties: government, grassroots, NGOs, and private sectors. Governments at the national or local level, for example, have developed more recycling centres across municipalities, such as plastic recycling and composting facilities. At the grassroots level, waste banks establishment also gain more popularity. Waste banks serve as a community hub that collects 'valuable' garbage from households to recycle or sell to recycling businesses. Another example comes from private sectors that harness ICT and create mobile apps that could support garbage re-commerce. The number of mobile apps in solid waste recycling sectors in Indonesia is also increasing. Recently, mobile apps that facilitate people to re-commerce trash have been seen as a circular business model that could provide benefits economically, socially, and environmentally.

In a circular economy model, it is vital to prolonging the product life cycle to minimise solid waste. One strategy to avoid products going to waste is by re-commerce them.[4] Re-commerce is an activity where consumers resell used products to other parties. Re-commerce is growing, especially in the fashion industry[5], where people can sell their used products to other individuals via internet-based digital platforms such as social media and particular mobile apps. With more trends in the circular economy, the expansion of re-commerce may also cover broader products in the future.

Scholars and development organisations agree that innovations and utilisation of ICT are encouraged as an enabler for the transition to sustainable and circular development.[6] Mobile apps are one example of ICT usage for sustainable

---

3 Navarro Ferronato and Vincenzo Torretta, "Waste Mismanagement in Developing Countries: A Review of Global Issues," *International Journal of Environmental Research and Public Health* 16, no. 6 (2019), https://doi.org/10.3390/ijerph16061060.

4 Saleh Md Arman and Cecilia Mark-Herbert, "Re-Commerce to Ensure Circular Economy from Consumer Perspective," *Sustainability (Switzerland)* 13, no. 18 (2021): 1–17, https://doi.org/10.3390/su131810242.

5 Rui Faria et al., "Circular Economy for Clothes Using Web and Mobile Technologies-A Systematic Review and a Taxonomy Proposal," *Information (Switzerland)* 11, no. 3 (2020): 1–15, https://doi.org/10.3390/info11030161.

6 Massimiliano Viglioglia et al., "Smart District and Circular Economy: The Role of Ict Solutions in Promoting Circular Cities," *Sustainability (Switzerland)* 13, no. 21 (2021), https://doi.org/10.3390/su132111732; Konstantinos Demestichas and Emmanouil Daskalakis, "Information and Communication Technology Solutions for the Circular Economy," *Sustainability (Switzerland)* 12, no. 18 (2020): 1–19, https://doi.org/10.3390/su12187272; EMF, "The Circular Economy: A Transformative Covid-19 Recovery Strategy," 2020, www.ellenmacarthurfoundation.org.

development transition.[7] In the solid waste management sector, waste-management-related mobile apps have potential roles in changing consumers' behaviours through persuasive technology.[8] With persuasive technology, mobile apps may stimulate the adoption of greener behaviours by offering convenience for users through personal features on smartphones. Thus, this paper aims to explore the roles of trash re-commerce mobile apps in enabling urban circular economy transition.

1. METHODS

The method used for this research is a content analysis of third party online open data. Those third party online open data include websites, online news, YouTube and social media videos. The information from those sources is transferred into text and then analysed using a qualitative approach such as thematic coding.

This research takes three trash re-commerce mobile apps in Indonesia as case studies. They are Octopus, Rapel, and Duitin. They are chosen for criteria: (1). They do not only serve as an educational platform but also seek to place the trash as an economic commodity and potentially provide profits in a more sustainable approach, so it is aligned with one of the circular economy principles; (2). They relatively serve larger geographical areas in Indonesia than other similar apps; (3). They conspire with various stakeholders from individuals, communities, governments, social facilities, and large private companies. According to those criteria, a comprehensive understanding of the roles of digital platforms in a circular economy could be optimally investigated.

2. RESULTS

Before going to the main findings, it is essential to understand how mobile apps operate. In general, the three mobile apps – Octopus, Rapel, and DuitIn – have relatively similar modus. The apps serve as door-to-door garbage collection systems that bridge inorganic trash sourced from households or businesses with recycling checkpoints that valorise trash. There are at least three parties involved in the essential operation of the re-commerce chains: users, waste collectors, and

---

7 Antonis Mavropoulos, Maria Tsakona, and Aida Anthouli, "Urban Waste Management and the Mobile Challenge," *Waste Management and Research* 33, no. 4 (2015): 381–87, https://doi.org/10.1177/0734242X15573819.

8 Makuochi Nkwo, Banuchitra Suruliraj, and Rita Orji, "Persuasive Apps for Sustainable Waste Management: A Comparative Systematic Evaluation of Behavior Change Strategies and State-of-the-Art," *Frontiers in Artificial Intelligence* 4, no. December (2021): 1–18, https://doi.org/10.3389/frai.2021.748454.

recycling enterprises (see Figure 1). First, users are people who use apps to sell trash and get money from it. They could be individuals, households, businesses such as small and medium enterprises, and public facilities. Second, collectors serve as intermediary agents who use apps to receive notifications on prospective clients (app users) who want to sell their trash. Collectors will visit their clients to pick up trash and transport them to recycling checkpoints. Collectors will pay users for their trash and will get paid by recycling checkpoints. Then, recycling checkpoints serve as the last re-commerce chain where trash is treated and recycled. Recycling checkpoints vary, including apps developers' owned recycling facilities or municipal recycling facilities and other recycling enterprises operated by private.

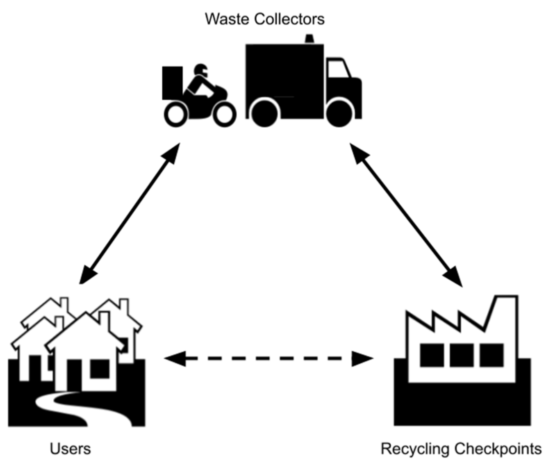


Figure 1. Basic Operation of Trash Re-commerce Apps

Source: Author's own, 2022

The following parts explain the main findings on benefits provided by waste re-commerce mobile apps for enabling an urban circular economy. The paper identified the benefits of the waste transactions mobile apps in Indonesia and matched those benefits with each vital stakeholder (see Table 1).

2.1. Increase Practicality

Practicality is a value that people seek, inclusively in partaking for better solid waste management.[9] Waste re-commerce mobile apps studied in this research

---

9 Syed Wasiul Hasan Rizvi, Saurabh Agrawal, and Qasim Murtaza, "Circular Economy under the Impact of IT Tools: A Content-Based Review," *International Journal of Sustainable Engineering* 14, no. 2 (2021): 87–97, https://doi.org/10.1080/19397038.2020.1773567.

could provide practicality for all involved stakeholders. Those practical procedures are aided by features offered by the mobile apps, such as interactive and near real-time engagement, time efficiency, and fewer efforts. Those features are explained as follows:

2.1.1. Interactive & Real-Time Engagement

The first benefit provided by the apps is a more interactive engagement for all parties. In the mobile apps studied, interactive features become the central excellence. There are at least three interactive features: real-time geotagging or geo-location information, trash image sharing, and real-time virtual chat. Those features may support users and collectors to interact and negotiate virtually before the meeting, saving time more efficiently. For example, suppose a user from a household would like to sell collected trash, that user just needs to take a picture of the garbage, tag the geographic location of their houses, and once any collector is interested. In that case, they may communicate via chat.

2.1.2. Reduce Efforts

Conventionally, collectors – who used to work as informal scavengers – had to go around their neighbourhood and city walking to find trash. Most of them usually collect trash from garbage bins in residential or commercial areas.[10] Not a few of them receive inhuman treatment when they are on duty. Now, with the support from mobile apps, collectors are seen as formal waste pickers that have a chance to interact with people in their neighbourhoods and make an appointment with them to collect the trash without wasting energy and time.

"So many of our partners who are collectors are no longer needing to go around houses looking for inorganic waste. They only need to pay attention to their application on their gadget from home, and they will be able to find out where the user is"

From the users' side, as explained above, they just need to take a picture of the trash they would like to sell and post it on the app. Collectors will directly contact them via the app, negotiate the price, and arrange appointments to meet at

10 Gabriel Andari Kristanto, Dini Kemala, and Paras A.C. Nandhita, "Challenges Confronting Waste Pickers in Indonesia: An on-Field Analysis," *Waste Management and Research*, 2021, https://doi.org/10.1177/ 0734242X211029181.

clients' places. This convenient method becomes one of the benefits that motivate people to involve in circular solid trash management.

2.1.3. Time-Efficient

One of the requirements to sell trash using the apps are a minimum size based on garbage types such as cardboard, plastics, glass bottles, and even used cooking oil. Users are required to collect their trash until the minimum size, usually one kilogram or one litre depending on the type of trash. Once the minimum size of trash has reached, they could post it on the app and wait for a collector to respond to their post. From the collectors' side, the minimum size of trash helps them pick up the trash efficiently.

Table 1. Potential Roles of Trash Re-Commerce Apps in Indonesia

Potential Roles	**Users (Waste Generators)**	**Collectors**	**Recycling Checkpoints**	**App Developers**	**Production Companies**	**Municipalities**
More interactive engagement for all parties	**B**	**B**	**?**	**P**	**n/a**	**n/a**
Time-efficient	**B**	**B**	**?**	**P**	**n/a**	**n/a**
Reduce efforts	**B**	**B**	**B**	**P**	**?**	**B**
Income and business opportunities	**B**	**B**	**P& B**	**P & B**	**?**	**P & B**
EPR Supports	**P**	**P**	**P**	**P**	**B**	**P**
Municipal Solid Waste Management Partnerships	**B**	**P**	**P**	**P**	**?**	**B**
Assimilation with Sharing Economy	**B**	**B**	**B**	**B**	**B**	**?**

B = beneficiaries; P = provider; ? = further observation needed

Source: Author's analysis, 2022

2.1.4. Income and Business Opportunities

The emergence of waste re-commerce mobile apps also potentially provides more income and business opportunities for the public. Income and business opportunities could be achieved by various stakeholders, including households, collectors, recycling checkpoints, and even municipalities. For example, households or communities that start an initiation to collect their inorganic waste may sell it via the app. Furthermore, the more households or communities participate in selling their solid waste, the more collectors and recycling checkpoints receive materials for transactions. While recycling centres are owned by privates or municipalities, more recyclable materials collected from households or businesses potentially increase their outputs. With more solid waste treated, recycling facilities would be more likely to hire more staff, which increases job opportunities for people.

2.2. Prospective Collaborations

2.2.1. EPR (Extended Producers Responsibility) Supports

The mobile apps could also assist the mechanism of extended producers' responsibility (EPR), where producers are responsible for treating post-consumption waste. EPR is now gaining popularity in South-east Asian countries as a joint scheme to reduce plastic waste.[11] In the circular economy context, the EPR scheme puts producers as a party responsible for byproducts and waste recycling. Private companies usually face difficulties in collecting their byproducts, at this stage, the role of third parties is needed. The circular economy mobile app companies may contribute as the third party that provide services for collection, sorting, and transportation. Partnerships between Octopus, Duitin, Rapel and private companies give empirical illustrations. For example, Octopus is now working with AQUA-Danone (one of the largest bottled drinks companies) to collect and recycle its used water bottles in Bali.

[11] Hendro Putra Johannes et al., "Applying the Extended Producer Responsibility towards Plastic Waste in Asian Developing Countries for Reducing Marine Plastic Debris," *Waste Management and Research* 39, no. 5 (2021): 690–702, https://doi.org/10.1177/0734242X211013412; Lewis Akenji et al., "Policy Responses to Plastic Pollution in Asia: Summary of a Regional Gap Analysis," *Plastic Waste and Recycling*, January 1, 2020, 531–67, https://doi.org/10.1016/B978-0-12-817880-5.00021-9.

Another example is the collaboration between Rapel and The Body Shop (a multinational skincare company) in the Solo City area to collect and treat their recyclable plastic packaging.[12] Cooperation within the EPR scheme is also done by Duitin and SIG Combibloc (a multinational producer of aseptic packaging) for the collection and distribution of the used packaging.[13] Those companies will buy the byproducts to users – usually individuals or communities – and collectors at slightly higher prices.

Although the collection of those packaging waste is not yet a hundred percent covered by the services provided by mobile apps, this still could be a valuable starting step for Indonesia to reduce solid waste pollution. Future collaborations between circular economy apps, their collectors, and private companies within the EPR scheme are potential strategies for waste reduction in the circular economy transition.

2.2.2. Municipal Solid Waste Management Partnerships

Another potential role of these apps is to support municipal solid waste management through a partnership. Collaborations of the apps with local governments of municipalities in Indonesia are increasing. For example, Octopus has started their partnership with West Java Province and 27 municipalities under it. With this cooperation, Octopus will increase the number of waste collectors all over 27 West Java municipalities and provide app users services. The Octopus collectors would collect valuable trash from the sources (such as houses, restaurants, retailers, or public facilities) and then process them at their recycling checkpoint. This alliance was initiated by Octopus and was endorsed by the Governor of West Java.

Partnerships with municipalities are also run by Rapel and several municipalities in Central Java dan Yogyakarta Region. For example, Rapel supports the solid waste management system in Sleman by collecting and transporting inorganic waste to recycling businesses. With the lack of segregated waste transporting fleet in Sleman, Rapel provides supports to Sleman residents and enterprises to sort their waste and resell it to gain additional money.

12 Rapel Indonesia, "Apa Kata The Bodyshop Di Solo Tentang Rapel," 2021.

13 SIG Combibloc, "SIG Dan Duitin Jalin Kerja Sama Untuk Ciptakan Generasi Way Beyond Good," 2021, https://duitin.id/blog/content/sig-dan-duitin-jalin-kerja-sama-untuk-ciptakan-generasi-way-beyond-good.

2.2.3. Assimilation with Sharing Economy

The integration between the sharing economy and circular economy is advisable by scholars to provide more economical and environmental opportunities.[14] The common ground of both notions lies mainly in multi parties' shared roles in co-creation, co-producing, co-distributing, co-selling, and co-consuming. With 'sharing', society may reduce redundancy as fewer resources would be used, and less waste would be generated.[15] Even in the context of sustainability, co-responsibility may be added.

Interestingly, the trash re-commerce business model is potentially assimilated with the sharing economy business model. This assimilation is illustrated by cooperation between Octopus and Restock, a fintech company that is engaged in peer-to-peer lending. This cooperation provides more considerable opportunities to waste collectors to lend money from the crowd and expand their recycling businesses.

"We have not seen a model like this before where scavengers could be an investment target or could be given a loan. [...] It is quite interesting and profitable."[16]

3. DISCUSSION

Literature and world best practices have shown that solid waste separation at sources is crucial for the waste recycling process.[17] In Indonesian cities, waste segregation and recycling are very challenging due to conditions. First, not all Indonesian cities have sophisticated recycling facilities. Secondly, waste

---

14 Marvin Henry et al., "The Battle of the Buzzwords: A Comparative Review of the Circular Economy and the Sharing Economy Concepts," *Environmental Innovation and Societal Transitions* 38, no. November 2020 (2021): 1–21, https://doi.org/10.1016/j.eist.2020.10.008; Sebastian Kortmann and Frank Piller, "Open Business Models and Closed-Loop Value Chains: Redefining the Firm-Consumer Relationship," *California Management Review* 58, no. 3 (2016): 88–108, https://doi.org/10.1525/cmr.2016.58.3.88.

15 Filippo Corsini et al., "The Advent of Practice Theories in Research on Sustainable Consumption: Past, Current and Future Directions of the Field," *Sustainability 2019, Vol. 11, Page 341* 11, no. 2 (January 11, 2019): 341, https://doi.org/10.3390/SU11020341; Monique Retamal, "Collaborative Consumption Practices in Southeast Asian Cities: Prospects for Growth and Sustainability," *Journal of Cleaner Production* 222 (June 10, 2019): 143–52, https://doi.org/10.1016/J.JCLEPRO.2019.02.267.

16 Presented by Restock in a webinar, 2020

17 Alessandra Varotto and Anna Spagnolli, "Psychological Strategies to Promote Household Recycling. A Systematic Review with Meta-Analysis of Validated Field Interventions," *Journal of Environmental Psychology* 51 (2017): 168–88, https://doi.org/10.1016/j.jenvp.2017.03.011; Venkatachalam Anbumozhi and Fukunari Kimura, "Industry 4.0: Empowering ASEAN for the Circular Economy," *Economic Research Institute for ASEAN and East Asia*, 2018, 1–402, http://www.eria.org/uploads/media/ERIA-Books-2018-Industry4.0-Circular_Economy.pdf.

segregation infrastructure is not optimally provided and implemented. Waste segregation has not been applied in waste transport facilities, so if people separate their waste at home, their waste will be remixed during the waste collection and transportation process. With those conditions, it is hard to encourage residents to participate in sustainable waste management like segregation and recycling. In contrast, the existence of facilities strongly correlates with people's behaviour in waste reduction and recycling.[18] While most Indonesian cities lack integrated waste facilities, the presence of these three apps plays a role in motivating people to have more sustainable behaviours on solid waste management. By using one of these apps, people could sell their waste, and collectors will provide door-to-door service, which is very convenient for households or enterprises who would like to involve.

The practicality offered by trash re-commerce mobile apps coupled with massive collaborations with municipalities will also enhance people's chances to participate in sustainable waste management. At the moment, the use of trash re-commerce mobile apps is still a voluntary act. Given the fact that residents' participation is a key factor for successful waste management, this voluntary act is a worthy starting point. In the future, making the use of these apps a compulsory action for residents and businesses could be an option to encourage more involvement in circular waste management. This idea, however, is not a panacea for waste problems. The use of trash re-commerce mobile apps must also be backed with better solid waste infrastructure provision together with robust policies and long-term commitment.

From the private sector companies' point of view, this circular business model could support them to be more responsible for trash generated from the consumption of their products. While the use of plastics is still unavoidable for some fast-moving consumer goods, the company must integrate a closed-loop value chain within their business model[19] and place recycling products' waste as a part of the producer's responsibility.[20] Cooperation with third parties such as trash re-commerce mobile apps will benefit them to accomplish the closed-loop value chain.

---

18 Lorraine E. Whitmarsh, Paul Haggar, and Merryn Thomas, "Waste Reduction Behaviors at Home, at Work, and on Holiday: What Influences Behavioral Consistency across Contexts?," *Frontiers in Psychology* 9, no. DEC (2018): 1–13, https://doi.org/10.3389/fpsyg.2018.02447.

19 Kortmann and Piller, "Open Business Models and Closed-Loop Value Chains: Redefining the Firm-Consumer Relationship."

20 Johannes et al., "Applying the Extended Producer Responsibility towards Plastic Waste in Asian Developing Countries for Reducing Marine Plastic Debris."

CONCLUSION

This paper has shown the prospective roles of trash re-commerce mobile apps in enabling urban circular economy transition, especially in the context of Indonesia. The paper identifies that the use of ICT in the form of trash re-commerce mobile apps is the potential to (1) increase people's motivations to take part in waste reduction activities due to practicality and opportunities offered to gain alternative incomes, and (2) prospectively improve collaborations amongst various stakeholders to take circular actions.

This paper suggests further research. First, to observe the prospective roles of similar mobile apps in assisting production companies in implementing Extended Producer Responsibility (EPR). Second, to identify the possibility of scaling up the use of similar mobile apps for city-wide level and support municipal solid waste management services.

BIBLIOGRAPHY

1. Akenji, Lewis, Magnus Bengtsson, Yasuhiko Hotta, Mizuki Kato, and Matthew Hengesbaugh. "Policy Responses to Plastic Pollution in Asia: Summary of a Regional Gap Analysis." *Plastic Waste and Recycling*, January 1, 2020, 531–67. https://doi.org/10.1016/B978-0-12-817880-5.00021-9.
2. Anbumozhi, Venkatachalam, and Fukunari Kimura. "Industry 4.0: Empowering ASEAN for the Circular Economy." *Economic Research Institute for ASEAN and East Asia*, 2018, 1–402. http://www.eria.org/uploads/media/ERIA-Books-2018-Industry4.0-Circular_Economy.pdf.
3. Arman, Saleh Md, and Cecilia Mark-Herbert. "Re-Commerce to Ensure Circular Economy from Consumer Perspective." *Sustainability (Switzerland)* 13, no. 18 (2021): 1–17. https://doi.org/10.3390/su131810242.
4. Corsini, Filippo, Rafael Laurenti, Franziska Meinherz, Francesco Paolo Appio, and Luca Mora. "The Advent of Practice Theories in Research on Sustainable Consumption: Past, Current and Future Directions of the Field." *Sustainability 2019, Vol. 11, Page 341* 11, no. 2 (January 11, 2019): 341. https://doi.org/10.3390/SU11020341.
5. Daniel, J. M. "Danone-AQUA Fighting Bali's Plastic Waste," 2021. https://balidiscovery.com/danone-aqua-fighting-balis-plastic-waste/.
6. Demestichas, Konstantinos, and Emmanouil Daskalakis. "Information and Communication Technology Solutions for the Circular Economy." *Sustainability (Switzerland)* 12, no. 18 (2020): 1–19. https://doi.org/10.3390/su12187272.
7. EMF. "The Circular Economy: A Transformative Covid-19 Recovery Strategy," 2020. www.ellenmacarthurfoundation.org.

8. Faria, Rui, Inês Lopes, Ivan Miguel Pires, Gonçalo Marques, Solange Fernandes, Nuno M. Garcia, José Lucas, Aleksandar Jevremovic, Eftim Zdravevski, and Vladimir Trajkovik. "Circular Economy for Clothes Using Web and Mobile Technologies-A Systematic Review and a Taxonomy Proposal." *Information (Switzerland)* 11, no. 3 (2020): 1–15. https://doi.org/10.3390/info11030161.
9. Ferronato, Navarro, and Vincenzo Torretta. "Waste Mismanagement in Developing Countries: A Review of Global Issues." *International Journal of Environmental Research and Public Health* 16, no. 6 (2019). https://doi.org/10.3390/ijerph16061060.
10. Henry, Marvin, Daan Schraven, Nancy Bocken, Koen Frenken, Marko Hekkert, and Julian Kirchherr. "The Battle of the Buzzwords: A Comparative Review of the Circular Economy and the Sharing Economy Concepts." *Environmental Innovation and Societal Transitions* 38, no. November 2020 (2021): 1–21. https://doi.org/10.1016/j.eist.2020.10.008.
11. Jambeck, Jenna, Roland Geyer, Chris Wilcox, Theodore R Siegler, Miriam Perryman, Anthony Andrady, Ramani Narayan, and Kara Lavender Law. "Plastic Waste Inputs from Land into the Ocean." *Marine Pollution* 347, no. 6223 (2015): 768–71. https://science.sciencemag.org/ CONTENT/347/6223/768.abstract.
12. Johannes, Hendro Putra, Michikazu Kojima, Fusanori Iwasaki, and Ellen Putri Edita. "Applying the Extended Producer Responsibility towards Plastic Waste in Asian Developing Countries for Reducing Marine Plastic Debris." *Waste Management and Research* 39, no. 5 (2021): 690–702. https://doi.org/10.1177/0734242X211013412.
13. Kortmann, Sebastian, and Frank Piller. "Open Business Models and Closed-Loop Value Chains: Redefining the Firm-Consumer Relationship." *California Management Review* 58, no. 3 (2016): 88–108. https://doi.org/10.1525/cmr.2016.58.3.88.
14. Kristanto, Gabriel Andari, Dini Kemala, and Paras A.C. Nandhita. "Challenges Confronting Waste Pickers in Indonesia: An on-Field Analysis." *Waste Management and Research*, 2021. https://doi.org/10.1177/0734242X211029181.
15. Lebreton, L., B. Slat, F. Ferrari, B. Sainte-Rose, J. Aitken, R. Marthouse, S. Hajbane, et al. "Evidence That the Great Pacific Garbage Patch Is Rapidly Accumulating Plastic." *Scientific Reports* 8, no. 1 (2018): 1–15. https://doi.org/10.1038/s41598-018-22939-w.
16. Mavropoulos, Antonis, Maria Tsakona, and Aida Anthouli. "Urban Waste Management and the Mobile Challenge." *Waste Management and Research* 33, no. 4 (2015): 381–87. https://doi.org/10.1177/0734242X15573819.
17. Nkwo, Makuochi, Banuchitra Suruliraj, and Rita Orji. "Persuasive Apps for Sustainable Waste Management: A Comparative Systematic Evaluation of Behavior Change Strategies and State-of-the-Art." *Frontiers in Artificial Intelligence* 4, no. December (2021): 1–18. https://doi.org/10.3389/frai.2021.748454.
18. Octopus Indonesia. "Dapat Untung Bersama Pemulung Melalui Ekonomi Sirkular Octopus - Webinar," 2020. https://www.youtube.com/watch?v=s6tI5qhSyg8.
19. Rapel Indonesia. "Apa Kata The Bodyshop Di Solo Tentang Rapel," 2021.

20. Retamal, Monique. "Collaborative Consumption Practices in South-east Asian Cities: Prospects for Growth and Sustainability." *Journal of Cleaner Production* 222 (June 10, 2019): 143–52. https://doi.org/10.1016/J.JCLEPRO.2019.02.267.
21. Rizvi, Syed Wasiul Hasan, Saurabh Agrawal, and Qasim Murtaza. "Circular Economy under the Impact of IT Tools: A Content-Based Review." *International Journal of Sustainable Engineering* 14, no. 2 (2021): 87–97. https://doi.org/10.1080/19397038.2020.1773567.
22. SIG Combibloc. "SIG Dan Duitin Jalin Kerja Sama Untuk Ciptakan Generasi Way Beyond Good," 2021. https://duitin.id/blog/content/sig-dan-duitin-jalin-kerja-sama-untuk-ciptakan-generasi-way-beyond-good.
23. Varotto, Alessandra, and Anna Spagnolli. "Psychological Strategies to Promote Household Recycling. A Systematic Review with Meta-Analysis of Validated Field Interventions." *Journal of Environmental Psychology* 51 (2017): 168–88. https://doi.org/10.1016/j.jenvp.2017.03.011.
24. Viglioglia, Massimiliano, Matteo Giovanardi, Riccardo Pollo, and Pier Paolo Peruccio. "Smart District and Circular Economy: The Role of Ict Solutions in Promoting Circular Cities." *Sustainability (Switzerland)* 13, no. 21 (2021). https://doi.org/10.3390/su132111732.
25. Whitmarsh, Lorraine E., Paul Haggar, and Merryn Thomas. "Waste Reduction Behaviors at Home, at Work, and on Holiday: What Influences Behavioral Consistency across Contexts?" *Frontiers in Psychology* 9, no. DEC (2018): 1–13. https://doi.org/10.3389/fpsyg.2018.02447.

KARTEPE SUMMIT

24-27 MARCH 2022

Chapter 8

ACCELERATING THE CREATION OF RESILIENT CITIES AND CITIZENS THROUGH DIGITAL INCLUSION STRATEGY: A PROPOSED INTEGRATED FRAMEWORK

Shathees Baskaran* - Logaiswari Indiran** - Nomahaza Mahadi*** - Kesavan Nallaluthan****

INTRODUCTION

The term "resilience" has emerged as a new way of thinking and also gained a lot of traction in academic and policy development efforts in recent years[1]. Later, the term "urban resilience" was introduced at the American Annual Conference on Ecology[2] to describe the ability of individuals, communities, organizations, enterprises, and systems in a city to survive, adapt, and develop in the face of chronic or acute shocks[3]. Since then, urban resilience has become a more popular concept as cities continue to develop and face disruptions. In recent years, there has been a lot of research on urban resilience, including urban sustainability and resilience studies[4,5,6], studies on community resilience[7,8], and development and applicability of the resilient city model[9,10,11].

---

* Address: Azman Hashim International Business School, T-08, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia, Email: shathees@utm.my

** Address: Azman Hashim International Business School, T-08, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia, Email: logaiswari@utm.my

*** Address: Azman Hashim International Business School, Level 10, Menara Razak, Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia, Email: nomahaza.kl@utm.my

**** Address: Faculty of Management and Economy, Universiti Pendidikan Sultan Idris, Tan-jong Malim, Perak, Malaysia, Email: kesavan@fpe.upsi.edu.my

1 Meerow, Sara, and Joshua P. Newell. 2015. Resilience and Complexity: A Bibliometric Review and Prospects for Industrial Ecology. Journal of Industrial Ecology 19(2): 236-251.

2 Meerow, S, J.P. Newell, and M. Stults. 2016. Defining Urban Resilience: A Review. Landscape and Urban Planning 147: 38-49.

3 Spaans, Marjolein, and Bas Waterhout. 2017. Building up Resilience in Cities Worldwide – Rotterdam as Participant in the 100 Resilient Cities Programme. Cities 61: 109-116.

4 Kalantari, Z. 2021. Enlivening Our Cities: Towards Urban Sustainability and Resilience. Springer Science & Business Media: Berlin, Germany.

City labels such as low carbon city, eco-city, green city, resilient city, and sustainable city describe key aspects of urban development succinctly. Despite various city labels, cities, which are frequently portrayed as an extremely complex system due to the vast population, numerous buildings, extensive social networks, and vulnerability to natural or man-made calamities have emerged as an attractive perspective in the study of resilience concept[12]. Accordingly, the study of the resilient city has piqued the interest of both academics and society. To date, the majority of current research on city resilience focuses on the characteristics of the system[13,14,15], construction[16,17,18], evaluation system[19] and policy[20,21,22].

Despite the relevance of current studies and the protracted discussion on resilience and the process of building resilient cities, an integrated approach to urban resilience remains lacking[23]. Addressing this concern is relevant because the

5 Romero-Lankao, P, D.M. Gnatz, O. Wilhelmi, and M. Hayden. 2016. Urban Sustainability and Resilience: From Theory to Practice. Sustainability 8(12): 1224.

6 Elmqvist, T., G. Barnett, and C. Wilkinson. 2014. Exploring Urban Sustainability and Resilience. In Resilient Sustainable Cities, Routledge: New York, NY, USA.

7 Fabbricatti, K, L. Boissenin, and M. Citoni. 2020. Heritage Community Resilience: Towards New Approaches for Urban Resilience and Sustainability. City, Territory and Architecture 7(1): 17.

8 Dobson, Skye. 2017. Community-Driven Pathways for Implementation of Global Urban Resilience Goals in Africa. International Journal of Disaster Risk Reduction 26: 78-84.

9 Liang, Zifeng. 2021. Assessment of the Construction of a Climate Resilient City: An Empirical Study Based on the Difference in Differences Model. International Journal of Environmental Research and Public Health 18(4): 2082.

10 Zuniga-Teran, A.A, A.K. Gerlak, B. Mayer, T.P. Evans, and K.E. Lansey. 2020. Urban Resilience and Green Infrastructure Systems: Towards a Multidimensional Evaluation. Current Opinion in Environmental Sustainability 44: 42-47.

11 Arafah, Y., H. Winarso, and D. Suroso. 2018. Towards Smart and Resilient City: A Conceptual Model. In Proceedings of the IOP Conference Series: Earth and Environmental Science, Bandung, 3-5 April 2018 (pp.158), Indonesia, IOP Publishing Ltd.

12 Batty, Michael. 2008. The Size, Scale, and Shape of Cities. Science 319(5864): 769-71.

13 Vale, Lawrence J. 2013. The Politics of Resilient Cities: Whose Resilience and Whose City? Building Research & Information 42(2): 191-201.

14 Desouza, Kevin C., and Trevor H. Flanery. 2013. Designing, Planning, and Managing Resilient Cities: A Conceptual Framework. Cities 35: 89-99.

15 Stumpp, Eva-Maria. 2013. New in Town? On Resilience and 'Resilient Cities. Cities 32: 164-166.

16 Jabareen, Yosef. 2013. Planning the Resilient City: Concepts and Strategies for Coping with Climate Change and Environmental Risk. Cities 31: 220-229.

17 Pickett, S.T.A., M.L. Cadenasso, and J.M. Grove. 2004. Resilient Cities: Meaning, Models, and Metaphor for Integrating the Ecological, Socio-Economic, and Planning Realms. Landscape and Urban Planning 69(4): 369-384.

18 Godschalk, David R. 2003. Urban Hazard Mitigation: Creating Resilient Cities. Natural Hazards Review 4(3): 136-143.

19 Liu, X, S. Li, X. Xu, and J. Luo. 2021. Integrated Natural Disasters Urban Resilience Evaluation: The Case of China. Natural Hazards 107(3): 2105-2122.

20 Shamout, S, P. Boarin, and S. Wilkinson. 2021. The Shift from Sustainability to Resilience as a Driver for Policy Change: A Policy Analysis for More Resilient and Sustainable Cities in Jordan. Sustainable Production and Consumption 25: 285-298.

21 Poku-Boansi, Michael, and Patrick Brandful Cobbinah. 2018. Are We Planning for Resilient Cities in Ghana? An Analysis of Policy and Planners' Perspectives. Cities 72: 252-260.

22 Henstra, Daniel. 2012. Toward the Climate-Resilient City: Extreme Weather and Urban Climate Adaptation Policies in Two Canadian Provinces. Journal of Comparative Policy Analysis: Research and Practice 14(2): 175-94.

23 Yang, Q, D. Yang, P. Li, S. Liang, and Z. Zhang. 2021. Resilient City: A Bibliometric Analysis and Visualization. Discrete Dynamics in Nature and Society 2021: 1-17.

economies and the citizens of the cities require a more robust approach to have meaningful and holistic development by being resilient to the direct and indirect interferences, hence being able to respond to present risks and mitigate the implications of future risks despite uncertain interruptions. To ensure the realization of this aspiration, government structures, and governance systems must be flexible, responsive, and appropriately resourced with both financial and technical resources[24,25,26] in tandem with real responsiveness to the needs of all citizens to create resilient cities and citizens. This necessitates a resilience concept that provides an integrated view of urban resilience dimensions, dimensions of a resilient city, the digital city qualities and characteristics to be resilient, approaches to digital inclusion strategy, and the best practices for the digital transformation of the cities.

As a result, to transition to an integrated approach to city and citizen's resilience and to assist interested stakeholders in developing a comprehensive and resilience-based framework, this research is a preliminary attempt to define key concepts surrounding resilient cities and citizens to draw upon a more integrated approach to accelerate resilient city and citizens' formation through digital inclusion strategies. We envisage that a clear and systematic overview of a resilient city and citizen's concept can help scholars, practitioners, and policymakers form a comprehensive understanding of the resilient city and citizen's research.

1. LITERATURE REVIEW STRATEGY

The focal phenomenon technique was used in this conceptual paper. The paper concentrated on unknown phenomena and the accompanying links among key notions linked with the target topic. We discovered many crucial principles that help to understand this hitherto unknown phenomenon. The essential ideas were chosen based on their best match to the phenomena as well as their complementary value in conceiving it. In developing the framework, the link between the fundamental ideas was analyzed, and hitherto undiscovered associations between domains were discussed.

---

24 Davidson, K, T.M.P Nguyen, R. Beilin, and J. Briggs. 2019. The Emerging Addition of Resilience as a Component of Sustainability in Urban Policy. Cities 9: 1-9.

25 Sanchez, A.X., J. van der Heijden, and P. Osmond. 2018. The City Politics of an Urban Age: Urban Resilience Conceptualisations and Policies. Palgrave Communications 4(1): 25.

26 Tyler, Stephen, and Marcus Moench. 2012. A Framework for Urban Climate Resilience. Climate and Development 4(4): 311-326.

2. URBAN RESILIENCE

During the previous decade, the concept of urban resilience has been heavily emphasized in urban discourse[27] since it is undoubtedly a critical concept for city management scenarios. Urban resilience denotes the ability to recover from natural and manmade shocks, seeking catastrophe avoidance and limiting negative consequences, and eventually achieving sustainability[28]. This is evident in the literature where urban resilience is also viewed as a key notion for sustainability[29,30,31]. According to Redman[32], a high degree of urban resilience in the face of unanticipated changes reflects stronger sustainability. Improvement of vulnerability and adaptability to change is critical to establishing urban resilience[33] as it allows restoration and recovery of basic and essential functions when confronted by a crisis. Hence, promoting urban resilience in environmental, socioeconomic, and institutional areas has piqued the interest of scholars and municipal governments alike[34,35,36]. Nonetheless, with the start of COVID-19, urban resilience was generally viewed as a term tied very closely to technological capabilities[37]. Regardless of its developments, integrated thinking[38,39] and an integrated strategy for urban resilience development are becoming a necessity.

---

27 Sanchez, A.X., J. van der Heijden, and P. Osmond. 2018. The City Politics of an Urban Age: Urban Resilience Conceptualisations and Policies. Palgrave Communications 4(1): 25.

28 Han, S, J. Sim, and Y. Kwon. 2021. Recognition Changes of the Concept of Urban Resilience: Moderating Effects of Covid-19 Pandemic. Land 10(10): 1099.

29 Deng W, and A. Cheshmehzangi. 2018. Eco-development in China: Cities, communities, and buildings. Singapore: Palgrave Macmillan.

30 Tabibian, Manouchehr, and Sepideh Movahed. 2016. Towards Resilient and Sustainable Cities: A Conceptual Framework. Scientia Iranica 23(5): 2081-2093.

31 Walker, Brian, and David Salt. 2012. Resilience Thinking Sustaining Ecosystems and People in a Changing World. Washington: Island Press.

32 Redman, Charles L. 2014. Should Sustainability and Resilience Be Combined or Remain Distinct Pursuits? Ecology and Society 19(2): 37.

33 Min-Seok, K, Y.M. Jeon, and J.S. Lee. 2017. A Comparative Analysis of the Level of Urban Resilience in the City Comprehensive Plan. WIT Transactions on Ecology and the Environment 223: 517-526.

34 Cheshmehzangi, Ali. 2020. Reflection on Early Lessons for Urban Resilience and Public Health Enhancement during the COVID-19." Health 12(10): 1390-1408.

35 Fouda, A, N. Mahmoudi, N. Moy, and F. Paolucci. 2020. The COVID-19 Pandemic in Greece, Iceland, New Zealand, and Singapore: Health Policies and Lessons Learned. Health Policy and Technology 9(4): 510-524.

36 Kang, D, H. Choi, J-H. Kim, and J. Choi. 2020. Spatial Epidemic Dynamics of the Covid-19 Outbreak in China." International Journal of Infectious Diseases 94: 96-102.

37 Han, S, J. Sim, and Y. Kwon. 2021. Recognition Changes of the Concept of Urban Resilience: Moderating Effects of Covid-19 Pandemic. Land 10(10): 1099.

38 Coaffee, Jon. 2013. Towards next-Generation Urban Resilience in Planning Practice: From Securitization to Integrated Place Making. Planning Practice and Research 28(3): 323-39.

39 Cheshmehzangi, Ali. 2016. Multi-Spatial Environmental Performance Evaluation towards Integrated Urban Design: A Procedural Approach with Computational Simulations. Journal of Cleaner Production 139: 1085-93.

Hence assessment of urban resilience requires comprehensive focus towards system-based approaches and social systems which include the natural environment, man-made infrastructure, and governance systems as well as human behaviour. Accordingly, the three dimensions as follows should be seen as a comprehensive illustration of the urban resilience concept: people's resilience, place's resilience, and institution's resilience.

2.1. People's Resilience

People's resilience which is also known as social resilience or community resilience refers to people's self-organization and skills mobilization to scout for potential opportunities to behave cooperatively in the aftermath of a disruption. This necessitates community ties and a sense of community for people to be resilient. Flint[40] confirms that citizens should think that to create a dynamic community, they must cultivate a sense of community. Key elements of social resilience include collective self-esteem that is an attitude of pride in the place where the community lives. On the other hand, Adger[41] explains that community resilience portrays the community's capacity to handle shocks with and within its social infrastructures. Such social ties and community identities allow solidarity among the communities which in turn creates a socially cohesive society. Nevertheless, people's and communities' resilience is the consequence of a complex interplay of elements impacted by many systems at various levels, and by a diverse set of stakeholders. The challenge is that a widely used asset-based approach focusing on physical assets in ensuring resilience tends to neglect the influence of human behaviour including social networks in ensuring urban resilience. As a result, dealing with the contemporaneous and simultaneous shocks necessitates a comprehensive strategy involving the social networks.

2.2. Place's Resilience

The appearance of cities, as well as their landscape setting, has a significant impact on their ability to recover and prosper in the face of pressures and

[40] Flint, R.Warren. 2013. Practice of sustainable community development, a participatory framework for change. Springer: Berlin.

[41] Adger, W. Neil. 2000. Social and Ecological Resilience: Are They Related? Progress in Human Geography 24(3): 347-64.

disruptions. This place's resilience includes green and blue infrastructure which describe the urban ecosystem and also systems around its infrastructure. Muller et al[42] posit that wellbeing and quality of life in a city have a close association with the urban environment and its ecosystem. Attainment of wellbeing and quality of life in a city needs dependence on ecosystems before a city claims itself to be a sustainable city. Therefore, taking responsibility for the seamless connectedness and resource footprint of cities impact cities' potential to increase resilience and facilitate sustainable transitions[43]. However, Vale[44] opined that a place's resilience in a city is still a problematic area as the many social, institutional, and economic vulnerabilities connected with citizens vary across a city although the resilience offers promising benefits. Vale promotes a more comprehensive and interdisciplinary concept of progressive resilience with a larger social component. The resilient urban planning ideally should seek to reconcile the social, environmental, and economic components of resilience in spatial design by viewing cities as complex adaptive systems. Hillier[45] provided some direction to this idea by positing that spatial planning must be strategized through resilience thinking where novel approaches to conceiving and practicing urban planning in unpredictable environments should be identified reflected by active adaptability in response to changing environments and conditions. This requires continuous strategic navigation which allows constant sensitivity to complexity and indeterminacy allowing strategic spatial planning to work adaptively to create more resilient cities. Davoudi et al[46] who introduced Transformability, Adaptability, Preparedness, and Persistence (TAPP) approach added that a place's resilience is also subject to human intervention when a place is confronted by crisis or uncertainty where communities play a vital role in shaping a resilient place.

---

42 Muller N, P. Werner, and J.G. Kelcey. 2010. Urban Biodiversity and Design. Chichester, UK: Wiley-Blackwell.

43 McPhearson, T, E. Andersson, T. Elmqvist, and N. Frantzeskaki. 2015. Resilience of and through Urban Ecosystem Services. Ecosystem Services 12: 152-156.

44 Vale, Lawrence J. 2013. The Politics of Resilient Cities: Whose Resilience and Whose City? Building Research & Information 42(2): 191-201.

45 Hillier, Jean. 2011. Strategic Navigation across Multiple Planes: Towards a Deleuzean-Inspired Methodology for Strategic Spatial Planning. Town Planning Review 82(5): 503-527.

46 Davoudi, S, E. Brooks, and A. Mehmood. 2013. Evolutionary Resilience and Strategies for Climate Adaptation. Planning Practice and Research 28(3): 307-22.

2.3. Institutions' Resilience

An institution's resilience indicates the process to which an institution evolves through its inclusivity or exclusivity, and networks[47] involving flexible and polycentric institutional processes[48]. Institutions that work effectively in times of stability may become inefficient or disintegrate during times of crisis, or they may struggle to recover from a shock. This highlights an issue of resilience among institutions. Generally, an institution's resilience revolves around its ability to deliver and enhance results over time, commonly known as institutional efficacy. This necessitates proactive leadership which is a core component to building urban resilience[49]. According to Barma, Huybens, and Vinuela[50], the source of an institution's resilience resides in its legitimacy and credibility. Besides, two broadly considered dimensions underpin an institution's resilience namely community partnerships and change-maker connections. From a community partnership perspective, institutions that develop relationships with citizens and acquire their confidence are found to be more robust in the long run. Citizens must be empowered to co-design, co-create, and co-produce urban spaces to share responsibility and accountability for the present and future of urban resilience. This can be done by enabling citizens to participate in the decision-making[51]. Institutions are also required to engage with change-makers and take into account their profound connections for designing and implementing solutions. To collaboratively support and nurture more resilient cities, governments, funders, investors, policymakers, and the business sector must first agree on what makes a resilient city and how it may be done[52]. This should also be extended to the global system of cities through potential collaborations where policymakers must create a more inclusive process to determine pathways that will offer desired institutions' resilience. This demonstrates that fostering institutional resilience entails more than just institutional performance, accountability, and inclusivity.

47 Adger, W. Neil. 2013. Vulnerability. Global Environmental Change 16(3): 268-81.

48 Aligica, Paul Dragos, and Vlad Tarko. 2013. Institutional Resilience and Economic Systems: Lessons from Elinor Ostrom's Work. Comparative Economic Studies 56(1): 52-76.

49 Prasad, N, F. Ranghieri, F. Shah, Z. Trohanis, E. Kessler, and R. Sinha. 2008. Climate Resilient Cities: A Primer on Reducing Vulnerabilities to Disasters. The World Bank, Washington, DC.

50 Barma, N., E. Huybens and L. Vinuela. 2014. Institutions Taking Root: Building State Capacity in Challenging Contexts, World Bank Group, Washington, DC.

51 Newman, Peter, and Isabella Jennings. 2012. Cities as Sustainable Ecosystems Principles and Practices. Washington: Island Press.

52 Nedaei, A, M. Seyednaghavi, M. Firouzfar, and N. Zamani. 2021. A Comparative Study of Urban Resilience in Coping with the Crisis in the Metropolises of Tehran and Mashhad. International Journal of Disaster Resilience in the Built Environment 13(1): 51-71.

3. CITIES RESILIENCE

As the twenty-first century progresses, cities will house an increasing proportion of the global population. Risk is also becoming more unexpected as a result of the complexity of city systems and the uncertainty associated with numerous risks. This posts an immediate challenge of building up pressures and occurrence of abrupt shocks which potentially may lead to physical (systems) collapse, economic deprivation, or societal disintegration[53], necessitating the formation of resilient cities. This is because the well-being of a city is demonstrated by the interconnected institutions, infrastructure, information, and social system. The notion of resilient cities has piqued the interest of a wide range of stakeholders in recent years conveying a commendable sense of urgency and action[54]. In the context of cities, the aim of cities resilience is not to prevent or mitigate consequences arising from specific events, instead of ensuring the operability and functionality of the entire ecosystem in the face of multiple unpredicted hazards. Cities must continuously adapt in both domains to thrive. However, making meaning of urban resilience is also dependent on the nature of the danger - resilience against what, or resilience against whom? To be robust in an increasingly interconnected environment, cities must have and maintain some progressive focus by understanding interconnections among the various domains in embracing resilience. A city is subject to changing environment hence requiring constant adaptation to create an ecosystem's ability to retain or restore functionality in the case of a disruption or disturbance to its physical or social systems. In a nutshell, city resilience reflects a city's ability to function in such a way that the city and the people who live and work there survive and prosper regardless of the pressures or shocks they face.

4. DIMENSIONS OF RESILIENT CITY

Arup with funding from the Rockefeller Foundation conducted extensive research in cities and eventually developed the City Resilience Framework (CFR). The framework provides a prism through which to comprehend the complexities of cities and the factors that contribute to their resilience. According to the CFR, four

[53] Nedaei, A, M. Seyednaghavi, M. Firouzfar, and N. Zamani. 2021. A Comparative Study of Urban Resilience in Coping with the Crisis in the Metropolises of Tehran and Mashhad. International Journal of Disaster Resilience in the Built Environment 13(1): 51-71.

[54] Vale, Lawrence J. 2013. The Politics of Resilient Cities: Whose Resilience and Whose City? Building Research & Information 42(2): 191-201.

specific dimensions namely health and wellbeing, economy and society, infrastructure and environment, and leadership and strategy explain essential systems of a city.

4.1. Health and Well-Being

The first dimension, health, and wellbeing relate to the citizens living and working in a city. This component evaluates the extent to which the city enables everyone to achieve their fundamental needs, particularly during times of crisis. This dimension also evaluates if a city's routine and emergency healthcare provisions are enough to protect its population's health. The ultimate aim of this dimension is to minimize underlying human vulnerabilities to reach a level of living that exceeds basic survival, allowing them to deal and cope with unanticipated occurrences. A well met physiological need is predicted to allow the city residents to respond proactively to changing conditions while maintaining a sufficient level of wellbeing. This requires integration between people, infrastructure, and institutions for the citizens to stay connected during a crisis.

4.2. Economy and Society

The second dimension within CFR is economy and society. This dimension explains the organization of cities. More specifically, the dimension touches on the social and economic systems and the extent to which these two systems are co-existing to ensure peaceful and collaborative life for urban citizens. This dimension emphasizes enforcement of transparent and ethical law and order systems to promote citizenship in daily life through a safe living environment apart from creating collective identity and mutual support in the city and among the city residents. The dimension articulates that attainment of these goals is possible when the citizens' basic physiological needs are met and at the same time, they are active and well-connected with one another displayed through community engagement, strong social networks, and social integration as well as with city authorities to contribute to the creation of a resilient city. This is seen as an essential element to anticipate and overcome unforeseen circumstances collectively for fast and peaceful recovery. Besides, a resilient city also requires a robust economic system to maintain the needs of the city for better living conditions for its communities. It includes financial support which is paramount not only to overcome crises but also to ensure the long-term development and prosperity of the cities.

4.3. Infrastructure and Environment

Infrastructure and environment play a critical role in city development. The infrastructure and environment dimension revolve around the place dimension within urban resilience. This dimension focuses on infrastructure and ecosystems and its quality in connecting the entire ecosystem as it becomes vital to the city's operation, especially during times of crisis. Well-maintained infrastructures and management practices are better equipped to handle sudden demand and manage exceptional stresses to restore disrupted services and to continue functioning. Notably, infrastructure and ecosystem which is robust possess a better ability to manage unforeseen circumstances, hence protecting the city and citizens during a crisis. While disruptions are unavoidable during unforeseen events, continuity of essential and critical services and well-designed social system infrastructures portray a higher level of city resilience. Additionally, environmental asset conservation safeguards the natural protection provided by ecosystems to cities. It includes tidal surges and resulting flooding events which reflects the resilience of the design and construction of infrastructure. Both natural and man-made assets, when combined, contribute to increased protection against unforeseen circumstances when elements of resilience are established within the city development. This promotes a healthy working and living environment, strengthens social solidarity, and allows for extensive communication and speedy recovery during crises.

4.4. Leadership and Strategy

The dimension of leadership and strategy revolves around the domain of knowledge. Leadership is an important component in motivating individuals and communities to act proactively during difficult circumstances. Alongside, it requires effective leadership and urban management which takes a wider view in ensuring that the city development efforts are aligned between its vision and long-term directions and well-integrated with strategies pursued by its stakeholders. Plans that are well-integrated provide a systematic framework for dealing with numerous challenges. Only leadership that is clear and purposeful fosters trust, solidarity, and a common sense of a city's direction. Dedicated city development and management that makes choices based on strong evidence helps a city to grow daily and adjust to shocks and challenges. Experience allows a city to take appropriate actions based on the facts in the process of becoming a resilient city.

An inclusive strategy involving government, business, and civil society who makes up the ecosystem of a city must be in place in making such evidence-based decisions. These stakeholders should be equipped with access to important information so that they are empowered to act upon the most appropriate actions in the face of shocks and stresses. As a result, city stakeholders are more equipped to act, learn, and adjust. Only the presence of a vision, an integrated development strategy, and plans that are evaluated and revised regularly demonstrate the strong existence of leadership and strategy for ensuring city resilience.

5. RESILIENT DIGITAL CITY CHARACTERISTICS

According to published literature, resilient cities exhibit specific qualities or characteristics which are applicable at the city and individual system levels that enable them to endure, respond to, and adapt to shocks and pressures more easily, hence being resilient. These qualities or characteristics are (1) reflective, (2) resourceful, (3) robust, (4) redundant, (5) flexible, (6) inclusive, and (7) integrated.

5.1. Reflective

Reflective is a characteristic that relies on prior experience to guide future directions and decisions. In today's environment, reflective systems acknowledge the inherent and ever-increasing unpredictability and change. The reflective system does not rely on the status quo instead continuously evolves and modifies present standards, norms, and the needs of the city and community based on emerging evidence. This requires that the domain of people, place, and institution highlighted in the urban resilience learn systematically from the past experience to guide their decisions of the future.

5.2. Robust

A city's resilience is reflected in well-conceived, built, and maintained systems. This reflects the robustness of a digital city. A robust system will be able to endure the effects of hazardous occurrences without major harm or loss to the operability of the functions. The robustness of a digital city is attained proactively by anticipating probable system failures as well as establishing mechanisms to create warning signs of known or predictable failures. Besides, the deployment of advanced technologies following the latest developments will create pathways for an ecosystem that connects infrastructure, services, and the citizens in delivering continued service even during times of disruptions. The existence of robust city development and management systems will allow avoidance of catastrophic collapses which if unattended will affect the citizens residing in the city.

5.3. Redundant

Disruptions to a city and its citizens due to unforeseen events require the city management to plan spare capacity to address such shocks. In this sense, redundancy is spare capacity designed to accommodate disruptions and surges in demand and supply balances during a crisis. The characteristics of redundancy are achieved by allowing diversity that enables a city to fulfill the needs for services during difficult times. The spare capacity designed and developed should be prioritized and purposeful in line with the needs of the city and citizens, cost-effective, and should become an effective redundancy when needed. This is important as the redundancy should be adaptable and reliable across multiple scenarios that should function well among different networks to manage potential known and unknown disruptions.

5.4. Flexible

Flexible systems and structure and involvement of the citizens in the city are key to achieving a resilient digital city. Digital city planning should accommodate the desire and capacity to change the existing systems to adopt alternate techniques in response to changing conditions, hence making it flexible to encounter and overcome shocks. Decentralized and modular methods to infrastructure or ecosystem management may benefit from these flexible systems. Technology adoption according to the nature and needs of the city and the citizens will allow the achievement of flexibility by introducing new practices to manage the city. This must include community engagement so that they can adapt themselves to the new environment with new or advanced practices in receiving all kinds of services that exist in the city. This is one of the ways where the citizens affect the changes and create an impact in the city for the city to be resilient.

5.5. Resourceful

The capacity of a city to restore critical systems and its operation, potentially under extreme conditions, is aided by resourcefulness. During a shock or while under stress, people and institutions who are resourceful can quickly discover other methods to achieve their goals or meet their requirements. The resourcefulness characteristics require the city to coordinate and mobilize all kinds of resources including human resources, financial resources, physical resources, and technological resources. The designing of the types of resources should be based on predictions about future conditions and ongoing and future priorities.

5.6. Inclusive

The development of a digital city resilience requires an inclusive approach. An inclusive approach allows the creation of a shared sense of ownership in building digital city resilience. Inclusion emphasizes the need for wide community dialogue and involvement, especially the most disadvantaged groups, to foster a feeling of shared ownership in decision-making to create a resilient digital city. It is important to note that when disruptions faced by a specific domain (e.g. location, community) are addressed in isolation, it would reflect an anathema to the notion of resilience. With the adoption of relevant flexible technologies, an inclusive environment can be made accessible to all and this should automatically drive the citizens to adopt and embrace this approach towards a joint vision to build city resilience.

5.7. Integrated

Integration reflects an ability to bring together a range of distinct systems and institutions. While the engagement of all stakeholders is pertinent to the creation of a resilient digital city, integration, and alignment of various systems surrounding city management and governance become undoubtedly important. An integrated system will promote commitments and consistency across the stakeholders in making decisions to achieve a common goal. An integrated system is highly connected and will allow seamless transmission of information within and across multiple systems in a city enabling the entire functions and stakeholders throughout the city to move collectively and address and respond to escalating issues rapidly when confronted by a crisis.

6. DIGITAL INCLUSION STRATEGY

The concept of digital inclusion has gained prominence in policy and research and was regarded as more than just the giving of access. Rapid digital change, which was already underway before the COVID-19 crisis, has intensified throughout the pandemic, resulting in increased prospects for digital inclusion. Deficiencies in capabilities during crises have pushed digital inclusion as an important strategy to overcome such phenomena. In most situations, considerations and strategies for digital inclusion are addressed in terms of economic and social advantages which is in alignment with the very logic that modern class societies are built upon. Given the inherent connection of the digital gap and existing socioeconomic disparity, especially during the crisis, it is critical to increasing efforts to promote digital inclusion to create a city's resilience. Today, digital inclusion is seen as the strategy of enabling cities and citizens to participate in various matters surrounding them while gaining control over them. Damodaran and Olphert[55] posit that citizens must be actively involved in the development of sociotechnical systems since they are makers and shapers of the technology requirements in a truly inclusive digital society. We propose that digital inclusion strategy should be based on underlying dimensions of urban resilience which are people's resilience, place's resilience, and also institution's resilience, therefore, this article proposes digital citizenship, digital infrastructure, and digital governance as digital inclusion strategies in the formation of urban resilience in general and resilient digital city in particular.

6.1. Digital Citizenship

Digital citizenship is a new and evolving idea in information technology. Acquiring abilities to navigate and survive in an increasingly complicated, digitally mediated environment is what digital citizenship entails. Digital technologies have been firmly ingrained in the economic and societal fabric during the last two decades. The citizens must have significant access to new technology, information, and communication technologies to become digital citizens. However, access to technology is still limited to certain communities and the digital divide continues to take place despite the city's aspiration to be resilient at all times. This means

55 Damodaran, Leela, and Olphert, Wendy. 2006. Informing Digital Futures: Strategies for Citizen Engagement", Springer: Dordrecht.

the digital gap must be addressed and narrowed since citizens must acquire the digital skills to respond to emergencies. Despite this challenge, bringing citizens, more importantly, disadvantaged citizens into new modes of awareness and making them access many sources of knowledge necessitates a well-defined approach. To accomplish this, Yusuf et al[56] listed education and empowerment as the key. Digital competence is necessary for the process of moving citizens towards digital citizenship since they should possess the ability to use digital devices and communication applications and networks to access information in the face of crises. Digital citizenship promotes social integration[57] and this is an essential channel for information exchange during shocks and disruptions. The development of digital citizenship among citizens for the formation of a resilient digital city involves nine elements according to Ohler[58]. These elements are shown in Figure 1.

The idea of digital citizenship has a close association with the concept of resilience. The development of resilient cities and citizens through digital spaces can be contributed by the nine elements of digital citizenship. An adequately prepared digital citizen will directly support efforts in view of resilience and therefore, digital awareness will become of fundamental importance. The access and ease of use during crises among the citizens are proportionate to their needs and the extent to which they can access the digital devices in support of place's and institution's resilience expectations. This is due to the fact that digital technology is now being used efficiently to manage various situations. Digital citizenship behaviour will significantly contribute to the development of an educated digital society, which will play an important role in favourably impacting institutional efforts and helping resilient city development. Ultimately, giving citizens unrestricted digital space to engage in digital citizenship behaviour helps in the development of resilient cities through digital engagement.

56 Yusuf, M, C. Adams, and K. Dingley. 2016. Digital Citizen Participation within Schools in the United Kingdom and Indonesia: An Actor-Network Theory (ANT) Perspective. Information 7(4): 69.

57 Czerniewicz, Laura, and Brown, Cheryl. 2010. Born into the Digital Age in the south of Africa: the reconfiguration of the 'digital citizen'. In Proceedings of the 7th International Conference on Networked Learning, 3-4 May 2010, Lancaster, (pp. 859-865), Denmark, Lancaster University.

58 Ohler, Jason B. 2010. Digital Community, Digital Citizen. Thousand Oaks: Corwin Press.

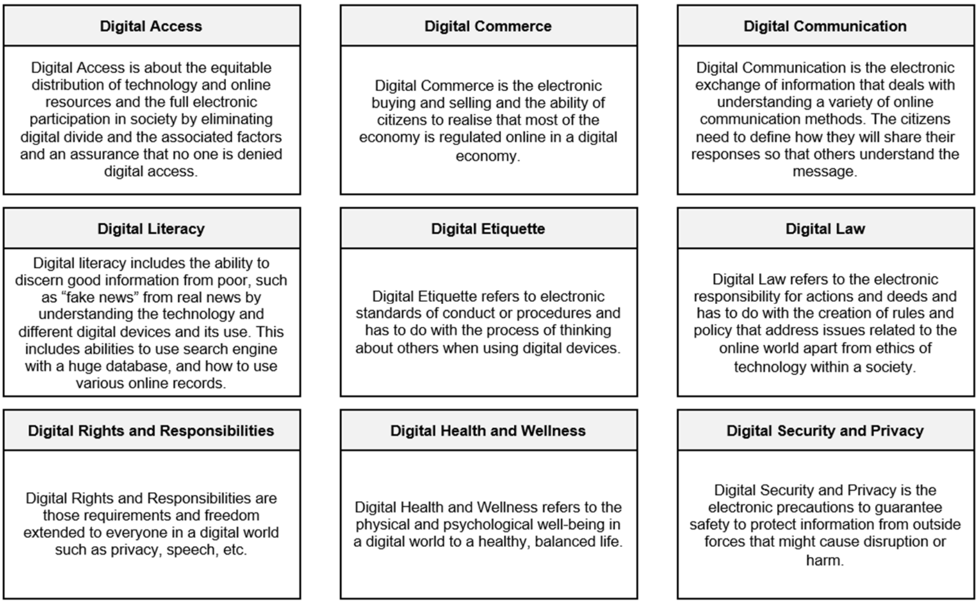


Figure 1: Elements of Digital Citizenship

6.2. Digital Infrastructure

Many events have highlighted the crucial significance of robust digital infrastructure in crisis coordination. In times of crisis, digital connectivity is vital to city resilience and social resilience. As a result, compared to pre-crisis levels, the latest developments of city management are experiencing increasing use of digital infrastructure although its magnitude can vary between the cities. Now, government institutions and other stakeholders are becoming more aware of the critical need of investing in digital infrastructure. Urban management is also prioritizing investing and growing the capacity of digital infrastructure. With the crisis scenario caused by profound uncertainty, developing a robust digital infrastructure is a proactive and preventative strategy that can assure the viability of city operations in both normal and severe conditions. The digital inclusion strategy will build a better future given that the digital infrastructure is inexpensive, dependable, and accessible to all citizens. However, reduced affordability and less competitive digital connectivity in the cities may result in decreasing resilience of digital infrastructure. Long-term strategies should aim to improve resilience and inclusivity by encouraging investment in redundant digital infrastructure. Hence, the effort to create digital infrastructure resilience requires interventions from digital infrastructure operators, regulators, and commercial investors to ensure the appropriateness and effectiveness of digital infrastructure.

6.3. Digital Institutional Governance

Emerging types of e-government are now increasingly recognized and described as 'digital era governance'[59]. The concept of digital era governance was coined by Margetts and Dunleavy[60] emphasizing modern technology as drivers for digital governance. There is a plethora of research on e-mechanisms and e-governance which has focused on governance quality and how digital transformation has revolutionized the interaction between the governmental institutions and the citizens[61,62,63,64] to improve the delivery of public services or increasing community participation[65,66] through an appropriate institutional design[67]. Digitalization of governance according to Margetts and Dunleavy[68] refers to the transformation of the public sector to fully embrace and integrate electronic delivery at the heart of the government business model. This digital inclusion is embraced through online facilities according to Margetts and Dunleavy which provides considerable citizen engagement potential, highlighting the need for digital inclusion strategy[69].

59 Tassabehji, R, R. Hackney, and A. Popovič. 2016. Emergent Digital Era Governance: Enacting the Role of the 'Institutional Entrepreneur' in Transformational Change. Government Information Quarterly 33(2): 223-236.

60 Margetts, Helen, and Patrick Dunleavy. 2013. The Second Wave of Digital-Era Governance: A Quasi-Paradigm for Government on the Web. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 371: 20120382.

61 Linde, Jonas, and Martin Karlsson. 2013. The Dictator's New Clothes: The Relationship between e-Participation and Quality of Government in Non-Democratic Regimes. International Journal of Public Administration 36(4): 269-281.

62 Barrett, M, G. David, and Wailes, N. 2006. ICT and Organizational Change: Introduction to the Special Issue. The Journal of Applied Behavioral Science 42(1): 6-22.

63 Katchanovski, Ivan, and Todd La Porte. 2005. Cyberdemocracy or Potemkin E-Villages? Electronic Governments in OECD and Post-Communist Countries. International Journal of Public Administration 28(7-8): 665-681.

64 Gascó, Mila. 2003. New Technologies and Institutional Change in Public Administration. Social Science Computer Review 21(1): 6-14.

65 Kim, Soonhee, and Jooho Lee. 2012. E-Participation, Transparency, and Trust in Local Government. Public Administration Review 72(6): 819-828.

66 Linders, Dennis. 2012. From e-Government to We-Government: Defining a Typology for Citizen Coproduction in the Age of Social Media. Government Information Quarterly 29(4): 446-454.

67 Bertot, J.C., P.T. Jaeger, and J.M. Grimes. 2010. Using ICTs to Create a Culture of Transparency: E-Government and Social Media as Openness and Anti-Corruption Tools for Societies. Government Information Quarterly 27(3): 264-71.

68 Margetts, Helen, and Patrick Dunleavy. 2013. The Second Wave of Digital-Era Governance: A Quasi-Paradigm for Government on the Web. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 371: 20120382.

69 Bekkers, Victor and Vincent, Homburg. 2007. The Myths of e-Government: Looking beyond the Assumptions of a New and Better Government. The Information Society 23(5): 373-82.

Nevertheless, the implementation of various digital inclusions has varying implications depending on the governance mechanisms used in distinct policy domains and governance situations.

Despite these implications, digital inclusion for digital institutional governance offers many advantages according to Misuraca and Viscusi[70] who introduced four topologies in an ICT-enabled governance process. One of the technical and incremental changes an institution may gain is the automation of repetitious administrative activities and, as a result, increased efficiency of governance processes. Next, from an organizational and sustained change perspective, the inclusion of digital strategy strengthens governance systems by facilitating or supplementing current efforts and procedures. A view of transformative and disruptive change postulates that digital inclusion strategy will enable institutions to launch or improve new services, or develop new procedures for service delivery or policymaking that would be hard to implement without technology. Finally, transformative and radical change perspectives indicate that digital strategy will try to change the existing governance systems or drastically alter the present policy-making procedures by engaging a wide range of stakeholders. Misuraca and Viscusi highlight that technical and incremental change and organizational and sustained change indicate a continuous process of adaptation and technological change. As a result, they concentrate on digital governance systems, which are mostly the outcome of attaching significance to efficiency and effectiveness as value drivers, which influence the underlying governance model features involving external stakeholders.

On the other hand, transformative and disruptive change and transformative and radical change topologies concentrate on digital governance systems, which arise primarily from the importance of openness and inclusivity. Several scholars[71],[72],[73] agreed that digital technologies come with high potential of transforming the

---

70 Misuraca, Gianluca, and Gianluigi Viscusi. 2014. Digital governance in the public sector: challenging the policy-maker's innovation dilemma. Proceedings of the 8th International Conference on Theory and Practice of Electronic Governance, Guimaraes, 27-30 October 2014 (pp.146-154), Portugal, Association for Computing Machinery, New York, United States.

71 Fattore, G, F. Hans and A. Lapenta. 2012. Measuring New Public Management and Governance in Political Debate. Public Administration Review 72(2): 218-27.

72 Rhodes, Rod A. 2011. One-Way, Two-Way, or Dead-End Street: British Influence on the Study of Public Administration in America since 1945. Public Administration Review 71(4): 559-571.

73 Fountain, Jane E. 2002. Building the Virtual State: Information Technology and Institutional Change. Washington, D.C.: Brookings Institution Press.

government and the governance process to be more agile, less complex institutionally, simplified and automated, and more importantly, digital governance will become more responsive to citizens and their needs. Typically, each government is in charge of determining the appropriate digitalization governance plan based on the country's culture, customs, and economic demands[74]. It will become critical for governments, in collaboration with other stakeholders in the industry, academia, NGOs, and the general public, to iteratively improve and adapt to digital governance to balance technological gains against the potential for social and environmental disruption and externalities. Accelerated policies may result in direct public involvement in the implementation of digital governance. There is, therefore, a need for a digital inclusion strategy for resilient management of the city and the formation of resilient citizens.

7. DIGITAL TRANSFORMATION BEST PRACTICES

Transforming into a digital city is a multi-step process that involves the integration of many demands, systems, and partners to create a blueprint that meets the particular needs of each city. Cities must become resilient to prevent, reduce, and effectively manage various scenarios to prepare for shocks and pressures, minimize disruption, and keep the city operational. In reality, to survive, adapt, and flourish in the face of shocks and pressures, such resilience practices must be supported by a strong underlying foundation of adaptability. Digital transformation and corresponding best practices including disasters and calamities forecasting systems with warning signs and citizens' involvement through digital platforms are critical facilitators of resilience. By reducing the time it takes to obtain information and enhancing agility, digital practices improve the adaptability of a city's management capacities and procedures. A similar shift comprises the digital inclusion of citizens by enabling them socially and economically via digital tools and infrastructure. However, when building solutions and best practices for digital inclusion, differences in socioeconomic factors must also be taken into account.

Despite digitizing procedures and systems, a city cannot become digitally inclusive until it harnesses the potential of the data it generates. A major enabler is a data

[74] Linkov, I, B.D. Trump, K. Poinsatte-Jones, and M-V. Florin. 2018. Governance Strategies for a Sustainable Digital World. Sustainability 10(2): 440.

layer that is backed by solid governance, security procedures, and effective administration. A range of scalable solutions that can perpetuate digital inclusion which contributes to increased resilience is seen as one of the best practices of digital inclusion strategy. Various data sources might also aid in the planning of prediction scenarios (e.g. geolocation data during a crisis for restoring normalcy). As a result, governments must invest in creating a data foundation with suitable security and protection mechanisms in place, comprised of various internal and external data sources. Business entities that have extensive citizen knowledge are one possible source of such external data which is the foundational element for achieving digital transformation. City administration may profit from this knowledge by collaborating with private organizations as it emphasizes issues, reflects demands, and provides insights to create solutions for residents in the development of resilient cities and citizens. This must be completed by complete data governance, security, and management approach. In promoting a digitally inclusive strategy, the high dependence of citizens on connectivity should be seen carefully. Frictionless urban mobility will encourage the citizens in becoming acquainted with new and useful technologies.

8. AN INTEGRATED FRAMEWORK FOR CITY AND CITIZEN’S RESILIENCE

We opined that what was lacking is an integrated framework which addresses various constituents of a resilient city and citizens that is relevant in the context of economic, physical, and social disruption. By taking these constituents into account and establishing what leads a city to handle and absorb fast urbanization difficulties, a framework may be built that will guide the formation of resilient cities. In other words, the framework tries to address the various ways the cities and citizens can exhibit resilience. The concept of a "resilient city" will receive a fresh progressive perspective when reframed in this manner by incorporating interconnections among the various domains embracing resilience. With this in mind, there is a clear need for an integrated strategy to create resilient cities and citizens through the promotion of digital inclusion strategy (refer to Figure 2).

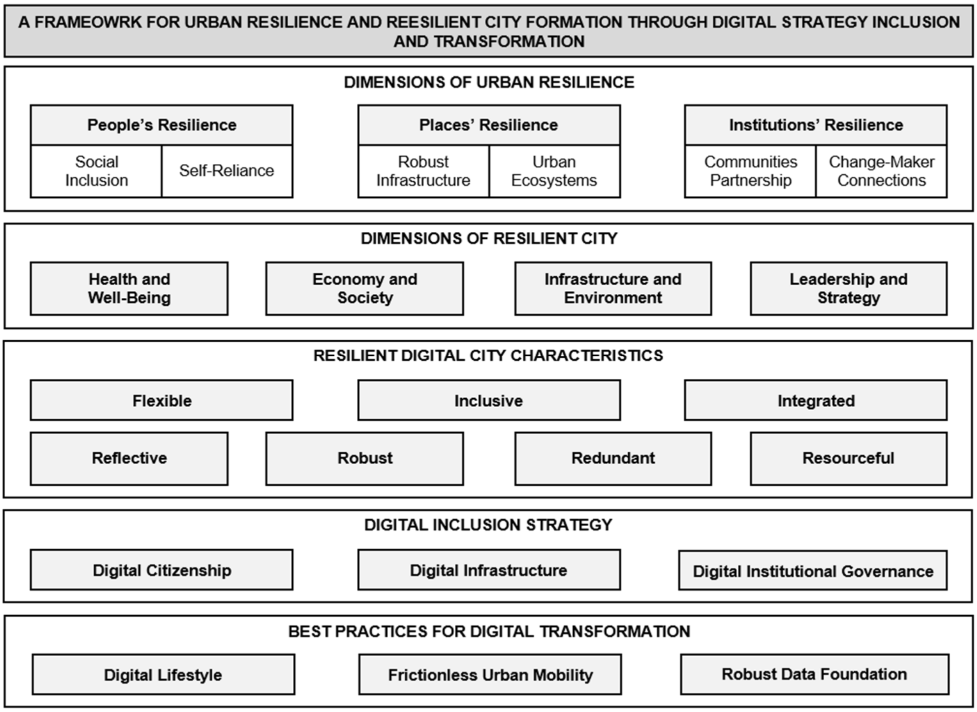


Figure 2: An Integrated Framework for City and Citizen's Resilience

CONCLUSION

This brief overview of the city and citizens' resilience may seem to be insufficient to reach definite conclusions as the synthesis may not be exhaustive or comprehensive. Nonetheless, this paradigm has the potential to bridge both theory and practice that integrates the knowledge of people, place and institutional resilience with a concern for the overall well-being of the city and its citizens. The suggested framework is also designed to foster discourse among stakeholders who are working to make cities and citizens more resilient. This implies that resilience-seeking efforts will always involve a more ongoing process rather than a single point of achievement hence, cities must make an ongoing effort to improve their urban resilience and this topic will remain relevant to academics, practitioners and policymakers for a long time to continuously explore collaborations between cities and citizens. Some of the future pathways in planning a resilient city and citizen may include social innovation enhancement through open dialogue spaces that sparkle discussions, reimagining how existing spaces can be used to inspire radical action for urban resilience, being receptive to new and multi-faceted ideas, approaches, and solutions that become essential to build and attain future urban resilience, continuous exploration, learning and the development of digital governance competence and more importantly aligning city development agenda towards an integrated approach of sustainable development and well-being. Besides, the role of citizens should not be overlooked, instead, they should be engaged to create a sense of ownership throughout all possible stages of resilience building.

REFERENCES

1. Adger, W. Neil. 2000. Social and Ecological Resilience: Are They Related? Progress in Human Geography 24(3): 347-64.
2. Adger, W. Neil. 2013. Vulnerability. Global Environmental Change 16(3): 268-81.
3. Aligica, Paul Dragos, and Vlad Tarko. 2013. Institutional Resilience and Economic Systems: Lessons from Elinor Ostrom's Work. Comparative Economic Studies 56(1): 52-76.
4. Arafah, Y., H. Winarso, and D. Suroso. 2018. Towards Smart and Resilient City: A Conceptual Model. In Proceedings of the IOP Conference Series: Earth and Environmental Science, Bandung, 3-5 April 2018 (pp.158), Indonesia, IOP Publishing Ltd.
5. Audirac, Ivonne. 2005. Information Technology and Urban Form: Challenges to Smart Growth. International Regional Science Review 28(2): 119-45.
6. Barma, N., E. Huybens and L. Vinuela. 2014. Institutions Taking Root: Building State Capacity in Challenging Contexts, World Bank Group, Washington, DC.
7. Barrett, M, G. David, and Wailes, N. 2006. ICT and Organizational Change: Introduction to the Special Issue. The Journal of Applied Behavioral Science 42(1): 6-22.
8. Batty, Michael. 2008. The Size, Scale, and Shape of Cities. Science 319(5864): 769-71.
9. Bekkers, Victor and Vincent, Homburg. 2007. The Myths of e-Government: Looking beyond the Assumptions of a New and Better Government. The Information Society 23(5): 373-82.
10. Bertot, J.C., P.T. Jaeger, and J.M. Grimes. 2010. Using ICTs to Create a Culture of Transparency: E-Government and Social Media as Openness and Anti-Corruption Tools for Societies. Government Information Quarterly 27(3): 264-71.
11. Brännström, Inger. 2012. Gender and Digital Divide 2000–2008 in Two Low-Income Economies in Sub-Saharan Africa: Kenya and Somalia in Official Statistics. Government Information Quarterly 29(1): 60-67.
12. Cheshmehzangi, Ali. 2016. Multi-Spatial Environmental Performance Evaluation towards Integrated Urban Design: A Procedural Approach with Computational Simulations. Journal of Cleaner Production 139: 1085-93.

13. Cheshmehzangi, Ali. 2020. Reflection on Early Lessons for Urban Resilience and Public Health Enhancement during the COVID-19." Health 12(10): 1390-1408.
14. Coaffee, Jon. 2013. Towards next-Generation Urban Resilience in Planning Practice: From Securitization to Integrated Place Making. Planning Practice and Research 28(3): 323-39.
15. Czerniewicz, Laura, and Brown, Cheryl. 2010. Born into the Digital Age in the south of Africa: the reconfiguration of the 'digital citizen'. In Proceedings of the 7th International Conference on Networked Learning, 3-4 May 2010, Lancaster, (pp. 859-865), Denmark, Lancaster University.
16. Damodaran, Leela, and Olphert, Wendy. 2006. Informing Digital Futures: Strategies for Citizen Engagement", Springer: Dordrecht.
17. Davidson, K, T.M.P Nguyen, R. Beilin, and J. Briggs. 2019. The Emerging Addition of Resilience as a Component of Sustainability in Urban Policy. Cities 9: 1-9.
18. Davoudi, S, E. Brooks, and A. Mehmood. 2013. Evolutionary Resilience and Strategies for Climate Adaptation. Planning Practice and Research 28(3): 307-22.
19. Deng W, and A. Cheshmehzangi. 2018. Eco-development in China: Cities, communities, and buildings. Singapore: Palgrave Macmillan.
20. Desouza, Kevin C., and Trevor H. Flanery. 2013. Designing, Planning, and Managing Resilient Cities: A Conceptual Framework. Cities 35: 89-99.
21. Dobson, Skye. 2017. Community-Driven Pathways for Implementation of Global Urban Resilience Goals in Africa. International Journal of Disaster Risk Reduction 26: 78-84.
22. Elmqvist, T., G. Barnett, and C. Wilkinson. 2014. Exploring Urban Sustainability and Resilience. In Resilient Sustainable Cities, Routledge: New York, NY, USA.
23. Fabbricatti, K, L. Boissenin, and M. Citoni. 2020. Heritage Community Resilience: Towards New Approaches for Urban Resilience and Sustainability. City, Territory and Architecture 7(1): 17.
24. Fattore, G, F. Hans and A. Lapenta. 2012. Measuring New Public Management and Governance in Political Debate. Public Administration Review 72(2): 218-27.
25. Flint, R.Warren. 2013. Practice of sustainable community development, a participatory framework for change. Springer: Berlin.
26. Fouda, A, N. Mahmoudi, N. Moy, and F. Paolucci. 2020. The COVID-19 Pandemic in Greece, Iceland, New Zealand, and Singapore: Health Policies and Lessons Learned. Health Policy and Technology 9(4): 510-524.
27. Fountain, Jane E. 2002. Building the Virtual State: Information Technology and Institutional Change. Washington, D.C.: Brookings Institution Press.
28. Gascó, Mila. 2003. New Technologies and Institutional Change in Public Administration. Social Science Computer Review 21(1): 6-14.
29. Godschalk, David R. 2003. Urban Hazard Mitigation: Creating Resilient Cities. Natural Hazards Review 4(3): 136-143.

30. Han, S, J. Sim, and Y. Kwon. 2021. Recognition Changes of the Concept of Urban Resilience: Moderating Effects of Covid-19 Pandemic. Land 10(10): 1099.
31. Henstra, Daniel. 2012. Toward the Climate-Resilient City: Extreme Weather and Urban Climate Adaptation Policies in Two Canadian Provinces. Journal of Comparative Policy Analysis: Research and Practice 14(2): 175-94.
32. Hill, S, D. Lorenz, P. Dent, and T. Lützkendorf. 2013. Professionalism and Ethics in a Changing Economy. Building Research & Information 41(1): 8-27.
33. Hillier, Jean. 2011. Strategic Navigation across Multiple Planes: Towards a Deleuzean-Inspired Methodology for Strategic Spatial Planning. Town Planning Review 82(5): 503-527.
34. Jabareen, Yosef. 2013. Planning the Resilient City: Concepts and Strategies for Coping with Climate Change and Environmental Risk. Cities 31: 220-229.
35. Janda, Kathryn B., and Yael Parag. 2013. A Middle-out Approach for Improving Energy Performance in Buildings. Building Research & Information 41(1): 39-50.
36. Kalantari, Z. 2021. Enlivening Our Cities: Towards Urban Sustainability and Resilience. Springer Science & Business Media: Berlin, Germany.
37. Kang, D, H. Choi, J-H. Kim, and J. Choi. 2020. Spatial Epidemic Dynamics of the Covid-19 Outbreak in China." International Journal of Infectious Diseases 94: 96-102.
38. Katchanovski, Ivan, and Todd La Porte. 2005. Cyberdemocracy or Potemkin E-Villages? Electronic Governments in OECD and Post-Communist Countries. International Journal of Public Administration 28(7-8): 665-681.
39. Kim, Soonhee, and Jooho Lee. 2012. E-Participation, Transparency, and Trust in Local Government. Public Administration Review 72(6): 819-828.
40. Liang, Zifeng. 2021. Assessment of the Construction of a Climate Resilient City: An Empirical Study Based on the Difference in Differences Model. International Journal of Environmental Research and Public Health 18(4): 2082.
41. Linde, Jonas, and Martin Karlsson. 2013. The Dictator's New Clothes: The Relationship between e-Participation and Quality of Government in Non-Democratic Regimes. International Journal of Public Administration 36(4): 269-281.
42. Linders, Dennis. 2012. From e-Government to We-Government: Defining a Typology for Citizen Coproduction in the Age of Social Media. Government Information Quarterly 29(4): 446-454.
43. Linkov, I, B.D. Trump, K. Poinsatte-Jones, and M-V. Florin. 2018. Governance Strategies for a Sustainable Digital World. Sustainability 10(2): 440.
44. Liu, X, S. Li, X. Xu, and J. Luo. 2021. Integrated Natural Disasters Urban Resilience Evaluation: The Case of China. Natural Hazards 107(3): 2105-2122.
45. Margetts, Helen, and Patrick Dunleavy. 2013. The Second Wave of Digital-Era Governance: A Quasi-Paradigm for Government on the Web. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 371: 20120382.

46. McPhearson, T, E. Andersson, T. Elmqvist, and N. Frantzeskaki. 2015. Resilience of and through Urban Ecosystem Services. Ecosystem Services 12: 152-156.
47. Meerow, Sara, and Joshua P. Newell. 2015. Resilience and Complexity: A Bibliometric Review and Prospects for Industrial Ecology. Journal of Industrial Ecology 19(2): 236-251.
48. Meerow, S, J.P. Newell, and M. Stults. 2016. Defining Urban Resilience: A Review. Landscape and Urban Planning 147: 38-49.
49. Min-Seok, K, Y.M. Jeon, and J.S. Lee. 2017. A Comparative Analysis of the Level of Urban Resilience in the City Comprehensive Plan. WIT Transactions on Ecology and the Environment 223: 517-526.
50. Misuraca, Gianluca, and Gianluigi Viscusi. 2014. Digital governance in the public sector: challenging the policy-maker's innovation dilemma. Proceedings of the 8th International Conference on Theory and Practice of Electronic Governance, Guimaraes, 27-30 October 2014 (pp.146-154), Portugal, Association for Computing Machinery, New York, United States.
51. Muller Norbert. 2010. Urban Biodiversity and Design. Chichester: Wiley-Blackwell.
52. Muller N, P. Werner, and J.G. Kelcey. 2010. Urban Biodiversity and Design. Chichester, UK: Wiley-Blackwell.
53. Nedaei, A, M. Seyednaghavi, M. Firouzfar, and N. Zamani. 2021. A Comparative Study of Urban Resilience in Coping with the Crisis in the Metropolises of Tehran and Mashhad. International Journal of Disaster Resilience in the Built Environment 13(1): 51-71.
54. Newman, Peter, and Isabella Jennings. 2012. Cities as Sustainable Ecosystems Principles and Practices. Washington: Island Press.
55. Ohler, Jason B. 2010. Digital Community, Digital Citizen. Thousand Oaks: Corwin Press.
56. Pickett, S.T.A., M.L. Cadenasso, and J.M. Grove. 2004. Resilient Cities: Meaning, Models, and Metaphor for Integrating the Ecological, Socio-Economic, and Planning Realms. Landscape and Urban Planning 69(4): 369-384.
57. Poku-Boansi, Michael, and Patrick Brandful Cobbinah. 2018. Are We Planning for Resilient Cities in Ghana? An Analysis of Policy and Planners' Perspectives. Cities 72: 252-260.
58. Prasad, N, F. Ranghieri, F. Shah, Z. Trohanis, E. Kessler, and R. Sinha. 2008. Climate Resilient Cities: A Primer on Reducing Vulnerabilities to Disasters. The World Bank, Washington, DC.
59. Redman, Charles L. 2014. Should Sustainability and Resilience Be Combined or Remain Distinct Pursuits? Ecology and Society 19(2): 37.
60. Rhodes, Rod A. 2011. One-Way, Two-Way, or Dead-End Street: British Influence on the Study of Public Administration in America since 1945. Public Administration Review 71(4): 559-571.
61. Romero-Lankao, P, D.M. Gnatz, O. Wilhelmi, and M. Hayden. 2016. Urban Sustainability and Resilience: From Theory to Practice. Sustainability 8(12): 1224.

62. Sanchez, A.X., J. van der Heijden, and P. Osmond. 2018. The City Politics of an Urban Age: Urban Resilience Conceptualisations and Policies. Palgrave Communications 4(1): 25.
63. Shamout, S, P. Boarin, and S. Wilkinson. 2021. The Shift from Sustainability to Resilience as a Driver for Policy Change: A Policy Analysis for More Resilient and Sustainable Cities in Jordan. Sustainable Production and Consumption 25: 285-298.
64. Spaans, Marjolein, and Bas Waterhout. 2017. Building up Resilience in Cities Worldwide – Rotterdam as Participant in the 100 Resilient Cities Programme. Cities 61: 109-116.
65. Stumpp, Eva-Maria. 2013. New in Town? On Resilience and 'Resilient Cities. Cities 32: 164-166.
66. Tabibian, Manouchehr, and Sepideh Movahed. 2016. Towards Resilient and Sustainable Cities: A Conceptual Framework. Scientia Iranica 23(5): 2081-2093.
67. Tassabehji, R, R. Hackney, and A. Popovič. 2016. Emergent Digital Era Governance: Enacting the Role of the 'Institutional Entrepreneur' in Transformational Change. Government Information Quarterly 33(2): 223-236.
68. Tyler, Stephen, and Marcus Moench. 2012. A Framework for Urban Climate Resilience. Climate and Development 4(4): 311-326.
69. Vale, Lawrence J. 2013. The Politics of Resilient Cities: Whose Resilience and Whose City? Building Research & Information 42(2): 191-201.
70. Walker, Brian, and David Salt. 2012. Resilience Thinking Sustaining Ecosystems and People in a Changing World. Washington: Island Press.
71. Yang, Q, D. Yang, P. Li, S. Liang, and Z. Zhang. 2021. Resilient City: A Bibliometric Analysis and Visualization. Discrete Dynamics in Nature and Society 2021: 1-17.
72. Yusuf, M, C. Adams, and K. Dingley. 2016. Digital Citizen Participation within Schools in the United Kingdom and Indonesia: An Actor-Network Theory (ANT) Perspective. Information 7(4): 69.
73. Zuniga-Teran, A.A, A.K. Gerlak, B. Mayer, T.P. Evans, and K.E. Lansey. 2020. Urban Resilience and Green Infrastructure Systems: Towards a Multidimensional Evaluation. Current Opinion in Environmental Sustainability 44: 42-47.

Chapter 9

CORONAVIRUS AND FOOD SECURITY IN DEVELOPING COUNTRIES

Yogeeswari Subramaniam*

INTRODUCTION

On 11 March 2020, Coronavirus pandemic 2019 (COVID-19) was declared by the World Health Organization (WHO) as a global pandemic due to the rapid rise in cases outside China that has affected almost all countries across the globe (WHO, 2020). COVID-19 has spread to over 210 countries with more than 3.29 million are infected and 232,806 deaths around the world as of May 2, 2020. Thereby the WHO director, Tedros Adhanom Ghebeyesus said "*the word pandemic is not just a worldwide outbreak of a new diseases, it is able to infect people easily and spread from person to person in efficient and sustainable way in multiple countries*" (Ducharme, 2020). Therefore, the WHO recommends that the public protect themselves by taking protective measures against the COVID-19 including wash hands with soap and water, maintain social distance and avoid touching eyes, nose and mouth as well as practice respiratory hygiene (WHO, 2020).

Commonly, most countries infected with the COVID-19 will experience a health crisis, resulting in human suffering and upend people's lives. The risk of serious illness is more severe for the elderly and those with underlying medical conditions, such as obesity, diabetes, chronic respiratory and cancers (Worldometer, 2020; WHO, 2020). Although human health condition is the most commonly discussed, COVID-19 also affects the world beyond human health crisis. COVID-19 can also bring in disastrous impact on other sectors, including international food security crisis. The Food and Agriculture Organization (FAO, 2020) predicts COVID-19 as a

* Universiti Teknologi Malaysia, yogeeswari.s@utm.my

new virus threatening the worlds food system and thereby jeopardizing food security for all, especially the hardcore poor living in poor countries (FAO, 2020). There are several reasons in which peoples can potentially engage in food insecurity during the COVID-19: (a) COVID-19 disrupts food supply chain[1] and trade through border closures,[2] (b) logistic bottlenecks or not being able to move food from place A to place B within a country,[3] (c) indirectly through disrupt the movement of agricultural labor[4] (FAO, 2020; World Bank, 2020). For instance, restriction of movement, as well as movement of labor and supply of inputs may pose critical challenge to food production, food-related logistic services, and thus negatively influence food availability and price of a food. The lessons from the mainly located in Sub-Saharan Africa deadly Ebola outbreak have become another supporting evidence that restrictions and market closures have disrupted food flows and supplies (Kodish et al., 2019).[5] Fear of the infectiousness and restrictions in movement which prevented some farmers from attending their fields have affected the production of cash and food crops. Reduced crop production, leading to lower availability of food and higher market prices, thus restricting people's access to adequate food, especially in Guinea, Liberia and Sierra Leone. It leads to a spike of hunger and malnutrition that led Africans to become impoverished. Hence, we cannot neglect food security issues as one of the possible consequences of COVID-19 that needs to be tackled simultaneously alongside the need to find vaccine to contain the effect of COVID-19.

Currently, 820 million people are chronically hungry, of which 113 million of them face acute poverty. COVID-19 then expected to expose them to imminent risk to

---

1 Among the examples are: (i) in the United States (US), retailers struggle to keep up with a huge surge in demand from pantry loading and buying panic, (ii) protein supply has been disrupted when covid-19 shocked China supply of pork, and (iii) restaurant closures also upend supply chains leading to disruption to food service companies as dramatical reduction in demand for milk, butter, cheese and other food in many parts of the world (https://www.spglobal.com/en/research-insights/featured/covid-19-is-taking-a-bite-out-of-food-supply-chains).

2 Among the real examples are: (i) Russia limits the grain exports to 7 million tonnes between April and June 2020, (ii) Ukraine decides to ban buckwheat exports until July 1, 2020, (iii) Kazakhstan introduces quotas on exports of sugar, buckwheat, potatoes and onion, in replacement to original ban, (iv) Vietnam and Cambodia temporarily suspend rice exports until at the time this paper is written, and (v) Egypt halts exports of legumes to preserve local supply (https://www.reuters.com/article).

3 Particularly the one that involves interstate delivery. The pressing issue is that delivery hardly can be on time.

4 For instance, India inevitably has to limit the exports of rice, due to labour shortages and logistic problem (https://www.reuters.com/article).

5 The latest issues could be during 2014-2016 originating from a small village in Guinea, later on spread to Italy, Mali, Nigeria, Senegal, Spain, the United Kingdom and the United States as well as in 2018 in Democratic Republic of Congo (www.cdc.gov).

their livelihoods. (FAO, 2019). Thereby, the ongoing global outbreak of COVID-19 may intensify the complexity of food crisis in countries already facing severe food insecurity. To highlight this issue, the scatter plot in Figure 1 displays the correlation between COVID-19 as measured by Global COVID-19 Susceptibility Index (GCSI) and food security as measured by Global Hunger Index (GHI). The plot shows that a country with more susceptible to the COVID-19 are generally suffer higher levels of food insecurity. Particularly, China as the first country to suffer seriously from the outbreak of COVID-19 has also positioned itself as among the most susceptible countries to COVID-19. At the same time, China also has a serious hunger index between 2018 and 2019. Thus, we suspect that COVID-19 may have partly impacted, if not fully the condition of food security in China.

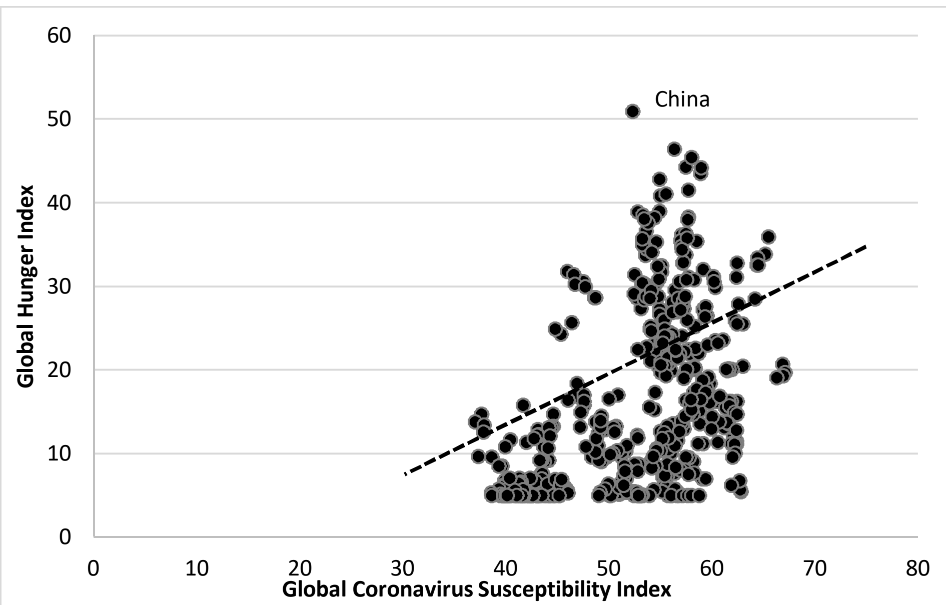


Figure 1: Correlation between population growth and food security from 2019-2021.

Source: von Grebmer et al. (2018) and Knoema (2020).

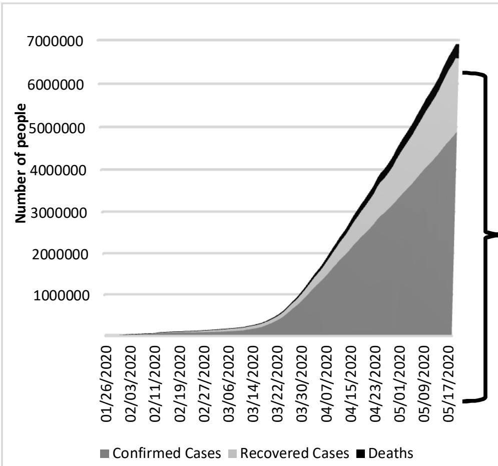
Hence, the objective of this study is to examine the implication of COVID-19 on food security in the selected countries. The organization of this study is as follows: the second section offers another insight about the COVID-19 and food security condition in developing countries.

1. BACKGROUND OF ECONOMY

COVID-19

COVID-19 are originated from a family of Zoonotic viruses that able to be transmitted from animals to humans. In humans, COVID-19 cause a range of illness from the common cold to severe respiratory diseases. According to WHO (2020), COVID-19 can spread from person to person via small droplet from the nose or mouth of infected person, often during sneezing or coughing. The most common signs of COVID-19 infection are tiredness, fever, dry cough, but some people may experience aches and pain, runny nose, sore throat, and diarrhea (WHO, 2020). It takes on average 5-6 days for someone to display signs to be infected with the virus, but it can take up to 14 days. Although all ages groups are at risk of infecting COVID-19, older people and people who have chronic medical conditions such as asthma, diabetes and heart disease are likely at higher risk for serious COVID-19 illness and death (WHO, 2020).

Cases of COVID-19 first emerged in Wuhan, Hubei province, China in late 2019. China governments records indicate that the first person infected with COVID-19 is a Hubei resident aged 55, then the number of infected people increased 266 in the same year (Ji, 2020). Following a sharp increase in the COVID-19 cases and total death, the central government of China imposed lockdown in Wuhan and other cities in Hubei. Also, a COVID-19 outbreak is confirmed outside China in Thailand as a first-recorded case, followed by Japan, Korea, the United Kingdom, Russia, Sweden and Spain (Worldometer, 2020). At last, COVID-19 was declared a pandemic by the WHO as a result of the rapid rise in outside China, affecting a growing number of countries (210 countries and territories worldwide).



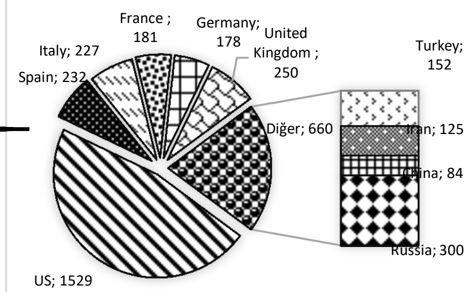


Figure 2: World total cases of COVID-19. **Figure 3:** Total cases of COVID-19 in selected countries.

Source: Knoema (2020). **Source:** Knoema (2020).

Accordingly, the total COVID-19 cases and death from 20th January to 17th May over the world are is illustrated in Figure 2 and 3. Confirmed cases of COVID-19 worldwide exceeded 4.6 million, with over 1.67 million recoveries (Singhal, 2020). In China, almost 80,000 of the COVID-19 cases occurred, specifically in the province of Hubei. The number of peopled recovered standing at 816,685 with the death toll increased to 202,846 peoples. Across the world, the total number of COVID-19 cases and death in the United States exceed 80,000 and 50,000, the highest country in the world after China is turning the tide on COVID-19 (WHO, 2020). As the official number suggests a decrease in the number of new cases reported in China, countries with escalating outbreaks are eager to learn how China escaped from the COVID-19 break. Through implementing a nation-lockdown, China has controlled the epidemic of cavities, and other countries have now taken the same measure to control this viral pandemic (Ji, 2020; WHO, 2020). Therefore, ending the illness would demand a continued effort by individuals, communities and governments to continue to suppress and control the fatal new COVID-19.

Food security

What is food security? There are more than 450 indicators and 200 definitions of food security. In the 1996 World Food Summit, Mercy Corps defines food security as a situation whereby "all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (Maxwell, 1996, p. 3). From this concept, the FAO introduces four dimensions of food security, namely food availability (i.e. sufficient, safe and nutritious food), accessibility (i.e. physical and economic access), utilization (i.e. to meet their dietary needs and food preferences) and stability (i.e. for all people at all times) (Ghattas, 2014; Subramaniam et al., 2019). All four dimensions must be simultaneously fulfilled and satisfied in order to achieve the goal of food security. Food availability has the goal of ensuring that enough food is available to everyone but may not be sufficient to promote food security. Then, the concept of food security is expanded to include the ability of households to obtain foods (food accessibility), more importantly healthy food. Finally, food stability is needed as the fourth dimension to ensure that all people are food secure now and, in the future, (Webb and Rogers, 2003).

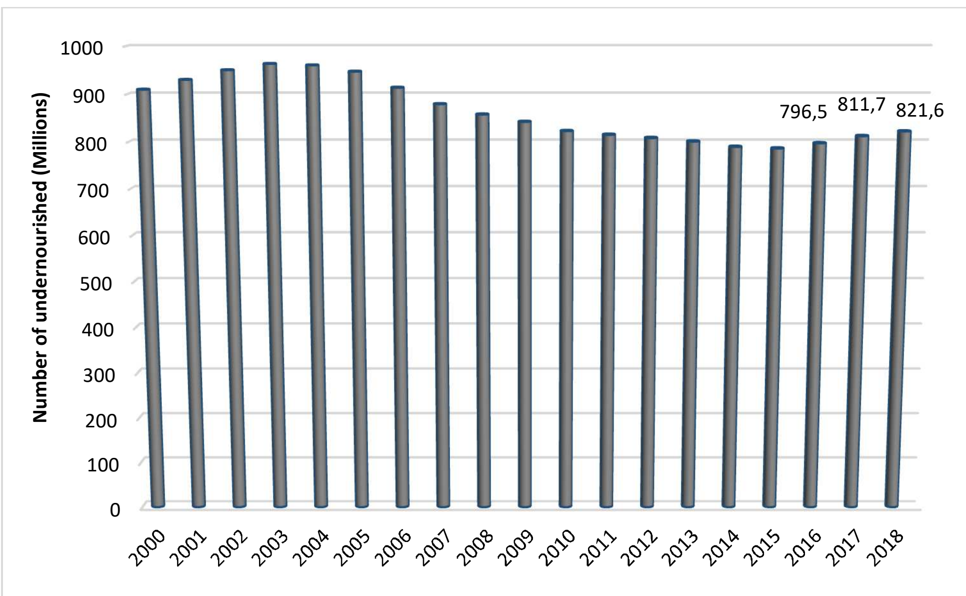


Figure 4: Number of undernourished people in the World, 2000-2018.

Source: FAOSTAT (2020).

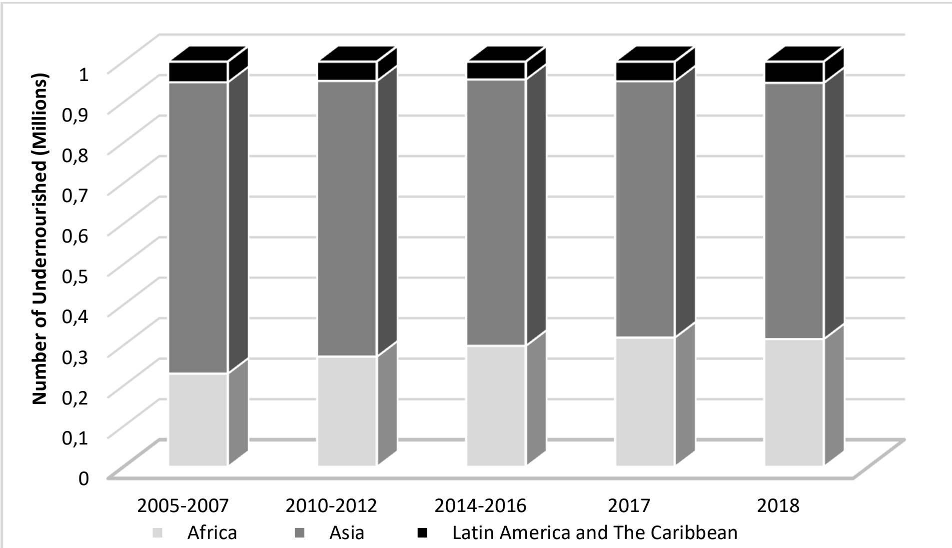


Figure 5: Number of undernourished people by region, 2000-2018.

Source: FAOSTAT (2020).

Recent FAO report have shown that after decades of steady decline in hunger, measured by the prevalence of undernourishment, it has risen again in 2015 and remained unchanged in the last three years. Figure 4 indicates the number of undernourished people in the world between 2000 and 2018. The total number of undernourished people increased slowly from 2015 to 2018, reaching 821.6 million people in 2018. In fact, developing countries host the majority (or 819.18 million people) of the undernourished than developed countries. Two thirds of the total undernourished are placed under Asia region, followed by Africa (256.10 million people), and Latin America and Caribbean (42.5 million people) (refer Figure 5). This hunger trend can be confirmed by moderate and severe food insecurity estimates, which computed using the food insecurity experience scale. The number of people experiencing severe food insecurity is more than 700 million people in 2018, implying reduction in the quantity and quality of food consumed and can have adverse effect for health, nutrition and well-being (FAO, 2020). Consistent with the discoveries for the undernourished, Asia is the region with the highest number of severe food insecurity, reaching 353.6 million in 2018 up from 288.5 million in 2015. Severe food insecurity is also increasing in Africa, followed by Latin America and Caribbean. Moreover, the moderate level of food insecurity reveals that an additional two million of the world population affected by moderate level of food insecurity from one million people in 2017. Hence, these two billion additional people had no daily access to healthy and adequate food. All of this led to us on a mission to end hunger, food insecurity and malnutrition so that "no one is left behind".

2. METHODOLOGY

The method of approach applied in this paper is based on the following two categories of research

i. The fundamental relationship between COVID-19 and food supply chain resulting in food security.

ii. The empirical relationship between COVID-19 and food security through four dimensions of food security.

To find the empirical relationship between COVID-19 and food security for the panel of 99 countries the following model is proposed:

$$FS_i = A_0 POP_i^{\alpha_{1i}} REM_i^{\alpha_{2i}} GCSI_i^{\alpha_{3i}} \tag{1}$$

The logarithm transformation of *Eq. (1)* is given by

$$\ln(FS_i) = \alpha_0 + \alpha_{1i}\ln(POP_i) + \alpha_{2i}\ln(REM_i) + \alpha_{3i}\ln(GCSI_i) + \varepsilon_i \tag{2}$$

Where $\alpha_0 = \ln(A_0)$ and the subscript *i* represents *i*th country. FS is the food security measured by global food security index (GFSI), POP indicates population growth (% population of the total), REM is remittances (% total remittances of the GDP), and GSCI is Global COVID-19 Susceptibility Index as proxy for COVID-19. Here α_1, α_2, and α_3 represents the long-run elasticities of food security with respect to POP, REM, and GCSI, respectively. We conduct the analysis using Ordinary least squares (OLS) that has commonly been used to estimate the parameters of a linear regression model. Regression has five main assumptions, and if these assumptions are valid for linear regression, OLS produce the best estimates. OLS assumes linearity in parameter; exogeneity where disturbances are not correlated with any regressors; the disturbances have constant variance (homoscedasticity) and are not related with each other (no autocorrelation); the observation on the independent variables are not stochastic but fixed in repeated sample without measurement errors and no multicollinearity problem (Zietz et al., 2008).

On the measurement of food security, this study employs GFSI. GFSI by DuPont is the most known measure of food security across most of the countries of the world. The GFSI is designed to monitor food security trends in a country. The GFSI index score is based on the four broad dimensions affordability that measure consumers' ability to purchase food; availability that measures the sufficiency of the national food supply; quality and safety that measure variety and nutritional quality of average diets and safety of the food supply and natural resources that ensure a country's exposure to the impacts of climate change.

For COVID-19, instead of directly applying total number of cases of COVID-19, this study uses Global COVID-19 Susceptibility Index (GCSI). The GCSI from Knoema offers provides an investigation on countries' vulnerability to COVID-19 transmission based on some of the factors that currently affect the exposure of countries and their ability to respond to the virus. The Knoema constructs the index based on the average of five components, namely healthcare quality and resources, economic interconnectedness, digital infrastructure, demographic susceptibility and trust in government. Each component has its own but different sets of elements (see Table 1).

Table 1: The components of Global Coronavirus Susceptibility Index

Component	**Elements**
Healthcare quality and resources	Health expenditure per capita in PPP IHME healthcare access and quality Physicians (per 1,000) Nurses and midwives (per 1,000 people) Hospital beds (per 1,000 people)
Economic interconnectedness	Trade in goods and services to GDP ratio Manufacturing and trade to GDP ratio Air transport, passengers carried to population ratio
Digital infrastructure	ICT Development Index
Demographic susceptibility	Urbanization Population density Population 80+ Population 65+, % of total
Trust in government	Government effectiveness Rule of law

Note: Knoema (2020)

On the measurement of GCSI, Knoema normalized the elements scores and then aggregated across components to enable a comparison of broader concepts across countries. For the elements where high value indicates a lesser risk such as healthcare access and quality index, nurses and midwives, ICT development index, physicians, government effectiveness, and rule of law have been normalized on the basis of $X = \frac{X - \min(among\ countries)}{max - min}$ to make it directly comparable with other elements. Finally, the GCSI calculated using an average of five components. Therefore, the GCSI is expressed as a value between 0 and 100 where the higher the value of susceptibility, the more susceptible level is.

3. RESULTS AND DISCUSSION

The fundamental relationship between COVID-19 and food supply chain resulting in food security

A food supply chain is a process describing how food from the farm ends on our fork. The processes include all activities related to the production, storage, processing, distribution, transport, trade and food retailing that affect human health and nutrition's (Bourlakis and Matopoulos, 2010; Zhong and Wang, 2017). Figure 6 shows the core activities of the global food supply chain. Food supply chains begin from the primary phase of agriculture, which encompasses all aspects of farm inputs, including land, machinery, farmers, seeds, fertilizers and pesticides are continuously involved in growing, processing, distributing and consuming food. Farming relies on the use of inputs, including adequate water and soil, efficient machinery to plough and plant the crops, fertilizers to supplement natural soil nutrients, pesticides to protect crops against insects for growing and harvesting agricultural commodities. Applying more and better agricultural inputs to agriculture will allow for an average increase in crop yields and can help to produce more and healthier crops (Bourlakis and Weightman, 2004). The food crops are then passed on to the manufactures to produce packaged food items or final product. There are two levels of food processing, namely, primary processing and secondary processing. Primary processing involves cutting, cleaning, packaging, storage and refrigeration to transform agricultural crops to foods that can be consumed (MacDonald and Reitmeier, 2017). For instances, pasteurization of milk, milling of wheat, cleaning, sorting and grading for grains, and sorting and refrigeration of meat. Secondary processing or advanced processing involves transformation of food from the primary production stage into more usable or edible forms (MacDonald and Reitmeier, 2017). Secondary foods include condensed milk, flours, edible oils, sugars and starches. In some cases, secondary food processing also used heating, cooling, drying, smoking, and fermentation treatment, food additives and packaging to extend the shelf life of food and to ensure the quality and safety of the products produced. The food product supplied by the manufacturing and processing sector are mostly transferred to the wholesale industry and then deliver to retail and final consumers (Ibrahim et al., 2019). The wholesale industry consists of companies that buy and store foodstuffs in a network of warehouse facilities, then sell and distribute food products to retail outlets and service sector using a transport system. The retail outlets are a grocery store, convenience store, vending machines and food service sector includes restaurants, fast-food outlets, cafeteria, eating and drinking establishments where consumer buy food products for own preparation and consumption. Finally, the customer represents the end actors who purchase food to eat or be prepared at home or elsewhere or who eat in a food service establishment.

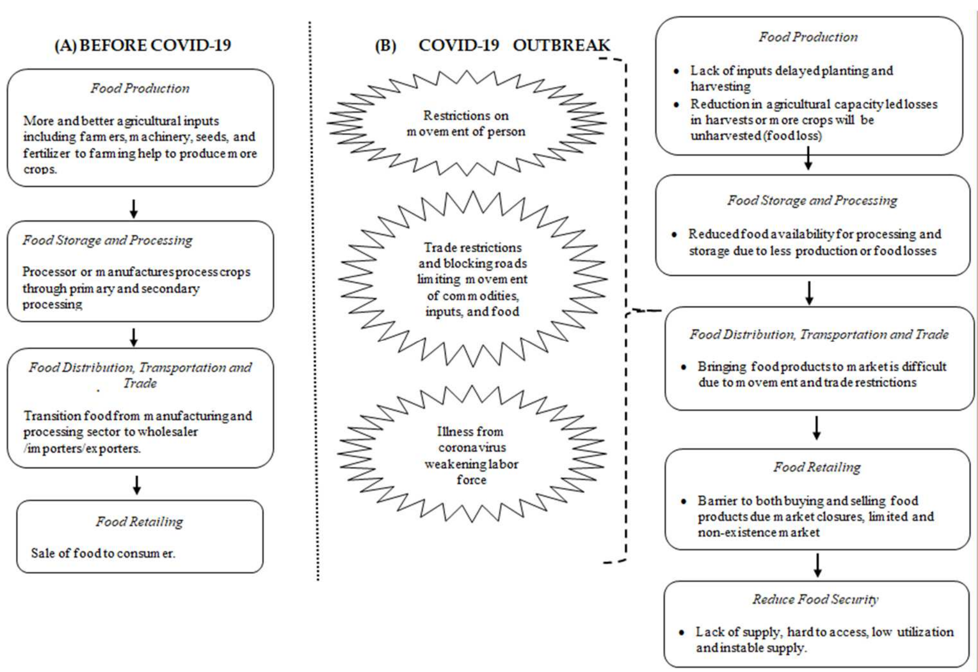


Figure 6: The COVID-19 impact on food supply chain

Here the question is how the pandemic affecting food security? To understand the impact of COVID-19 on global food security, it is crucial to start by considering the processes involved in the food supply chain, as discussed above. A food supply chain is a complex network consisting of agricultural inputs, transportation, processing and storage, that interact with a processor, manufacturer, retailers and consumers at all levels. Since the COVID-19 pandemic has prompted countries all over the World to take a variety of measures, it may affect food supply chains and have a significant effect on food security. Hence, Figure 6(B) highlights the impacts of COVID-19 on the food supply chain from the farm to our tables, resulting in food insecurity (Hobbs, 2020).

To reduce the spread of COVID-19, the governments around the world restricted people's movements by imposing partial or complete road and border closure and community quarantines. However, in doing so, food security is negatively impacted due to the disruption of farmers on farming, food processors on handling agricultural production and from processing as well as hinder people's from accessing sufficient and nutritious sources of food. For instance,

"...can hinder food-related logistic services, disrupt entire food supply chains and affect the availability of food. Impacts on the movement of agricultural labor and on the supply of inputs will soon pose critical challenges to food production, thus jeopardizing food security for all people..." (FAO, 2020).

Figure 6(B) illustrates the core components of the global food supply chain, which organized from food production to food retailing combined with food security. COVID-19 initially affected the food production phase of the food value chain, as trade restrictions and workers' illness reduced labour-power, and commodity movements. Lack of or insufficient agricultural input for cultivation may delay planting and harvesting. For instance, an acute scarcity of labour and availability of inputs had poses serious challenge for farmers in Madhya Pradesh, Haryana, Punjab and Rajasthan (Krar et al., 2020). Farmers have faced difficulties in harvesting winter-seed crops (wheat) and planting the next crop due to prolonged lockdowns aimed at stopping COVID-19 spread. Thereby, it leads to a reduction in the quantity and quality of crops harvested on the farm (production). On another side, reduction in agricultural capacity led losses in harvests or more crops will be unharvested (food loss). Weak logistics and infrastructure combine harvester shortages, as transport and machines from other countries cause food loss during harvesting and gathering.

Reduced food production subsequently leads to less availability of food for storage and processing. Processing and storage phase usually pose a tremendous impact on crops behaviour, transforming into higher-value packaged, marketable and processed food products. The impairment of health and workforce productivity directly as well as indirectly is another effect of COVID-19 on food processing, as some workers remain in their homes to avoid the virus from being brought back to their families. If this is the case, then labor shortages would disrupt food production and cause food loss, particularly in labor-intensive industries, in relation to food products handling, stocking and packaging. Then, restriction on transportation, border closures and trade will make food flow from the manufacturer to the distributor or wholesaler becomes tougher. Distribution of food also involves global trade (export and import), where the food product produced in one country are exporting or importing to another country. As the outbreaks of COVID-19 spread globally, the logistics sector seriously disrupted and harmed food flows to China, the largest importer of food. For example, Vietnam, the World's third-largest exporter of rice, following a domestic supply shortage, bans shipping rice to foreign countries (Krar et al., 2020; VOA News, 2020). In the last stages, COVID-19 affects the retailers who purchase food products directly from producers, distributors or processors. Closures, limited and non-existence of entire markets, restaurants and stories avoid buyers and sellers from buying and selling food products. In some cases, COVID-19 has led to panic buying by people around the world, leading to shortages and emptiness in some outlets (Nicola et al., 2020). Thereby, it further disrupted the supply chains in the agricultural industry and threaten food security globally. Hence, the underlying COVID-19 impact on food security can be observed from lack of supply, hard to access, low utilization of nutritious foods and instable supply.

The relationship between COVID-19 and food security through four dimensions of food security

Accordingly, the threat to the global food supply chain from the COVID-19 pandemic will shift to four dimensions of food security, namely food availability, accessibility, utilization and stability. As mentioned above, the potential impact of COVID-19 on the food supply chain, resulting in food insecurity are graphically present in Figure 7. The disrupted food supply chain may adversely affect food availability because a decrease in food production contained at the food production stage. Food production tend to be at a low level due to the restrictions on movement and fear of contagion, which kept some farmers away. This, in turn, may cause the availability of food to be less than the food required by the population during the outbreak.

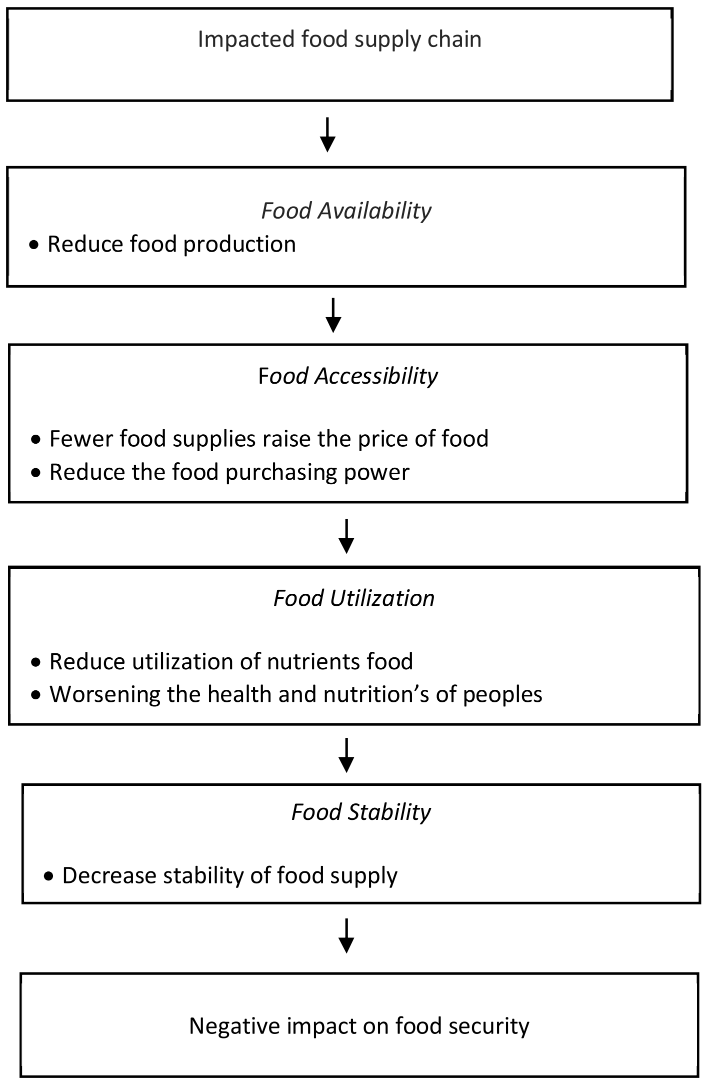


Figure 7: COVID-19 and four dimensions of food security.

Subsequently, a decrease in food supply relative to demand will lead to an increas e in food price. The rise in food prices will contribute to lower household purchasing power, which can eventually reduce nutritional and health consumption. This indicates that a reduction in the level of food intake will result in increased undernourishment and adversely affect the utilization of food.

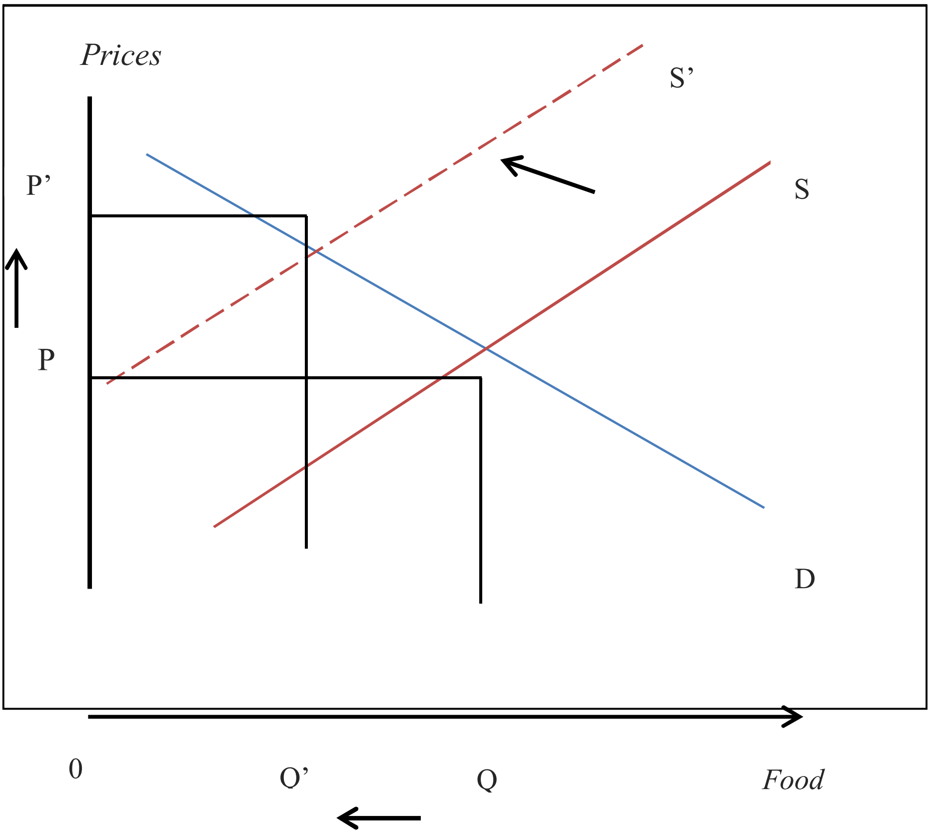


Figure 8: Food supply and demand

Note: *S* represents food supply, *D* represents food demand, *P* represents food prices and *Q* represents quantity of food.

Evidently, Figure 8 shows that a drop-in food supply shifts the supply curve to the left reflecting lower food availability, thus increasing food prices. Thus, it reduces their purchasing power and lead to higher price food consumption for people. Moreover, higher food price combined reduction in household income further impacting food insecurity in the worst affected countries. Household income reduced as a result of the slowdown of the main economic sector, including the primary sector, the manufacturing sector and the service sector. According to Nagarajan (2020), China's gross domestic product falls almost seven per cent in the first quarter of 2020 due to a sharp reduction in the productivity of economic activities. Reduction of economic growth believed to expand China's income inequality and pushing more people into poverty in 2020. Eventually, the COVID-19 outbreak might bring a decline in the availability of food, price rises and lower-income further erode the stability of supplies.

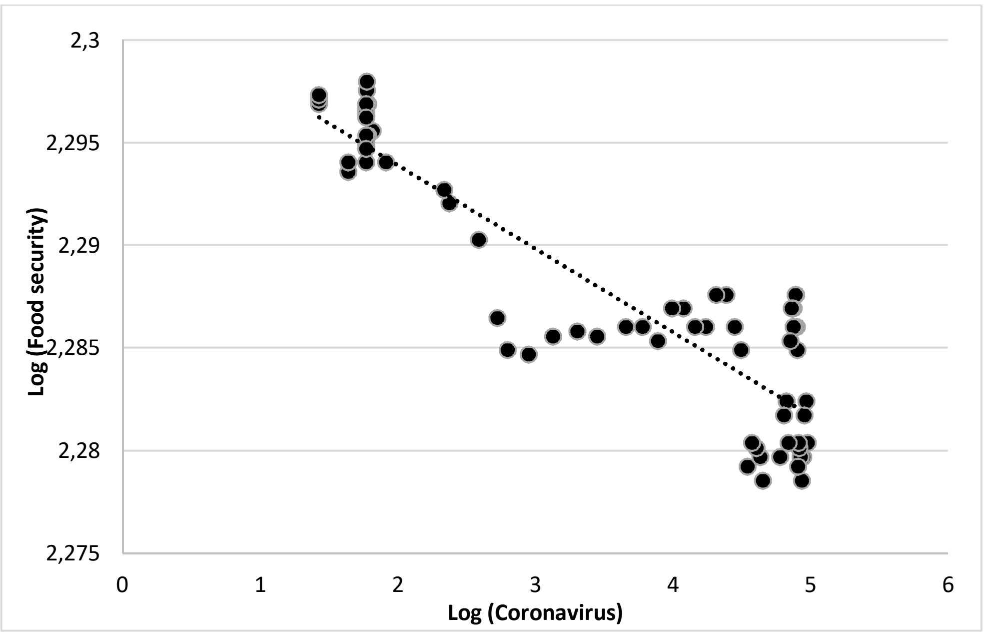


Figure 9: The correlation between COVID-19 and food security in the world during 31 December 2019- 19 August 2021

Source: Knoema (2020) and FAO (2020)

Empirically, we show a simple correlation for the aggregation effect when testing the relationship between the COVID-19 and food security. Here, we utilize food price index as a measure of food security and number of confirmed COVID-19 cases for COVID-19. Figure 9 shows that an increase in food prices leads to a decrease in food demand, reflecting the ability of people to continue buying food to feed themselves and their families. Subsequently, it reduces consumer willingness to purchase food and threatens the country's food security status. The number of confirmed COVID-19 cases is considered as a proxy for COVID-19 outbreaks to assist in understanding the spread of the pandemic.

Accordingly, the relationship between those two variables is represented graphically in a scatter plot. Relationship direction is negative between two variables. This finding supports the idea that the epidemic of COVID-19 will hurt the level of food security of affected countries in the world (Deaton and Deaton, 2020). The effect of a pandemic on food security is identified with production, as mentioned in the above section. Shocks to the food supply chain, including transportation and trade disruption, shortage of labour, and farming inputs may reduce the production of crops, which can have an impact on the food availability of a country. Such a lack of food supply may lead to a shortage of food in the global market. Also, it is important to remember that the fear of food shortages leads consumers to panic buying, resulting in shortages of grocery store shelves and increasing food demand. If this is the case, low supply and high demand rise food price in the short term. Higher food prices may prevent households from buying food products which, in turn, would result in increased undernourishment and lower food utilization. Overall, the outbreak of COVID-19 substantially reduced food production aggravated the problem of food insecurity in COVID-19 affected countries.

Besides using the simple correlation, we also further estimate the specification using simple OLS regression (See Table 2). We also estimate the specification using additional food security determinant, namely population growth, and remittances. Among the controlled variables, population growth and environmental degradation seem to have a negative effect on food security, while remittances affect food security positively. Rapid population growth followed by increased demand for more food leads to the shortage of food to feed the entire population, thereby exacerbating the food insecurity issues (Tian et al., 2016; Hall et al, 2017; Dithmer and Abdulai, 2017; Prosekov and Ivanova, 2018). In terms of remittances, remittance as a source of income seen as a solution to food security through increased income (Atuoye et al., 2017; Mabrouk and Mekni, 2018; Sulemana et al., 2018). Increased incomes can help people to reduce hunger by allowing them access to adequate and quality food.

Table 2: Regression analysis [DV: *ln (FS)*]

	(1)	(2)	(3)
C	7.0088*** [20.78]	0.1396*** [2.79]	6.3239*** [14.39]
ln (POP)	-0.0061** [-2.61]	-5.9490*** [-8.99]	-0.0143** [-2.28]
ln (REM)	0.0439*** [3.51]	3.1657* [2.04]	0.0368*** [2.78]
ln (GCSI)	-0.7290*** [-8.50]	-2.0939*** [-4.98]	-0.5490*** [-4.86]
Country Dummies			
Algeria	-	5.9389** [2.19]	-
Angola	-	18.7332* [2.05]	-
Argentina	-	15.7701* [2.01]	-
Australia	-	20.5668* [1.98]	-
Austria	-	7.0692* [2.06]	-
Azerbaijan	-	-2.5086** [-2.12]	-
Bangladesh	-	1.0920** [2.19]	-
Belarus	-	3.1314* [2.03]	-
Belgium	-	0.8559*8 [2.15]	-
Benin	-	-11.5292** [-2.27]	-
Bolivia	-	-7.2497** [-2.18]	-
Bosnia and Herzegovina	-	0.7430* [1.99]	-
Botswana	-	-6.9484*** [-2.90]	-
Brazil	-	19.9382* [2.03]	-
Bulgaria	-	-4.5671* [-2.09]	-

Burkina Faso	-	-5.8565*** [-3.99]	-
Cambodia	-	-9.8644*** [-2.56]	-
Cameroon	-	-2.3651*** [-2.79]	-
Canada	-	20.0098* [2.00]	-
Chile	-	15.2454* [2.05]	-
China	-	18.9407* [2.09]	-
Colombia	-	3.0611** [2.11]	-
Congo	-	-15.3338* [-2.03]	-
Costa Rica	-	-8.0577* [-1.92]	-
Côte d'Ivoire	-	0.7728** [2.50]	-
Czech Republic	-	-0.9860*** [-3.54]	-
Denmark	-	1.4758* [2.04]	-
Dominican Republic	-	-14.1674*** [-2.95]	-
Ecuador	-	-5.0620** [-2.14]	-
Egypt	-	0.3257** [2.32]	-
El Salvador	-	-21.2755*** [-8.97]	-
Ethiopia	-	10.0546* [2.01]	-
Finland	-	7.2415*** [3.93]	-
France	-	15.8356** [4.17]	-
Germany	-	17.1179*** [4.00]	-
Ghana	-	-6.3301*** [-5.11]	-

Greece	-	5.2471* [2.04]	-
Guatemala	-	-13.9090*** [-4.95]	-
Haiti	-	-22.3349*** [-6.99]	-
Honduras	-	-18.4548*** [-2.57]	-
Hungary	-	-2.5490*** [-3.04]	-
India	-	14.4116* [2.06]	-
Indonesia	-	11.1087* [2.07]	-
Ireland	-	3.5107* [2.09]	-
Israel	-	2.8154** [2.20]	-
Italy	-	9.1903* [2.08]	-
Japan	-	24.9278* [2.00]	-
Jordan	-	-12.4468*** [-7.99]	-
Kazakhstan	-	8.7069** [3.19]	-
Kenya	-	2.2754* [1.96]	-
Korea	-	17.2807* [1.97]	-
Lao PDR	-	-7.7278* [-2.00]	-
Madagascar	-	-6.2794* [-2.06]	-
Malawi	-	-3.1190*** [-4.92]	-
Malaysia	-	5.0546** [2.15]	-
Mali	-	-8.6690** [-2.27]	-
Mexico	-	5.1130** [2.11]	-

Morocco	-	-4.2880*** [-3.11]	-
Mozambique	-	-2.2937** [-2.11]	-
Myanmar	-	-2.2892** [-2.26]	-
Nepal	-	-11.2934*** [-5.00]	-
Netherlands	-	9.1994* [2.03]	-
New Zealand	-	5.8821* [1.99]	-
Nicaragua	-	-17.4674** [-4.19]	-
Niger	-	-4.3265* [-2.01]	-
Nigeria	-	2.8510* [2.02]	-
Norway	-	13.4977*** [8.13]	-
Oman	-	4.9887* [2.08]	-
Pakistan	-	1.8739** [2.20]	-
Panama	-	-8.1406*** [-4.13]	-
Paraguay	-	-9.4134*** [-4.95]	-
Peru	-	0.5910** [2.15]	-
Philippines	-	-1.9024*** [-2.71]	-
Poland	-	7.0012* [2.01]	-
Portugal	-	-2.3137* [-1.98]	-
Romania	-	1.4726* [2.08]	-
Russia	-	18.8325*** [9.38]	-
Rwanda	-	-7.3413* [-2.01]	-

Samoa	-	6.7745** [2.65]	-
Saudi Arabia	-	18.2127* [2.01]	-
Senegal	-	-12.5914** [-2.17]	-
Serbia	-	-8.7086* [-2.05]	-
Seychelles	-	-3.7779* [-2.01]	-
Sierra Leone	-	-7.5455*** [-2.85]	-
South Africa	-	10.9852* [2.05]	-
Spain	-	9.2438* [2.02]	-
Sri Lanka	-	-7.4632*** [-2.98]	-
Sudan	-	-0.6859* [-1.90]	-
Sweden	-	6.6046*** [2.96]	-
Switzerland	-	5.0776* [2.02]	-
Tajikistan	-	-15.0820*** [-4.0]	-
Tanzania	-	5.3749* [2.19]	-
Thailand	-	4.5167** [2.12]	-
Tunisia	-	-9.3091*** [-3.98]	-
Turkey	-	13.8801*** [5.07]	-
Uganda	-	-4.8949** [-2.98]	-
Ukraine	-	1.6030* [1.90]	-
United Kingdom	-	15.6309* [2.08]	-
United States	-	28.4919** [2.24]	-

Regional Dummies			
East Asia and Pacific	-	-	0.0032* [2.05]
Europe and Central Asia	-	-	0.0305*** [2.55]
Latin America & the Caribbean	-	-	0.0330** [2.16]
Middle East and North Africa	-	-	0.0069* [2.09]
North America	-	-	0.0747*** [2.64]
South Asia	-	-	-0.0108*** [-3.13]
Sub-Saharan Africa	-	-	-0.1558*** [-2.70]
		Model Criteria	
Adj-R^2	0.4941	0.61829	0.5611
F-Stat (Overall)	33.88*** [0.00]	21.85*** [0.00]	13.79*** [0.00]

Note: Asterisks *, **, and*** denote the 10%, 5%, and 1% levels of significance, respectively. Figures in [ ] stand for t-statistics.

As shown in Table 2, the coefficient of GCSI is negative and a significant determinant of food security at conventional levels. this suggesting that COVID-19 is threatening the level of food security, in particular in the affected countries. Recall from the discussion above that, Border restrictions, quarantine and trade disturbances are obstacles that impede the production of food and restrict the people's access to adequate and nutritious food. The pandemic, in turn, poses a higher risk to food stability in countries affected by the virus or already highly vulnerable to food insecurity. Therefore, the finding reinforces the view that COVID-19 is more influential in exacerbating a country's level of food security.

CONCLUSION

The impact of COVID-19 on food security is examined from two different perspectives. From a food supply chain perspective, the outbreak of COVID-19 and the resulting consequences disrupted the food chain from production to retail. The disrupted food chain will have a detrimental effect on the global food system and the ability to provide adequate, accessible and safe food throughout. Concerning the second perspective, the impact of COVID-19 on food security is negative across the four dimensions of food security. This indicates that COVID-19 has contributed to lower food supply, higher prices, lower consumption and unstable food supplies. Therefore, the COVID-19 outbreak has the potential to exacerbate the problem of food insecurity throughout the country.

Regarding the implications, the government should provide law-enforcement authorities with specific guidance reminding them that agricultural inputs and food movement should give priority. At the same time, to avoid disruptions to the food supply chain and food production, government needs to urge all sectors of the economy, namely the primary sector, the manufacturing sector and the service sector, to keep international trade open and to take measures to protect their food supply chain. To ensure the continued availability of food to all people during the COVID-19 outbreak, the government needs to mitigate panic buying and storing behavior among consumers. For example, the government may provide customers with an overview of the effect of panic purchases on food security, which further amplifies the effect of the pandemic.

REFERENCES

1. Atuoye, K. N., Kuuire, V. Z., Kangmennaang, J., Antabe, R. and Luginaah, I. (2017). Residential remittances and food security in the Upper West Region of Ghana. *International Migration, 55(4),* 18-34.
2. Bourlakis, M., and Matopoulos, A. (2010). Trends in food supply chain management. In Delivering Performance in Food Supply Chains (pp. 511-527). Woodhead Publishing Series in Food Science, Technology and Nutrition: Sawston, Cambridge.
3. Bourlakis, M. and Weightman, P. (2004). Introduction to the UK food supply chain, in: Bourlakis, M.,Weightman, P. (eds.), Food Supply Chain Management, Blackwell Publishing, Oxford, UK, Chapter 1,1-10.
4. Deaton, B. J., and Deaton, B. J. (2020). Food security and Canada's agricultural system challenged by COVID-19*. Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie. 68, forthcoming.*
5. Dithmer, J. and Abdulai, A. (2017). Does trade openness contribute to food security? A dynamic panel analysis. *Food Policy, 69 (May),* 218-230.
6. Ducharme, J. (2020). World Health Organization Declares COVID-19 a'Pandemic.'Here's What That Means. Time. https://time. com/5791661/who-coronavirus-pandemic-declaration.
7. FAO (2020). Novel Coronavirus (COVID-19). Retrieved April 2020 from: http://www.fao.org/2019-ncov/q-and-a/en.

8. FAOSTAT (2020). Food and agriculture data. Retrieved April 2020 from: http://www.fao.org/faostat/en/#data
9. Hall, C., Dawson, T. P., Macdiarmid, J. I., Matthews, R. B. and Smith, P. (2017). The impact of population growth and climate change on food security in Africa: looking ahead to 2050. *International Journal of Agricultural Sustainability, 15(2),* 124-135.
10. Hobbs, J. (2020). Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 68, forthcoming*
11. Ji, Y., Ma, Z., Peppelenbosch, M. P., & Pan, Q. (2020). Potential association between COVID-19 mortality and health-care resource availability. *The Lancet Global Health, 8(4),* 480-481.
12. Knoema (2020). Coronavirus Outbreak – Data and Insights.Retrieved April 2020 from: https://knoema.com/insights?tag=Coronavirus.
13. Kodish, S. R., Bio, F., Oemcke, R., Conteh, J., Beauliere, J. M., Pyne-Bailey, S., Rohner, F., Ngnie-Teta, T., B. Jalloh,M., & Wirth, J. P. (2019). A qualitative study to understand how Ebola Virus Disease affected nutrition in Sierra Leone—A food value-chain framework for improving future response strategies. *PLoS neglected tropical diseases, 13(9),*1-19.
14. Krar et al. (2020). Labour shortage to delay crop harvest. Retrieved April 2020 from:
15. https://economictimes.indiatimes.com/news/economy/agriculture/labour-shortage-to-delay-crop-harvest/articleshow/75057570.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
16. Mabrouk, F. and Mekni, M. M. (2018). Remittances and food security in African Countries. *African Development Review, 30(3),* 252-263.
17. MacDonald, R. and Reitmeier, C. (2017). Understanding Food Systems: Agriculture, Food Science, and Nutrition in the United States, Elsevier/Academic Press: London.
18. Nagarajan, S. (2020). China's economy suffers its first contraction in 28 years, shrinking 6.8% in an 'extraordinary shock' to the global economy. Retrieved April 2020 from: https://www.businessinsider.my/china-economy-falls-first-quarter-2020-after-half-century-growth-2020-4?r=US&IR=T.
19. Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-Jabir, A., Iosifidis, C., Agha, M., and Agha, R. (2020). The socio-economic implications of the coronavirus and COVID-19 pandemic: A review. *International Journal of Surgery,78(June),* 185-193.
20. Prosekov, A. Y. and Ivanova, S. A. (2018). Food security: The challenge of the present. *Geoforum, 91 (May),* 73-77.
21. Singhal, T. (2020). A review of coronavirus disease-2019 (COVID-19). *The Indian Journal of Pediatrics, 87(February),* 1-6.
22. Sulemana, I., Bugri Anarfo, E. and Quartey, P. (2019). International remittances and household food security in Sub-Saharan Africa. *Migration and Development, 8(2),* 264-280.

23. Tian, J., Bryksa, B. C., & Yada, R. Y. (2016). Feeding the world into the future–food and nutrition security: the role of food science and technology. *Frontiers in Life Science, 9(3),* 155-166
24. VOA News (2020). Vietnam Considers Resuming Rice Shipments Amid Virus-driven Stockpiling. Retrieved April 2020 from: https://www.voanews.com/east-asia-pacific/vietnam-considers-resuming-rice-shipments-amid-virus-driven-stockpiling.
25. von Grebmer, K., Bernstein, J., Hossain, N., Brown, T., Prasai, N., Yohannes, Y., ... & Foley, C. (2017). 2017 Global hunger index: The inequalities of hunger. Bonn/Washington, DC/Republic of Ireland: Deutsche Welthungerhilfe (German AgroAction), International Food Policy Research Institute, and Concern Worldwide.
26. WHO (2020).Coronavirus disease (COVID-19) pandemic. Retrieved April 2020 from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019.
27. Worldometer (2020). COVID-19 Coronavirus pandemic. Retrieved April 2020 from: https://www.worldometers.info/coronavirus.
28. Zhong, R., Xu, X., & Wang, L. (2017). Food supply chain management: systems, implementations, and future research. *Industrial Management & Data System, 117(9),*2085-2114.
29. Zietz, J., Zietz, E. N., & Sirmans, G. S. (2008). Determinants of house prices: a quantile regression approach. *The Journal of Real Estate Finance and Economics, 37(4),* 317-333.

Chapter 10

THE FRAMEWORK OF GRASSROOTS INITIATIVES DEVELOPMENT IN HANDLING SOCIAL SERVICES DURING COVID-19 PANDEMIC

Zulfikar Dinar Wahidayat Putra*

INTRODUCTION

In raising inequality and disparity of urban development in developing countries, many children cannot access the formal educational service. They face some dilemmas, such as affordability, bureaucracy, and preference to work than study[1]. Their parents have a low income and need more revenue to survive. COVID-19 worsened it because most activities within cities are affected by the government restrictions resulting in lower parents' income and less possibility of the children studying in a formal school[2].

The condition can be seen in Yogyakarta City, where children in an informal waste picker settlement area do not go to schools because their parents ask them to make money on the streets (i.e., becoming a waste picker, busker, beggar). With this condition, the city government tend to ignore them because of civil administration and the illegal status of their settlement area. Instead, this condition was then handled by a grassroots organisation called *"Komunitas Sekolah Marjinal"* ("Marginal School Community" ("MSC")), which local activists

---

* Department of Architecture and Planning, Gadjah Mada University, Centre for Advanced Spatial Analysis, University College London

1 Damon, Amy, Paul Glewwe, Suzanne Wisniewski, and Bixuan Sun. "Education in Developing Countries – What Policies and Programmes Affect Learning and Time in School?" Stockholm, 2016.

2 Pitoyo, Agus Joko, Bagas Aditya, Ikhwan Amri, and Akbar Abdul Rokhim. "Impacts and Strategies Behind COVID-19-Induced Economic Crisis: Evidence from Informal Economy." *The Indian Journal of Labour Economics* 64, no. 3 (September 1, 2021): 1. https://doi.org/10.1007/S41027-021-00333-X.

initiated in October 2019. They aim to assist the children in studying and getting formal education certificates, ranging from elementary to high school-age students focusing on the informal waste picker settlement. The initiative then also expands to environmental and health-related activities within the settlement. It consists of a committee member with more than 30 volunteers and about 20 students. The community also interact with external organisations, such as NGOs, universities, government institutions, and other local communities. During the pandemic, they still held activities, such as giving students and local inhabitants free health consultations.

However, the development of the MSC is not identified yet. At the same time, it is necessary to identify the development mechanism through stakeholder interaction to achieve the end goal of the initiative. Therefore, this study aims to investigate the stakeholder and outcome of grassroots initiatives using "Marginal School Community" as a case study. Two questions are formulated: (1) How is the stakeholder interaction within the "Marginal School Community"? (2) To what extent does each stakeholder define the "Marginal School Community" outcome?

1. METHODS

This study used primary data collected through a questionnaire to get the following information: (1) stakeholder's role and their interactions; (2) respondent's views on the outcome of the MSC activities. The data collection was conducted from October to December 2021 in *"Kampung Kledokan",* Yogyakarta City. The selection of respondents was based on eight stakeholder categories as follows: (1) Students, (2) Parents, (3) Informal settlers, (4) Marginal School Community's committee, (5) Marginal School Community's volunteer, (6) Government institution, (7) Higher education, (8) Other organisations (Community/NGO). Each group was purposefully selected based on the availability and ease of reaching out using a convenience sampling method[3]. Thirty-four respondents participated in this study representing each stakeholder category.

The gathered data from each respondent was then analysed using stakeholder analysis and descriptive analysis. The stakeholder analysis was conducted using a power-interest weighted matrix that represents the position of each stakeholder

3 Battaglia, Mike. "Convenience Sampling." In *Encyclopedia of Survey Research Methods*, edited by Paul J. Lavrakas. Thousand Oaks, CA: SAGE Publications, 2008. https://doi.org/10.4135/9781412963947.

category quantitatively in each quadrant of the matrix[4] (see Table 1). There are four quadrants within the matrix, namely key players (high power, high interest), keep satisfied (high power, low interest), keep informed (low power, high interest), and minimum effort (low power, low interest). The higher the weight, the higher their power/influence towards the initiative.

Table 1. Weighting Criteria for the Power-Interest Matrix

Weight	Criteria	
	Power	**Interest**
1	Have no institutional and legal power	Have no interest in the initiative
2	Have low institutional power	Have low interest for the initiative to roll, develop, and sustain
3	Have a moderate institutional power	Have a moderate interest in the initiative to roll, develop, and sustain
4	Have high institutional power	Have high interest for the initiative to roll, develop, and sustain
5	- Have the highest institutional and legal power - Act as regulator and authority	- Have the highest interest for the initiative to roll, develop, and sustain - Act as coordinator, manager, and organizer

Source: Author's Analysis, 2022

2. RESULT AND DISCUSSION

2.1. Stakeholder Interaction within the "Marginal School Community"

The stakeholder position within the power-interest matrix and their interaction are analysed (see Figure 1). It shows that the MSC's committee has a central role in interacting with other stakeholders with different power and interest. The MSC's committee themselves have a solid organisational structure that uses grassroots actors to build an institutional capacity (i.e., students, activists, entrepreneurs) that act as the day-to-day manager of the initiative. In this position, the organisation become an intermediary actor to bridge external stakeholders, such as the government, higher education, and other organisations to interact with internal stakeholders, such as the students and informal settlers. In this role, the

4 Reed, M.S., and R. Curzon. "Stakeholder Mapping for the Governance of Biosecurity: A Literature Review." *Journal of Integrative Environmental Sciences* 12, no. 1 (January 2, 2015): 15–38. https://doi.org/10.1080/1943815X.2014.975723.

committee is assisted by the MSC's volunteers who teach the students and communicate with the parents and external stakeholders. Here, the parents have a high power because they are the legal guardian of the children that act as students and can withdraw their children from the learning process if they feel uncomfortable with the activities. Both MSC's committee and the parents are the most crucial stakeholders in the initiative who need to be encouraged and influenced to keep the initiative going. At the same time, the MSC's volunteers take the role to bridge these key actors with the students.

The higher education and other organisations, as the external stakeholders, act to support the initiative occasionally based on their program. These stakeholders communicate with the MSC's committee to propose and coordinate activities for the initiative. When the committee has agreed to collaborate with them, these external stakeholders can interact with the students to make several teaching and learning activities. However, in the COVID-19 pandemic, they also interacted with the informal settlers because they created several activities for them, such as health consultation and hygiene socialisation. Higher education has more power than other organisations because communities/NGOs usually informally collaborate with MSC. Higher education usually proposes their program in a more formal manner (i.e., from a university student organisation).

The informal settlers are people who need to be kept satisfied within this initiative because it operates within their settlement area which sometimes conflict can happen between the settlers with the MSC's committee because of several things (i.e., some settlers do not like the activities and then try to shut down the activities; or misunderstanding in electricity usage). Therefore, in a grassroots social services provision, local inhabitants are essential stakeholders whose relationship must be well managed by the grassroots initiators.

Finally, the government does not have a clue about the existence of the MSC. Therefore, the MSC's committee tried to approach several government institutions to introduce themselves while also taking several missions, namely helping the students get a formal educational certificate and assisting the informal settlers in getting citizenship of Yogyakarta City. However, that interaction only happens in the one-sided direction from the MSC to the government because the government seems to refuse their demands and neglect the need of the children and settlers. The most frequent reason from the government related to this is that the settlers inhabit an illegal land. They are not Yogyakarta City's citizens (no proof of ID card), and because of that, their children cannot get a formal education certificate. It shows the power of the government and their influence on the vision of a grassroots organisation like the MSC. However, the MSC needs to keep them satisfied because they only hope for these children and settlers. They have the authority to regulate and decide "right or wrong" and "yes or no" for all the stakeholders. Thereby, the grassroots initiators need to develop a strategy to make the government interested in the initiative and then re-negotiate with them.

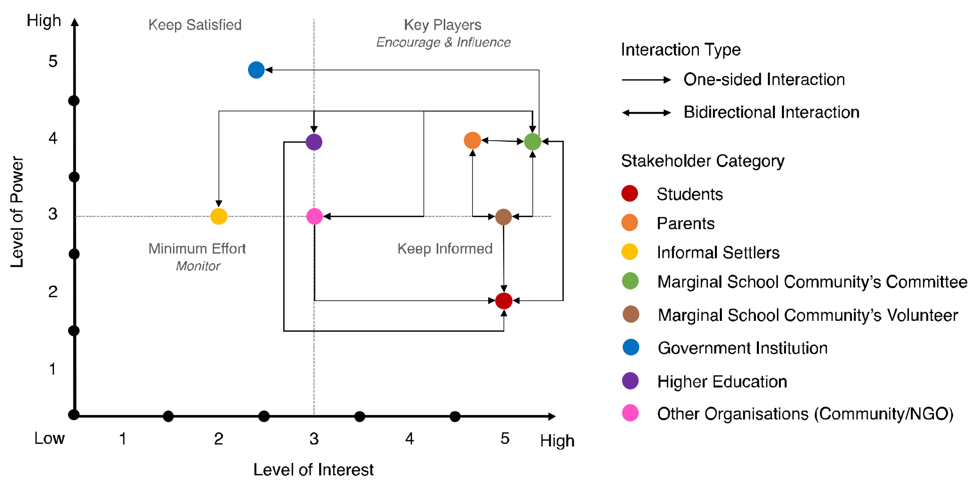


Figure 1. Stakeholder Analysis of "Marginal School Community"

Source: Author's Analysis, 2022

2.2. Stakeholder's Perspective on the Outcome of "Marginal School Community"

The stakeholders also give several feedbacks on the outcome of the MSC based on their interaction with activities within the MSC. The outcome is divided into two categories, namely tangible and intangible outcomes. However, it must be noted that the government did not give feedback because they did not respond to the questionnaire. Therefore, only seven stakeholders shared their perspectives on the outcome of MSC in which each respondent can give more than one feedback. Regarding the tangible outcomes, the new learning venue is seen as the most tangible outcome created by the MSC (see Figure 2). It makes sense because the core activity of MSC is learning and they then built a learning facility together with the local settlers whereby the building new building marks a new social space that they see and use every day. The stakeholders also seem to appreciate the area's better environmental quality, which is shown by their judgment that the settlement area becomes cleaner with more learning facilities, plants, parks, tap water and sanitary infrastructure, and parking area. It shows that a grassroots initiative focuses not only on the facility that they need, like in this case, a learning venue, but also surrounding environments and facilities to support the venue and activities within it. During COVID-19, the activities follow necessary protocols, such as wearing masks, physical distancing, and hand cleansing.

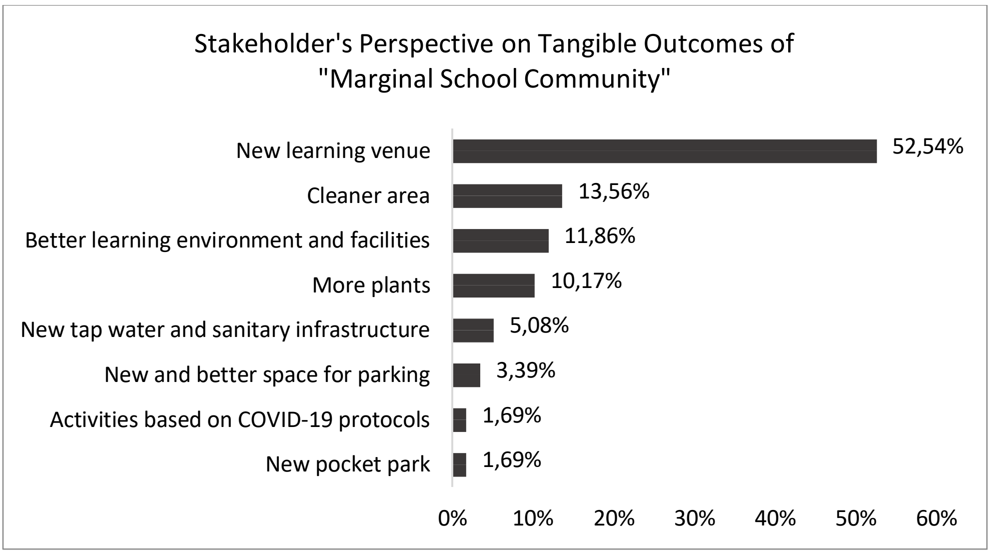


Figure 2. Stakeholder's Perspective on Tangible Outcomes of "Marginal School Community"

(**Note:** 60 statements were gathered from 34 respondents, each respondent can state more than one outcome)

Source: Author's Analysis, 2022

Regarding the intangible outcomes, after the MSC's initiative was conducted, most stakeholders see that children can have an opportunity to study appropriately for free (i.e., there is a study space, voluntary teachers, and learning facilities) (see Figure 3). This intangible outcome is supported by the learning venue that has been built. Therefore, spatial aspects within grassroots initiatives are important to create a place-dependence activity that acts as a platform to maintain related intangible activities of the initiative. This space also becomes a multiuse space, meaning that it is used for studying and other events, such as health consultation and community gatherings. In this sense, the spatial aspect becomes more dominant to enable intangible activities. Because of it, local settlers feel satisfied because they get free health-related events. By this, they feel that they are being taken care of by others.

Other outcomes come from the impact of the activities, which show improved manners of the children and the settlers (i.e., become more religious, open to outsiders, and be polite to others), increased motivation to study, and increased awareness of the parents, children, and settlers on the importance of education and health. This initiative also gives children a space to brainstorm between them and the MSC's volunteers related to a particular subject topic.

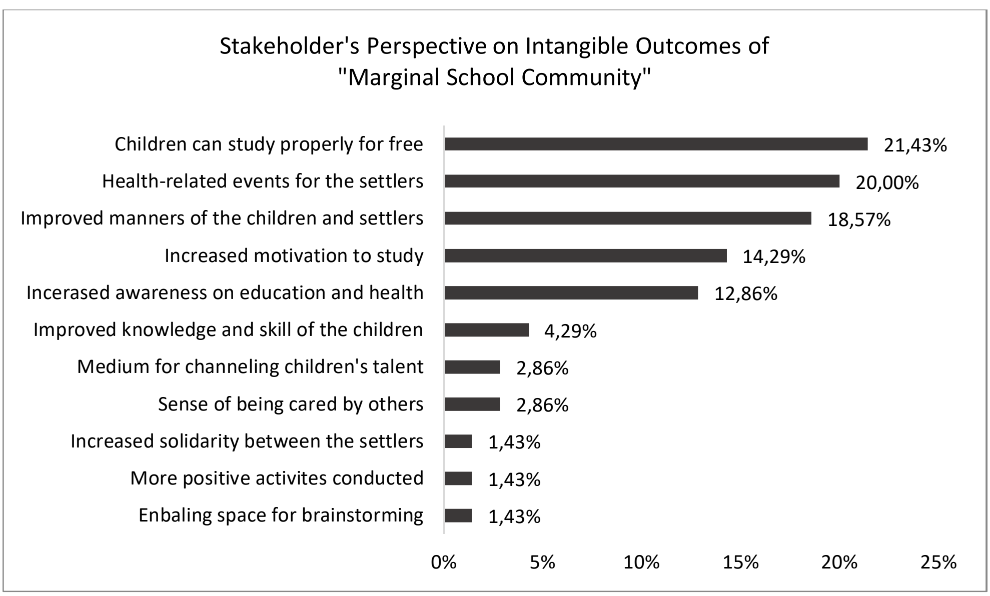


Figure 3. Stakeholder's Perspective on Intangible Outcomes of "Marginal School Community"

(**Note:** 70 statements were gathered from 34 respondents, each respondent can state more than one outcome)

Source: Author's Analysis, 2022

The results show that interactions among grassroots stakeholders with different power-interest give mostly positive outcomes for the targeted stakeholder, namely the children, parents, and local settlers. These "invisible" activities help a particular city area improve without necessarily being assisted and supported by the government. With their resources, they can collaborate with other stakeholders to implement the initiative while maintaining the relationship with other stakeholders. The "invisible" interaction is then shown by tangible outcomes seen and used by the stakeholders.

These tangible outcomes were also spatially organised and became a new social identity for the MSC and the settlement area. Activities can then be conducted within these organised spaces resulting intangible outcomes. Thus, a framework of grassroots initiatives development can be developed based on its type of outcomes (see Figure 4). Within this framework, non-spatial aspects take most of the activities within the grassroots initiative development, which include interacting with stakeholders and intangible outcomes from the initiative. However, the spatial element seems to be an important element in the initiative development because it supports intangible outcomes usually the initiative's end goal.

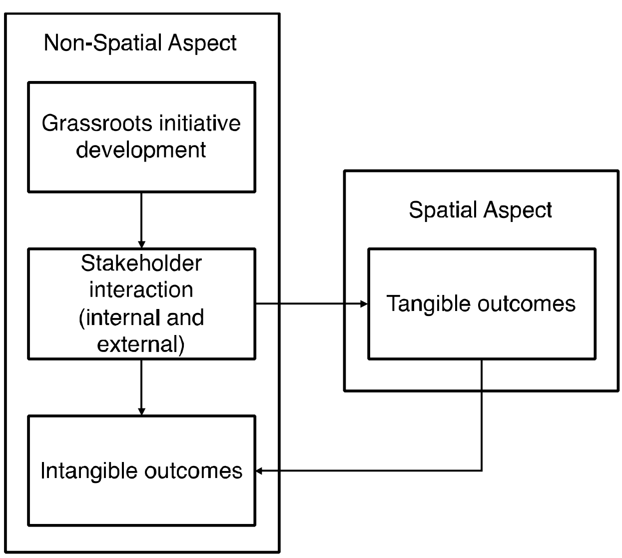


Figure 4. Grassroots Initiative Development Framework

Source: Author's Analysis, 2022

CONCLUSION

This study aimed to investigate the stakeholder and outcome of grassroots initiatives to create a framework of grassroots initiatives development in handling social services, especially during the pandemic. The results show that the grassroots initiators act as the backbone and intermediary actor for the whole initiative. They have a bidirectional interaction with both internal and external stakeholders supported by volunteers. These interactions work like a system to make the initiative happen, revealing tangible and intangible outcomes. Regarding this, the interactions as a non-spatial aspect create tangible outcomes representing the spatial aspect of the initiative. This spatial aspect supports the grassroots organisation to achieve its end goal, which comes into intangible outcomes. Further studies need to be conducted regarding the framework development. It might be that the framework is going circular, meaning after the organisation achieve the end-goal as intangible outcomes, it implicates the grassroots development to expand their activities and scale-up.

ACKNOWLEDGEMENT

This work was supported by the Department of Architecture and Planning, Faculty of Engineering, Gadjah Mada University, under the Department's research grant scheme 2021.

REFERENCES

1. Battaglia, Mike. 2008. "Convenience Sampling." In *Encyclopedia of Survey Research Methods*, edited by Paul J. Lavrakas. Thousand Oaks, CA: SAGE Publications. https://doi.org/10.4135/9781412963947.
2. Damon, Amy, Paul Glewwe, Suzanne Wisniewski, and Bixuan Sun. 2016. "Education in Developing Countries – What Policies and Programmes Affect Learning and Time in School?" Stockholm.
3. Pitoyo, Agus Joko, Bagas Aditya, Ikhwan Amri, and Akbar Abdul Rokhim. 2021. "Impacts and Strategies Behind COVID-19-Induced Economic Crisis: Evidence from Informal Economy." *The Indian Journal of Labour Economics* 64 (3): 1. https://doi.org/10.1007/S41027-021-00333-X.
4. Reed, M.S., and R. Curzon. 2015. "Stakeholder Mapping for the Governance of Biosecurity: A Literature Review." *Journal of Integrative Environmental Sciences* 12 (1): 15–38. https://doi.org/10.1080/1943815X.2014.975723.

KARTEPE SUMMIT

24-27 MARCH 2022

Chapter 11

TESTING THE LIMITS OF RESILIENCE: MIGRATION

Nahide Işıl Çetinkaya Istikbal*

INTRODUCTION

Resilience frequently defined as a "buzzword" which is not only been discussed in the field of public administration, but also in other disciplines such as health, economics, psychology and so on. Therefore, it does not seem possible to make a single definition of the term. Still, from an all-disciplinary perspective, its key feature is that it relates to change.

Dealing with change has always been a major issue, especially when it comes to public administration. While radical reforms are made in public administration in order to keep up with the changes encountered in the recent years, resistance to change is accepted as a natural reflex of public sector. In other words, public sector is *intrinsically conservative* and the reason for governments to reform in public administration is not the desire for change, but the need for change caused by the crisis as the Peter Drucker states.[1]

Traditional role of public administration is to ensure the continuity of the system in the current bureaucratic order.[2] Though as it is well known, maintaining order can be challenging occasionally. Especially in the times of unexpected situations. When the governments are not prepared enough or when they do not have sufficient resources, these unexpected situations can simply turn into crisis. The degree of coping with unforeseen circumstances leading to such crisis, is an important element that reveals the success of states.

* Istanbul Medeniyet University/Politic Science and Public Administration, isil.istikbal@medeniyet.edu.tr

1 J. A. Oliveira Rocha and Gonçalves J. B. Zavale, "Innovation and Change in Public Administration," Open Journal of Social Sciences, no 9 (2021): 285-297.

2 Fadillah Putra, "Crisis Management in Public Administration," Journal of Community and Regional Planning, Volume 13/14 (2009): 152.

The more sudden the occurrence of a crisis, the more difficult it gets to intervene and develop appropriate policies. The most basic feature needed at this point, is the flexibility of the government -up to a certain point- in order to make quick decisions, develop and implement policies. Resilience has emerged as a concept that has been increasingly used in recent years, indicating this decisive feature of governments.

Since 2010s, there has been a large migration wave from Middle East to Turkey which increased the population significantly. This irregular and sudden increase in population caused an effect that spread to almost every social area. Increasing social, economic, environmental and administrative problems with irregular migration waves have brought questions about how the public administration can be more effective and efficient.

Strengthening resilience is accepted as an essential step in both solving current problems and preventing future problems. Each country has its own unique approach to strengthening resilience, and a national plan shaped by this approach. In order to achieve comprehensive policy implementation throughout the country, all levels of government should cooperate and involve in the process. In this study, it will be focused on what Turkey has done to increase resilience regarding the problem of irregular migration.

1. THE CONCEPT OF RESILIENCE

It is possible to define the 21st century as a period in which, uncertainties and radical changes increase. One day, dealing with a pandemic that develops on a global scale is the main issue, the next day, fires in many parts of the country or massive migration waves from abroad can set the agenda. Existing strategic plans and policies lose their validity and effectiveness when such sudden and unforeseen situations occur recurrently. In order to manage this –soon to be- crisis situations and fill this administrative strategy gap, the concept of resilience has been used widely in recent years.

Resilience is a term that focuses on, not gradual but sudden changes and the uncertainties brought about by change. The origin of the word resilience is based on the Latin word *resilire*, which means to revive and to bounce back, whereas the first academic use of the term was in physics, when it was associated with timber's resistance to some sudden impacts.[3] However, in the following years, its

[3] McAslan, Alastair, The Concept of Resilience. Understanding its Origins, Meaning and Utility, Adelaide, Australia: Torrens Resilience Institute (2010), p. 2.

use was not limited to physics and materials, the resilience of individuals, states, organizations and societies became an important research area in social sciences and was shaped as an element to be considered in the public policy making process.[4]

Resilience is a versatile concept. In this study this term will be limited with the organizational resilience in the public sector, mainly the resilience of the government. An organization would be named as resilient when it is able to cope with sudden challenges. When it comes to governments, the crisis types are diverse. Therefore, it is of great importance that they know very well the environment in which they operate and take appropriate action.[5]

Resilience's most characteristic feature is its continuity. Because resilience means not only managing the crisis successfully, but also being ready for the next crisis by absorbing the consequences and adapting to new state of equilibrium that will occur after the crisis. This transformation should include not only an instrument or two, but all the components of the system. Since both internal and external factors should be considered. [6]

2. RESILIENCE AND PUBLIC ADMINISTRATION

Although well-constructed public administrations include reforms occasionally, they operate mostly with long-term policies that have been created already. When a crisis arises and a government cannot perform its standard procedures on an issue, these long-term policies fall short. After that point, the flexibility of the public administration in generating solutions and capability of adopting these solutions with all their instruments and stakeholders in short time become important.

Bureaucracy is still an important feature of public administration system. It is not possible to expect an administration that is largely dependent on bureaucratic elements to show high flexibility to ensure resilience, since bureaucracy is rigid. From this point of view, it would not be wrong to state that resilience and bureaucracy are not an inseparable duo. In fact, they are not often found together. In order to have flexibility, an environment where the strict rules of bureaucracy

---

4 McAslan, The Concept of Resilience, 11.

5 McAslan, "The Concept of Resilience. Understanding its Origins, Meaning and Utility", p.7.

6 Bruneckiene et al, "Measuring Regional Resilience to Economic Shocks by Index", *Inzinerine Ekonomika-Engineering Economics*, 29/4 (2018), p. 407.

are softened is needed, as well as *more flexible, adaptable and transformational* public administration understanding.[7]

The above considerations have been replaced by a more flexible bureaucracy understanding, with the pressure of the recent global crises, especially the Covid-19 pandemic. The main characteristics of this new approach that is named as resilient bureaucracy are listed by the World Bank as; having the capacity to adopt the changes, having legal mechanisms that can be flexible when necessary, having a technological infrastructure to be able to reach recent, reliable data on time, authorized mid-level administrators that can take rapid action and strengthened coordination mechanisms both at central and local levels. [8]

Resilient administrative structures and their operations differ from Weberian bureaucracies in so many aspects. Firstly, there are no strict hierarchical linkages between the units for a better and faster communication. Secondly, the efficient operation of the system is basically related to the diversity of the acquired knowledge and its resources. Thirdly, knowing the financial, personnel and technological capacity is important, however, it is more important to allocate a spare resource by increasing this capacity to be used in the times of crises. Fourthly, not only the top-level administrators should discuss on the policies, but also the other stakeholders should participate the whole process. When employees have the opportunity to create solutions for an unexpected situation, the level of resilience of an organization would increase. Finally, learning from the previous experiences and social learning considered as vital elements. [9]

Although all stakeholders -whether private or public, national or local- in a country have a role in ensuring resilience, public administration plays a leading role. The process of strengthening resilience would work efficiently, with the leadership of a well-functioning public administration and the active participation of other actors.[10]

3. STEPS TOWARDS A MORE RESILIENT STATE

Due to growing global interest towards the term resilience, it is possible to observe that various countries and international organizations have made some

---

7 Alina Georgiana Profiroiu and Corina-Cristiana Nastacă, "What Strengthens Resilience in Public Administration Institutions?", *Eastern Journal of European Studies*, 12 (2021), p.101.

8 "What Are Key Features of a Resilient Bureaucracy?", The World Bank, last update 8 Feb., 2022, https://blogs.worldbank.org/governance/what-are-key-features-resilient-bureaucracy

9 Andreas Duit "Resilience Thinking: Lessons for Public Administration", *Public Administration*, 94/2 (2016), p. 364.

10 Profiroiu and Nastacă, "What Strengthens Resilience in Public Administration Institutions?", p.102.

arrangements. Developing certain standards and preparing guidelines to ensure resilience at national level should be considered as a fundamental step. The Organizational Resilience Standard, prepared by the American National Standards Institute in 2009, sets an international example in this regard. In this standard, general requirements, management policy for organizational resilience, planning, implementation, evaluation and management review are covered in detail in this document as well as the guidance on the use of the standard.[11]

A few years later in 2017, the concept of resilience and its importance were included in the National Security Strategy by the United States under the title of "Promote American Resilience". In this document resilience defined as the capability cope with sudden and unexpected adverse occurrences such as disasters, economic crisis, terrorist attacks etc., and to get back to normal as soon as possible. The most essential areas to ensure resilience are determined as transportation, communication, health, security, energy and finance. Establishing a society based on preparedness and paying more attention on risk management, planning and sharing information are defined as primary issues for a resilient state.[12]

The United States is not the only country that has made resilience an important part of public administration. The United Kingdom's Cabinet Office launched the Resilience Capabilities Programme in 2013, to increase the capabilities when there is a civil emergency.[13] The UK also reviewed the former one and published a new National Resilience Strategy in 2021, with the effects of the COVID-19 pandemic. This new strategy primarily focuses on setting more realistic objectives for both individuals and organizations to ensure resilience. Main principles to create a resilient nation are determined as understanding the risks and their impacts, taking measures to prevent the event before it occurs and involving all actors in the process.[14]

Japan is another country that make various legal regulations to ensure national resilience and implement policies to strengthen it. Basic Act for National Resilience Contributing to Preventing and Mitigating Disasters for Developing Resilience in the

---

11 ASIS SPC.1-2009, "Organizational Resilience Standard: Security, Preparedness and Continuity Management Systems – Requirements with Guidance for Use", American National Standards Institute, Inc., last update 07 Feb, 2022, https://www.ndsu.edu/fileadmin/emgt/ASIS_SPC.1-2009_Item_No._1842.pdf

12 "National Security Strategy of the United States of America", access 10 Feb, 2022, https://trumpwhitehouse.archives.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf

13 "Preperation and Planning for Emergencies", Access 10 Feb, 2022, https://www.gov.uk/guidance/preparation-and-planning-for-emergencies-the-capabilities-programme

14 "The National Resilience Strategy", Access 10 Feb, 2022, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1001404/Resilience_Strategy_-_Call_for_Evidence.pdf

Lives of the Citizenry (2016), Fundamental Plan for National Resilience (2018), Action Plan for National Resilience (2014) and also the Meeting of the Liaison Conference of Relevant Ministries and Agencies for Building National Resilience (2013) are the main adjustments about resilience. However, looking at these regulations, it is seen that Japan's statement of resilience is limited to disaster management.[15]

Also, international organizations such as OECD and European Commission are taking steps for the governments to adopt the term. The social and economic effects of COVID-19 on public administration and all stakeholders, have led international organizations to put more emphasis on this concept and to try to show member countries a way out.[16] European Commission's first attempt in this direction was adopting an Action Plan for Resilience in Crisis Prone Countries in 2013. The 2020 Strategic Foresight Report included statements that would take the situation to another level and pave the way for future EU policies to be shaped on the basis of resilience. In this report, resilience defined as not only being able to bounce back from challenges, but also *bouncing forward* and being democratic, fair and sustainable while doing so.[17] In the year 2021 with the establishment of The Recovery and Resilience Facility these initiatives towards resilience have gained a more systematic basis. The purpose of this facility, which was established temporarily, is to act like *a temporary recovery instrument* and provide resources for the investments and reforms that member countries will make to eliminate the effects of COVID-19 until 2026.[18]

OECD developed the Resilience Systems Analysis in 2014, with the aim of supporting its members to develop strategies and programs. Risks and challenges such as natural disasters, economic crisis, pandemics are issues that every country faces, but cannot find a common ground on how to respond. With Resilience Systems Analysis, the OECD aimed to draw a roadmap for its members about what can be done other than the traditional crisis managements when faced with these challenges. Three competencies that need to be supported to strengthen resilience are defined as absorptive, adaptive and transformative capacity.[19]

---

15 "Building National Resilience", Access 8 Feb, 2022, https://www.cas.go.jp/jp/seisaku/kokudo_kyoujinka/index_en.html

16 Profiroiu and Nastacă, "What Strengthens Resilience in Public Administration Institutions?", p.101.

17 "2020 Strategic Foresight Report", Access 11 Feb, 2022. https://ec.europa.eu/info/sites/default/files/strategic_foresight_report_2020_1_0.pdf

18 "Regulation (EU) 2021/241 of the European Parliament and of the Council of 12 February 2021 establishing the Recovery and Resilience Facility", Access 11 Feb, 2022. http://data.europa.eu/eli/reg/2021/241/oj

19 "Guidelines for Resilience Systems Analysis", OECD, access 10 Feb, 2022. https://www.oecd.org/dac/Resilience%20Systems%20Analysis%20FINAL.pdf

OECD also launched the Resilient Cities Report in 2016 and point out 4 key areas that provide resilience as economy, governance, society and environment. Within this framework, OECD published a report on 45 national policy frameworks on resilience in its member countries. In this report, it is seen that each country takes different steps to provide resilience such as national plans, action plans, national development strategies etc., but 39 of them focus on the role of cities to develop a resilient system. Also, Turkey's Tenth Development Plan that includes the years 2014-2018, has drawn the basic framework of resilience. The plan is driven mainly by the changing economic environment and it aimed to increase transparency, participation and especially financial sustainability so that local governments can provide faster, more effective and qualified services.[20]

The issue of resilience has just started to be discussed in the public administration level in Turkey, and there is no legal regulation to improve it yet. Furthermore the scope of resilience is mainly related with the urban areas. Practitioners, scholars as well as the politicians, argue on if the cities are resilient, or what to do to strengthen their resilience. While the main axis of this study is the resilience of cities, the resilience of all public administration organizations in terms of migration will be emphasized.

4. MIGRATION POLICIES TOWARDS STRENGTHENING RESILIENCE: EXAMPLE OF TURKEY

Occasionally, migrations a country receives and how these migrations are managed, seems irrelevant with the concept of resilience. Since, the level of resilience of states can only be measured by their reaction in sudden and unexpected situations that might turn into crisis in the near future. However, in the recent 10 years irregular migration waves from Middle East towards Turkey are so enormous and continuous, that they have created an emergency and crisis situation both in economic, social and political sense, and have become a systemic threat. Therefore, resilience seems to be an important way to cope with this sudden and never-ending wave of migration and to re-establish the balance within the country.

The Syrian Civil War, which started in March 2011, has been the take-off point of the process called the Syrian Refugee Crisis and 2015 was the climax of this crisis. With the onset of the war, approximately 6.8 million Syrians have started to live

[20] "National Policy Frameworks on Resilience in OECD Countries", OECD, access 09 Feb, 2022, https://www.oecd.org/cfe/regionaldevelopment/national-policy-resilience-frameworks.pdf

as refugees in 129 different countries all over the world. However, this is not an even distribution, only the number of registered Syrian immigrants living in Turkey is expressed as 3.7 million (about 65%) according to official data.[21] Furthermore, while majority of these immigrants are dispersed throughout the country, only 51,000 continue to live in camps close to the border.[22] The inclusion of such a large number of immigrants in the society in a short period of time, led to many social, economic and administrative problems inevitably.

Another critical point about these immigrants is that they do not have a time limit on their stay, nor is there any compulsion for them to return. This situation makes their integration into the society they live in even more important, thus bringing local governments to the fore as an even more important actor. However, the fact that the Turkish administrative structure is highly centralized and no separate resources are allocated to the local governments for immigrants makes it difficult for local governments to fulfill this task successfully.

In the 2021 Strategic Foresight Report of the EU, shifts in global demography were evaluated as one of the key megatrends to be experienced in the future. Challenges brought by possible mass migrations have also been pointed out as a result of the shift in population.[23] It can be said that dramatic changes in population, can be considered as an issue on a global scale that pushes the limits of the resilience.

Migration fundamentally effects two social groups: natives and immigrants. It is vital that governments support both groups and create a balance. If public institutions are not prepared to fulfill their duties in this new balance that will be created, it will be difficult to intervene in the economic, social and administrative problems that will arise, leading to the growth of the crisis.[24]

Since such a large migration wave has the capacity to change all the balances in the society, it is imperative to take various measures at the local level as well as at the national level. However, Turkey's leading role in the Syrian refugee crisis necessitated cooperation at the international level as well. Thus, in this section, not only the regulations at the national and local level, but also the steps taken

[21] "Mid-Year Trends 2021", Access 05 Feb, 2022. https://reliefweb.int/sites/reliefweb.int/files/resources/618ae4694_0.pdf

[22] "Turkey – Migrant Presence Monitoring - Situation Report (January 2022)", access 13 Feb, 2022. https://reliefweb.int/sites/reliefweb.int/files/resources/Turkey_Sitrep_01_January_22.pdf

[23] "2021 Strategic Foresight Report". Access 11 Feb, 2022. https://ec.europa.eu/info/sites/default/files/strategic_foresight_report_2021_en.pdf

[24] Profiroiu and Nastacă, "What Strengthens Resilience in Public Administration Institutions?", p.101.

especially in cooperation with the European Union, in order for Turkey to have a structure that can be described as resilient will be covered.

4.1. Local Level

According to the World Bank data, more than %56 of the world population lives in the urban areas today.[25] In UN's latest projection, growing urbanization ratio is expected to increase to 68% in 2050.[26] The high urbanization rates caused cities to be affected more by the crises and increased their vulnerabilities against the uncertainties.

Migration is on its way to becoming an urban phenomenon. Usually immigrants prefer to settle in the cities, mostly for job opportunities and better living conditions. Based on this, it can be said that the units most affected by migration are cities. In order to manage the impacts of migration empowering local authorities is important. When we look at the example of Turkey, considering that a significant part of the immigrants (almost 98%) reside in cities, it is seen that the practices of local administrations are at least as important as the policies of the central government. It has been determined that immigrants cause an additional cost of 10% to municipalities, especially in cities with a large immigrant population.[27]

However, in a country like Turkey, where a strict centralist authority is exercised, the lack of authority of local governments to develop policies on a complex issue such as immigration and the lack of a separate resources for incoming immigrants complicates the administration.[28] Local governments, which are obliged to continue their existing municipal services, need to respond to the needs of immigrants and help them to adapt, as well as meet the demands of citizens.

Each local government exhibits a different policy on immigrants, according to their own values, opportunities and urban texture. In a study conducted in the districts of Istanbul, it was revealed that there are five distinct narratives that local governments use in their approaches to immigration policies. These five common expressions are classified as humanitarianism, equal rights, pragmatism, social

---

[25] The World Bank, Urban population (% of total population), https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2020&name_desc=true&start=1961&view=chart

[26] UN, World Urbanization Prospects The 2018 Revision (2018): 10. https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf

[27] "Suriyeli Sığınmacıların Türkiye'ye Etkileri", Report no: 195 (2020), p.36 https://www.tesev.org.tr/wp-content/uploads/rapor_Suriyeli_Siginmacilarin_Turkiyeye_Etkileri.pdf

[28] Vivien Lowndes and Rabia Karakaya Polat "How do local actors interpret, enact and contest policy? An analysis of local government responses to meeting the needs of Syrian refugees in Turkey", Local Government Studies. p.2.

cohesion and anti-refugee point of view.[29] The services and facilities provided by these local governments would vary according to this narrative.

Issues related to legislation are among the main problems faced by local governments in service delivery. There are also problems related to legal regulations regarding assistance to immigrants. The lack of a clear provision in the Municipal Law no. 5393 on how to serve or whether to serve non-citizens, prevents municipalities from acting jointly in this regard, and moreover, aids subject to inspection may result in investigations. The main problems faced by local governments are the lack of common practices of municipalities, financial difficulties arising from the unchanged share they receive from the central budget, communication problems with immigrants due to language differences, housing problems, health problems, difficulties with the education of immigrant children.[30]

Municipalities have developed different strategies to adopt large number of immigrants to the society and provide necessary services. Since it is not the subject of this study to examine the practices of each municipality individually, it is aimed to include general determinations and to reveal where local governments stand in this section.

4.2. National Level

Turkey has become the country hosting the largest immigrant population in the world in recent years. This is mostly because of being a transit country, located right in the middle of eastern and western world. Being the country with the highest number of immigrants, also makes it necessary to have a systematic and effective migration administration. The first step in this direction is in January 2005, adaptation of the National Action Plan for Asylum and Migration. Then, in 2013 the Law on Foreigners and International Protection no. 6458, which was prepared in accordance with the international law and EU *acquis.* Law no. 6458 constitutes the basic legal basis of the migration regulation in Turkey, as well as the Migration Board (before 2018; Migration Policy Board) and Directorate General of Migration Management. This institution released two strategic plans covering the years of 2017-2021 and 2019-2023. Both of these plans include regular migration, irregular migration, international protection, fighting human trafficking

29 Lowndes and Karakaya Polat, "How do local actors interpret, enact and contest policy? An analysis of local government responses to meeting the needs of Syrian refugees in Turkey", p.9.

30 Kamil Ateş, "Göç Yönetiminde Yerel Yönetimlerin Rolü", *Iğdır Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 5 (2020), p.29.

and protection of victims, compliance and communication, institutional capacity sections.[31] [32]

Migration Policy Board, which is another structure established with the Law No. 6458, re-established and took the name of Migration Board with the Presidential Decree No. 1 in 2018, after 5 meetings were held under the chairmanship of the Minister of Interior. Other councils and commissions established by the Law on Foreigners and International Protection are Permanent Councils and Commissions, Migration Advisory Council, International Protection Evaluation Commission, Coordination Board for Combatting Irregular Migration and Temporary Commissions. However, they were all eliminated with the Decree Law No. 703 in 2018, except the Protection Evaluation Commission.[33]

The 11th National Development Plan, differs from its antecedents by including a private chapter about external migration under the headline of "Qualified People, Strong Society". In the title where a more controllable and more systematic migration management is set as the target, issuing a Migration Strategy Paper, strengthening the international cooperation, monitoring irregular immigrants, sharing experiences on international platforms, ensuring social adaption, raising awareness in citizens, improving Turkish language skills were determined as the basic policies. [34]

4.3. International Level

Since the EU started the negotiations for full membership with Turkey in 2005, EU has become an important actor in shaping Turkey's migration policy. EU defines migration as one of the *key priority policy* areas and Turkey's partnership is considered urgent in this field. With this understanding, in 2013 –the same year- Readmission Agreement was signed and visa Liberalization Dialogue was initiated.

The Joint Action Plan (2015) and EU-Turkey Statement (18 March 2016) were introduced to draw the framework of this partnership. The EU-Turkey Statement has five main titles as return of irregular migrants, EU financial assistance for Syrian immigrants, visa exemption for Turkish citizens, reviving Turkey-EU full

31 "Stratejik Plan 2017-2021", Access 12 Feb, 2022. https://www.goc.gov.tr/kurumlar/goc.gov.tr/evraklar/Stratejik-Yonetim/Stratejik-Planlar/yeni/Stratejik-Plan-2017_2021.pdf

32 "Stratejik Plan 2019-2023", Access 12 Feb, 2022. https://www.goc.gov.tr/kurumlar/goc.gov.tr/Mali-Tablolar/STRATEJIK-PLAN-2019-2023/Stratejik-Plan-2019_2023.pdf

33 "Final Report Sector Study Migration and Asylum", Access 02 Feb, 2022. https://www.avrupa.info.tr/sites/default/files/2021-12/Final%20Report%20Sector%20Study%20Migration%20and%20Asylum.pdf

34 "Eleventh Development Plan 2019-2023", Access 12 Feb, 2022. https://www.sbb.gov.tr/wp-content/uploads/2021/12/Eleventh_Development_Plan_2019-2023.pdf

membership negotiations and updating the Customs Union. As a result, although some of the chapters in this agreement were not implemented (such as visa exemption, resumption of negotiations, updated Customs Union), immigration to European countries was largely blocked by Turkey's intervention. In the Final Sector Study Migration and Asylum Report prepared in 2020, current situation was evaluated by dividing in five areas as legal migration, irregular migration, human trafficking, asylum and integration.

On the legal basis EU points out three legal gaps. The first one is about the fact that the refugee status, which is given only to immigrants from Europe (based on the Geneva Convention signed in 1951), cannot be used for immigrants from other geographical regions. As a result, they are lack of permanent status and defined under the status of "temporary protection". The second point that is seen as a gap by EU, is about the last changes on the related law. Changes such as reduction of appeal time for detention and deportation decisions and provisions on people to be deported are criticized. The third gap is seen as the differences in implementation both in legal and administrative level.[35]

In this process, along with the EU institutions there were other efficient international actors in shaping Turkey's migration policy. The International Organization for Migration (IOM) and UN Refugee Agency (UNCHR) are the two most prominent organizations. In 2008, in order to prepare a draft for the Law on Foreigners and International Protection, the Asylum and Migration Bureau and the Bureau for Border Management were established within the framework of agreements with these organizations under the Ministry of Interior and administrative support was also provided by these organizations.[36] From this point of view, it can be stated that the law that came into force in 2013 was shaped in line with international migration policies.

CONCLUSION

A traditional understanding of crisis management is not sufficient to overcome the various, continuous and multidimensional challenges faced by public administrations today. With the influence of the COVID-19 experience, instead of applying the existing policies to overcome the difficulties encountered, the importance of bouncing back by creating a flexible structure that takes immediate decisions and puts it into practice has emerged. Resilience is the key word define the new structure.

35 "Final Report Sector Study Migration and Asylum".

36 Ayşen Üstübici, "The Impact of Externalized Migration Governance on Turkey: Technocratic Migration Governance and the Production of Differentiated Legal Status", *Comparative Migration Studies*, 7/46 (2019), p.

Resilience is usually relevant with the unforeseen crisis situations and the ability to recover. It is clear that the effects of an irregular migration wave that took place in a short time will lead to a crisis both in the short and long term. Even more, these effects will not be limited with one specific country but will also spread to the global scale. Therefore, it is inevitable that a country facing such a large-scale immigration problem, also needs policies to strengthen its resilience.

Turkey is giving a test of resilience with the irregular migration it has received in the last ten years. In a system where 3.7 million registered immigrants spread across the country (and there are as many unregistered immigrants), it is vital to cooperate with all the stakeholders. While the primary responsibility for the development and implementation of migration policies belongs to the central government, the cooperation of local governments is of great importance. Coordination of all levels of government is necessary but not enough. Private sector is also an important actor, in order to provide necessary information and keep that information safe. In this particular case, since Turkey has a position that largely prevents this wave of migration from spreading to Europe, cooperation at the international level, especially with the European Union, is inevitable.

In this study regulations and strategies both in international, national and local level were examined. The main issue seems to be the lack of coordination between these levels. On one hand European Union as the main international actor in this issue, claims that the implementations and recent regulations are moving away from the European acquis, on the other hand an obvious differentiation and disconnection between the local and national strategies can be seen.

Since the migration has an impact on almost every area of society, albeit at different levels, strategic plans should be multidimensional and achieving a strong coordination amongst these actors is vital.

One of the effects of the intense immigration that Turkey has received in a short time on the society has shown itself as xenophobia. The reaction against immigrants, who are thought to lead better lives than natives with the resources provided by the state and international organizations, has increased with the deepening of economic problems and the emergence of security gaps. Additionally, this problem is triggered by the fact that employers see undocumented immigrants as a source of cheap labor and prefer them instead of Turkish citizens in unqualified jobs. Although the penalty for employing illegal foreign workers is determined by law, it remains a current problem due to the problems encountered in detecting them, insufficient number of audit personnel, inefficacy of law and the indifference of the relevant institutions.37

The issue of social adaption of immigrants is one of the important problems that society directly faces. The main reason why social adaptation is still seen as a problem is the insufficient level of coordination between local governments and central government. In the face of an unprepared, unexpected and sudden migration wave, the lack of resources in local governments, the deficiencies in national and international legislation prevent steps to be taken to improve the situation of both local people and immigrants. As the length of stay of the immigrants increased, they began to settle permanently in their places, which led to the expansion of the services that the municipalities had to provide.

For resilience to have a place in Turkish public administration culture, both national and local level planning is needed. By preparing a Fundamental Plan for National Resilience and a Fundamental Plan for Regional Resilience, there will be a guide on how to proceed when unexpected situations such as the great migration wave in recent years or the COVID-19 pandemic are encountered. There has to be harmony amongst different levels of these plans and give clear instruction to public administration on how to be more flexible, dynamic and transformational in order to ensure resilience

BIBLIOGRAPHY

1. ASIS SPC.1-2009, "Organizational Resilience Standard: Security, Preparedness and Continuity Management Systems – Requirements with Guidance for Use", American National Standards Institute, Inc. Access 07 Feb, 2022, https://www.ndsu.edu/fileadmin/emgt/ASIS_SPC.1-2009_Item_No._1842.pdf
2. Aslantürk, Oğuzhan ve Yusuf Erdem Tunç. "Yabancıların Türkiye'de Kayıtdışı İstihdamı". *Aksaray Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*. 10/4 (2018), p.13-20. http://aksarayiibd.aksaray.edu.tr/tr/pub/issue/42407/497436
3. Ateş, Kamil, "Göç Yönetiminde Yerel Yönetimlerin Rolü", *Iğdır Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 5 (2020), p.23-40. https://dergipark.org.tr/en/download/article-file/2096608
4. Bruneckiene, Jurgita, Oksana Palekiene, Zaneta Simanaviciene and Joonas Rapsikevicius. "Measuring Regional Resilience to Economic Shocks by Index", *Inzinerine Ekonomika-Engineering Economics*, 29/4 (2018), p. 405-418. https://doi.org/10.5755/j01.ee.29.4.18731

[37] Oğuzhan Aslantürk ve Yusuf Erdem Tunç, "Yabancıların Türkiye'de Kayıtdışı İstihdamı", Aksaray Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 10/4 (2018), p. 18.

5. Duit, Andreas. "Resilience Thinking: Lessons for Public Administration". *Public Administration*. 94/2 (2016): 364–380. https://doi.org/10.1111/padm.12182
6. European Commission. "2020 Strategic Foresight Report". Access 11 Feb, 2022. https://ec.europa.eu/info/sites/default/files/strategic_foresight_report_2020_1_0.pdf
7. European Commission. "2021 Strategic Foresight Report". Access 11 Feb, 2022. https://ec.europa.eu/info/sites/default/files/strategic_foresight_report_2021_en.pdf
8. European Union "Final Report Sector Study Migration and Asylum". Access 02 Feb, 2022. https://www.avrupa.info.tr/sites/default/files/2021-12/Final%20Report%20Sector%20Study%20Migration%20and%20Asylum.pdf
9. European Union "Regulation (EU) 2021/241 of the European Parliament and of the Council of 12 February 2021 establishing the Recovery and Resilience Facility". Access 11 Feb, 2022. http://data.europa.eu/eli/reg/2021/241/oj
10. Göç İdaresi Genel Müdürlüğü. "Stratejik Plan 2017-2021". Access 12 Feb, 2022. https://www.goc.gov.tr/kurumlar/goc.gov.tr/evraklar/Stratejik-Yonetim/Stratejik-Planlar/yeni/Stratejik-Plan-2017_2021.pdf
11. Göç İdaresi Genel Müdürlüğü. "Stratejik Plan 2019-2023". Access 12 Feb, 2022. https://www.goc.gov.tr/kurumlar/goc.gov.tr/Mali-Tablolar/STRATEJIK-PLAN-2019-2023/Stratejik-Plan-2019_2023.pdf
12. Japan Cabinet Secretariat. "Building National Resilience". Access 08 Feb, 2022. https://www.cas.go.jp/jp/seisaku/kokudo_kyoujinka/index_en.html
13. Lowndes, Vivien and Rabia Karakaya Polat. "How do local actors interpret, enact and contest policy? An analysis of local government responses to meeting the needs of Syrian refugees in Turkey". *Local Government Studies*. https://doi.org/10.1080/03003930.2020.1825386
14. McAslan, Alastair. "The Concept of Resilience. Understanding its Origins, Meaning and Utility". *Adelaide, Australia: Torrens Resilience Institute* (2010), p. 1-13. https://www.flinders.edu.au/ content/dam/documents/research/torrens-resilience-institute/resilience-origins-and-utility.pdf (Access 07.02.2022).
15. OECD. "Guidelines for Resilience Systems Analysis" (2014). Access 10 Feb, 2022. https://www.oecd.org/dac/Resilience%20Systems%20Analysis%20FINAL.pdf
16. OECD. "National Policy Frameworks on Resilience in OECD Countries", Access 09 Feb, 2022. https://www.oecd.org/cfe/regionaldevelopment/national-policy-resilience-frameworks.pdf
17. ORSAM. "Suriyeli Sığınmacıların Türkiye'ye Etkileri". Report No: 195 (2015). https://www.tesev.org.tr/ wp-content/uploads/rapor_Suriyeli_Siginmacilarin_Turkiyeye_Etkileri.pdf
18. Presidency of the Republic of Turkey – Presidency of Strategy and Budget. "Eleventh Development Plan 2019-2023". Access 12 Feb, 2022. https://www.sbb.gov.tr/wp-content/uploads/2021/12/Eleventh_Development_Plan_2019-2023.pdf

19. Profiroiu, Alina Georgiana and Corina-Cristiana Nastacă. "What Strengthens Resilience in Public Administration Institutions?". *Eastern Journal of European Studies*. 12 (2021), p. 100-125.
20. Putra, Fadillah. "Crisis Management in Public Administration". *Journal of Community and Regional Planning*. 13/14 (2009): 152-173. https://repositories.lib.utexas.edu/bitstream/handle/2152/30369/planningforumv13-14.pdf?sequence=2&isAllowed=y
21. Rocha, J. A. Oliveira and Gonçalves J. B. Zavale. "Innovation and Change in Public Administration." *Open Journal of Social Sciences*, no 9 (2021): 285-297. https://www.scirp.org/ pdf/jss_2021062415342419.pdf (access 07.02.2022).
22. The International Organization for Migration. "Turkey – Migrant Presence Monitoring - Situation Report (January 2022)". Access 13 Feb, 2022. https://reliefweb.int/sites/reliefweb.int/files/resources/Turkey_Sitrep_01_January_22.pdf
23. The UK Cabinet Office. "Preperation and Planning for Emergencies". Access 10 Feb, 2022. https://www.gov.uk/guidance/preparation-and-planning-for-emergencies-the-capabilities-programme
24. The UK Cabinet Office. "The National Resilience Strategy". Access 10 Feb, 2022. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1001404/Resilience_Strategy_-_Call_for_Evidence.pdf
25. The UN Refugee Agency. "Mid-Year Trends 2021". Access 05 Feb, 2022. https://reliefweb.int/sites/reliefweb.int/files/resources/618ae4694_0.pdf
26. The White House. "National Security Strategy of the United States of America". Access 10 Feb, 2022, https://trumpwhitehouse.archives.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf
27. The World Bank. "Urban Population". Last update 7 Feb, 2022. https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2020&name_desc=true&start=1961&view=chart
28. The World Bank. "What Are Key Features of a Resilient Bureaucracy?". Last update 8 Feb, 2022. https://blogs.worldbank.org/governance/what-are-key-features-resilient-bureaucracy
29. UN, World Urbanization Prospects The 2018 Revision (2018) https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf
30. Üstübici, Ayşen. "The Impact of Externalized Migration Governance on Turkey: Technocratic Migration Governance and the Production of Differentiated Legal Status". *Comparative Migration Studies.* 7/46 (2019). p.1-18. https://doi.org/10.1186/s40878-019-0159-x
31. Van de Walle, Steven. "Building Resilience in Public Organizations: The Role of Waste and Bricolage." T*he Innovation Journal: The Public Sector Innovation Journal*, 19/2 (2014): 1-18. (access 07.02.2022).

Chapter 12

EVALUATION OF RAIN WATER IN TERMS OF NITROGEN AND PHOSPHORUS LOADS

Zarife Özsubaşı* - Elanur Küçük** - Pınar Ergenekon***

INTRODUCTION

In this project, Total Nitrogen and Phosphorus values in rainwater will be examined. Rainwater samples will be collected by using the rainwater collection device and Total Nitrogen and Phosphorus measurements will be made with the standard analysis methods. In order to examine the effect of nitrogen and phosphorus loads coming from the rain to the Northern Marmara Sea directly, a rainwater collection device was placed on the roof of the Environmental Engineering Department Building of Gebze Technical University Campus in Kocaeli/Çayırova district. Samples collected on the monthly basis will be analyzed upon collections for the pH, conductivity, and volume measurements immediately and then will be stored for further analysis for determination of the nutrient load. This study is in the first study about these parameters of the rain in Gebze region.

The result will be revealing the amount of rain is falling in this region seasonally, variation of pH, the conductivity, suspended solid concentrations, nutrient amount and together with the relationship of these parameters to wind direction, temperature and to each other.

Gebze's Climate and Precipitation Regime is generally a transitional feature between the Black Sea and Mediterranean regions. The summer season is hot and less rainy, the winter season is quite cool and rather rainy. The annual

* Gebze Technical University, Environment Engineering, zarife.ozsubasi2016@gtu.edu.tr
** Gebze Technical University, Environment Engineering, elanur.kucuk2017@gtu.edu.tr
*** Gebze Technical University, Environment Engineering, p.kus@gtu.edu.tr

precipitation average is 550 mm. The most precipitation is in December and January, and the least precipitation is in August. The hottest month average is August with 24.2°C, and the coldest month average is January with 6.5°C. The only creek that maintains its water levels during the summer and winter months is the 12 km long Dil Stream, which runs through Dilovası and empties into the Gulf of Izmit. Considering the air pollution problems that arise as a result of industrial activities, it is possible to encounter air pollutants in rainwater.

In addition, pesticides and fertilizers used for agricultural activities, especially in villages, are mixed with rainwater and streams in Gebze district. Pesticides and fertilizers used for agricultural activities are mixed with runoff from soil to streams due to precipitation. When nitrogen and phosphorus loads are transmitted to the aquatic environment due to surface flow, it causes an increase in organic load and therefore an increase in microbiological activities. In this study we will be looking at only direct nutrient load from the rain itself, it should be noted that runoffs through the agricultural areas will also cause increased nutrient discharge to the Marmara Sea. From this point of view, it is important to examine first the Nitrogen and Phosphorus loads coming from direct precipitation in Gebze district in order to examine the mucilage problem in the Marmara Sea.

Investigations have been made for wet deposition samples in many countries. For example, a study conducted in Singapore measured both inorganic and organic fractions of water-soluble Nitrogen and Phosphorus species in wet atmospheric precipitation in a tropical marine environment of Singapore [1] . In addition, in studies conducted in China and India, where the population is dense and air pollution problems are on the agenda, pollutant analyzes were made in wet precipitation. There are also studies on rainwater samples in Turkey. For example, in a study conducted for the town of Amasra, SO_4^{2-}, NO_3^-, PO_4^{2-}, Br^-, Cl^-, F^- and NO_2 analyzes were made in rainwater [2]. In another study, heavy metal pollution was investigated in rainwater samples taken from the Giresun coastal road [3]. The effects of heavy metals in surface waters in the Marmara region and their relationship with eutrophication were investigated. In this study, it was mentioned that heavy metals that naturally enter the aquatic environment through wind,

---

1 Rajasekhar Balasubramanian, Sundarambal Palani, and Pavel Tkalich, "Atmospheric Fluxes of Nutrients onto Singapore Strait," *Water Science & Technology 59(11):2287-95*, 2009, 1–11, https://doi.org/10.2166/wst.2009.262.

2 Tülay Balta et al., "No Title," *Hava Kirliliği ve Kontrolü Ulusal Sempozyumu*, 2008.

3 Alev Kara and Aysun Türkmen, "Giresun Sahil Yolundan Alınan Yağmur Suyu Örneklerindeki Ağır Metal Kirliliği," *Karadeniz Fen Bilimleri Dergisi , 5 (12)*, 2015.

stream, atmospheric transport and depending on the rock-water interaction process, are transported to aquatic environments due to industrial establishments and their concentration in aquatic ecosystems increases rapidly [4]. However, since there is no analysis on rainwater samples in terms of nitrogen and phosphorus loads in Turkey, especially in the Gebze region, this project will contribute to the literature and will set an example for future studies. Since the rainwater samples will be examined in the project, wet deposition samples for the Gebze district will be examined.

1. METHODS

1.1. Sampling Point

After cleaning with pure water and ethanol, the Rainwater Collector was placed on the roof of the Gebze Technical University Environmental Engineering Building at 11:05 on October 6, 2021. The location coordinates of the rainwater collection device are 40˚48'19.9"N 29˚21'44.1"E (40.805536, 29.362238) (Figure 1). The height of the sampling point was measured as 16 m.

Figure 1. Location of Rain Water Collector Device

4 Tülay Feyiz Caner, "Yağmur Suyu ve Atmosferik Parçacıklardaki İyonların, İz Elementlerin, Escherichia Coli ve Enterococcus Bakteri Türlerinin İncelenmesi," 2016, 1–121.

- **Gebze's Climate and Precipitation Regime:**

Generally, it has a transition feature between the Black Sea and Mediterranean regions. The summer season is hot and less rainy, the winter season is quite cool and rather rainy. The annual precipitation average is 550 mm. The most precipitation occurs in December and January, and the least in August. The warmest month average is August with 24.2 °C, and the coldest month average is January with 6.5 °C. Although there are no significant lakes, mountains or streams within the boundaries of the district, it can be mentioned that there are hills and ridges that do not exceed approximately 650 m in height. The highest of these hills is Gaziler Hill. However, instead of streams, there are streams and brooks. The only creek that maintains its water levels during the summer and winter months is the 12 km long Dil Stream, which crosses Dilovası and empties into the gulf of İzmit. Another name of this stream is Tavşanlı Creek [5].

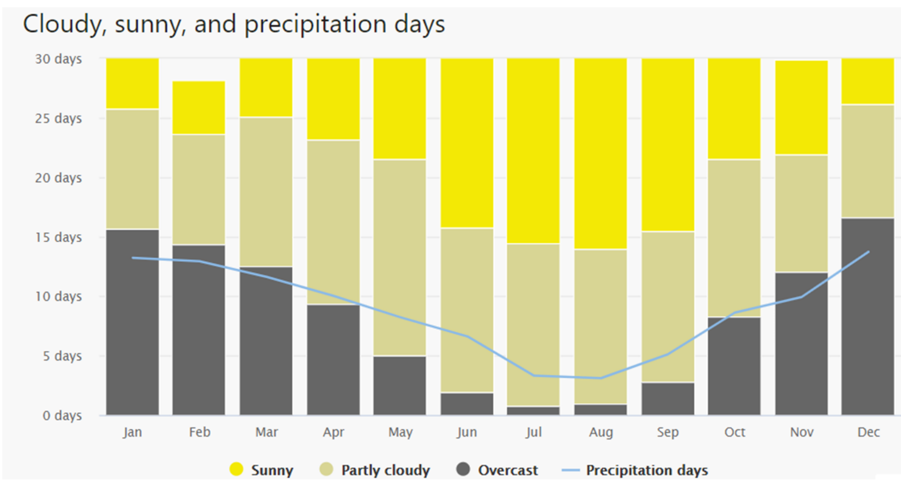


Figure 2. Cloudy, sunny and precipitation days in Gebze District [6]

Figure 2 shows the number of sunny, partly cloudy, cloudy and rainy days per month. Less than 20% cloudy days are considered sunny, those with 20-80% cloud cover are considered partly cloudy, and more than 80% cloudy days. Figure 3, the precipitation diagram for Gebze, shows on how many days per month certain precipitation amounts are reached.

---

[5] "Climate of Gebze," accessed October 18, 2021, https://gebze-mi-taniyor-ve-tanitiyorum.webnode.com.tr/gebze/gebzenin-iklimi/.

[6] "Climate, Gebze," accessed October 18, 2021, https://www.meteoblue.com/tr/hava/historyclimate/climatemodelled/gebze_türkiye_747014.

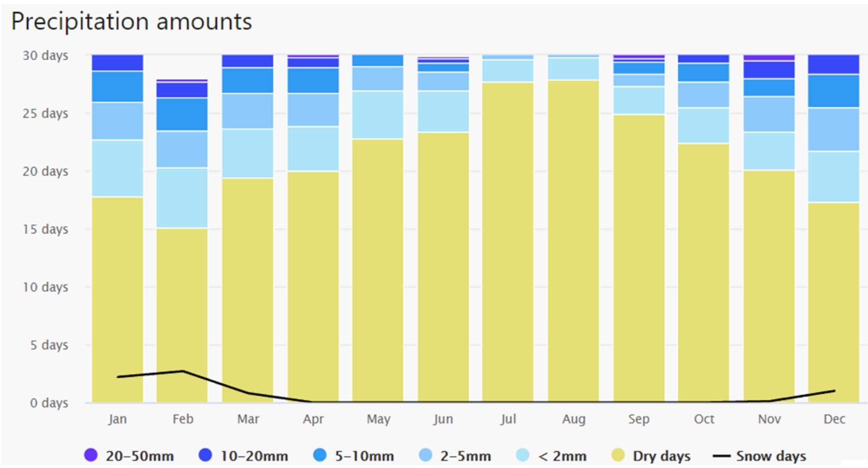


Figure 3. Precipitation Amounts of Gebze District [7]

The distance between the rain collector and the Gebze meteorological station was measured as 6,4 km over the Google Earth program (Figure 4).

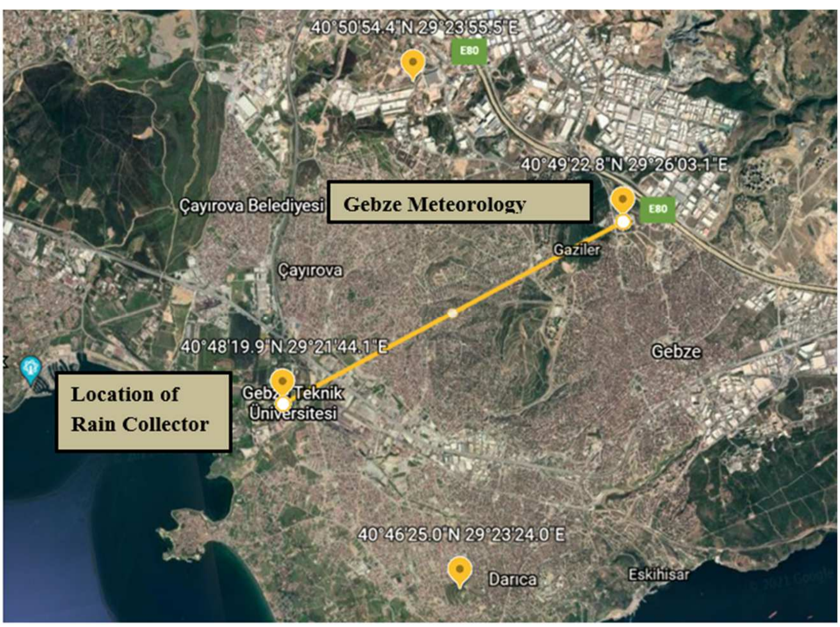


Figure 4. The Distance Between the Rainwater Collection Device on the Roof of the GTU Environmental Engineering Department and the Gebze Meteorology Station

7 "Climate of Gebze."

In Gebze meteorology station, Wind, Pressure, Soil Temperatures, Precipitation parameters are measured [8]. In Gebze District, there are two air monitoring stations, namely the Gebze Organized Industrial Zone and the Gebze Marmara Clean Air Center Directorate [9]. Gebze MCACD is closer to Gebze Technical University but considering the measured parameters the Gebze OIZ MCACD air monitoring station was chosen to compare the monthly parameters in the air with the parameters measured in the collected rainwater. Gebze OIZ MCACD' coordinates are 40°50'46.0"N 29°25'30.0"E and its distance to Gebze Technical University is 6,9 km (Figure 5). Pm2.5, SO2, NO2, NOx, O3 measurements are made at Gebze OIZ MCACD station [10].

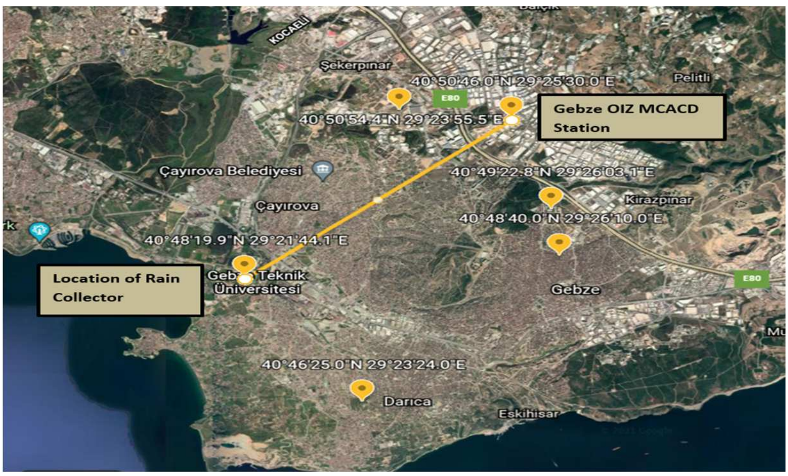


Figure 5. Distance between Gebze GOIZ MCACD Station and Rainwater collection device locations

2. SAMPLING METHOD AND SAMPLING STRATEGY

A custom-made rainwater collection device with a length of 1.5 m was used in this project (Figure 6-7). The device is made of steel. There are two 2 L PE rainwater sample containers inside the device (Figure 8). The upper part of the device has a cylindrical structure with a diameter of 30 cm and is closed with a grill. Because it is prevented that substances such as pests, insects and leaves are mixed with rainwater samples.

---

8 "Ministry of Agriculture and Forestry, General Directorate of Meteorology, Station Information Database," accessed October 18, 2021, https://mgm.gov.tr/kurumsal/istasyonlarimiz.aspx?il=Kocaeli.

9 "Geographic Information Map, Air Quality Index," accessed October 18, 2021, http://index.havaizleme.gov.tr/Map.

10 "Air Quality - Station Data Download," accessed October 18, 2021, https://sim.csb.gov.tr/STN/STN_Report/StationDataDownloadNew.

The bottles in the device are placed side by side inside the device. Rainwater collected for sample 1 will be taken from the left bottle. Rainwater collected for sample 2 will be taken from the right bottle. Rainwater samples will be stored periodically from month to month. However, in very rainy months, bottles will be checked according to precipitation and replaced as they become full. For this reason, the Kocaeli-Gebze District weather forecasts will be constantly monitored and the filled bottles will be replaced with new ones and the change dates will be noted. Collected samples will be stored at 4 °C in 250 mL sterile containers with lids for further analysis.

Figure 6. Rainwater Collector Device

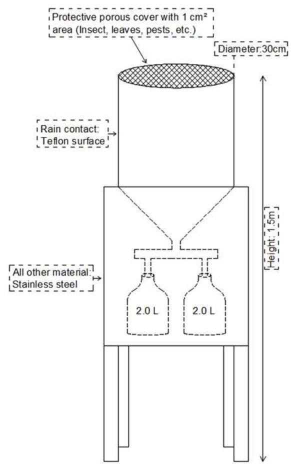


Figure 7. Rain Water Collector Drawing

Figure 8. Rainwater sample bottles inside the device

Figure 9 shows the steps for monthly rainwater samples collection procedure. Preliminary analysis will be carried out by combining sample 1 and sample 2. The sample will be passed through a 0.45 μm cellulose acetate filter and stored at +4 °C. The nitrogen and phosphorus content of the stored samples will be determined by the standard methods given below.

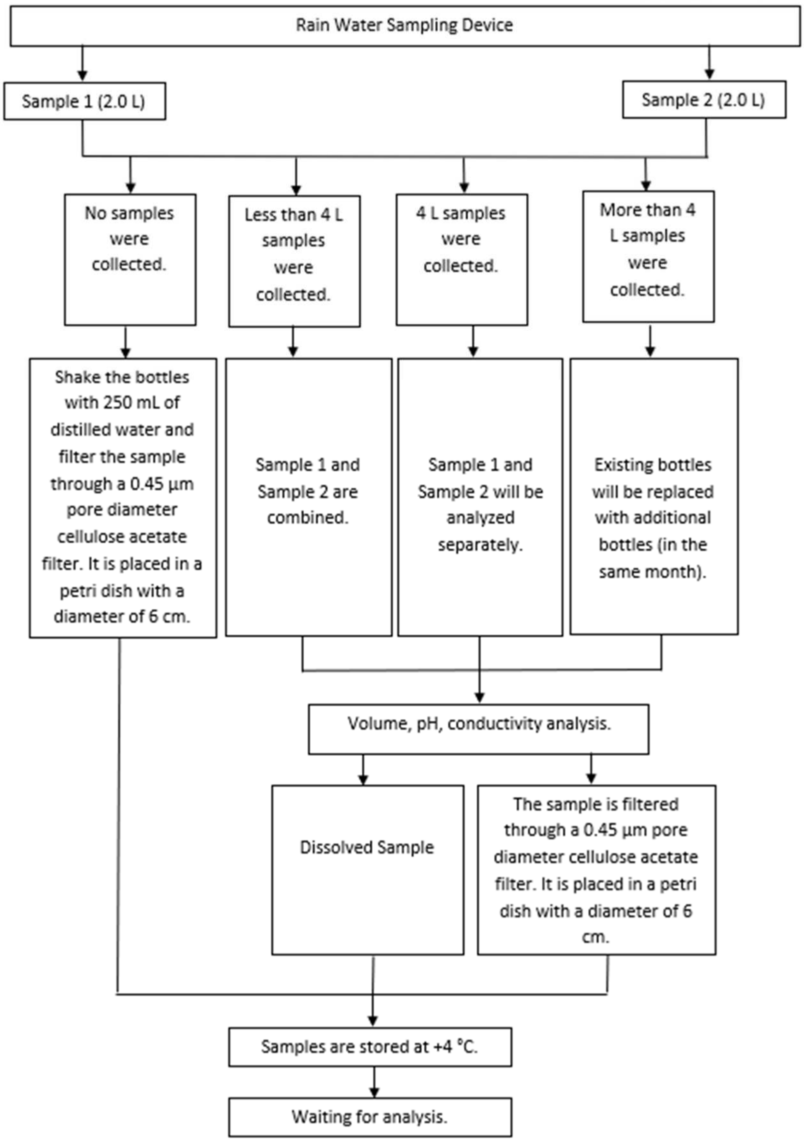


Figure 9. General Flowchart Diagram of Analysis Methods

2.1. Determination of Volume, pH, Conductivity, and SS

Bulk deposition samples were brought to the laboratory as they were collected, and volume, pH, SS and conductivity measurements will be made immediately on the same day. The pH and conductivity measurements of the samples will be made three times, and the average values of the measurements will be reported.

Upon collection of samples according to the procedure given in Figure 9, following measurement steps will be carried out.

Step 1- Sample volumes are measured in the laboratory with a precision graduated cylinder.

Step 2- The pH of the samples is measured with the EUTECH INSTRUMENTS® (Cyberscan pH 11- pH/mV/˚C Meter) branded pH meter, which is calibrated (with pH 4 and pH 7 buffer solutions).

Step 3: The conductivity value of the samples is measured with the EUTECH INSTRUMENTS® (Cyberscan CON 11- Conductivity/TDS/˚C Meter) branded conductivity meter, which is calibrated (with 1413 μS/cm calibration solution).

After the first three steps above to determine the nitrogen, phosphorus content, the samples will be refrigerated at +4 ˚C.

Step 4- 500 ml rainwater sample is filtered using a 0.45 μm cellulose acetate filter. Before the filtration process, the weight of the filter paper is measured with the help of precision scales. Filtered 500 ml rainwater sample is taken into 250 ml PE bottles. Filter paper is kept in a desiccator and then placed in a petri dish.

The processes applied to rainwater samples after the first three steps above in order to determine the nitrogen, phosphorus content is given below, respectively.

2.2. Total Nitrogen and Phosphorus Analysis Methods

Determination of Total Nitrogen

For Total Nitrogen Determination, the "Kjeldahl Nitrogen" method used in standard methods will be used.

The rainwater sample is acidified with H_2SO_4 and reacted with H_2O_2. All nitrogen compounds in the environment are oxidized to nitrate. The oxidized nitrogen compounds are then reduced to ammonium ions with iron powder (ferrum). In this way, the pre-treated water sample is evaporated for a while and placed in the kjeldahl flask. In the last step, all nitrogen is separated as ammonia nitrogen in distillation. The amount of nitrogen in the sample is determined colorimetrically or gravimetrically after the distillation process.

Reagents Required for Total Nitrogen Determination

- H_2SO_4-H_2O_2 reagent: Add 200 ml of concentrated H_2SO_4, (d= 1.84), to 275 ml of distilled water, carefully and with stirring. After cooling, this mixture is mixed with 25 ml of 30% H2O2.
- Concentrated H2SO4: Concentrated H_2SO_4 with the required purity (d= 1.84) is used for analysis.
- Iron powder: Pure iron powder containing as little nitrogen as possible is used.
- Selen reagent: This mixture consists of 500 parts anhydrous sodium sulfate, 8 parts anhydrous CuSO4 and 8 parts metallic selen. A spatula spoon that can hold 2.5-3 grams of substance is placed in this reagent and this scale is used during the experiment.
- NaOH, 32%: Pure market products with d= 1.35 are used for analysis. This solution is approximately 10.8 N.
- HCl, 0.02 N: Take 200 ml of 0.1 N HCl solution and make up to 1 liter with distilled water.
- Tashiro indicator: 200 mg methyl red and 100 mg methyl blue. They are dissolved separately in 100 ml of ethanol and mixed together.
- NaOH Solution, 0.02 N

Table 1. shows the choice of sample volume to be used in the experiment. The required sample volume will be determined based on preliminary analysis.

Table 1. Sample Volume Selection

Organic Nitrogen in the Sample mg/L	Sample Volume mL
0-1	500
1-10	250
10-20	100
20-50	50
50-100	25

Enough volume of rainwater sample is placed in long-necked 250 ml kjeldahl balloons. 5 ml of H_2SO_4-H_2O_2 reagent is added to the water sample and heated in an electric heater at medium temperature for 20 minutes. It is then kept at 100˚C for 15 minutes. The sample is cooled in a water bath. It is brought to room temperature by adding 10 ml of concentrated H_2SO_4. Then 600-800 mg of Fe powder is added, the sample is left for 30 minutes, and 2-3 grams of selene reagent is given by slightly heating. The sample is heated in an electric heater until it becomes clear. The sample is evaporated by gradually increasing the temperature of the sample. The temperature is gradually increased and the liquid in the balloon is kept at a boil. The boiling process is terminated when the salt residue evaporation residue is egg yolk in color and the supernatant is clear as water. The heating range is between 30-80˚C. It is necessary to heat for 30 minutes in this temperature range. After cooling the sample, 25 ml of distilled water is added to the flask and the flask is connected to the distillation apparatus for NH_3 distillation. 60 ml of concentrated NaOH is poured into the distillation vessel and the distillation is started by closing the mouth. 25 ml of 0.02 N HCl is placed in an Erlenmeyer flask and 2-3 drops of Tashiro indicator are dropped on it. The sample is collected on this solution in Erlenmeyer flask. The flow pipe of the cooler is immersed in this solution. The distillation process continues for about 10 minutes. In order to find the amount of ammonia in the sample by mass analysis, 25 ml of 0.22 N HCl and 2-3 drops of Tashiro indicator are added to the titration vessel. If too little HCl is given, the indicator will precipitate. If this is noticed in time, 25 ml of 0.025 N HCl is added a second time. After collecting 150 ml of distillate in the container containing the indicator, the sample is titrated with 0.02 N NaOH. The color change is observed as the solution turns from red violent to gray-green.

Calculation of Total Nitrogen Determination Result

$$CN = \frac{(B-V)xfx280.16}{V_0} \quad (1)$$

V0: The sample volume (mL), f: The factor of the NaOH solution, B: The amount of 0.02 N NaOH used for the blank (mL), V: The amount of 0.02 N NaOH (mL) used for the sample.

Determination of Total Phosphorus

To be able to determine total phosphourus content of the rainwater, spectrophotometric analysis will be used since molybdophosphoric acid is formed by stannous chloride and is reduced to the intensely colored molybdenum blue.

This method makes feasible measurements up to 7 μg P/L using increasing light path length.

Since the total phosphorus will be determined, the sample is brought to pH<2 by adding H_2SO_4 or HCl and cooled to 4˚C or frozen without any addition.

Reagents to be Used in the Experiment

- Phenolphthalein indicator aqueous solution.
- Strong acid solution: Slowly add 300 mL of concentrated H2SO4 to approximately 600 mL of distilled water. When cooled, 4.0 mL of concentrated HNO3 is added and diluted to 1 L.
- Ammonium molybdate reagent I: Dissolve 25 g (NH4)6Mo7O24.4H2O in 175 mL distilled water. Carefully add 280 mL of conc H2SO4 to 400 mL of distilled water. It is cooled, molybdate solution is added and diluted to 1 L.
- Tin chloride reagent I: Dissolve 2.5 g of fresh SnCl2.2H2O in 100 mL of glycerol. It is heated in a water bath and stirred with a glass rod to accelerate dissolution. This reagent is stable and requires no preservatives or special storage.
- Standard phosphate solution: 219.5 mg of anhydrous KH2PO4 is dissolved in distilled water and diluted to 1000 mL; 1.00 mL=50.0 μg PO4-3-P.

Reagents for extraction

- ✓ Benzene-isobutanol solvent: Equal volumes of benzene and isobutyl alcohol are mixed. (This solvent is highly flammable.)
- ✓ Ammonium molybdate reagent II: Dissolve 40.1 g of $(NH_4)_6Mo_7O_{24}.4H_2O$ in approximately 500 mL of distilled water. Slowly add 396 mL of ammonium molybdate reagent I. Refrigerated and diluted to 1 L.
- ✓ Alcoholic sulfuric acid solution: With continuous stirring, carefully add 980 mL of methyl alcohol to 20 mL of concentrated H_2SO_4.
- ✓ Dilute stannous chloride reagent II. Mix 8 mL of stannous chloride reagent I with 50 mL of glycerol. This reagent is stable for at least 6 months.

Experimental Procedure

Pre-sample treatment: 0.05 ml (1 drop) of phenolphthalein indicator is added to 100 ml of sample containing up to 200 μg P, free of color and turbidity. If the sample turns pink, a strong acid solution is added dropwise to return the color. If more than 25 mL (5 drops) is required, a smaller sample is taken and diluted to

100 mL with distilled water after turning pink in acid. Add 4.0 mL of molybdate reagent I and 0.5 mL (10 drops) of stannous chloride reagent I with stirring after each addition. After 10 minutes, color is measured photometrically at 690 nm. When increased sensitivity is desired or interactions need to be overcome, phosphate is extracted as follows: A 40 mL sample or a sample diluted to this volume is taken with a 125 mL separatory funnel. Add 50.0 mL of benzene-isobutanol solvent and 15.0 mL of molybdate reagent II. The funnel is immediately closed and shaken vigorously for exactly 15 seconds. If condensed phosphate is present, any delay will increase its conversion to orthophosphate. The stopper is removed and 25.0 mL of separated organic fraction is drawn using a ball pipette. Transfer a 50 mL flask, add 15 to 16 mL of alcoholic H2SO4 solution, mix, add 0.50 mL (10 drops) of dilute stannous chloride reagent II, mix and dilute with alcoholic H2SO4. It is mixed well. After 10 minutes, but before 30 minutes, the blank is read at 625 nm and then the sample is read. A blank is prepared with 40 mL of distilled water using the same procedure used for the sample. The phosphate concentration is read from a calibration curve prepared by taking known phosphate standards with the procedure used for the samples.

Total Phosphorus Calculation

$$mg\frac{P}{L} = \frac{mg\ P\ (50\ mL\ in\ final\ volume)x1000}{mL\ sample} \quad (2)$$

Standard Methods for Examining Water and Wastewater, 23rd Edition, for methods of Total Nitrogen and Total Phosphorus assays. (2017) book was used [11].

3. PRELIMINARY RESULTS

The volume, pH and conductivity measurements made for rainwater samples collected in October, November, December and January are shown in Table 2.

The total volume of the samples collected in October 2021 is 2124 mL. The pH of the sample is 7.56. The conductivity value is 103.4 μS/cm. According to the flow chart (Figure 11); Sample 1 and Sample 2 samples are combined with analyzes because less than 4 L samples are collected.

Total sample volume collected in November 2021 is 2530 mL. The pH of the sample is 7.25. The conductivity value is 77 μS/cm. According to the flow chart; Sample 1

[11] "Standard Methods for the Examination of Water and Wastewater," *23rd Edition*, 2017.

and Sample 2 samples are combined with analyzes because less than 4 L samples are collected.

The volumes of samples collected in December 2021 are 2050 mL and 2300 mL. The pH of the samples was 6.94 and 6.73, the conductivity values were 50 and 28.4 μS/cm, respectively. The range collected sample volume is 4350 ml. According to the flow chart; Sample 1 and Sample 2 samples were analyzed separately as more than 4 L samples were collected.

Total sample volume collected in January 2022 is 2935 mL. The pH of the sample is 6.90. The conductivity value is 63 μS/cm. According to the flow chart (Figure 11); Sample 1 and Sample 2 samples are combined with analyzes because less than 4 L samples are collected.

Table 2. Volume, pH, conductivity and SS values for rainwater samples collected in October, November, December and January

		October 2021	November 2021	December 2021		January 2022
		Sample 1 and Sample 2	Sample 1 and Sample 2	Sample 1	Sample 2	Sample 1 and Sample 2
Volume Measurements		2124 mL	2530 mL	2050 mL	2300 mL	2935 mL
pH Measurements		7.56	7.25	6.94	6.73	6.90
Conductivity Measurements		103.4 μS/cm	77 μS/cm	50 μS/cm	28.4 μS/cm	63 μS/cm
Temperature		21.8 °C	20 °C	11.8 °C		12.3 °C
Amount of rain per m^2		30,0 mm	38.5 mm	61.5 mm		41.5 mm
Filtration	Initial Filter Weight	0.0826 g	0.0820 g	0.0806 g		0.0798
	Amount of Filtered Rainwater	500 ml	500 ml	500 ml		500 ml
	Final Filter Weight	0.0828 g	0.0826 g	0.0818 g		0.0819 g
	SS Concentration	0.40 mg/L	1.2 mg/L	2.4 mg/L		4.2 mg/L

In Figure 10, change in pH of monthly rain samples can be seen. Samples collected from October 2021 to January 2022 varied in the range of 6.8-7.6. The lowest pH value was measured as 6.84 in December. The highest pH value was measured as 7.56 in October. In general, the pH value showed a decreasing trend.

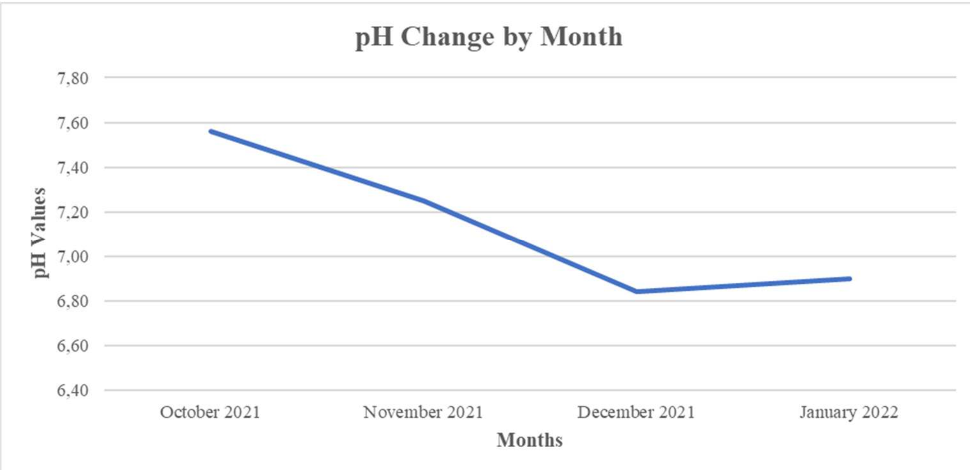


Figure 10. The pH values of the samples

As for conductivity for these four months can be seen in Figure 11. collected from October 2021 to January 2022 varied in the range of 105-35 μS/cm. The lowest conductivity value was measured as 39.2 μS/cm in December. The highest conductivity value was measured in October as 103.4 μS/cm.

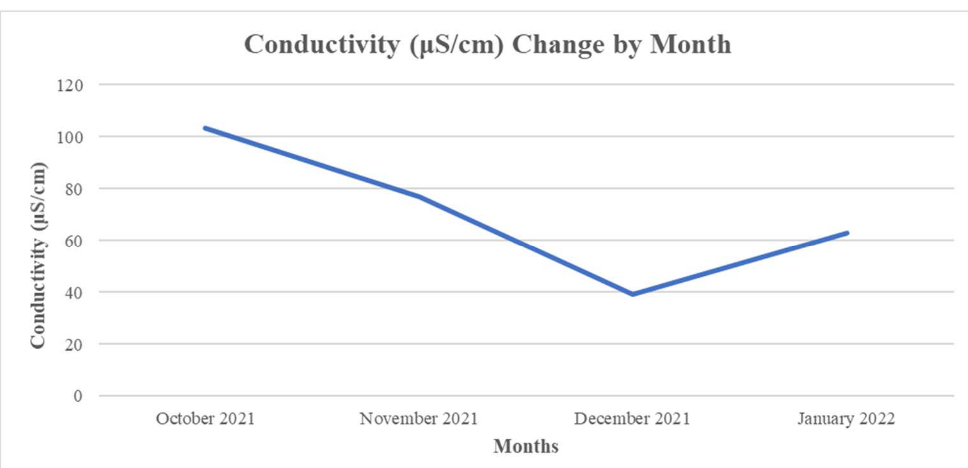


Figure 11. The conductivity values of the samples

Monthly rain amounts in mm can be seen in Figure 12. Monthly rain amounts from October 2021 to January 2022 varied in the range of 30-65 mm. The lowest amount of precipitation per m^2 was measured as 30 mm in October. The highest precipitation amount per m^2 was measured in December as 61.5 mm. The highest precipitation value was obtained in October when the lowest pH and conductivity values were measured.

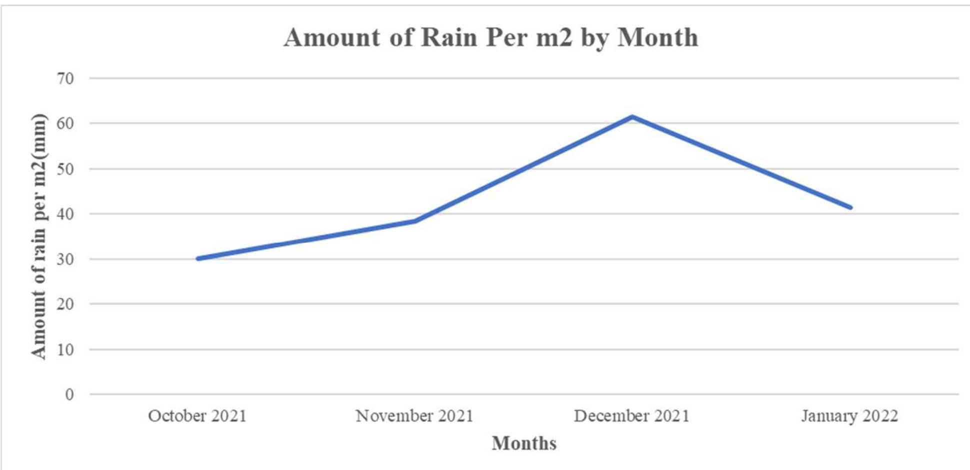


Figure 12. The precipitation amount per m2 of the samples

Monthly suspended solids values can be seen in Figure 13. Concentrations from October 2021 to January 2022 varied in the range of 0.4-4.5 mg/L. The lowest suspended solids value was measured as 0.4 mg/L in October. The highest suspended solids value was measured as 4.2 mg/L in January. Change in the amount of suspended solids shows an increasing trend.

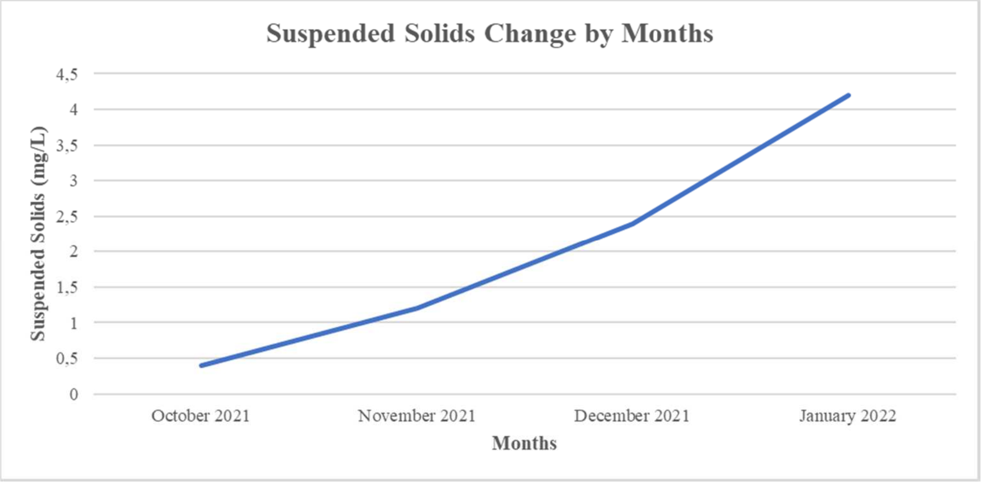


Figure 13. Suspended solids values of the samples

4. TOTAL PHOSPHORUS ANALYSIS

Table 3. Total Phosphorus Analysis

Rainwater Sample		**Total Phosphorus Concentration (mg/L)**
October 2021	Sample 1	0,001
	Sample 2	0
November 2021	Sample 1	0,033
	Sample 2	0,116
December 2021	Sample 1	0,009
	Sample 2	0,04
January 2022	Sample 1	0
	Sample 2	0

Total Phosphorus concentration values of rainwater samples specified in Table 3 were measured in ICP-OES device before determination of total phosphours with spectrometric analysis.

Figure 14. Total Phosphorus Measurement Results in Rainwater (ICP-OES Analysis)

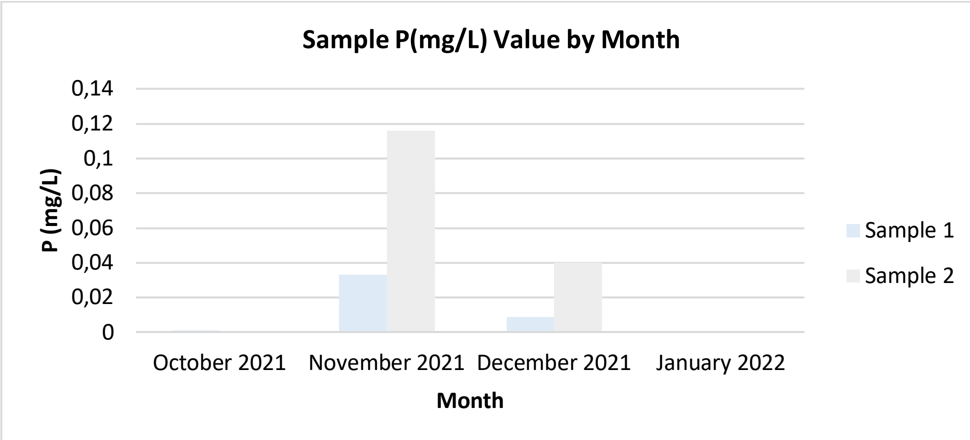


Figure 13. Suspended solids values of the samples

CONCLUSION

Monthly collected rain samples basic parameters were measured. For the Fall and winter seasons rain amount is 34.25 mm and 51.5 mm, respectively. pH values vary from 7,4 to 6.73. We can see that as the temperature drops, the pH values show a decrease. It might be caused partly by the sources become active in winter months such as domestic heating. Conductivity measurments on the other hand varied over a wide range from 100 □S/cm to 28 □S/cm. Phosphour content of the samples are measured between 0 and 0,116 mg/L. Particulate portion collected by the rain also shows an increasing trend as the temperature decreases. Highest suspendid solids amount was seen in January sample.

Completion of the collecting for spring and summer months together with the analysis of the rainwater for Total N and P will give a better understanding of the rain water effect on water bodies.

This project is carried out by two undergraduate students as their graduation project. Due to limited time, only selected few parameters will be analyzed. However, by storing the the rainwater samples adequately, samples can be analyzed for other parameters in the near future. Completing all the other analysis of the samples will definetely give a more detailed characterization of the wet deposition and its role in regional water bodies' water quality.

REFERENCES

1. "Air Quality - Station Data Download." Accessed October 18, 2021. https://sim.csb.gov.tr/STN/STN_Report/StationDataDownloadNew.
2. Balasubramanian, Rajasekhar, Sundarambal Palani, and Pavel Tkalich. "Atmospheric Fluxes of Nutrients onto Singapore Strait." *Water Science & Technology 59(11):2287-95*, 2009, 1–11. https://doi.org/10.2166/wst.2009.262.
3. Balta, Tülay, Kamil Çoşkun, Cihan Dündar, Ali İhsan İlhan, Fatma Eroğlu Kenet, Fatma Öztürk, Nezehat Öz, Gürhan Rasan, and Gürdal Tuncel. "No Title." *Hava Kirliliği ve Kontrolü Ulusal Sempozyumu*, 2008.
4. "Climate, Gebze." Accessed October 18, 2021. https://www.meteoblue.com/tr/hava/historyclimate/climatemodelled/gebze_türkiye_747014.
5. "Climate of Gebze." Accessed October 18, 2021. https://gebze-mi-taniyor-ve-tanitiyorum.webnode.com.tr/gebze/gebzenin-iklimi/.
6. Feyiz Caner, Tülay. "Yağmur Suyu ve Atmosferik Parçacıklardaki İyonların, İz Elementlerin, Escherichia Coli ve Enterococcus Bakteri Türlerinin İncelenmesi," 2016, 1–121.
7. "Geographic Information Map, Air Quality Index." Accessed October 18, 2021. http://index.havaizleme.gov.tr/Map.
8. Kara, Alev, and Aysun Türkmen. "Giresun Sahil Yolundan Alınan Yağmur Suyu Örneklerindeki Ağır Metal Kirliliği." *Karadeniz Fen Bilimleri Dergisi , 5 (12)*, 2015.
9. "Ministry of Agriculture and Forestry, General Directorate of Meteorology, Station Information Database." Accessed October 18, 2021. https://mgm.gov.tr/kurumsal/istasyonlarimiz.aspx?il=Kocaeli.
10. "Standard Methods for the Examination of Water and Wastewater." *23rd Edition*, 2017.

KARTEPE SUMMIT

24-27 MARCH 2022

Chapter 13

SUGGESTIONS FOR WATER MANAGEMENT IN TERMS OF INFRASTRUCTURAL ADAPTATION IN RESILIENT CITIES

İrem Öztürk* - Fatma Cansu Ulutuğ** - Emel Topuz***

INTRODUCTION

Cities are institutions that incorporate many elements of cultural, political, technological, economic and social concepts. Natural and man-made resources are the richness of the city that can support the stability of life. In order to sustain the well-being of natural sources, ecosystem and human, cities must be resilient, so that they can easily adapt to transformations in the requirements of cultural, political, technological, economic and social concepts. However, decay of natural sources and dramatic population growth in the cities due to rapid industrialization in the last century causes to take precautions to improve the resilience of the cities. For this reason, cities have started to adapt innovative systems for being resilient to transformations [1]. According to the definition of the Organization for Economic Co-operation and Development (OECD), resilient cities are cities that aim to improve economic, environmental, social and institutional risks and to protect cities against these threats [2]. Along with resilient city, Sustainability Development Goals were also put forward with a similar service by United Nations of Environmental protection [3]

* Gebze Technical University, Environment Engineering, iozturk@ gtu.edu.tr
** Gebze Technical University, Environment Engineering, cansu.ulutug2017@ gtu.edu.tr
*** Gebze Technical University, Environment Engineering, emeltopuz @ gtu.edu.tr

1 Leire Labaka et al., "Defining the Roadmap towards City Resilience." *Technological Forecasting and Social Change* 146, no. April (2019): 281–96

2 OECD,2022

3 United Nations Environment Programme, "Annual Report 2015". (2015), https://doi.org/10.1143/JJAP.47.2877.

Due to their organizational structure and the relevant components, cities are in important position for achieving sustainable development goals due to the resources they have [4]. In this context, the requirements for sustainable and resilient cities provide practical and innovative opportunities with restorative and regenerative nature, resulting in the recovery of resources such as water, nutrients, chemicals, heat and raw materials [5].

In recent years, water use efficiency has been achieved within the scope of protection and sustainability steps, and water sustainability has a vital importance in terms of protecting water basins, protecting the environment and public health, especially in regions under water stress and scarcity, where rapid population increases are observed [6]. Wastewater and storm water management are the key subjects in resilient cities in order to meet the needs of protecting water basins and to establish the environmental and economic balance. According to principles of sustainability, circularity is required in resilient city. It is important to recover the wastewater and convert storm water to beneficial uses. However, since these are not common in conventional cities where linear structure is applied for water management, it becomes momentous to identify and create the necessary infrastructures. In this study, attention is drawn to infrastructural issues that may be necessary for wastewater recovery and surface runoff.

Complex and inflexible supply and wastewater treatment units form the basis of traditional infrastructure. Piping and pumps have started to corrode and deteriorate over time, intentionally or unintentionally in urban water management [7]. It is crucial to assess transform water infrastructures into greener solutions. Infiltration, storage and advanced treatment process are key components of the discrete collection and blue/green infrastructure system in resilient cities[8]. It also includes components such as logistics and delivery to the market, as resource recovery takes place. Since cities

---

4 Kathleen Bolger and Andréanne Doyon, "Circular Cities: Exploring Local Government Strategies to Facilitate a Circular Economy", 2019 : 2184–2205, https://doi.org/10.1080/09654313.2019.1642854.

5 Carol Mungo and María Laura Franco-García, "A Sustainable Supply Chain Perspective in the Transition to Circular Cities." *Greening of Industry Networks Studies* 7 (2019): 183–204, https://doi.org/10.1007/978-3-030-15066-2_10.

6 Naveen Joseph et al., "A Review of the Assessment of Sustainable Water Use at Continental-to-Global Scale." *Sustainable Water Resources Management* 6, no. 2 (April 1, 2020): 1–20, https://doi.org/10.1007/S40899-020-00379-7/TABLES/3.

7 Nelson Carriço and Bruno Ferreira, "Data and Information Systems Management for the Urban Water Infrastructure Condition Assessment." *Frontiers in Water* 3, no. July (2021): 1–5, https://doi.org/10.3389/frwa.2021.670550.

8 Uğur Ünal and Dilek Eren Akyüz, "Sürdürülebilir Kentsel Drenaj Sistemlerinde Yağmur Hendeklerinin Değerlendirilmesi." *International Journal of Sustainable Engineering and Technology* 1, no. 1 (2017): 15–24, https://dergipark.org.tr/tr/pub/usmtd/issue/32428/335587.

have started to consider wastewater as a resource, old approaches have been abandoned and both technology and infrastructural transformations for water management have started to accelerate in resilient cities.

In Europe, there are no legal regulations regarding the using of treated wastewater or storm water. Many countries apply regional guidelines for water reuse. Cyprus, France, Greece, Spain, Italy and Portugal can be counted among the countries that have developed standards especially for the reuse of water. In studies on the treatment and reuse of wastewater and its usage areas, European Union Directives, United Nations Guidelines published by the Nations Environment Program and Environmental Protection Agencies, covering issues such as wastewater reuse, treatment, uses, potentials, risks and precautions [9]. Therefore, new systems for wastewater recovery and storm water management or adaption of the existing systems are expected to gain momentum afterwards. The point is that these new systems and adaptations may need various different infrastructure supports which are probably does not exist in conventional cities.

1. WASTEWATER RECOVERY AND INFRASTRUCTURE

Recovery of water, materials such as nutrients, cellulose, volatile fatty acids, alginate and fodder and energy from wastewater can be applied in the context of developing resilient cities. Recovered water can be used for urban purposes such as drinking water; irrigation of parks, recreation areas, school gardens, sports fields, highway sides, playgrounds, green areas around public buildings, facilities, shops and industries, golf courses; car washes, fire extinguishing and dust control [10]. Recovered materials can be used in agricultural activities and other products with market value are provided as raw materials to other industries [11]. Recovered energy can be benefited as heat or electricity on-site for being self-sufficient in terms of energy [12]. Technology for the recovery of wastewater is determined by

---

9 James R. Mihelcic et al., "Accelerating Innovation That Enhances Resource Recovery in the Wastewater Sector: Advancing a National Testbed Network." *Environmental Science and Technology* 51, no. 14 (2017): 7749–58, https://doi.org/10.1021/acs.est.6b05917.

10 Cristina Becerra-Castro et al., "Wastewater Reuse in Irrigation: A Microbiological Perspective on Implications in Soil Fertility and Human and Environmental Health." *Environment International* 75 (2015): 117–35, https://doi.org/10.1016/j.envint.2014.11.001.

11 Philipp Kehrein et al., "A Critical Review of Resource Recovery from Municipal Wastewater Treatment Plants-Market Supply Potentials, Technologies and Bottlenecks." *Environmental Science: Water Research and Technology* 6, no. 4 (2020): 877–910, https://doi.org/10.1039/c9ew00905a.

12 Andrea G. Capodaglio and Gustaf Olsson, "Energy Issues in Sustainable Urban Wastewater Management: Use, Demand Reduction and Recovery in the Urban Water Cycle." *Sustainability (Switzerland)* 12, no. 1 (2020), https://doi.org/10.3390/su12010266.

considering its reliability, ease of operation, environmental impacts, economic feasibility, and the quality criteria for reuse purposes. However, infrastructural needs are usually not contemplated or simply not accounted for in the decision-making process where most of the technology related aspects are included.

Infrastructural support including water supply, wastewater sewage, the elements required for operation of water recovery technologies and allocation of recovered sources to the end users are essential for an efficient resource recovery system. The fact that the existing infrastructure does not have some functional features to support recovery from wastewater, creates a problem to operate the system and deliver the recovered sources to end users. For a sustainable infrastructure system, the system must be flexible, adaptable, reliable, resilient, manageable and safe for operational stuff [13]. Wastewater recovery technologies can require adaptation in the infrastructure, even if the existing wastewater treatment systems are modified or new wastewater treatment facilities are established. For example, when an integrated system within the old facility is established, extraordinary effort is required for the piping lines, while infrastructure network can completely change in the construction of the new facility. Also, needs can change in both urban and industrial wastewater management. Urban wastewater management systems may require enormous infrastructural supports, especially, in the case of segregated wastewater collection in building scale. Infrastructural considerations will expand from municipal scale to building scale.

Requirements for developing infrastructure systems are the initial investment cost, a budget for the provision of sufficient space, and carbon emissions credit [14]. Investing to infrastructure systems is one of the most important steps for sustainable development. Release of pollutants such as lead and copper from the old infrastructure system pose a threat to water resources. It is necessary to construct a water supply infrastructure system not only for the threats posed by the old system, but also for water recovery technologies in resilient cities [15]. However, investment in water and sewer infrastructure remains insufficient in

[13] Jeremy S. Guest et al., "A New Planning and Design Paradigm to Achieve Sustainable Resource Recovery from Wastewater." *Environmental Science and Technology* 43, no. 16 (August 15, 2009): 6126–30, https://doi.org/10.1021/ES9010515.

[14] Mihelcic et al., "Accelerating Innovation That Enhances Resource Recovery in the Wastewater Sector: Advancing a National Testbed Network." 2017.

[15] Veera Gnaneswar Gude, "One Water - Evolving Roles of Our Precious Resource and Critical Challenges." *Aqua Water Infrastructure, Ecosystems and Society* 70, no. 4 (2021): 467–82, https://doi.org/10.2166/aqua.2021.154.

most countries [16]. Considerable amounts of money are spent to renew the infrastructure system in cities. UNEP shared that 41 trillion dollars need to be spent to repair the old infrastructure system for a city. About 23 trillion of this budget consists of only wastewater infrastructure system. It is obvious that technical infrastructural difficulties mainly bring financial difficulties [17]. According to the survey conducted with experts, 80 percent of the participants suggest hybrid approaches by integrating the existing infrastructure system with the infrastructure system of new technologies, instead of completely eliminating the old system[18].

Considering that wastewater recovery is being planned as the major component of water management for resilient cities, the required infrastructural adaptation is expected to be in building and local scale for wastewater collection and, sometimes, wastewater treatment and in municipal scale for wastewater treatment and allocation of recovered sources.

1.1. Building scale

Each building in resilient cities to be adapted to circularity is going to have to comply with concepts such as wastewater recovery and water reuse [19]. In this case, integrated infrastructure systems should be developed for old and new buildings to be constructed. Urban planners and architects form the constituent of the circular infrastructure system depending on the selected wastewater recovery. They can offer modern and sustainable solutions to decision makers with their specialized planning and design content. Energy, water or material can be recovered from wastewater in building scale; however, they require special infrastructural adaptations in building.

---

16 James R. Mihelcic et al., "Accelerating Innovation That Enhances Resource Recovery in the Wastewater Sector: Advancing a National Testbed Network." *Environmental Science and Technology* 51, no. 14 (July 18, 2017): 7749–58, https://doi.org/10.1021/ACS.EST.6B05917/ASSET/IMAGES/LARGE/ES-2016-05917H_0002.JPEG.

17 Daniel Feingold, Stef Koop, and Kees van Leeuwen, "The City Blueprint Approach: Urban Water Management and Governance in Cities in the U.S.." *Environmental Management* 61, no. 1 (2018): 9–23, https://doi.org/10.1007/s00267-017-0952-y.

18 Veera Gnaneswar Gude, "One Water – Evolving Roles of Our Precious Resource and Critical Challenges." *Journal of Water Supply: Research and Technology-Aqua* 70, no. 4 (June 1, 2021): 467–82, https://doi.org/10.2166/AQUA.2021.154.

19 Peter A. Wilderer and Hans Huber, "Integration of Water Reuse in the Planning of Livable Cities." *Intelligent Buildings International* 3, no. 2 (2011): 96–106, https://doi.org/10.1080/17508975.2011.579285.

In buildings, wastewater can be recycled and material can be recovered from wastewater with separate collection structures. Resources can be evaluated as water, energy and nutrient in building scale. The heat gained from laundry, dishwashing and shower water in buildings is practically made with heat exchangers. In such cases, the total wastewater is collected from a holding tank and heat is recovered from the heat exchange [20],[21].One of the infrastructural challenges in heat recovery from wastewater is the various flow and temperature values for different building types such as sports centers, restaurants' kitchens and hotel [22]. Selection of the length and diameter of the heat recovery pipe are important for the efficient operation of the system in designing phase. In the heat recovery to be gained from the bath, the parameters such as temperature of the wastewater, flowrate and periods should be well analyzed while system designing accordingly. Another difficulty in systems where heat can be recovered from wastewater to a large extent is clogging due to foreign materials and stratification over time [23]. The space requirement is also a limitation for establishing heat recovery systems in the buildings. As a result, it might be more realistic to construct infrastructure system in new buildings for heat recovery from wastewater. However, the payback period of the system is longer when it is revised for old buildings.

The concept of Ecological Sanitation (ECOSAN) considers wastewater as a resource and argues that separate wastewater streams such as grey, black, yellow and brown fractions can be transformed into components like irrigation and industrial water by adopting controlled treatment techniques [24]. The collection strategy of each stream and the product to be recovered varies. For example, while yellow water constitutes the lowest percentage of the total wastewater, it is used as fertilizer because it contains high nitrogen, phosphorus and potassium. Moreover, black water constitutes combination of human urine and feces, brown water is fraction of human feces and grey water represent all conventional wastewater except coming from toilet. Adaptation of wastewater segregation may need

20 Robert Sitzenfrei, Sebastian Hillebrand, and Wolfgang Rauch, "Investigating the Interactions of Decentralized and Centralized Wastewater Heat Recovery Systems." *Water Science and Technology* 75, no. 5 (2017): 1243–50, https://doi.org/10.2166/wst.2016.598.

21 Himanshu Nagpal et al., "Heat Recovery from Wastewater—a Review of Available Resource" *Water (Switzerland)* 13, no. 9 (2021), https://doi.org/10.3390/w13091274.

22 Nagpal et al., "Heat Recovery from Wastewater—a Review of Available Resource."

23 Nagpal et al. "Heat Recovery from Wastewater—a Review of Available Resource."

24 B. Beler-Baykal, "Stream Segregation in Household Use: A Review of Grey Water as an Alternative Source of Water and Yellow Water as an Alternative Source of Fertilizers." *Water Quality, Exposure and Health* 7, no. 1 (2015): 27–37, https://doi.org/10.1007/s12403-013-0105-3.

radical changes in the infrastructure in building scale such as the separate piping from toilets, sinks and usage of special toilets for separation. Compost and dry urine diverting toilets are common applications of ECOSAN system [25]. Life cycle assessment study was carried on rainwater harvesting flushing systems, urine separation and composting toilets. In economic point of view rainwater harvesting toilets need high cost in manufacturing and investment phase [26]. Motivation should be supported by incentives and administrative regulations for new technologies. Dry toilet differs from the traditional system so; toilets are going to be designed for flushing needs. Since pressure is an important parameter, a pressure monitoring device or even a large-scale SCADA system can be put into use [27]. Moreover, vacuum toilets are minimizing water consumption, collect black water separately and allowing for high nutrient recovery [28]. Although it consumes approximately 9 times [29] less water than conventional toilet systems, odor problem, scarcity of toilets in the market and not being preferred have prevented their widespread use. With DualFlushVac vacuum toilets, additional vacuum stations should be placed in the buildings [30]. Sound insulation can eliminate pumping and equipment noise pollution in these stations. After the new toilet systems are installed in residences and villas, it is important to convince people when buying a house. In this case, real estate agents and consultants are the elements needed in the marketing of separate toilets. Also, this structure is expected to be shaped by civil engineers and architects in terms of choice of flooring according to toilet types, bathroom design, and ventilation mechanism.

One of the prominent issues in wastewater conversions is the treatment and reuse of gray water in the building [31]. Gray water is considered to be the total of

---

25 Beler-Baykal., "Stream Segregation in Household Use: A Review of Grey Water as an Alternative Source of Water and Yellow Water as an Alternative Source of Fertilizers,"

26 Hui Gao et al., "Economic and Environmental Analysis of Five Chinese Rural Toilet Technologies Based on the Economic Input-Output Life Cycle Assessment." *Journal of Cleaner Production* 163 (2017): S379–91, https://doi.org/10.1016/j.jclepro.2015.12.089.

27 Daniel Todt et al., "Practical Performance and User Experience of Novel DUAL-Flush Vacuum Toilets." *Water (Switzerland)* 13, no. 16 (2021): 1–14, https://doi.org/10.3390/w13162228.

28 Hui Gao et al., "Economic and Environmental Analysis of Five Chinese Rural Toilet Technologies Based on the Economic Input–Output Life Cycle Assessment" *Journal of Cleaner Production* 163 (October 1, 2017): S379–91, https://doi.org/10.1016/J.JCLEPRO.2015.12.089.

29 Gao et al., "Economic and Environmental Analysis of Five Chinese Rural Toilet Technologies Based on the Economic Input–Output Life Cycle Assessment"

30 Todt et al., "Practical Performance and User Experience of Novel DUAL-Flush Vacuum Toilets."

31 M. S. Fountoulakis et al., "Single House On-Site Grey Water Treatment Using a Submerged Membrane Bioreactor for Toilet Flushing." *Science of The Total Environment* 551–552 (May 1, 2016): 706–11, https://doi.org/10.1016/J.SCITOTENV.2016.02.057.

the wastewater excluding the bathroom, shower, sink, washing machine, dishwasher and kitchen. Grey water contains 30–70% of the total urban water demand [32]. The level of treatment required for reuse of gray water varies according to the quality of gray water and beneficial usage. Grey water can be transferred to centralized wastewater treatment plant or it can be recovered in building level also. In building scale, there can be some suggestions in terms of infrastructural such as parallel piping and machinery requirements [33]. It is essential to establish systems and infrastructure that can collect, balance and prevent odor in pre-planned sites and houses. Since separate collection systems are not common, the control and management process can be handled by experienced people. Like a solid waste management, there is also a need for qualified staff for management of water systems.

Essential algal products and biofuels can be recovered from wastewater by phycoremediation technology in building scale. However, there is a need for internal and external stakeholders to make some adaptations specific to the building [34]. Since humans are in the lead role, they create the characterization and amount of wastewater. Therefore, the yield to be obtained from wastewater varies depending on the wastewater content. On the facades of buildings, where the photosynthesis reaction is occurred, if there is not enough light source, the recovery efficiency can decrease [35]. This type of building, which is open to discussion in terms of aesthetics, may not be suitable for some regions due to the light requirement. It has been observed that various knowledge gaps have emerged as a result of the above-mentioned issues about wastewater recovery. This knowledge gap indicates the applied environmental friendly activity itself has deficiencies in terms of the design and application of infrastructure [36].

---

[32] Mahdieh Khajvand et al., "Greywater Characteristics, Impacts, Treatment, and Reclamation Using Adsorption Processes towards the Circular Economy." *Environmental Science and Pollution Research 2021 29:8* 29, no. 8 (January 10, 2022): 10966–3, https://doi.org/10.1007/S11356-021-16480-Z.

[33] Gloria Amaris et al., "From Mathematical Models to Policy Design: Predicting Greywater Reuse Scheme Effectiveness and Water Reclamation Benefits Based on Individuals' Preferences." *Sustainable Cities and Society* 74, no. May (2021), https://doi.org/10.1016/j.scs.2021.103132.

[34] Anie Yulistyorini, "A Mini Review on the Integration of Resource Recovery from Wastewater into Sustainability of the Green Building through Phycoremediation." *AIP Conference Proceedings* 1887, no. 2017 (2017), https://doi.org/10.1063/1.5003531.

[35] Yulistyorini, "A Mini Review on the Integration of Resource Recovery from Wastewater into Sustainability of the Green Building through Phycoremediation."

[36] Hanen Filali et al., "Greywater as an Alternative Solution for a Sustainable Management of Water Resources—A Review." *Sustainability 2022, Vol. 14, Page 665* 14, no. 2 (January 7, 2022): 665, https://doi.org/10.3390/SU14020665.

While becoming a resilient city, systems should be established not only for the collection but also for the treatment of wastewater within the building itself. Although, gray water has a suitable characterization for reuse processes due to their low nitrogen and low pathogen content, regular COD, TOC and micro pollutants should be observed [37]. Treatment techniques such as advanced treatment methods are needed to remove emerging pollutants in large scale. Therefore, different infrastructural textures may be identified specifically. MBR and other sophisticated technologies are used at to recover and treat wastewater in building scale recently. These practical systems are used even in ships, hotels and high-rise buildings. Structures such as UV lamp, pump and collection tank are required to recover wastewater and supply recovered water in these systems. While it may seem possible to reuse water efficiently without need for centralized systems, MBR technologies may require space for electrical components and connecting pipes such as drain lines. Compared to centralized systems, the unit cost of water for decentralized systems, may seem higher. According to its quality, recovered water has many usage areas such as food industry, siphon water or in making bricks [38]. In many types of building which are called green buildings, it is possible to recover water from wastewater [39]. In green buildings, apart from a separate collection unit, separate pumps are used to collect gray water and rainwater. In system design, these parameters should be considered specific to the building [40]

Although smart solutions are produced to obtain useful products such as nutrient from the separation of black water and brown water in buildings, their full-scale application are not in production phase yet [41]. Furthermore, these systems have some vulnerabilities. For urine diverting and compost toilet systems extra pipeline and materials are needed in construction phase [42].

---

37 Lijie Zhou et al., "Novel Perspective for Urban Water Resource Management: 5R Generation," *Frontiers of Environmental Science & Engineering 2020 15:1* 15, no. 1 (August 8, 2020): 1–13, https://doi.org/10.1007/S11783-020-1308-Z.

38 Faye Duchin, "Resources for Sustainable Economic Development: A Framework for Evaluating Infrastructure System Alternatives," *Sustainability (Switzerland)* 9, no. 11 (2017), https://doi.org/10.3390/su9112105.

39 M. Zapater-Pereyra et al., "Constructed Wetroofs: A Novel Approach for the Treatment and Reuse of Domestic Wastewater," *Ecological Engineering* 94 (2016): 545–54, https://doi.org/10.1016/j.ecoleng.2016.05.052.

40 Zapater-Pereyra et al., "Constructed Wetroofs: A Novel Approach for the Treatment and Reuse of Domestic Wastewater."

41 João A.S. Almeida et al., "Urine Recovery at the Building Level," *Building and Environment* 156, no. April (2019): 110–16, https://doi.org/10.1016/j.buildenv.2019.04.006.

42 Tove A. Larsena et al., "Blue Dıversıon: A New Approach To Sanıtatıon In Informal Settlements," *Journal of Water Sanitation and Hygiene for Development* 5 (2015): 64–71, https://doi.org/https://doi.org/10.2166/washdev.2014.115.

1.2. Local scale (sewer)

When wastewater collected in buildings is transferred to the sewer system, municipalities need to manage wastewater and encourage its sustainable usage. Demand of resources, lack of accurate and timely risk analysis, and local regulations limit the recovery and reuse of water [43].

A threat to infrastructure systems is the indiscriminate maintenance and operation schedule. For new source separate systems to operate efficiently, both manpower and budget must be allocated for ongoing maintenance and monitoring. Also, unpredictable increases in the population can create load for the system [44]. Physical and digital precautions should be taken for cyber-attacks that may pose a threat to the reuse of water in local scale. In order for the system to function sustainably, valves, tanks and pumps should be monitored regularly and necessary corrections should be made [45].

After separate collection of wastewater, it can be distributed as a separate line. There are systems that can adapt to this. For example, in the SEMIZENTRAL infrastructure system, where wastewater is evaluated as a separate stream, it aims to achieve to meet efficient recovery and beneficially transferring to the system. While the recovered gray water is used for toilet flushing, it is recommended to use black water for irrigation [46].

In the local sewer line, the main problem is encountered in the systems where gray water and rainwater is collected together for reuse and it does not meet the demand. A collection station is required for gray water and rainwater coming into the system as a mixture, and an area is required for the disposal of solid wastes such as bulky objects also. Other factors that will affect the continuity of the system are the precipitation regime and the water use of the local people due to variable wastewater characterization and flow[47].

---

[43] Larsena et al., "Blue Dıversıon: A New Approach To Sanıtatıon In Informal Settlements."

[44] O. Bailey et al., "Predicting Impacts of Water Conservation with a Stochastic Sewer Model." *Water Science and Technology* 80, no. 11 (2019): 2148–57, https://doi.org/10.2166/wst.2020.031.

[45] Apurva Pamidimukkala et al., "Resilience in Water Infrastructures: A Review of Challenges and Adoption Strategies." *Sustainability (Switzerland)* 13, no. 23 (2021), https://doi.org/10.3390/su132312986.

[46] J. Tolksdorf, D. Lu, and P. Cornel, "First Implementation of a SEMIZENTRAL Resource Recovery Center." *Journal of Water Reuse and Desalination* 6, no. 4 (2016): 466–75, https://doi.org/10.2166/wrd.2016.129.

[47] Faye Duchin, "Resources for Sustainable Economic Development: A Framework for Evaluating Infrastructure System Alternatives." *Sustainability* 9, no. 11 (November 16, 2017): 2105, https://doi.org/10.3390/SU9112105.

Wastewater can be collected with different configurations like black, grey only or black, grey and yellow together. According to technical and infrastructural opportunity it changes. Recommended systems are generally city- or state-specific. The selection of hybrid systems focused on energy and water recovery from wastewater needs to be followed with interest. Regional needs should be correctly evaluated and classified [48]. If necessary, all systems should be evaluated and decision-making systems or guidelines should be established to guide the administrations that choose to implement it.

1.3. Municipal scale (WWTP)

Wastewater treatment systems are considered wastewater resource recovery facilities recently [49]. In resilient cities, the existing infrastructure system for resource recovery from wastewater can be adapted to new requirements, or new system can be established with its infrastructure network. Accordingly, municipal scale can be classified into separate and combined approaches.

Many technologies are proposed for resource recovery from wastewater. In separate systems, wastewater streams with distinctive characteristic come to the wastewater recovery center with different piping lines. Each stream contains potential resources. Therefore, the planning of wastewater recovery facilities can be complicated as they have to meet particular infrastructural requirements. For example, Extracellular Polymeric Substances (EPS) can be recovered from segregated stream of wastewater. The concentration of EPS obtained by the extraction method from wastewater sludge is determined according to the characterization and variability of the wastewater. System can be affected from infrastructural design failures. The biggest problem faced by recovery technologies in cities is overloading or under loading and contractors not doing it according to the plan during the construction phase [50]. However, many factors must be considered in new systems, such as logistics, storage and toxicity of the recovered material [51],[52]. Since different streams can come to a treatment plant to different

48 Duchin, “Resources for Sustainable Economic Development: A Framework for Evaluating Infrastructure System Alternatives.”

49 Anouk F. Duque et al., “Wastewater Valorization: Practice around the World at Pilot-and Full-Scale.” *International Journal of Environmental Research and Public Health* 18, no. 18 (2021), https://doi.org/10.3390/ijerph18189466.

50 Nancy Diaz-Elsayed et al., “Wastewater-Based Resource Recovery Technologies across Scale: A Review.” *Resources, Conservation and Recycling* 145, no. October 2018 (2019): 94–112, https://doi.org/10.1016/j.resconrec.2018.12.035.

51 Lihong Peng et al., “A Comprehensive Review of the Available Media and Approaches for Phosphorus Recovery from Wastewater.” *Water, Air, and Soil Pollution* 229, no. 4 (2018), https://doi.org/10.1007/s11270-018-3706-4.

units should be designed for each step. For material input and recovered material their storage is different consideration. In order to avoid all these difficulties, the planning stage is of great importance. The current situation of the city and its needs should be accurately analyzed and projected in the light of information to be obtained from government agencies or surveys. If necessary, decision-making systems should be used.

For the beneficial use of resources that can be obtained from wastewater, old systems need to be rearranged in some respects in order to adapt existing technologies Conventional wastewater treatment plants where wastewater and sludge are treated considered old approach. Innovative technologies such as resource recovery facilities are known new approaches. Therefore, integration of old and new systems requires symbiotic consistency.

Although, the process of water coming to the recovery facility and turning it into a resource efficiently is troublesome, the process of reaching the ultimate user of the resource is just as challenging [53]. The transmission line of the recovered water should be shaped according to the topographic characteristics of the city. If the water to be conveyed follows a long line, it may cause some biological problems. Although it may be preferable to reorganize the old infrastructure with new connections [54], the energy costs and environmental impact of the old system can be analyzed with life cycle analyses.

For energy recovery from wastewater, if an existing system is to be integrated, it is extremely important to determine the city's energy resources, consumption amounts, technology selection and scale for energy production, and finally the distribution plan and service routes [55]. The solids content of the water to be transferred from the conventional sewage system to the heat recovery unit must be low for heat recovery to be efficient [56]. For this, pre-treatment or disinfection for wastewater may be recommended at the entrance of the facility. In addition,

---

[52] Anouk F. Duque et al., "Wastewater Valorization: Practice around the World at Pilot- and Full-Scale." *International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 9466* 18, no. 18 (September 8, 2021): 9466, https://doi.org/10.3390/IJERPH18189466.

[53] Nancy Diaz-Elsayed et al., "Wastewater-Based Resource Recovery Technologies across Scale: A Review." *Resources, Conservation and Recycling* 145 (June 1, 2019): 94–112, https://doi.org/10.1016/J.RESCONREC.2018.12.035.

[54] Gude, "One Water – Evolving Roles of Our Precious Resource and Critical Challenges."

[55] Faye Duchin, "Resources for Sustainable Economic Development: A Framework for Evaluating Infrastructure System Alternatives." *Sustainability* 9, no. 11 (November 16, 2017): 2105, https://doi.org/10.3390/SU9112105

[56] Himanshu Nagpal et al., "Heat Recovery from Wastewater—a Review of Available Resource." *Water (Switzerland)* 13, no. 9 (May 1, 2021), https://doi.org/10.3390/W13091274.

the water in the sewer line far from the facility will lose energy until it reaches the facility [57].

1.4. Industrial scale

Recently, the recycling of industrial wastewater has been investigated in order to protect the basin of freshwater resources and to change the source of consumption [58]. Moreover, in the context of resilient cities, industrial wastewater recovery should be applied to decrease vulnerability of the cities for water scarcity. For material recovery, industrial wastewater can be a valuable source with its concentrated content. While it is possible to reconstruct old system which has completed its life together with the new systems, it is likely to reconcile the existing system with innovative technologies and put it into service. In the following section, two particular approaches are proposed for industrial wastewater management in resilient cities.

In industry, recycled water can be used in processes such as cooling towers, ash irrigation, dilution of waste, flue gas scrubbing, oil refineries, metal plants and boilers. Cooling waters alone constitute the largest industrial water demand and are the most common use of recycled water for many industries [59].

Wastewater characterization varies depending on industrial process. For example, some industrial processes may lead to oily, salty, or relatively clean wastewater which is close to drinking water quality Therefore, segregation of wastewater can be applied for industrial wastewater, as well. Potential products can be gained by collecting the wastewater at the end of the process as separate streams. The mixed wastewater flow in sewer makes it difficult to recover some products from the wastewater. Therefore, higher recovery yields can be obtained while collecting wastewater as separate streams from less complex wastewater. For instance, it is possible to produce PHA from industrial wastewater, recovery can only be achieved with pure culture that comes from separate wastewater line. There are administrative restrictions on opening the products obtained to the market.

[57] Nagpal et al., "Heat Recovery from Wastewater—a Review of Available Resource."

[58] Anshul Yadav, Pawan K. Labhasetwar, and Vinod K. Shahi, "Membrane Distillation Crystallization Technology for Zero Liquid Discharge and Resource Recovery: Opportunities, Challenges and Futuristic Perspectives." *Science of the Total Environment* 806 (2022): 150692, https://doi.org/10.1016/j.scitotenv.2021.150692.

[59] Éverton Hansen et al., "Water and Wastewater Minimization in a Petrochemical Industry through Mathematical Programming." *Journal of Cleaner Production* 172 (2018): 1814–22, https://doi.org/10.1016/j.jclepro.2017.12.005.

According to the Circular Economy Action Plan of the European Union, regulations are targeted for the launch of these products [60].

It is possible to recover energy from wastewater with biochemical technologies. There are innovative recovery technologies such as Microbial Fuel Cell that are not applied large scale yet. By MFC technology energy is gained in the form of electricity, hydrogen and intermediate products from textile wastewater [61]. Considering the large scale applications equipped electrodes, separators and electrical components are needed for the use of microbial fuel cell technology [62].

Overall, while separate systems do not require an integration management program with existing infrastructure, the establishment and construction of a new system requires knowledge and qualified manpower.

Instead of evaluating the urban wastewater treatment plant and industrial wastewater treatment plants separately, water recovery is obtained by combining them. However, at the end of the process, new lines are needed due to the insufficient piping system at the distribution stage of the recovered water. It is crucial to resort to infrastructural strategies. [63]. When wastewater treatment plants and industrial areas are planned to be established in a symbiotic relationship, it is paramount to choose the wastewater collection station in the right place in terms of the quality of the product to be recovered [64].

In conventional wastewater treatment plants, mathematical models are mostly used for optimization and system operation. Stoichiometric models are preferred instead of dynamic models for optimization since the stability will be less in wastewater recovery plants. In addition to models, the share of decision-making methods in the possible combination of existing wastewater treatment plants with industrial-scale systems is quite large [65].

---

60 Duque et al., "Wastewater Valorization: Practice around the World at Pilot- and Full-Scale."

61 Toral Shindhal et al., "A Critical Review on Advances in the Practices and Perspectives for the Treatment of Dye Industry Wastewater." *Bioengineered* 12, no. 1 (2021): 70–87, https://doi.org/10.1080/21655979.2020.1863034.

62 Pritha Chatterjee and M. M. Ghangrekar, "Design of Clayware Separator-Electrode Assembly for Treatment of Wastewater in Microbial Fuel Cells." *Applied Biochemistry and Biotechnology* 173, no. 2 (2014): 378–90, https://doi.org/10.1007/s12010-014-0846-x.

63 Sonja Bauer, Hans Joachim Linke, and Martin Wagner, "Combining Industrial and Urban Water-Reuse Concepts for Increasing the Water Resources in Water-Scarce Regions." *Water Environment Research* 92, no. 7 (2020): 1027–41, https://doi.org/10.1002/wer.1298.

64 Nadja Kabisch et al., "Nature-Based Solutions to Climate Change Mitigation and Adaptation in Urban Areas: Perspectives on Indicators, Knowledge Gaps, Barriers, and Opportunities for Action." *Ecology and Society, Published Online: Jun 01, 2016 / Doi:10.5751/ES-08373-210239* 21, no. 2 (June 1, 2016), https://doi.org/10.5751/ES-08373-210239.

65 Masego Montwedi et al., "Resource Recovery from and Management of Wastewater in Rural South Africa: Possibilities and Practices." *Journal of Water Process Engineering* 40, no. February (2021): 101978, https://doi.org/10.1016/j.jwpe.2021.101978.

On the other hand, depending on the chemical requirement of the product to be recovered, municipal wastewater treatment plants can be an organic carbon source for industrial wastewater treatment plants. Conversely, it is usual that industrial sludge is used for nutrient removal in conventional wastewater treatment plants [66]. Thus, waste from one industry can become a source for another industry in a closed loop. Optimization of this line should be set correctly to get valuable resources considering water management of a city.

Industrial symbiosis aims to shape the reuse of resources in the light of environmental and economic order [67]. Eco-parks are considered one of the best examples of industrial symbiosis. The wastewater in the wastewater treatment plant can be used in industrial processes such as fire, cooling, heating, rinsing, boiler feeding after certain treatment processes [68]. Treatment efficiency and water distribution lines will change according to the different quality water needs of industries. For example, if the recovered water is to be used as boiler water, water storage tank requirement may arise. Therefore, a disinfection unit may be needed to prevent biological contamination during the holding period. On the other hand, extra piping and logistics items can be a challenge for supplying the recovered water or source to the symbiotic facility.

For example, an industrial chemistry park in China consists of many integrated systems of wastewater treatment plant, water and energy supply and hazardous waste treatment plant. Different from conventional systems, wastewater is divided into four categories like municipal wastewater, organic, inorganic and rainwater [69]. Since a special company is responsible from all operations such as operation of industrial plant, incinerator, tanks and power plants [70], it is necessary to have a controller unit for the reliability of the system.

Another challenge with combined systems is the contractors' non-compliance with eco-industrial design and construction principles while adapting infrastructural

---

66 Huacai Wang et al., "Application of Internal Carbon Source from Sewage Sludge: A Vital Measure to Improve Nitrogen Removal Efficiency of Low c/n Wastewater." *Water (Switzerland)* 13, no. 17 (2021), https://doi.org/10.3390/w13172338.

67 M. A. Butturi et al., "Renewable Energy in Eco-Industrial Parks and Urban-Industrial Symbiosis: A Literature Review and a Conceptual Synthesis." *Applied Energy* 255 (December 1, 2019): 113825, https://doi.org/10.1016/J.APENERGY.2019.113825.

68 Wwap, "The United Nations World Water Development Report 2017." 2017, www.unwater.org.

69 Jeremy H. Yune et al., "Greening Chinese Chemical Industrial Park by Implementing Industrial Ecology Strategies: A Case Study." *Resources, Conservation and Recycling* 112 (2016): 54–64, https://doi.org/10.1016/j.resconrec.2016.05.002.

70 Yune et al.

networks. A requirement of industrial symbiosis is the correct analysis of the inlet and outlet of the material flow. The process from planning to installation should be managed optimally and all risks should be reviewed. Since the new adoption of industrial parks is limited by the gap in knowledge and inadequate regulations, infrastructural challenges are started to be solved by expert opinions [71].

2. STORM WATER MANAGEMENT

In resilient cities blue, green and grey infrastructures are offered for storm water management. Green roofs, rainwater barrels, pervious pavements [72], wetlands [73] and rain gardens [74] are the examples of this infrastructural approaches. Like in previous section storm water management strategies is divided into building, local and municipal.

2.1. Building scale

Co-management of storm water with wastewater in resilient cities is fundamental for realizing the United Nations' Sustainable Development Goals [75]. Rainwater is stored especially in regions with wet climates, for beneficial uses in building scale [76]. There can be some challenges while applying green strategies to the buildings. For example, green roofs can enhance the roof life yet, considering roof measures it should be placed properly. According to flow regimes, green roofs can cause some leakage problems because of their low durability. Research development has

---

71 Hongru Hong and Alexandros Gasparatos, "Eco-Industrial Parks in China: Key Institutional Aspects, Sustainability Impacts, and Implementation Challenges." *Journal of Cleaner Production* 274 (2020): 122853, https://doi.org/10.1016/j.jclepro.2020.122853.

72 Alida Alves et al., "Assessing the Co-Benefits of Green-Blue-Grey Infrastructure for Sustainable Urban Flood Risk Management." *Journal of Environmental Management* 239, no. February (2019): 244–54, https://doi.org/10.1016/j.jenvman.2019.03.036.

73 Perrine Hamel and Leanne Tan, "Blue–Green Infrastructure for Flood and Water Quality Management in Southeast Asia: Evidence and Knowledge Gaps." *Environmental Management*, 2021, https://doi.org/10.1007/s00267-021-01467-w.

74 R. Andrew Tirpak et al., "Conventional and Amended Bioretention Soil Media for Targeted Pollutant Treatment: A Critical Review to Guide the State of the Practice." *Water Research* 189 (2021): 116648, https://doi.org/10.1016/j.watres.2020.116648.

75 Maria Manso et al., "Green Roof and Green Wall Benefits and Costs: A Review of the Quantitative Evidence." *Renewable and Sustainable Energy Reviews* 135 (January 1, 2021): 110111, https://doi.org/10.1016/J.RSER.2020.110111.

76 Majed Abu-Zreig, Farah Ababneh, and Fayez Abdulla, "Assessment of Rooftop Rainwater Harvesting in Northern Jordan." *Physics and Chemistry of the Earth, Parts A/B/C* 114 (December 1, 2019): 102794, https://doi.org/10.1016/J.PCE.2019.08.002.

done to improve its stability and polymeric materials are used in production phase. However, polymeric materials are considered hazardous in some respect so life cycle assessment and risk analysis should be done before using green roofs in a building scale [77].

It is possible rooftop agriculture in building scale. The point to be considered in these systems is that the amount of fertilizer while considering growing conditions of each fruit or vegetable should be optimized. Since the system may require operating equipment, the space to be allocated on the roofs is very limited. The reliability and market value of foods preclude the prevalence of these approaches[78].

An integrated system can be created by placing green roofs with photovoltaic panels, but optimization of the system is required for the efficient work for both systems [79]. There are different types of green roofs such as extensive, intensive and non-vegetated roofs. All of them have maintenance requirements for technical equipment and infrastructural needs such as special cabling and flooring [80].

2.2. Local scale

Outside the buildings, local rainwater management is provided by permeable asphalt. In addition to solving the problems of cities such as flood transportation and water management, it is possible that the pollutants to be transported by water will clog the pores. Therefore, six types of asphalt such as porous asphalt, concrete grid pavers, plastic reinforcement grid, porous concrete, permeable interlocking concrete pavers, and natural rock pavers are built according to the structure of the soil and the city [81]. In infrastructural transformations, the choice of pavement suitable for the city will be required. Optimization studies are carried out

---

77 Muhammad Shafique, Reeho Kim, and Muhammad Rafiq, "Green Roof Benefits, Opportunities and Challenges – A Review." *Renewable and Sustainable Energy Reviews* 90 (July 1, 2018): 757–73, https://doi.org/10.1016/J.RSER.2018.04.006.

78 Yoshiki Harada and Thomas H. Whitlow, "Urban Rooftop Agriculture: Challenges to Science and Practice." *Frontiers in Sustainable Food Systems* 4, no. June (2020): 1–8, https://doi.org/10.3389/fsufs.2020.00076.

79 Maria Manso et al., "Green Roof and Green Wall Benefits and Costs: A Review of the Quantitative Evidence." *Renewable and Sustainable Energy Reviews* 135, no. July 2020 (2021), https://doi.org/10.1016/j.rser.2020.110111.

80 Yinghong Qin, "Urban Flooding Mitigation Techniques: A Systematic Review and Future Studies." *Water (Switzerland)* 12, no. 12 (2020), https://doi.org/10.3390/w12123579.

81 Charles E. Sprouse et al., "Advancing Pervious Pavements through Nomenclature, Standards, and Holistic Green Design." *Sustainability (Switzerland)* 12, no. 18 (2020), https://doi.org/10.3390/SU12187422.

on technical, mechanical and physical properties of permeable systems through research and development programs [82].

While some of the green and blue infrastructures are laboratory-scale, there are also large-scale applications [83]. Infiltration ditches or percolation trenches are channels that constitute from stones and gravels. According to permeability of soil and groundwater level, rainwater can be collected safely [84]. For example, while performing infrastructural adaptations parameters such as soil type, basin slope, gravel layer and depth are taken into account during the application of infiltration trenches in cities.

2.3. Municipal scale

Storm water management has a large share in resilient cites. Recently, collecting and harvesting of rainwater in both buildings and cities has become widespread, with natural or artificial systems. Strategic planning and decision analysis is crucial in these systems at municipal scale. Topographic Wetness Index (TWI) tool facilitates the optimization of the collection tank, precipitation regime forecasting and management in green infrastructures [85]. Therefore, modeling studies are substantial for blue/green infrastructures in cities. With the data obtained from the general directorate of meteorology, idea about the amount and frequency of precipitation can gathered. Uncertainty of the fate of the pollutants, climate conditions, characterization of rainwater and soil conditions create problems. Moreover, during the planning phase of the system, the correct selection of the basin, the suitability of the dimensions, the optimization of the retention time and the recording of the data are recommended [86].

Besides modelling studies, material supply is also another concern to establish infrastructure at municipal scale. Special green products such as geo-membranes are needed for green infrastructures. However, since these are new systems,

[82] Othman AlShareedah and Somayeh Nassiri, "Pervious Concrete Mixture Optimization, Physical, and Mechanical Properties and Pavement Design: A Review." *Journal of Cleaner Production* 288 (2021): 125095, https://doi.org/10.1016/j.jclepro.2020.125095.

[83] Kaan İlker Demirezen and Cevza Melek Kazezyılmaz-Alhan, "Evaluation of the Hydrological Performance of Infiltration Trench with Rainfall-Watershed-Infiltration Trench Experimental Setup." *Journal of Hydrologic Engineering* 27, no. 3 (2022): 1–10, https://doi.org/10.1061/(asce)he.1943-5584.0002161.

[84] Yinghong Qin, "Urban Flooding Mitigation Techniques: A Systematic Review and Future Studies." *Water 2020, Vol. 12, Page 3579* 12, no. 12 (December 20, 2020): 3579, https://doi.org/10.3390/W12123579.

[85] Urban Stormwater Management Plan, 2018

[86] Fatih Ozsolak and Patrice M. Milos, "RNA Sequencing: Advances, Challenges and Opportunities." *Nature Reviews Genetics 2010 12:2* 12, no. 2 (December 30, 2010): 87–98, https://doi.org/10.1038/nrg2934.

production is not carried out in every country. This situation makes cities dependent on foreign countries. In green applications where many disciplines work together, it is difficult to develop projects with the consensus of engineering branches such as environment, machinery, transportation and construction [87].

Wetlands are known to be quite common among green infrastructures, retaining storm water and nutrients. However, the high total solids and floatables create the need for pretreatment. Since it is a separate system, it may require maintenance, repair and continuous monitoring for the fast and efficient operation of the system [88]. Rain gardens that can handle lower water volumes and flow rates, require less excavation and piping compared to other green systems. Infrastructural considerations are the installation of a monitoring station for the water level, and the establishment of a pond to transfer the overflow [89].

Overall, different measures must be taken at three different levels of the city to manage storm water. Essential elements such as pipes, water tanks, storage tanks, pumps, valves should be selected and placed in the system in an optimized way after data such as rain flow, flow rate and water demand are obtained.

CONCLUSION

In the context of water management, resource recovery from wastewater and storm water is accelerating in order to increase the resilience of the cities to natural source scarcity and climate change conditions. Therefore, linear models for water management of the cities are transformed to circular models that brings the infrastructural adaptations in the city. This study points out that adaptation of building, local and large scale infrastructure systems is needed. Wastewater might be separated into black, brown, yellow and gray water at building scale to recover water, energy and nutrients efficiently that can lead to dramatic changes in infrastructure of the buildings including the selection of proper separate toilets, piping and pumping systems. At the local scale, sewage systems may also need to be separated for segregation of the wastewater streams. In any case, whether the wastewater is separated at source or not, municipal treatment plants are

87 Muhammad Shafique and Reeho Kim, "Recent Progress in Low-Impact Development in South Korea: Water-Management Policies, Challenges and Opportunities." *Water (Switzerland)* 10, no. 4 (2018), https://doi.org/10.3390/w10040435.

88 Wendong Tao et al., "Constructed Wetlands for Treatment of Combined Sewer Overflow in the US: A Review of Design Challenges and Application Status." *Water (Switzerland)* 6, no. 11 (2014): 3362–85, https://doi.org/10.3390/w6113362.

89 K. Ishimatsu et al., "Use of Rain Gardens for Stormwater Management in Urban Design and Planning." *Landscape and Ecological Engineering* 13, no. 1 (2017): 205–12, https://doi.org/10.1007/s11355-016-0309-3.

going to be adopted for wastewater recovery technologies and various technologies may be needed in a single facility that infrastructure can get complicated in terms of layout of the plant. In industries, innovative solutions defined for the symbiotic resource management strategy may lead to infrastructural adaptations in the site layout and sewage system in the municipal scale. For storm water management, green roof, pervious pavements and wetlands are recommended methods and they may require special infrastructure adaptions in building, local and city scale. In the context of water management in resilient cities; social factors are coming forward much more than for the other environmental issues; because most of the required infrastructural adaptations are directly affecting the daily routine life and habits of the society. In general, transformation and adaptation processes require intensive knowledge transfer, academic and field work, and economic financial support to be expanded for the dissemination of resilient cities. A strict cooperation within the stakeholders of governmental and municipal authorities, infrastructure industries, architects, technology developers, engineers and civil society organizations is crucial in order to handle technological, economic, environmental and social aspects efficiently.

REFERENCES

1. Abu-Zreig, Majed, Farah Ababneh, and Fayez Abdulla. "Assessment of Rooftop Rainwater Harvesting in Northern Jordan." *Physics and Chemistry of the Earth, Parts A/B/C* 114 (December 1, 2019): 102794. https://doi.org/10.1016/J.PCE.2019.08.002.
2. "Administration & Management Strategic Plan." n.d.
3. Almeida, João A.S., Ana L. Azevedo, Michael Brett, António Tadeu, Armando Silva-Afonso, Andreia Costa, Emanuel Rufo, and Sandra Além. "Urine Recovery at the Building Level." *Building and Environment* 156, no. April (2019): 110–16. https://doi.org/10.1016/j.buildenv.2019.04.006.
4. AlShareedah, Othman, and Somayeh Nassiri. "Pervious Concrete Mixture Optimization, Physical, and Mechanical Properties and Pavement Design: A Review." *Journal of Cleaner Production* 288 (2021): 125095. https://doi.org/10.1016/j.jclepro.2020.125095.
5. Alves, Alida, Berry Gersonius, Zoran Kapelan, Zoran Vojinovic, and Arlex Sanchez. "Assessing the Co-Benefits of Green-Blue-Grey Infrastructure for Sustainable Urban Flood Risk Management." *Journal of Environmental Management* 239, no. February (2019): 244–54. https://doi.org/10.1016/j.jenvman.2019.03.036.
6. Amaris, Gloria, Richard Dawson, Jorge Gironás, Stephane Hess, and Juan de Dios Ortúzar. "From Mathematical Models to Policy Design: Predicting Greywater Reuse Scheme Effectiveness and Water Reclamation Benefits Based on Individuals' Preferences." *Sustainable Cities and Society* 74, no. May (2021). https://doi.org/10.1016/j.scs.2021.103132.

7. Bailey, O., T. C. Arnot, E. J.M. Blokker, Z. Kapelan, and J. A.M.H. Hofman. "Predicting Impacts of Water Conservation with a Stochastic Sewer Model." *Water Science and Technology* 80, no. 11 (2019): 2148–57. https://doi.org/10.2166/wst.2020.031.
8. Bauer, Sonja, Hans Joachim Linke, and Martin Wagner. "Combining Industrial and Urban Water-Reuse Concepts for Increasing the Water Resources in Water-Scarce Regions." *Water Environment Research* 92, no. 7 (2020): 1027–41. https://doi.org/10.1002/wer.1298.
9. Becerra-Castro, Cristina, Ana Rita Lopes, Ivone Vaz-Moreira, Elisabete F. Silva, Célia M. Manaia, and Olga C. Nunes. "Wastewater Reuse in Irrigation: A Microbiological Perspective on Implications in Soil Fertility and Human and Environmental Health." *Environment International* 75 (2015): 117–35. https://doi.org/10.1016/j.envint.2014.11.001.
10. Beler-Baykal, B. "Stream Segregation in Household Use: A Review of Grey Water as an Alternative Source of Water and Yellow Water as an Alternative Source of Fertilizers." *Water Quality, Exposure and Health* 7, no. 1 (2015): 27–37. https://doi.org/10.1007/s12403-013-0105-3.
11. Bolger, Kathleen, and Andréanne Doyon. "Circular Cities: Exploring Local Government Strategies to Facilitate a Circular Economy." *Https://Doi.Org/10.1080/09654313.2019.1642854* 27, no. 11 (November 2, 2019): 2184–2205. https://doi.org/10.1080/09654313.2019.1642854.
12. Butturi, M. A., F. Lolli, M. A. Sellitto, E. Balugani, R. Gamberini, and B. Rimini. "Renewable Energy in Eco-Industrial Parks and Urban-Industrial Symbiosis: A Literature Review and a Conceptual Synthesis." *Applied Energy* 255 (December 1, 2019): 113825. https://doi.org/10.1016/ J.APENERGY.2019.113825.
13. Capodaglio, Andrea G., and Gustaf Olsson. "Energy Issues in Sustainable Urban Wastewater Management: Use, Demand Reduction and Recovery in the Urban Water Cycle." *Sustainability (Switzerland)* 12, no. 1 (2020). https://doi.org/10.3390/su12010266.
14. Carriço, Nelson, and Bruno Ferreira. "Data and Information Systems Management for the Urban Water Infrastructure Condition Assessment." *Frontiers in Water* 3, no. July (2021): 1–5. https://doi.org/10.3389/frwa.2021.670550.
15. Chatterjee, Pritha, and M. M. Ghangrekar. "Design of Clayware Separator-Electrode Assembly for Treatment of Wastewater in Microbial Fuel Cells." *Applied Biochemistry and Biotechnology* 173, no. 2 (2014): 378–90. https://doi.org/10.1007/s12010-014-0846-x.
16. Demirezen, Kaan İlker, and Cevza Melek Kazezyılmaz-Alhan. "Evaluation of the Hydrological Performance of Infiltration Trench with Rainfall-Watershed-Infiltration Trench Experimental Setup." *Journal of Hydrologic Engineering* 27, no. 3 (2022): 1–10. https://doi.org/10.1061/ (asce)he.1943-5584.0002161.
17. Diaz-Elsayed, Nancy, Nader Rezaei, Tianjiao Guo, Shima Mohebbi, and Qiong Zhang. "Wastewater-Based Resource Recovery Technologies across Scale: A Review." *Resources, Conservation and Recycling* 145, no. October 2018 (2019): 94–112. https://doi.org/10.1016/ j.resconrec.2018.12.035.

18. Duchin, Faye. "Resources for Sustainable Economic Development: A Framework for Evaluating Infrastructure System Alternatives." *Sustainability (Switzerland)* 9, no. 11 (2017). https://doi.org/10.3390/su9112105.
19. Duque, Anouk F., Riccardo Campo, Angeles Val Del Rio, and Catarina L. Amorim. "Wastewater Valorization: Practice around the World at Pilot- and Full-Scale." *International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 9466* 18, no. 18 (September 8, 2021): 9466. https://doi.org/10.3390/IJERPH18189466.
20. Feingold, Daniel, Stef Koop, and Kees van Leeuwen. "The City Blueprint Approach: Urban Water Management and Governance in Cities in the U.S." *Environmental Management* 61, no. 1 (2018): 9–23. https://doi.org/10.1007/s00267-017-0952-y.
21. Filali, Hanen, Narcis Barsan, Dalila Souguir, Valentin Nedeff, Claudia Tomozei, and Mohamed Hachicha. "Greywater as an Alternative Solution for a Sustainable Management of Water Resources—A Review." *Sustainability 2022, Vol. 14, Page 665* 14, no. 2 (January 7, 2022): 665. https://doi.org/10.3390/SU14020665.
22. Fountoulakis, M. S., N. Markakis, I. Petousi, and T. Manios. "Single House On-Site Grey Water Treatment Using a Submerged Membrane Bioreactor for Toilet Flushing." *Science of The Total Environment* 551–552 (May 1, 2016): 706–11. https://doi.org/10.1016/ J.SCITOTENV. 2016.02.057.
23. Gao, Hui, Chuanbin Zhou, Feng Li, Baolong Han, and Xiuxia Li. "Economic and Environmental Analysis of Five Chinese Rural Toilet Technologies Based on the Economic Input–Output Life Cycle Assessment." *Journal of Cleaner Production* 163 (2017): S379–91. https://doi.org/10.1016/ j.jclepro.2015.12.089.
24. Gude, Veera Gnaneswar. "One Water - Evolving Roles of Our Precious Resource and Critical Challenges." *Aqua Water Infrastructure, Ecosystems and Society* 70, no. 4 (2021): 467–82. https://doi.org/10.2166/aqua.2021.154.
25. Guest, Jeremy S., Steven J. Skerlos, James L. Barnard, M. Bruce Beck, Glen T. Daigger, Helene Hilger, Steven J. Jackson, et al. "A New Planning and Design Paradigm to Achieve Sustainable Resource Recovery from Wastewater." *Environmental Science and Technology* 43, no. 16 (August 15, 2009): 6126–30. https://doi.org/10.1021/ES9010515.
26. Hamel, Perrine, and Leanne Tan. "Blue–Green Infrastructure for Flood and Water Quality Management in Southeast Asia: Evidence and Knowledge Gaps." *Environmental Management*, 2021. https://doi.org/10.1007/s00267-021-01467-w.
27. Hansen, Éverton, Marco Antônio Siqueira Rodrigues, Marcelo Escobar Aragão, and Patrice Monteiro de Aquim. "Water and Wastewater Minimization in a Petrochemical Industry through Mathematical Programming." *Journal of Cleaner Production* 172 (2018): 1814–22. https://doi.org/10.1016/j.jclepro.2017.12.005.
28. Harada, Yoshiki, and Thomas H. Whitlow. "Urban Rooftop Agriculture: Challenges to Science and Practice." *Frontiers in Sustainable Food Systems* 4, no. June (2020): 1–8. https://doi.org/10.3389/fsufs.2020.00076.

29. Hong, Hongru, and Alexandros Gasparatos. "Eco-Industrial Parks in China: Key Institutional Aspects, Sustainability Impacts, and Implementation Challenges." *Journal of Cleaner Production* 274 (2020): 122853. https://doi.org/10.1016/j.jclepro.2020.122853.
30. Ishimatsu, K., K. Ito, Y. Mitani, Y. Tanaka, T. Sugahara, and Y. Naka. "Use of Rain Gardens for Stormwater Management in Urban Design and Planning." *Landscape and Ecological Engineering* 13, no. 1 (2017): 205–12. https://doi.org/10.1007/s11355-016-0309-3.
31. Joseph, Naveen, Dongryeol Ryu, Hector M. Malano, Biju George, and K. P. Sudheer. "A Review of the Assessment of Sustainable Water Use at Continental-to-Global Scale." *Sustainable Water Resources Management* 6, no. 2 (April 1, 2020): 1–20. https://doi.org/10.1007/S40899-020-00379-7/TABLES/3.
32. Kabisch, Nadja, Niki Frantzeskaki, Stephan Pauleit, Sandra Naumann, McKenna Davis, Martina Artmann, Dagmar Haase, et al. "Nature-Based Solutions to Climate Change Mitigation and Adaptation in Urban Areas: Perspectives on Indicators, Knowledge Gaps, Barriers, and Opportunities for Action." *Ecology and Society, Published Online: Jun 01, 2016 / Doi:10.5751/ES-08373-210239* 21, no. 2 (June 1, 2016). https://doi.org/10.5751/ES-08373-210239.
33. Kehrein, Philipp, Mark Van Loosdrecht, Patricia Osseweijer, Marianna Garfí, Jo Dewulf, and John Posada. "A Critical Review of Resource Recovery from Municipal Wastewater Treatment Plants-Market Supply Potentials, Technologies and Bottlenecks." *Environmental Science: Water Research and Technology* 6, no. 4 (2020): 877–910. https://doi.org/10.1039/ c9ew00905a.
34. Khajvand, Mahdieh, Ali Khosravanipour Mostafazadeh, Patrick Drogui, Rajeshwar Dayal Tyagi, and Emmanuel Brien. "Greywater Characteristics, Impacts, Treatment, and Reclamation Using Adsorption Processes towards the Circular Economy." *Environmental Science and Pollution Research 2021 29:8* 29, no. 8 (January 10, 2022): 10966–3. https://doi.org/10.1007/S11356-021-16480-Z.
35. Labaka, Leire, Patricia Maraña, Raquel Giménez, and Josune Hernantes. "Defining the Roadmap towards City Resilience." *Technological Forecasting and Social Change* 146, no. April (2019): 281–96. https://doi.org/10.1016/j.techfore.2019.05.019.
36. Larsena, Tove A., Heiko Gebauera, Harald Gründlb, Rahel Künzlea, Christoph Lüthia, Ulrike Messmera, Eberhard Morgenrotha, and Bernhard Ranner Charles B. Niwagabad. "BLUE DIVERSION: A NEW APPROACH TO SANITATION IN INFORMAL SETTLEMENTS." *Journal of Water Sanitation and Hygiene for Development* 5 (2015): 64–71. https://doi.org/https://doi.org/ 10.2166/washdev.2014.115.
37. Manso, Maria, Inês Teotónio, Cristina Matos Silva, and Carlos Oliveira Cruz. "Green Roof and Green Wall Benefits and Costs: A Review of the Quantitative Evidence." *Renewable and Sustainable Energy Reviews* 135, no. July 2020 (2021). https://doi.org/10.1016/ j.rser.2020.110111.

38. Mihelcic, James R., Zhiyong Jason Ren, Pablo K. Cornejo, Aaron Fisher, A. J. Simon, Seth W. Snyder, Qiong Zhang, et al. "Accelerating Innovation That Enhances Resource Recovery in the Wastewater Sector: Advancing a National Testbed Network." *Environmental Science and Technology* 51, no. 14 (2017): 7749–58. https://doi.org/10.1021/acs.est.6b05917.
39. Montwedi, Masego, Mujuru Munyaradzi, Luc Pinoy, Abhishek Dutta, David S. Ikumi, Emilia Motoasca, and Bart Van der Bruggen. "Resource Recovery from and Management of Wastewater in Rural South Africa: Possibilities and Practices." *Journal of Water Process Engineering* 40, no. February (2021): 101978. https://doi.org/10.1016/j.jwpe.2021.101978.
40. Mungo, Carol, and María Laura Franco-García. "A Sustainable Supply Chain Perspective in the Transition to Circular Cities." *Greening of Industry Networks Studies* 7 (2019): 183–204. https://doi.org/10.1007/978-3-030-15066-2_10.
41. Nagpal, Himanshu, Jan Spriet, Madhu Krishna Murali, and Aonghus McNabola. "Heat Recovery from Wastewater—a Review of Available Resource." *Water (Switzerland)* 13, no. 9 (2021). https://doi.org/10.3390/w13091274.
42. Ozsolak, Fatih, and Patrice M. Milos. "RNA Sequencing: Advances, Challenges and Opportunities." *Nature Reviews Genetics 2010 12:2* 12, no. 2 (December 30, 2010): 87–98. https://doi.org/10.1038/nrg2934.
43. Pamidimukkala, Apurva, Sharareh Kermanshachi, Nikhitha Adepu, and Elnaz Safapour. "Resilience in Water Infrastructures: A Review of Challenges and Adoption Strategies." *Sustainability (Switzerland)* 13, no. 23 (2021). https://doi.org/10.3390/su132312986.
44. Peng, Lihong, Hongliang Dai, Yifeng Wu, Yonghong Peng, and Xiwu Lu. "A Comprehensive Review of the Available Media and Approaches for Phosphorus Recovery from Wastewater." *Water, Air, and Soil Pollution* 229, no. 4 (2018). https://doi.org/10.1007/s11270-018-3706-4.
45. Qin, Yinghong. "Urban Flooding Mitigation Techniques: A Systematic Review and Future Studies." *Water (Switzerland)* 12, no. 12 (2020). https://doi.org/10.3390/w12123579.
46. "Resilient-Cities @ Www.Oecd.Org." n.d.
47. Shafique, Muhammad, and Reeho Kim. "Recent Progress in Low-Impact Development in South Korea: Water-Management Policies, Challenges and Opportunities." *Water (Switzerland)* 10, no. 4 (2018). https://doi.org/10.3390/w10040435.
48. Shafique, Muhammad, Reeho Kim, and Muhammad Rafiq. "Green Roof Benefits, Opportunities and Challenges – A Review." *Renewable and Sustainable Energy Reviews* 90 (July 1, 2018): 757–73. https://doi.org/10.1016/J.RSER.2018.04.006.
49. Shindhal, Toral, Parita Rakholiya, Sunita Varjani, Ashok Pandey, Huu Hao Ngo, Wenshan Guo, How Yong Ng, and Mohammad J. Taherzadeh. "A Critical Review on Advances in the Practices and Perspectives for the Treatment of Dye Industry Wastewater." *Bioengineered* 12, no. 1 (2021): 70–87. https://doi.org/10.1080/21655979.2020.1863034.

50. Sitzenfrei, Robert, Sebastian Hillebrand, and Wolfgang Rauch. "Investigating the Interactions of Decentralized and Centralized Wastewater Heat Recovery Systems." *Water Science and Technology* 75, no. 5 (2017): 1243–50. https://doi.org/10.2166/wst.2016.598.
51. Sprouse, Charles E., Conrad Hoover, Olivia Obritsch, and Hannah Thomazin. "Advancing Pervious Pavements through Nomenclature, Standards, and Holistic Green Design." *Sustainability (Switzerland)* 12, no. 18 (2020). https://doi.org/10.3390/SU12187422.
52. Tao, Wendong, James S. Bays, Daniel Meyer, Richard C. Smardon, and Zeno F. Levy. "Constructed Wetlands for Treatment of Combined Sewer Overflow in the US: A Review of Design Challenges and Application Status." *Water (Switzerland)* 6, no. 11 (2014): 3362–85. https://doi.org/10.3390/w6113362.
53. Tirpak, R. Andrew, ARM Nabiul Afrooz, Ryan J. Winston, Renan Valenca, Ken Schiff, and Sanjay K. Mohanty. "Conventional and Amended Bioretention Soil Media for Targeted Pollutant Treatment: A Critical Review to Guide the State of the Practice." *Water Research* 189 (2021): 116648. https://doi.org/10.1016/j.watres.2020.116648.
54. Todt, Daniel, Iemke Bisschops, Paraschos Chatzopoulos, and Miriam H.A. Van Eekert. "Practical Performance and User Experience of Novel DUAL-Flush Vacuum Toilets." *Water (Switzerland)* 13, no. 16 (2021): 1–14. https://doi.org/10.3390/w13162228.
55. Tolksdorf, J., D. Lu, and P. Cornel. "First Implementation of a SEMIZENTRAL Resource Recovery Center." *Journal of Water Reuse and Desalination* 6, no. 4 (2016): 466–75. https://doi.org/10.2166/wrd.2016.129.
56. Ünal, Uğur, and Dilek Eren Akyüz. "Sürdürülebi̇li̇r Kentsel Drenaj Si̇stemleri̇nde Yağmur Hendekleri̇ni̇n Değerlendi̇ri̇lmesi̇." *International Journal of Sustainable Engineering and Technology* 1, no. 1 (2017): 15–24. https://dergipark.org.tr/tr/pub/usmtd/issue/32428/335587.
57. United Nations Environment Programme. "Annual Report 2015." 2015. https://doi.org/10.1143/JJAP.47.2877.
58. Wang, Huacai, Cancan Jiang, Xu Wang, Shengjun Xu, and Xuliang Zhuang. "Application of Internal Carbon Source from Sewage Sludge: A Vital Measure to Improve Nitrogen Removal Efficiency of Low c/n Wastewater." *Water (Switzerland)* 13, no. 17 (2021). https://doi.org/ 10.3390/w13172338.
59. Wilderer, Peter A., and Hans Huber. "Integration of Water Reuse in the Planning of Livable Cities." *Intelligent Buildings International* 3, no. 2 (2011): 96–106. https://doi.org/10.1080/ 17508975.2011.579285.
60. Wwap. "The United Nations World Water Development Report 2017." 2017. www.unwater.org.
61. Yadav, Anshul, Pawan K. Labhasetwar, and Vinod K. Shahi. "Membrane Distillation Crystallization Technology for Zero Liquid Discharge and Resource Recovery: Opportunities, Challenges and Futuristic Perspectives." *Science of the Total Environment* 806 (2022): 150692. https://doi.org/10.1016/j.scitotenv.2021.150692.
62. Yulistyorini, Anie. "A Mini Review on the Integration of Resource Recovery from Wastewater into Sustainability of the Green Building through Phycoremediation." *AIP Conference Proceedings* 1887, no. 2017 (2017). https://doi.org/10.1063/1.5003531.

63. Yune, Jeremy H., Jinping Tian, Wei Liu, Lujun Chen, and Cathy Descamps-Large. “Greening Chinese Chemical Industrial Park by Implementing Industrial Ecology Strategies: A Case Study.” *Resources, Conservation and Recycling* 112 (2016): 54–64. https://doi.org/10.1016/ j.resconrec.2016.05.002.
64. Zapater-Pereyra, M., S. Lavrnić, F. van Dien, J. J.A. van Bruggen, and P. N.L. Lens. “Constructed Wetroofs: A Novel Approach for the Treatment and Reuse of Domestic Wastewater.” *Ecological Engineering* 94 (2016): 545–54. https://doi.org/10.1016/j.ecoleng.2016.05.052.
65. Zhou, Lijie, Hongwu Wang, Zhiqiang Zhang, Jian Zhang, Hongbin Chen, Xuejun Bi, Xiaohu Dai, Siqing Xia, Lisa Alvarez-Cohen, and Bruce E. Rittmann. “Novel Perspective for Urban Water Resource Management: 5R Generation.” *Frontiers of Environmental Science & Engineering 2020 15:1* 15, no. 1 (August 8, 2020): 1–13. https://doi.org/10.1007/S11783-020-1308-Z.

Chapter 14

ROLE OF CRITICAL INFRASTRUCTURES IN URBAN DEVELOPMENT

Hazal Ertem* - Koray Velibeyoğlu**

INTRODUCTION

Swilling[1] remarks that cities are consequences of complex connections among overlapping sociopolitical, cultural, institutional and technical networks. In other words, cities have various layers which are strongly interrelated to each other. On the other hand, the population has grown in years. Especially, in 2007, number of people live in urban areas are more than 50 percent for the first time and it has been increasing since then[2]. Also, it is expected that population of the world will reach to 11.2 billion in 2100[3]. As a result of these trends, "Anthropocene era" that is new geographical epoch has emerged by dominance of human activities in the city and urbanization[4]. Therefore, there is a population and density pressure in urban areas. This makes more complex the interactions in cities.

Correspondingly, the number of risks also has increased as a result of planetary urbanization. On the one hand, the process of urbanization and its consequences cause increasing the impacts of disasters or crises. For example, in 2020, 389

* Department of City and Regional Planning, Izmir Institute of Technology, hazalertem@iyte.edu.tr

** Department of City and Regional Planning, Izmir Institute of Technology, korayvelibeyoglu@iyte.edu.tr

1 Mark Swilling, "Reconceptualising Urbanism, Ecology and Networked Infrastructures," Social Dynamics 37, no. 1 (2011), p.79

2 Hannah Ritchie and Max Roser, "Urbanization," 2018, https://ourworldindata.org/urbanization.

3 United Nations, "World Population," 2017, https://www.un.org/en/desa/world-population-projected-reach-98-billion-2050-and-112-billion-2100.

4 Kate Driscoll Derickson, "Urban Geography III: Anthropocene Urbanism," Progress in Human Geography 42, no. 3 (2018): 425–35,

disasters were recorded, and millions of people are affected from them[5]. On the other hand, because cities become more and more complex structures, dealing with any disaster becomes harder. Chronic stresses (climate change, social inequalities etc.) and sudden shocks (flooding, extreme weathers, drought etc.) are emerged in cities.

Considering urbanization processes and risks in cities, infrastructure systems are very important for cities. Each of infrastructure sectors have different roles. Also, they have different response to natural or human-made disasters. Like Swilling, Serre and Heinzlef[6] also make a definition of cities with a mention of "networking" and they state that "cities are developing links between people, activities, properties, infrastructures and networks and create by this way a quality of life and dynamic activities". Today, cities have limitless number of mobile interplays between different scales and distances, which facilitated by telecommunications, transport, energy and water networks[7]. Critical infrastructures are important part of these networks. They are basically more vital ones comparing with others. The interdependencies of sectors are a reason why infrastructures are critical. Although, they were defined for the national security of countries, nowadays, they are discussed in various new topics such as green infrastructures[8]. However, there is still lacks in the literature of urban planning.

Consequently, within the scope of this paper, the uneasy interplay between critical infrastructures and urban development is examined. Traditionally, infrastructures are tools of a creating desirable urban order or "the good city"[9]. Today, infrastructures have also an important role in urban planning. While urban developments are in parallel with economic developments, it also aims to provide resilience to chronic stresses and sudden shocks in cities. Therefore, three different typologies of urban developments (mega, transit oriented and neighborhood) are examined and discussed in the light of critical infrastructures by a secondary data

5 CRED, "Global Trends and Perspectives Executive Summary," 2021, 8, p.1

6 Damien Serre and Charlotte Heinzlef, "Assessing and Mapping Urban Resilience to Floods with Respect to Cascading Effects through Critical Infrastructure Networks," International Journal of Disaster Risk Reduction 30, no. February (2018): 235–43, p. 236

7 Stephen Graham and Simon Marvin, Splintering Urbanism, Routledge, 2001, p.8.

8 Hazal Ertem, Koray Velibeyoglu, and Deniz Gerçek, "A Review on Critical Infrastructure and Its Applications," in Conference: 2nd International Disaster&Resilience Congress (IDRC 2020), 2020.

9 Graham and Marvin, Splintering Urbanism, p.12.

analysis. Examples from the world are analyzed and which critical infrastructure sectors are related with these developments are discussed.

In the first part, a brief information on critical infrastructure, sectors and their interdependencies are given. Second part consists of urban development examples, critical infrastructure sectors that are related with each development are explained.

1. CRITICAL INFRASTRUCTURE, SECTORS AND INTERDEPENDENCIES

Critical infrastructure is a recent concept seen since 1990s. Criticality refers that lack of these infrastructure sectors causes destruction in the urban areas. In general, critical infrastructures are the more important infrastructures among urban equipment[10]. Cantelmi, Di Gravio, and Patriarca[11] indicates that critical infrastructures systems function interdependently to produce essential goods and services. Also, OECD[12] makes definition of critical infrastructures: "Critical infrastructures are systems, assets, facilities and networks that provide essential services for the functioning of the economy and the safety and well-being of the population". Therefore, damage of these systems affects the wellbeing and security of the society.

There are various sectors in the scope of critical infrastructure, and they may vary according to countries', regions' or more small units' policies. However, OECD identifies sectors according to survey that are made with countries in a general sense (Table 1). In addition, there are recent studies that mentions green infrastructures are also critical in cities[13].

---

10 Serre and Heinzlef, "Assessing and Mapping Urban Resilience to Floods with Respect to Cascading Effects through Critical Infrastructure Networks.", p.235

11 R. Cantelmi, G. Di Gravio, and R. Patriarca, Reviewing Qualitative Research Approaches in the Context of Critical Infrastructure Resilience, Environment Systems and Decisions, vol. 41 (Springer US, 2021), p.341

12 OECD, Good Governance for Critical Infrastructure Resilience, 2019, p.205

13 Jakob Derks, Lukas Giessen, and Georg Winkel, "COVID-19-Induced Visitor Boom Reveals the Importance of Forests as Critical Infrastructure," Forest Policy and Economics 118, no. April (2020): 102253.

Table 1: Critical infrastructure sectors[14]

Critical Infrastructure Sectors
Energy
Nuclear sector
ICT
Transportation
Water
Dams & flood defense
Food supply & distribution
Health
Finance & banking
Government
Public safety
Chemical industry
Defense industry
Critical manufacturing
Green infrastructure

In addition to identifying critical sectors, interdependencies between them should also be examined. The term interdependence refers that one infrastructure crisis affects another[15]. Therefore, interdependencies in critical infrastructures create an unpredictable cascading effect in infrastructure damages[16]. This makes them more complex, and it may cause vulnerabilities in entire urban activities and systems (Figure 1).

[14] OECD, Good Governance for Critical Infrastructure Resilience; Derks, Giessen, and Winkel, "COVID-19-Induced Visitor Boom Reveals the Importance of Forests as Critical Infrastructure."

[15] Margarita Tsavdaroglou et al., "Proposed Methodology for Risk Analysis of Interdependent Critical Infrastructures to Extreme Weather Events," International Journal of Critical Infrastructure Protection 21 (2018): 57–71.

[16] Serre and Heinzlef, "Assessing and Mapping Urban Resilience to Floods with Respect to Cascading Effects through Critical Infrastructure Networks.", p.236.

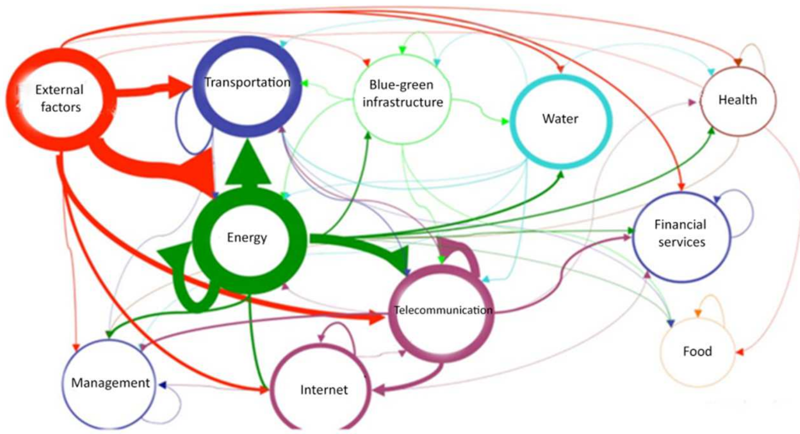


Figure 1: Interdependencies among various critical infrastructure sectors

As a result, this study considers sectors that are mentioned above and their interdependencies. Also, it analyzes critical infrastructure sectors in mega, transit oriented and neighborhood scale urban developments.

2. URBAN DEVELOPMENT EXAMPLES

Mega Urban Developments

In the world, various stakeholders such as governments or private sector give credence to large scale development projects planning and implementations in the last decades[17]. They are a result of globalization, neoliberalism, global interest to development and competitiveness and adapting to changing local national and global competitive situations[18]. Buildings, structures, infrastructures are some of examples of mega urban developments that dramatically affect and reshape the urban environment. They have become main intervention in urban areas. Swyngedouw and others[19] define mega projects as "strategic instruments aiming

17 Erik Swyngedouw, Frank Moulaert, and Rodriguez Arantxa, "Neoliberal Urbanization in Europe : Large-Scale Urban Development Projects and the New Urban Policy," Antipode 34 (2002): 542–77, p.543

18 Gerardo del Cerro Santamaria, "Megaprojects, Development and Competitiveness: Building the Infrastructure for Globalization and Neoliberalism," Athens Journal of Social Sciences 6, no. 4 (2019): 263–90, https://doi.org/10.30958/ajss.6-4-1; Swyngedouw, Moulaert, and Arantxa, "Neoliberal Urbanization in Europe : Large-Scale Urban Development Projects and the New Urban Policy.", p.265.

19 Swyngedouw, Moulaert, and Arantxa, "Neoliberal Urbanization in Europe : Large-Scale Urban Development Projects and the New Urban Policy.", p.562

at reshaping the city". On the other hand, Eizenberg[20] indicates that mega urban developments form new public-private relations and new planning cultures as well as new urban demographic transformations.

On the one hand, mega projects are a result of competitive circumstances of neoliberalism and globalization. On the other hand, they influence urban development. Del Cerro Santamaria[21] states megaprojects as response to neoliberalism and they have direct impact on urbanization process and cities. After a brief explanation of this development, the paper will continue by describing the features of large-scale urban development and their relationship to critical infrastructures. These projects are selected according to their scale. The first example focuses on a regional project that covers whole city of Paris.

2.1. Example 1 – The Grand Paris Express

Grand Paris project is a new transit system project of Paris. It covers a rapid transit system which forms a large loop around the city, and it has four lines[22]. Figure 2. demonstrates the lines of the project. Besides, the project aims to develop a sustainable transit system and urban development and to make better quality of life in suburban areas by developing housing and transportation solutions[23]. The project promises to create more environment friendly transportation system by reducing individual trips and increasing public transportation usage.

The Grand Paris project include 4 additional lines, 200 km of new railway lines, 68 brand new interconnected stations, 2 million passengers every day, a train every 2 to 3 minutes, a 100% automatic metro system and 90% of lines will be built underground[24].

The project aims to increase public transportation demand and decrease carbon footprint level. In addition to its environmental benefits, the Grand Paris project

---

20 Efrat Eizenberg, "Large-Scale Urban Developments and the Future of Cities: Possible Checks and Balances," Urban Planning 4, no. 4 (2019): 1–3, https://doi.org/10.17645/up.v4i4.2643, p.1

21 del Cerro Santamaria, "Megaprojects, Development and Competitiveness: Building the Infrastructure for Globalization and Neoliberalism." P.265

22 "The Grand Paris Project, a 20-Year Endeavor," 2018, https://www.planete-energies.com/en/medias/close/grand-paris-project-20-year-endeavor.

23 "The Grand Paris Project, a 20-Year Endeavor."

24 "Grand Paris Express, the Largest Transport Project in Europe," n.d., https://www.societedugrandparis.fr/info/grand-paris-express-largest-transport-project-europe-1061.

has impact on spatial development. Especially, places where stations locate are planned to be mixed use districts[25]. Figure 2 explains the relationship between urban development and Grand Paris project that includes industrial, business, commercial, research zones aligned with new lines and stations.

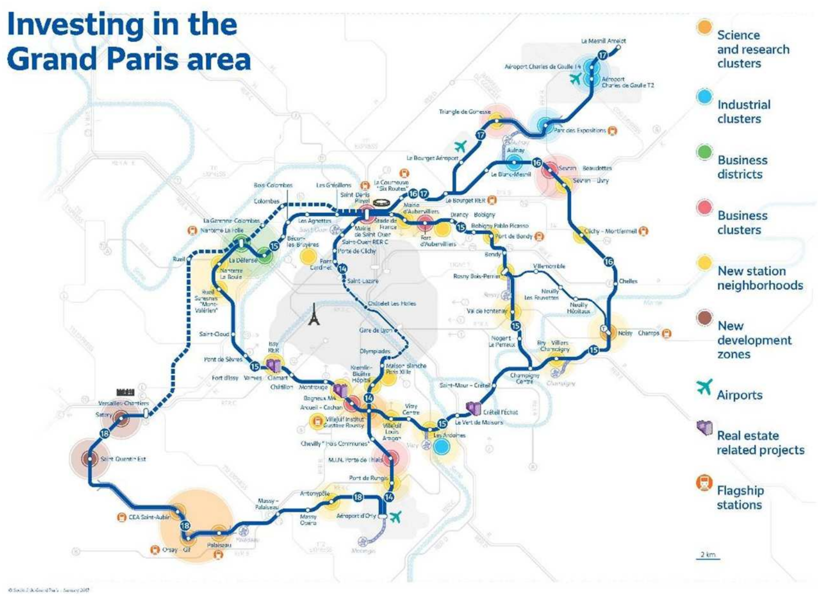


Figure 2: Grand Paris project and urban development

Source: "Grand Paris Express, an Asset for the Capital Region, a Catalyst for France."

There are 68 stations in the scope of this future metro lines. These stations are planned to be spaces for more than just walking. They will have multifunctional activities such as shopping, commuting, living and working. The Société du Grand Paris defines these stations as "welcoming, recognizable from an architectural standpoint, accessible, safe, intermodal, digital, lively and practical"[26].

The Société du Grand Paris was established by French government to run Grand Paris Project in 2010. They are responsible for building of the new lines, stations, structures and facilities, purchasing rolling stock and station and their environment development.

25 "Grand Paris Express, an Asset for the Capital Region, a Catalyst for France," n.d., https://www.societedugrandparis.fr/info/asset-capital-region-catalyst-france-1062.

26 "Grand Paris Express, the Largest Transport Project in Europe."

The government of the foundation has three bodies:

1. The Supervisory Board has 21 members. They represent the state and local government authorities.
2. The Management Board is responsible for operating the project.
3. The Strategic Committee has 182 members. Members include representatives of municipalities through the project line, 4 members of parliament and socio-economic stakeholders. This body organizes a forum for discussion related with grand Paris network[27].

2.2. Example 2 - New Century Global Centre

New Century Global Center opened in city of Chengdu in China in September 2013. It is an attractive center for tourists[28]. Chengdu is located in the south-west of China and the building is located 10 kilometers away from city center (Figure 3).

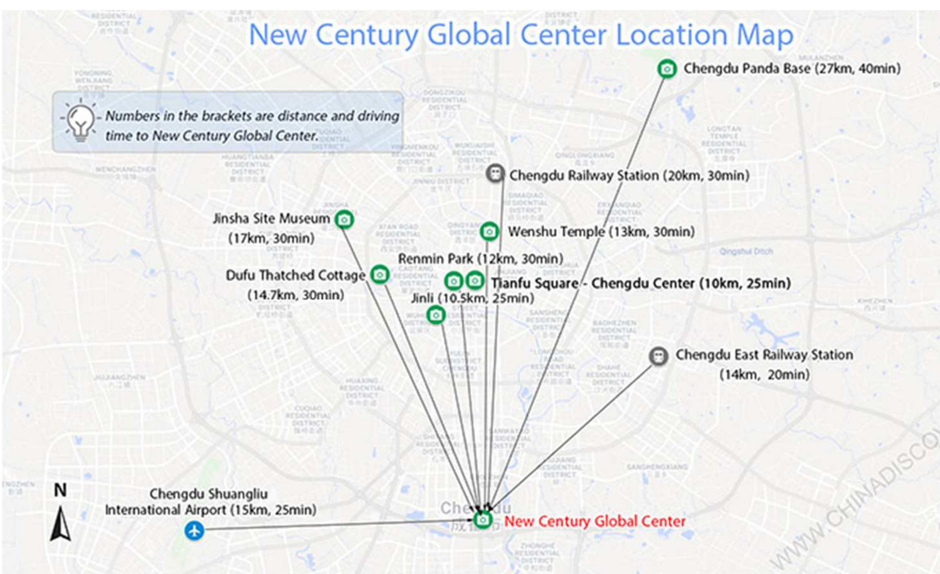


Figure 3: Location of Global Center

Source: "New Century Global Center (Chengdu) - World's Largest Building by Floor Area," n.d., https://www.chinadiscovery.com/sichuan/chengdu/global-center.html.

[27] "Grand Paris Express, an Asset for the Capital Region, a Catalyst for France."

[28] Kelly Pang, "New Century Global Center," 2022, https://www.chinahighlights.com/chengdu/attraction/new-century-global-center.htm.

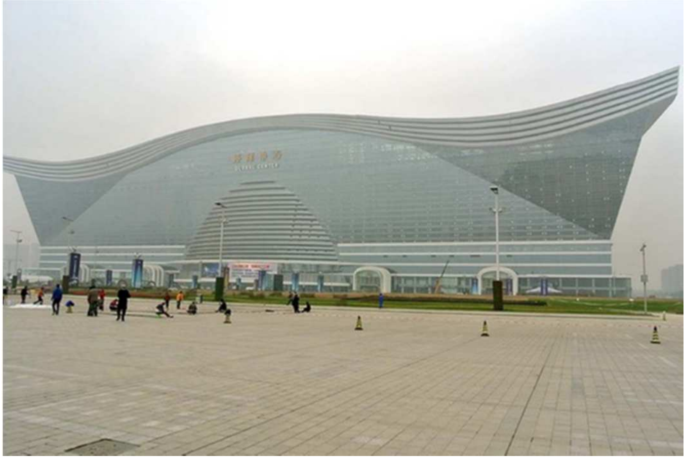


Figure 4: Photo of New Century Global Center

Source: Neoli, "New Century Global Center," 2013, https://bee-inc.com/2013/07/27/new-century-global-center/.

Figure 5: Photo of New Century Global Center

Source: "New Century Global Centre," n.d., https://en.wikiarquitectura.com/building/new-century-global-centre/.

This project aims not only being a shopping mall but also a multifunctional place. It consists of offices, conference rooms, commercial centers, hotels, cinemas etc. (Figure 4). Even, there is a university complex in the center[29]. Besides, it includes

[29] Sebastien Blanc, "China Is Building A Structure 20 Times Bigger Than The Sydney Opera House," 2012, https://www.businessinsider.com/new-century-global-centre-chengdu-china-2012-12.

an artificial beach with an artificial sun light which is shining for 24 hours[30] (Figure 5). Correspondingly, it has as many functions as a person want to demand. The slogan of this complex building is "The One of Everything"[31].

2.3. Discussion on examples

Two examples of mega development are different from each other in the scope of their scale and providing services. On the one hand, the Grand Paris project is a transportation project that covers the whole city of Paris. The critical infrastructure sector that this project depends on is transportation (Figure 6). In addition, there are sectors that interdependent with transportation. For example, Grand Paris express benefits from ICT for the line or time information or in the stations. This project provide connection between suburban areas in the city and the center. Therefore, food, finance, health and services other critical infrastructure sectors are connected via the express lines. Stations are another pillar of the project. They are planned to serve close neighborhoods as a transportation hub and social facilities and green areas.

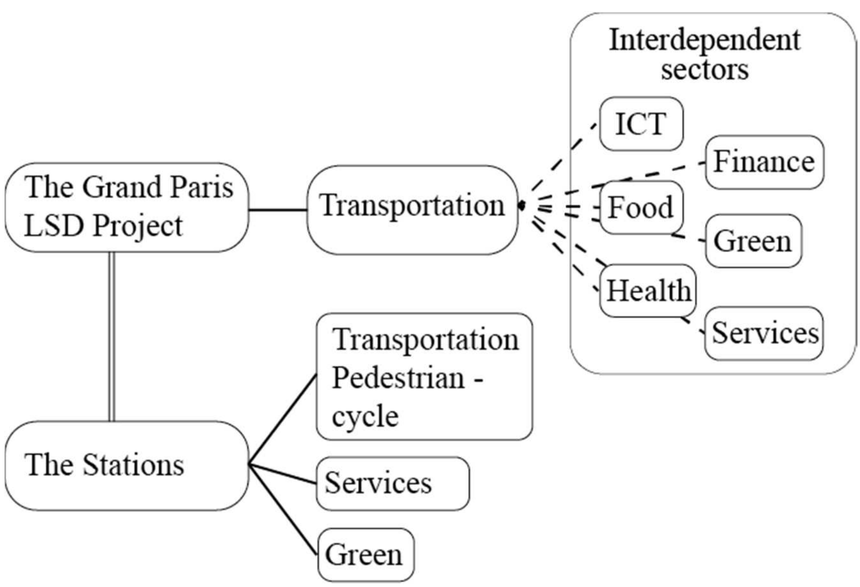


Figure 6: The Grand Paris Project CI Diagram

30 Neoli, "New Century Global Center."

31 Christopher Beam, "One Man, 1.7 Million Square Meters," 2013, https://newrepublic.com/article/115463/worlds-largest-building-area-chinas-new-century-global-center.

On the other hand, New Century Global Center is a complex building rather than a network connecting the city (Figure 7). The main service provided by this project is a living space for the clients. Therefore, critical sector cover finance, services and food distribution. Education, entertainment and commercial are sub sectors of services.

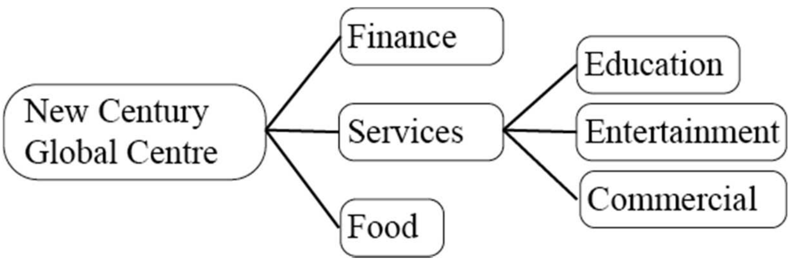


Figure 7: New Century Global Center Project CI Diagram

Public Transit-oriented development

Public transit-oriented development started to be seen in 1990s and it was developed by Peter Calthorpe[32]. It is basically a mixed-use urban development approximately 600 meters walking distance of a transit stop and core commercial area[33]. It aims a safe mix residential, commercial, open spaces, and public uses to travel by public transportation and bicycle or foot as an alternative to car[34]. Dense and compact development is an important character of TOD[35].

Although it was developed in the late 20th century, railway systems in 19th century have an impact on transit-oriented development by providing infrastructures[36]. This development is mainly related with transportation sectors especially non-motorized modes. It is important to ensure interdependencies between transportation modes and land uses in an area. In the next part, two examples are explained. The both examples are common in locating near a train station.

---

32 Todor Stojanovski, Tesad Alam, and Marcus Janson, "Transit-Oriented Development (TOD): Analyzing Urban Development and Transformation in Stockholm," Simulation Series 46, no. 7 (2014): 1–8.

33 Calthorpe Associates, "Transit-Oriented Development Design Guidelines," 1992,

34 Calthorpe Associates.

35 The Center For Neighborhood Technology, "Transit-Oriented Development in the Chicago Region: Efficient and Resilient Communities for the 21st Century," 2013,

36 Justin Jacobson and Ann Forsyth, "Seven American TODs: Good Practices for Urban Design in Transit-Oriented Development Projects," Journal of Transport and Land Use 1, no. 2 (2008): 51–88, p.53

2.4. Example 1 - Transit-Oriented Community, Bridge Station in York Region, Toronto

In order to build a sustainable transit, the government plans to develop Transit-oriented communities (TOC). Like general TOD approaches, TOC also aims to create a high-density, mixed-use communities linked to transit stations[37]. Municipalities of City of Toronto, Mississauga, Brampton, Vaughan and Markham are located in Greater Toronto Region develop TOCs[38]. Especially in the post pandemic city, supplying health walkable communities gain importance. Housing, public services and social services are located near a public transit in the scope of TOC, so it aims to increase public benefits[39].

Bridge Station is one of TOD planned by The Government of Ontario. This project aims to develop a dense mixed-use area and create a community 15-minute walk from end to end[40] (Figure 8 and 9).

Figure 8: Bridge Station TOC Site

Source: Virtual Event, "Engage Bridge Public Engagement Summary Report," 2021, http://engagebridge.ca.

37 "Transit-Oriented Communities," n.d., https://www.ontario.ca/page/transit-oriented-communities.

38 Matti Siemiatycki and Drew Fagan, "Transit-Oriented Communities: Why We Need Them And How We Can Make Them Happen," 2021, https://on360.ca/policy-papers/transit-oriented-communities-why-we-need-them-and-how-we-can-make-them-happen/.

39 Siemiatycki and Fagan.

40 Virtual Event, "Engage Bridge Public Engagement Summary Report," 2021, http://engagebridge.ca.

Figure 9: Bridge Station TOC Site Plan

Source: Virtual Event, "Engage Bridge Public Engagement Summary Report," 2021, http://engagebridge.ca.

The vision of this project is creating "a 15-minute walkable community, completely connected and highly accessible, prioritize parks and open space"[41]. There are six highlights in the context of Bridge TOD project. They are transit, parks and green spaces, partnerships, jobs, housing and sustainable planning. It is located near bus stations, rapid transit, subway station and transit way. Green areas, parks, tree planting are important infrastructures in this project. On the other hand, job opportunities and housing including affordable housing are parts of the project[42].

There are four main aims. First of all, a linked system of park and open spaces are designed. Secondly, it is aimed that the transit stops are 10-15 minutes away. Pedestrian, cyclist and motorist friendly design principles are taken considered. Finally, mixed use design principles are planned[43].

2.5. Example 2 – BART (The San Francisco Bay Area Rapid Transit District) Fruitvale Transit Village Transit Oriented Development

BART is the large-scale transportation development in San Francisco Bay area. BART work with partnership of communities to accomplish regional and local development[44]. Correspondingly, development of stations also serves for

41 Virtual Event.

42 "Project Highlights," 2021, http://engagebridge.ca/#project-highlights.

43 "Engage Bridge," n.d., http://engagebridge.ca/wp-content/uploads/2021/12/Bridge-TOC-Open-House-Presentation_Dec14FINAL-1.pdf.

44 BART, "Transit-Oriented Development Policy," 2020, 3–5.

neighborhoods that located near stations well beings. Fruitvale station is located on the BART line in San Francisco. It was developed in the early 2000s by The Unity Council[45]. This station is located at the center of Fruitvale neighborhood. Fruitvale TOD is an important example that provide a renewal of economically depressed area[46].

As seen in the figure 10, Fruitvale station is located on an intersection of several lines. It is a mixed-use development and a favorite example of transit-oriented development[47]. Commercial areas, offices and apartments are parts of Fruitvale transit-oriented development (Figure 11).

Figure 10: BART Rail System Map

"System Map," n.d., https://www.bart.gov/system-map.

45 "Fruitvale Village," n.d., https://unitycouncil.org/property/fruitvale-village/.

46 Jacobson and Forsyth, "Seven American TODs: Good Practices for Urban Design in Transit-Oriented Development Projects.", p.68-69

47 The Great Communities Collaborative, "Transit-Oriented for All: The Case for Mixed-Income Transit-Oriented Communities in the Bay Area," 2007, https://communityinnovation.berkeley.edu.

Figure 11: Google earth view of Fruitvale Village

Fruitvale has the traditional transit-oriented development properties such as mixed-use retail and housing close to transportation modes. On the other hand, this project differs by providing social services such as senior center, library, preschool, and medical clinic. In addition to be an example of providing equal services, a participation process takes place during planning[48]. Train lines, bus lines, pedestrian areas, bike lines and parking areas, car parking areas are the different modes that serve for transit-oriented development in the Fruitvale Village[49] (Figure 12 and 13).

Figure 12: Entrance to Fruitvale Village

Source: Gray-O'Connor, "Fruitvale Transit Village."

48 Jen Gray-O'Connor, "Fruitvale Transit Village," 2015, https://critical-sustainabilities.ucsc.edu/fruitvale-transit/.

49 National Institute for Transportation and Communities, "Trip and Parking Generation at Transit-Oriented Developments," 2017.

Figure 13: Pedestrian ways in the Village

Source: "Fruitvale Transit Village," n.d., https://pgadesign.com/projects/fruitvale-transit-village/.

2.6. Discussion on examples

Toronto and BART examples have similar functions. They both depends on transportation as a critical sector. Sub sectors are pedestrian ways, bicycle paths and public transportation. Green infrastructure, services, health, food distribution and public safety are critical sectors that are interdependent to transportation (Figure 14).

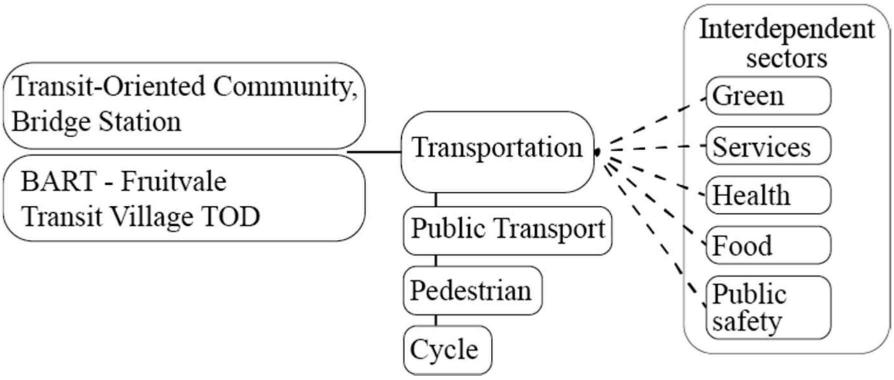


Figure 14: TOD Projects CI Diagram

X Minutes Neighborhood Developments

Crisis in the world such as the pandemic, climate crisis cause new approaches in neighborhood design. Correspondingly, '20-minute neighbourhood' (also known as 15-minute cities) has an important role in the world's agenda to provide a livable environment[50]. These neighborhoods encourage walking or cycling to reach necessary services. As seen in Figure 15, there are some characteristics of a 20 minute neighborhood. Well connectedness, affordability, public services are some of them.

Although the names of this concept (i.e., 15-minute city in Paris, 20-minute neighborhood in Melbourne), the main idea is being 'complete, compact and connected' place. Also, the outcomes of this development model are healthy communities, clean air, strong local economies and resilience to climate change and other risks[51].

Figure 15: Features of 20-minutes neighborhood

Source: TCPA, "20-Minute Neighbourhoods," 2021

50 "The 20-Minute Neighbourhood," n.d., https://www.tcpa.org.uk/the-20-minute-neighbourhood.

51 TCPA, "20-Minute Neighbourhoods," 2021,

2.7. Example 1 – Melbourne 20-minute neighborhoods

Plan Melbourne 2017–2050 which is a long-term strategy of the government has strategies about "20-minute neighborhoods". This concept gives a chance to people to "meet most of their daily needs within a 20-minute return walk from home, with access to safe cycling and local transport options"[52]. These neighborhoods mainly have 800-meter walking distance from starting point to the destination. Local shopping centers, health facilities, education, public transportation are some facilities that one person can reach them in maximum 20 minutes[53] (Figure 16).

Figure 16: Features of 20-Minute Neighborhood

Source: "20-Minute Neighbourhoods," 2021, https://www.planning.vic.gov.au/policy-and-strategy/planning-for-melbourne/plan-melbourne/20-minute-neighbourhoods.

52 "20-Minute Neighbourhoods," 2021, https://www.planning.vic.gov.au/policy-and-strategy/planning-for-melbourne/plan-melbourne/20-minute-neighbourhoods.

53 "20-Minute Neighbourhoods."

The Minister for Planning started a pilot program for 20-minutes neighborhoods in 2018. In the scope of this program, Strathmore, Croydon South and Sunshine West are determined as pilot projects. This program mainly aims to test the implementation of 20-minutes neighborhood, to prepare a guideline for the concept and to work with partnership between state and local government[54]. In the pilot programs, existing situations in neighborhoods are investigated, and opportunities are determined considering community feedback, workshops and the technical assessments[55].

2.8. Discussion on example

Although 20-minute neighborhoods have similar approaches with transit-oriented development, they have differences. Unlike TOD, this development model covers a complete neighborhood with a walking distance. Critical infrastructure sectors and sub sectors that are seen in the figure 17 are locates in an approximately 600 meters away from starting point. This development focuses on mostly services as critical infrastructure. They are services that someone can each in 20 minutes walking distance.

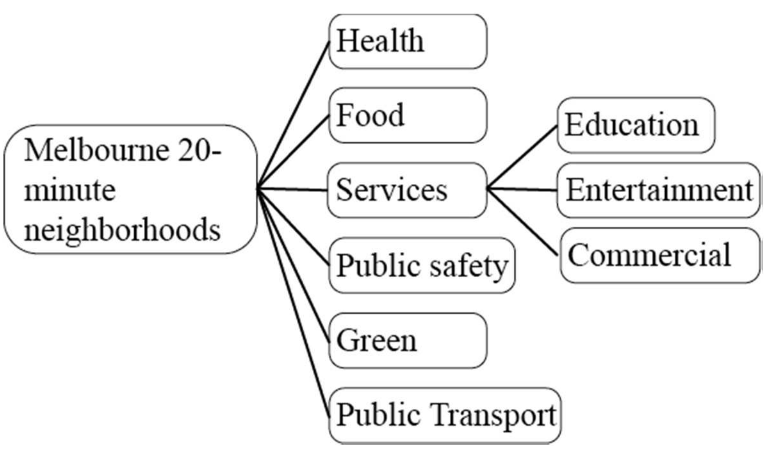


Figure 17: 15-Minute Neighborhood Project CI Diagram

54 Victoria State Government, "20-Minute Neighbourhoods," n.d., https://www.planning.vic.gov.au/__data/assets/pdf_file/0031/428908/Creating-a-more-liveable-Melbourne.pdf.

55 "20-Minute Neighbourhoods."

CONCLUSION

Critical infrastructures are vital parts of urban areas because their destruction may cause serious problems. Lack of critical infrastructures leads to hitches in daily life or in crisis circumstances. On the other hand, they are interdependent to each other. Therefore, when one is damaged or out of function, other infrastructures that are interdependent are affected. At that sense, identifying critical infrastructures is essential to control the unexpected situations and cascading events. Critical infrastructures are generally included by governmental policies that mentions natural or man-made disasters. However, they are very related with urban developments.

In this paper, relationships between three different urban development types and their CI diagrams are investigated. They have different scales, characteristics and planning processes. Therefore, they are connected with different critical sectors. For example, the Grand Paris is a city scale project and interdependencies among the sectors is very important. The project itself create a connection among sectors. On the contrary, New Century Global Center is a building complex that have critical sectors. It does not have relations with sectors outside the building. On the other hand, transit-oriented development and neighborhood development are small scale developments. The sectors meet the needs of limited number population. They are generally local sectors.

These projects have various governance ways. Some are owned by private sector while others public private partnership. Examples in transit-oriented development and neighborhood development projects also have public participation. For example, Melbourne 20-minutes neighborhoods are planned considering opportunities identified by public surveys.

Although critical infrastructure sectors are determined in a top-down process, citizens should have a place in this process. As seen in the examples, whatever the scale is citizens are influenced from urban developments and correspondingly critical infrastructures.

REFERENCES

1. "20-Minute Neighbourhoods," 2021. https://www.planning.vic.gov.au/policy-and-strategy/planning-for-melbourne/plan-melbourne/20-minute-neighbourhoods.
2. BART. "Transit-Oriented Development Policy," 2020, 3–5.
3. Beam, Christopher. "One Man, 1.7 Million Square Meters," 2013. https://newrepublic.com/article/115463/worlds-largest-building-area-chinas-new-century-global-center.
4. Blanc, Sebastien. "China Is Building A Structure 20 Times Bigger Than The Sydney Opera House," 2012. https://www.businessinsider.com/new-century-global-centre-chengdu-china-2012-12.
5. Calthorpe Associates. "Transit-Oriented Development Design Guidelines," 1992. https://www.sandiego.gov/sites/default/files/legacy/planning/community/profiles/southeasternsd/pdf/transitorienteddevelopmentdesignguidelines1992.pdf.
6. Cantelmi, R., G. Di Gravio, and R. Patriarca. Reviewing Qualitative Research Approaches in the Context of Critical Infrastructure Resilience. Environment Systems and Decisions. Vol. 41. Springer US, 2021. https://doi.org/10.1007/s10669-020-09795-8.
7. Cerro Santamaria, Gerardo del. "Megaprojects, Development and Competitiveness: Building the Infrastructure for Globalization and Neoliberalism." Athens Journal of Social Sciences 6, no. 4 (2019): 263–90. https://doi.org/10.30958/ajss.6-4-1.
8. CRED. "Global Trends and Perspectives Executive Summary," 2021, 8. file:///C:/Users/asadzadeh.ISBK/Desktop/2020_The Non-COVID Year in Disasters .pdf.
9. Derickson, Kate Driscoll. "Urban Geography III: Anthropocene Urbanism." Progress in Human Geography 42, no. 3 (2018): 425–35. https://doi.org/10.1177/0309132516686012.
10. Derks, Jakob, Lukas Giessen, and Georg Winkel. "COVID-19-Induced Visitor Boom Reveals the Importance of Forests as Critical Infrastructure." Forest Policy and Economics 118, no. April (2020): 102253. https://doi.org/10.1016/j.forpol.2020.102253.
11. Eizenberg, Efrat. "Large-Scale Urban Developments and the Future of Cities: Possible Checks and Balances." Urban Planning 4, no. 4 (2019): 1–3. https://doi.org/10.17645/up.v4i4.2643.
12. "Engage Bridge," n.d. http://engagebridge.ca/wp-content/uploads/2021/12/Bridge-TOC-Open-House-Presentation_Dec14FINAL-1.pdf.
13. Ertem, Hazal, Koray Velibeyoglu, and Deniz Gerçek. "A Review on Critical Infrastructure and Its Applications." In Conference: 2nd International Disaster&Resilience Congress (IDRC 2020), 2020.
14. "Fruitvale Transit Village," n.d. https://pgadesign.com/projects/fruitvale-transit-village/.
15. "Fruitvale Village," n.d. https://unitycouncil.org/property/fruitvale-village/.
16. Graham, Stephen, and Simon Marvin. Splintering Urbanism. Routledge, 2001.
17. "Grand Paris Express, an Asset for the Capital Region, a Catalyst for France," n.d. https://www.societedugrandparis.fr/info/asset-capital-region-catalyst-france-1062.

18. “Grand Paris Express, the Largest Transport Project in Europe,” n.d. https://www.societe-dugrandparis.fr/info/grand-paris-express-largest-transport-project-europe-1061.
19. Gray-O’Connor, Jen. “Fruitvale Transit Village,” 2015. https://critical-sustainabilities.ucsc.edu/fruitvale-transit/.
20. Jacobson, Justin, and Ann Forsyth. “Seven American TODs: Good Practices for Urban Design in Transit-Oriented Development Projects.” Journal of Transport and Land Use 1, no. 2 (2008): 51–88. https://doi.org/10.5198/jtlu.v1i2.67.
21. National Institute for Transportation and Communities. “Trip and Parking Generation at Transit-Oriented Developments,” 2017.
22. Neoli. “New Century Global Center,” 2013. https://bee-inc.com/2013/07/27/new-century-global-center/.
23. “New Century Global Center (Chengdu) - World’s Largest Building by Floor Area,” n.d. https://www.chinadiscovery.com/sichuan/chengdu/global-center.html.
24. “New Century Global Centre,” n.d. https://en.wikiarquitectura.com/building/new-century-global-centre/.
25. OECD. Good Governance for Critical Infrastructure Resilience, 2019. http://www.oecd.org/governance/good-governance-for-critical-infrastructure-resilience-02f0e5a0-en.htm%0A https://www.oecd-ilibrary.org/governance/good-governance-for-critical-infrastructure-resilience_02f0e5a0-en.
26. Pang, Kelly. “New Century Global Center,” 2022. https://www.chinahighlights.com/chengdu/attraction/new-century-global-center.htm.
27. “Project Highlights,” 2021. http://engagebridge.ca/#project-highlights.
28. Ritchie, Hannah, and Max Roser. “Urbanization,” 2018. https://ourworldindata.org/urbanization.
29. Serre, Damien, and Charlotte Heinzlef. “Assessing and Mapping Urban Resilience to Floods with Respect to Cascading Effects through Critical Infrastructure Networks.” International Journal of Disaster Risk Reduction 30, no. February (2018): 235–43. https://doi.org/10.1016/j.ijdrr.2018.02.018.
30. Siemiatycki, Matti, and Drew Fagan. “Transit-Oriented Communities: Why We Need Them And How We Can Make Them Happen,” 2021. https://on360.ca/policy-papers/transit-oriented-communities-why-we-need-them-and-how-we-can-make-them-happen/.
31. Stojanovski, Todor, Tesad Alam, and Marcus Janson. “Transit-Oriented Development (TOD): Analyzing Urban Development and Transformation in Stockholm.” Simulation Series 46, no. 7 (2014): 1–8.
32. Swilling, Mark. “Reconceptualising Urbanism, Ecology and Networked Infrastructures.” Social Dynamics 37, no. 1 (2011): 78–95. https://doi.org/10.1080/02533952.2011.569997.

33. Swyngedouw, Erik, Frank Moulaert, and Rodriguez Arantxa. "Neoliberal Urbanization in Europe : Large-Scale Urban Development Projects and the New Urban Policy." Antipode 34 (2002): 542–77.
34. "System Map," n.d. https://www.bart.gov/system-map.
35. TCPA. "20-Minute Neighbourhoods," 2021. https://www.tcpa.org.uk/Handlers/Download.ashx?IDMF=f214c4b8-ba4d-4196-9870-e9d240f86645.
36. "The 20-Minute Neighbourhood," n.d. https://www.tcpa.org.uk/the-20-minute-neighbourhood.
37. The Center For Neighborhood Technology. "Transit-Oriented Development in the Chicago Region: Efficient and Resilient Communities for the 21st Century," 2013. http://www.cnt.org/sites/default/files/publications/CNT_TODInChicagoRegion.pdf.
38. "The Grand Paris Project, a 20-Year Endeavor," 2018. https://www.planete-energies.com/en/medias/close/grand-paris-project-20-year-endeavor.
39. The Great Communities Collaborative. "Transit-Oriented for All: The Case for Mixed-Income Transit-Oriented Communities in the Bay Area," 2007. https://community-innovation.berkeley.edu.
40. "Transit-Oriented Communities," n.d. https://www.ontario.ca/page/transit-oriented-communities.
41. Tsavdaroglou, Margarita, Saad H.S. Al-Jibouri, Thomas Bles, and Johannes I.M. Halman. "Proposed Methodology for Risk Analysis of Interdependent Critical Infrastructures to Extreme Weather Events." International Journal of Critical Infrastructure Protection 21 (2018): 57–71. https://doi.org/10.1016/j.ijcip.2018.04.002.
42. United Nations. "World Population," 2017. https://www.un.org/en/desa/world-population-projected-reach-98-billion-2050-and-112-billion-2100.
43. Victoria State Government. "20-Minute Neighbourhoods," n.d. https://www.planning.vic.gov.au/__data/assets/pdf_file/0031/428908/Creating-a-more-liveable-Melbourne.pdf.
44. Virtual Event. "Engage Bridge Public Engagement Summary Report," 2021. http://engagebridge.ca.

KARTEPE SUMMIT

24-27 MARCH 2022

Chapter 15

WATER SENSITIVE ANKARA CITY: EXISTING PRACTICES, CHALLENGES AND OPPORTUNITIES

Md Moynul Ahsan*

INTRODUCTION

Though cities are the engines of growth and development, but its existence is dependent on water. Starting from the Fertile Crescent around 9,000 BCE, the rivers and marshlands were very crucial for rising civilization. The water, water bodies provide the changing needs and conditions at that time. However, after the 1980's, the introduction of "Ecological Urbanism"[1], the cities were then considered capable of adapting to conditions and changing needs. Then, the rise of environmental movement brought environmental concerns and ecological planning methods into the mainstream of landscape architecture, city planning, and public policy[2]. A new vision of the relationship between planning, open space, and water has been promoted and later on water issues became important to be considered both local to international level. The introduction of "Ecological Urbanism" was the starting point of a process that later developed the concept of Water Sensitive City (WSC), Water Wise City, Water Sensitive Urban Design[3], Water Sensitive Urban Planning and Design[4]. Presently, along with other factors, climate induced impact and COVID-19 pandemic are pressurizes to excessive use of water, lack of water

* Department of Real Estate Development and Management, Ankara University, moynulurp01@gmail.com

1 Forest Stearns, Tom Montag. *The Urban ecosystem: a holistic approach.* New York: Halsted Press, 1975

2 Fumero, Andera. '*Water Sensitive Urban Design (WSUD) as a climate adaptation strategy*'. KTH Royal Institute of Technology, School of architecture and the built environment, 2020.

3 Fumero, 5

4 Centre for Science and Environment. "Water Sensitive Urban Design And Planning: A Practitioner's Guide, 2017, Centre for Science and Environment, India.

storage, too much consumption, lack of rainfall, existing adverse geographic and topographical conditions, arid/semi-arid situations and the like, all pose challenges for resilience of a city. We know that the concept of urban resilience acts to prepare for and respond to regular forces (such as climate change) and disruptive forces (such as pandemics). Cities need to better respond and enhance people's lives and livelihoods despite different types of forces. In this respect, "water-sensitive" or "water-wise cities" concept in cities can be acted as a strategy for urban resilience, life and livelihood of city people. Many cities have developed new urban water transitions through different concepts such as "water supply city", "sewered city", "drained city", "forest city". Such stages have been mainly based on grey structure development, while the later stages of "waterways city", "water cycle city" and "water-sensitive city" contextualize "water" as a cross-sectoral topic. Therefore, in this study, what types of new urban water transitions have been performed or are being performed at nowadays or will be performed through different Nature Based Solutions concepts.

Again, good water governance is key to performance of water sector in cities and towns. Effective governance at national, local and community level and respective capacities are essential for the development of sustainable cities. It is not only essential for ensuring reliable and effective water services to the population, but also to establish the sector's financial sustainability. Respective government policies regarding service delivery, service levels, operating performance, and incentives are critical to focus. As the current conventional stormwater management systems are not adequate in Ankara city, therefore, the Water Sensitive City concept can help to overcome future challenges in the city areas. Though it is a new approach it poses a pedagogical approach toward citizens or users. The WSC promotes the use of water as an aesthetic element for the neighborhood. Water sensitivity can significantly change attitudes promoting the intelligent use of water resources and citizen involvement[5]. It's practices address different types of challenges that are not only relevant for water issues or urban development issues but also for global development challenges. The practices of WSC can potentially achieve the following SDGs such as Climate action for adaptation, resilience and mitigation (SDG 13), Water management (SDG 6), Green space, habitats and biodiversity (SDG 15), Environmental quality, including air

---

[5] Wong, Tony H. F. "An Overview of Water Sensitive Urban Design Practices in Australia", *Water Practice & Technology 1(1),* 2006.

quality and waste management (in city perspective) (SDG 11), Regeneration, land-use, land cover change, and urban planning, development and design (SDG 11), Inclusive and effective governance (SDG 16), Social justice, cohesion and equity (SDG 10), Health and well-being (SDG 3), Economic development and decent employment (SDG 8), Cultural heritage, urban beauty, and cultural diversity (SDG 11), Sustainable consumption and production (SDG 12)[6].

Ankara, the capital of Turkey, is located in the middle region of the country. Total land and green land per person have decreased since the 1950's due to the population growth, urbanisation and so on. The population density of the province is 222 persons per km^2 and average land per person is 0.45 hectare and per capita water consumption was 211 liters/day and has increased to 250 liters/day in 2021[7] due to COVID-19, climate change and other forces[8]. Management of water in Ankara city plays a vital role to its resilience. However, the Ankara Metropolitan Municipality (AMM) and municipalities in Ankara need a better response to ensure water security. As water-sensitive cities are characterized as more resilient, livable, productive, and sustainable, therefore many cities have taken various approaches. Therefore, in this study, what types of new urban water transitions have performed or are performing nowadays or will be performed under the Nature Based Solutions concept of Ankara city should be evaluated.

1. METHODOLOGY OF THE STUDY

To explore research questions, the study has been conducted secondary based research including a literature review of the explanation of the WSC concept, existing scenario of WSC prospects for Ankara city, WSC practice cases from the municipalities, challenges and opportunities by the institutions. The literature review has tried to focus the integration of different issues related to the research questions of the study. After the literature review, a desk review of a set of articles, research reports, web portals of municipalities, government organizations in Ankara were done. This study tries to answer the following questions: how "water" could serve as a strategic entry point to integrated, inclusive and resilient

6 Almassy, Dora et al., "Urban Nature Atlas: A Database of Nature-Based Solutions Across 100 European Cities", 2018.

7 Olcay, Ömer. Başkentte 110 günlük su kaldı' uyarısı. Accessed 5 January, 2021. https://www.aa.com.tr/tr/turkiye/baskentte-110-gunluk-su-kaldi-uyarisi/2099031.

8 Ahsan Md Moynul. "Strategic decisions on urban built environment to pandemics in Turkey: Lessons from COVID-19", *Journal of Urban Management,* 9 No.3, (September 2020): 281-285. https://doi.org/10.1016/j.jum.2020.07.001

urban development that is guided by the SDG framework? What types of WSC practices are available and how can these practices be scaled and regularly updated to serve as a basis for inclusive and future-oriented municipal planning approaches? How can effective and sustainable water-sensitive urban development be fostered in Ankara city? In respect of finding challenges of NbS practice, the challenges from the perspective of ecologically sustainable, socially justified, economically viable, culturally transferable, institutionally acceptable, and technological and managerial innovations etc. all are needed to take into consideration in order to meet sustainability for the future[9]. Again, cities deep uncertainties, changing societal values and justification, economic viability, cultural transferability, technological and managerial innovations are not covered in this study but this study focused from existing climate and environment and institutional perspective because both of these dimensions are firstly needed to consider for Ankara city perspective. Again, as the scope of water sensitive city practices is diverse such as in streets, car parks, homes and buildings, precincts etc. but this study is focused specifically on water sensitive parks and open spaces in Ankara city.

2. WATER SENSITIVE CITY: A CONCEPTUAL FRAMEWORK

The water service delivery has passed through a transition that functions on different divers and challenges in time to time considering its various factors like water supply, resiliency, climate change and so on. Brown et al.[10] (2009) proposed about urban water transitions framework and presented a typology of six different city development states in Australian city perspective such as 'Water Supply City', 'Sewered City', 'Drained City', 'Waterways City', 'Water Cycle City', and 'Water Sensitive City'. Among the stages, 'Water Sensitive City' is more diverse, adaptive, multifunctional infrastructure and urban planning and design, water sensitive behaviour all derived from socio-political issues including intergenerational equity, resilience to climate change, uncertainty and risk (e.g. pandemic). A water-sensitive city can be described as one that is livable, resilient, sustainable and productive[11]. It acts as a potential guide for the water-relevant urban

[9] Pusalkar, Vandana et al. "Future city - challenges and opportunities for water-sensitive sustainable cities in India" *E3S Web of Conferences 170, 06017,* 2020, https://doi.org/10.1051/e3sconf/202017006017

[10] Brown, R. ET AL. "Urban water management in cities: Historical, current and future regimes." *Water, Science and Technology: A Journal of the International Association on Water Pollution Research*, 59(5), 847–55. 2009.

[11] CRC Water Sensitive Cities. "What is a water sensitive city?". Accessed 5 December, 2021. https://watersensitivecities.org.au/what-is-a-water-sensitive-city/

transformations as the specification of urban resilience in the cities of the world. These water-relevant urban transformations should be carried out in such a way that all water within the city will be managed properly by maximizing the achievement of urban livability outcomes, and resilience to unexpected events including pandemic related shocks[12], while replenishing the environment[13].

In WSC concept, water can be managed in such a way so that people can get diversified benefit. In this respect, Cooperative Research Centre for Water Sensitive Cities (CRCWSC) described three pillars of a water-sensitive city: (i) Cities act as water supply catchments, providing a range of different water sources at a range of different scales, and for a range of different uses, (ii) Cities provide ecosystem services and a healthy natural environment, thereby offering a range of social, ecological, and economic benefits, (iii) Cities comprise water-sensitive communities, where citizens have the knowledge and desire to make wise choices about water, are actively engaged in decision-making, and demonstrate positive behaviour's related to water[14] [15]. International Water Association (IWA) focused that the following principles should be taken into consideration while designing urban within the viewpoint of "Water Sensitive" issues such as enabling regenerative water services, designing urban spaces to reduce flood risks, enhancing liability with visible water, modifying and adapting urban materials to minimize environmental impact. IWA also focused that in order to promote water-wise communities the following principles should be taken into consideration such as: empowering citizens, professionals should be aware of water co-benefits, transdisciplinary planning teams, policy makers should enable water-wise action and leaders should engage and engender trust[16]. It's tools can be categorized as belows[17]:

- Rainwater use: it can be designed as Rainwater harvesting,

12 Ahsan Md Moynul. "Climate Change Adaptation-Based Strategies on Water and its Security: A Study on Dhaka and Ankara", *Journal of Security Sciences,* (February 2020): 79-93. DOI:10.28956/gbd.695924.

13 IWA. "The IWA Principles Water Wise Cities 2nd Edition", International Water Association. Accessed 9 February, 2022. https://iwa-network.org/wp-content/uploads/2016/10/IWA_Brochure_Water_Wise_Communities_SCREEN-1.pdf

14 CRC Water Sensitive Cities. "What is a water sensitive city?". Accessed 5 December, 2021. https://watersensitivecities.org.au/what-is-a-water-sensitive-city/

15 Fergusona, Briony C. et al. "A strategic program for transitioning to a Water Sensitive City", *Landscape and Urban Planning 117,* 2013. https://doi.org/10.1016/j.landurbplan.2013.04.016

16 IWA. "The IWA Principles Water Wise Cities 2nd Edition", International Water Association. Accessed 9 February, 2022. https://iwa-network.org/wp-content/uploads/2016/10/IWA_Brochure_Water_Wise_Communities_SCREEN-1.pdf

17 Hoyer, Jacqueline et al. "Water Sensitive Urban Design. Principles and Inspiration for Sustainable Stormwater Management in the City of the Future". Manual. HafenCity Universität, 2011.

- Treatment: stormwater treatment through bioretention areas, biotopes, gravel or sand filters.
- Detention and infiltration such as Rooftop retention, Green facade, Permeable paving, Infiltration zones and trenches, swales, geo-cellular systems, detention pond (dry), detention pond (wet), water square etc.
- Conveyance through open stormwater canals/ drains,
- Evapotranspiration: Passive evapotranspiration by vegetative elements in urban areas or by active evapotranspiration by using rainwater walls, fountains, and pools.

3. NECESSITY OF WATER SENSITIVE CITY APPROACH FOR ANKARA CITY

In order to portray the necessity of WSC for Ankara city, the existing state of water in Ankara, climate and rainfall, topography and geology, land cover pattern and land use pattern should focus in this study. In terms of location and climate, Ankara's position in Central Anatolia poses semi-arid climate[18] with a hot-summer. Under the Trewartha climate classification, Ankara has a middle latitude steppe climate. Due to its elevation and inland location, Ankara has cold, somewhat snowy winters and hot, dry summers. It is considered a high risky district in terms of drought in Turkey[19]. Rainfall occurs mostly during the spring and autumn, its annual average precipitation is around 388 millimetres, is one of the lowest precipitating areas in Turkey, yet precipitation can be observed throughout the year. Ankara's annual mean temperature is 12.02˚C, and monthly mean temperatures range between 0.2˚C and 23.5˚C. Monthly mean temperatures range from 0.3 ˚C (32.5 ˚F) in January to 23.5 ˚C (74.3 ˚F) in July, with an annual mean of 12.02 ˚C (53.6 ˚F). Average maximum precipitation is 88.9 kg/m^2 resulted in 11.06.1997; maximum snow height 33.0 cm resulted in 31.01.1950[20]. Table 1 represents extreme maximum, minimum and average temperatures for long period (˚c) in Ankara in different periods.

18 Ahsan Md Moynul. "Climate Change Adaptation-Based Strategies on Water and its Security: A Study on Dhaka and Ankara", *Journal of Security Sciences,* (February 2020): 79-93. DOI:10.28956/gbd.695924

19 Türkeş, Murat. "Drought Vulnerability and Risk Analysis of Turkey with Respect to Climatic Variability and Socio-Ecological Indicators", *Aegean Geographical Journal, 26* No.2, 2017.

20 Department of Meteorology. "Cities & Holiday Resorts: Ankara. 2022. Accessed 12 February, 2022. https://www.mgm.gov.tr/eng/forecast-cities.aspx

Table 1. Extreme maximum, minimum and average temperatures in Ankara

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temp (1981-2010)	0.7	2.0	6.2	11.4	16.3	20.3	23.7	23.7	19.0	13.2	6.6	2.6
Avg. Max. Temp. (1981-2010)	4.7	6.6	11.8	17.2	22.3	26.7	30.3	30.5	26.2	19.9	12.3	6.5
Avg. Min. Temp. (1981-2010	-2.7	-2.11	1.1	15.8	9.8	13.3	16.4	16.6	12.2	7.7	2.4	-0.5

Source: Department of Meteorology, 2022

Regarding Ankara's topography and geology, it's steppe vegetation has characterized semi-arid conditions and gypsaceous and marley-gypseous soils visible in Çankırı and Beypazarı districts. Ankara lies in United States hardiness zones 7b (in this zone, the minimum average of temperatures are 0˚ to 10˚F) and located within a basin called Ankara Basin, and is bounded with a series of highlands. In the vicinity of the study area, metamorphic rocks, greywacke black shales, crystalline limestone, limestone, clay-silt-sand-gravel and alluvium constitute the main lithological units[21].

Besides the existing state of natural challenges, Ankara also facing human-induced impacts and challenges in its land cover. Major changing pattern could be visible over the last few decades. The following figure 1 shows that there is a decline of green area and water area from the years of 1988-2020[22]. In 2008, the water area was 0.96%, has reduced to 0.75% in 2018 and 0.64% in 2000. Again, the amount of green area has been decreased rapidly however it could be able to increase in 2020 due to governmental intervention. The city manmade area has been increasing and the expansion is continuing in all directions. It has found that there has been an increase of 4.6 times in the population, 6.5 times in the number of houses and 4.5 times in the number of buildings in Ankara in the period of 1960-

21 Teoman, M.B. et al. "Assessment of slope stability in Ankara clay: a case study along E90 highway", *Env Geol 45*, 2004.

22 Tanrıvermiş et al. "Land cover monitoring techniques and spatial development: The case of capital of Turkey", International Journal of Geography and Geography Education (IGGE), 45, 2022. http://dx.doi.org/10.32003/igge.1007780

2018[23] (TurkStat 2019). It is estimated that the man-made area will be increased by around half of the study area in 2050. This means that man-made built-up areas will continue to grow. It has observed that the number of buildings in the city has increased at similar rates, and the city's spread and the city's growth has been balanced with the population growth. The number of high-rise buildings has increased rapidly over time, with an increase in technological development, high unit cost of land acquisition for residential areas in the city centre, landscaping, reduction of roof and ground costs.

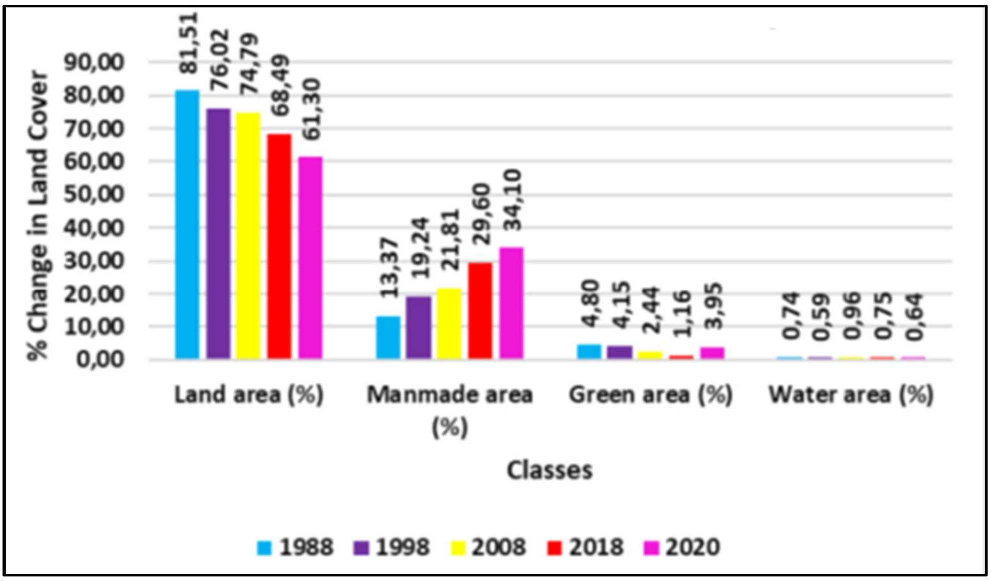


Figure 1: Land cover change in Ankara in different intervals (1988-2020).

Source: Tanrıvermiş, Sevgen & Tanrıvermiş (2022)

With regard to the state of water in Ankara, around 98.5% of water supply is dependent on surface water resources[24] so, a small portion of water is dependent on ground water. According to Ankara Water and Sewerage Administration (2019), approximately 69.42% of the municipal water used with domestic purposes, 12.02%

[23] TurkStat. Turkish Statistical Institute Database. 2019. Accessed 12 February, 2022. http://www.tuik.gov.tr/Start.do

[24] Ahsan Md Moynul. "Climate Change Adaptation-Based Strategies on Water and its Security: A Study on Dhaka and Ankara", *Journal of Security Sciences,* (February 2020): 79-93. DOI:10.28956/gbd.695924

in the public, 9.89% in commercial, 6.44% in green space and remaining 2.23% in industrial sector[25]. People's demand on water and consumption rate has increased in the last few years. In 2014, the per capita water consumption was 211 liters/day and has increased to 250 liters/day in 2021[26]. In general, domestic water use in Turkey is 5% higher than the world average. Conversely, in EU standards, the amount of wastewater treatment per capita per year in Ankara is only 4.2 m^3 which is the lowest in Turkey[27]. One of the primary objectives of Ankara water and sewerage authority is to collect wastewater and rainwater from settlements and discharge them after treatment, and for this purpose, necessary structural investments and treatment activities have been carried out. As per Ankara Metropolitan Municipality Bulletin (In Turkish: *Başkent bülteni*, January 2021), during 2020, the water retention rate in the dams was only 20.91% and it seemed water sufficient for only 110 days was left in 2021[28]. It's really alarming news in this metropolitan municipality. Table 2 represents that water reservoirs are not increasing in proportion with the demand of the city's population in the last few years. An alarming situation is clearly visible from 2020 to 2021 data[29].

25 Ankara Water and Sewerage Administration, Accessed 11 August, 2021. https://www.aski.gov.tr/TR/Anasayfa.

26 Olcay, Ömer. Başkentte 110 günlük su kaldı' uyarısı. Accessed 5 January, 2021. https://www.aa.com.tr/tr/turkiye/baskentte-110-gunluk-su-kaldi-uyarisi/2099031

27 egedebirgun.com. Accessed 27 July, 2021. https://www.egedebirgun.com/belediye-atik-su-istatistikleri-aciklandi/8345/

28 Olcay, Ömer. Başkentte 110 günlük su kaldı' uyarısı. Accessed 5 January, 2021. https://www.aa.com.tr/tr/turkiye/baskentte-110-gunluk-su-kaldi-uyarisi/2099031.

29 Ankara Water and Sewerage Administration, Accessed 12 February, 2022. https://www.aski.gov.tr/TR/Baraj.aspx.

Table 2. Amount of water reserves and population from 2007 to 2021 in Ankara[30][31]

Year	Population (in million)	Water reservation (m^3)
2007	4,466,756	158,780,975
2008	4,548,939	200,948,671
2009	4,650,802	627,056,100
2010	4,771,716	638,059,813
2011	4,890,893	324,211,194
2012		

[30] Turkish Statistical Institute, 2022. Nüfus ve Demografi. https://data.tuik.gov.tr/Kategori/GetKategori?p=Nufus-ve-Demografi-109 (accessed 2 April 2022)

[31] Ankara Water and Sewerage Administration, Accessed 12 February, 2022. https://www.aski.gov.tr/TR/Baraj.aspx.

4,965,5424.965.542

486,014,705

2013

5,045,083

372,070,717

2014

5,150,072

270,337,026

2015

5,270,575

500,252,056

2016

5,346,518

369,095,205

2017

5,445,026

383,189,314

2018

5,503,985

384,897,018

2019

5,639,076

495,799,679

2020

5,663,322

508,687,470

2021

5,747,325

392,802,102

Source: Turkish Statistical Institute, 2022; Ankara Water and Sewerage Administration, 2022

4. EXISTING “WATER SENSITIVE CITY” PRACTICES IN PARKS AND OPEN SPACES OF ANKARA CITY

At present, there are a total of 20 parks and gardens in Ankara and among them, one is currently closed, and other 19 are open to service in accordance with activities. Nowadays, metropolitan municipalities and municipalities are taking a number of projects to ensure sustainable parks, including Ankara. For instance, nationwide "Nation Gardens (*Millet Bahçesi*) projects" by the Ministry of Environment, Urbanisation and Climate Change aim to make people interlinked with nature, protect natural values, ensure liveability, sustainability and so on. Again, AMM has taken the "Climate Resistant Sustainable Parks Project" within the scope of adaptation to climate change. The use of rainwater and the use of less water consuming plant species adapted to the Ankara climate are planned with the project, in which a self-sufficient sustainable park will be created in terms of the water needs of the city people (Ankara Metropolitan Municipality, 2020). The following sections are discussed as different water sensitive city approaches by the municipalities of Ankara.

4.1. Biological pond

Ponds are normally described as depressions in the ground. It allows infiltration of storm water with a permanent or semi-permanent volume of water[32]. Waterbodies in city areas like lakes and ponds are playing an important role in maintaining the natural hydrological cycle, offering numerous benefits to the ecology, environment and healthy recreation. But water bodies are often getting contaminated due to mixing of wastewater from its catchment area and it is needed to treat pollution from such waterbodies. Among the ponds, biological ponds are self-cleaning ponds without the need for any chemicals. Like other landscaping projects, biological pond construction starts with the exploration work. Appropriate planning is needed to take into account as per variables such as soil structure, geographical features, annual precipitation and temperature statistics in the area where the pond will be built. Among the Municipalities of Ankara, Çankaya municipality has first in built biological pond in Ankara, and at present there are 6 biological ponds in its metropolitan area such as Ahlatlıbel Atatürk Park, Uğur Mumcu Park, Yaşar Kemal Park, İlhan Cavcav Park, İsmet İnönü Park and Zafer Park. The biological pond of Ahlatlıbel Atatürk Park with an area of 518 m² was also awarded by the Healthy Cities Association. Other biological ponds include 1500 m² in Uğur Mumcu Park, 500 m² in Yaşar Kemal Park, 426 m² in İlhan Cavcav Park, 1495 m² in İsmet İnönü Park and 1384 m² in Zafer Park.

	
Biological pond of İsmet İnönü Park	Biological pond of Zafer Park

32 Rohilla, Suresh Kumar et al. "Potential of Water-Sensitive Urban Design and Planning in Delhi: Stormwater Harvesting in Parks and Open Spaces", Centre for Science and Environment, New Delhi. 2020

	
Biological pond of İlhan Cavcav	Biological pond of Yaşar Kemal Park
	
Biological pond of Uğur Mumcu Park	Biological pond of Ahlatlıbel Atatürk Park

Figure 2. Biological ponds in Çankaya Municipality

4.2. Rainwater harvesting in parks

The collection, storage, and use of rainwater are an extremely effective method both in terms of the environment and water resources, economic gain etc. However, its practices are dependent on adaptation and adoption by the users or effective practice by the service delivery organisations[33]. The inclusion of rainwater by the municipalities through zoning regulations in Turkey provides an example of the importance given to this issue. Rainwater harvesting at different parks in the Ankara Metropolitan Municipality has started to provide such opportunities. The Mayor of AMM has announced plans to store rainwater in 40 parks in Ankara. Its first attempt has been made from Göksu Park. It will help to meet irrigation facilities in all green areas (parks) of Ankara by establishing a rainwater tank. Even ABB Mayor has planned to collect rainwater that accumulates on the roofs and use it to irrigate the green area which focuses on the sustainable way use of water for the future generations. The ANFA General Directorate first established water tank to collect rainwater from the roofs of administrative buildings and

[33] Ahsan Md Moynul, Özbek Nimet and Mahmood Shah S. M. "Assessment of Rainwater Harvesting in Coastal Bangladesh: A Comparative Study Between Southwest and Central Coast of Bangladesh. *E-journal of Social and Legal Studies.* 1 No. 3, 2015

enterprises. It is planned to create rainwater storage areas with a capacity of 20 tons and planned for more in all parks in the capital. The AMM, aiming to reduce the waste of water to a great extent, aims to use the water resources of the capital city correctly and effectively, as the water level in the dams falls to the lower limits[34]. The following figure 3 shows the rainwater tank in a park[35].

Figure 3. Rainwater Harvesting Tank in the park

4.3. Grey Water Recycling and Reuse

Grey water or sullage is generated in households or office buildings from streams without fecal contamination. The sources of greywater include sinks, showers, baths, washing machines or dishwashers. It is generally safer to handle and easier to treat and reuse onsite for toilet flushing, landscape or crop irrigation, and other non-potable uses. The application of greywater reuse in urban water systems provides substantial benefits for both the water supply subsystem, by reducing the demand for fresh clean water[36] as 50-80 wastewater belongs to domestic wastewater. They implemented Gray Water Recovery project in February 2020. It is also intended to save 50 liters of water per person per day on average, as well as to reduce bills by up to 50%.

Among the municipalities in Ankara, Gölbaşi Municipality has first taken up a rainwater recycling project in 2021. Within the scope of the "Rainwater Recycling" project, the municipality started to collect rainwater from the roofs of the

34 Ankara Water and Sewerage Administration, Accessed 12 February, 2022. https://www.aski.gov.tr/TR/Baraj.aspx.

35 en.rayhaber.com, ankaraya yagmur suyu depose parklar yagmur suyu ile sulanacak. Accessed 12 February, 2022. https://en.rayhaber.com/2021/04/ankaraya-yagmur-suyu-deposu-parklar-yagmur-suyu-ile-sulanacak/

36 tehrantimes.com. "Graywater reuse a sustainable solution to water scarcity. Accessed 12 February, 2022. https://www.tehrantimes.com/news/430436/Graywater-reuse-a-sustainable-solution-to-water-scarcity

buildings to tanks. The municipality has installed a 20-ton rainwater storage tank in its Parks and Gardens Directorate. Again, a total area of 23,076 m² will be irrigated by the collected rainwater from the rainwater storage tank. The Mayor has intended to expand rainwater harvesting practices in parks of Gölbaşı municipality. Again, in order to increase the water holding capacity of the soil, improving soil condition, planting drought-resistant plants that require less water, using ground cover plants instead of grass areas and thereby saving water by establishing an automatic irrigation system in order to ensure effective use of water when the rainwater storage tank is insufficient[37].

5. CHALLENGES OF WATER SENSITIVE CITIES IN ANKARA

Water sensitive cities encompass a wide range of activities such as source control, urban design, water reuse, green infrastructure, run-off volume reduction (Farrant, 2019). There are various challenges faced by the implementation of WSC. Among them, climatic, institutional and societal challenges are significant. This study has discussed briefly about these challenges below:

5.1. Climatic challenges

Climate change impact due to flood, drought or heatwave is major in these respects. Due to climate change and other related factors, Ankara is experiencing floods that are mainly caused by unpredictable heavy rainfall, inadequate infrastructure, and topographical conditions, and climate change has intensified this[38]. Ankara represents below average level in terms of water and soil potential compared to other provinces in Turkey. The impact of change puts an ultimate strain on existing city dwellers and incoming migrants' access to, availability of, and use of water[39]. It has already been discussed that the geographical and topographical conditions create particular challenges in Ankara. During the dry season, Ankara is also considered one of the driest areas in Turkey. Ankara faced a water supply crisis during a drought in 2007. Statistics show that Ankara can presume a drought once every four years and that the return period for a severe drought that affects 50% of the region is five years[40].

---

37 Golbaşı Municipality. Accessed 7 February, 2022. https://www.ankaragolbasi.bel.tr/haberler/golbasi-belediyesi-su-yuna-sahip-cikiyor-39727.html.

38 Ahsan Md Moynul. "Climate Change Adaptation-Based Strategies on Water and its Security: A Study on Dhaka and Ankara", *Journal of Security Sciences,* (February 2020): 79-93. DOI:10.28956/gbd.695924

39 Ahsan, 80

40 Ahsan, 82

5.2. Institutional challenges

In Ankara city, 'parks' and 'open spaces' are parts of civic amenities planned, designed, implemented, and maintained by the Ankara Metropolitan Municipality. Municipalities are constructing and maintaining new parks through their financial and human resources. In case of retrofitting existing parks with WSC features, the Municipal authority is responsible for implementation. Maintenance of WSC interventions should be undertaken along with regular maintenance activities in the parks[41] (Centre for Science and Environment, 2017). The institutional responsibilities for various activities with respect to WSC interventions in parks and open spaces are mentioned in Table 3.

Table 3. Institutional set-up for WSC in parks and open spaces

WSC intervention	Plan, project, operation and maintenance	Organization
Planning norms for parks	City plans	Municipality, Ministry of urbanisation, environment and climate change
Identification of parks and open spaces	City drainage plan	Municipality, Ministry of Urbanisation, environment and climate change
Implementation and operation	WSC projects	Municipality/ metropolitan municipality
Maintenance and monitoring	Operation and maintenance schedule and activities	Municipality/ metropolitan municipality

Institutions are also facing some challenges and opportunities regarding planning and coordination; financial management; existing acts, bye-laws, rules and regulations; community participation, and culture/knowledge/capacity.

Table 4. Institutional challenges and opportunities in water sector

Challenges and opportunities	Existing actions	Comments
Planning and coordination	Coordinated planning is available	Inter-departmental collaborative initiatives are needed from central to local level.
Finance management	Çankaya Municipality implemented a pilot park, but it later implemented 5 more	Çankaya municipality has received funds from the European Union's Horizon 2020 research and innovation programme under grant

[41] Centre for Science and Environment. "Water Sensitive Urban Design And Planning: A Practitioner's Guide, 2017, Centre for Science and Environment, India.

	parks under their own budget. Golbaşı municipality and Ankara metropolitan Municipality in general has taken some initiative. Other municipalities still lack innovative financially viable solutions and conventional cost intensive approaches.	agreement no. 730468. Municipality implemented a pilot park, however later it has implemented 5 more parks under their own budget. Other municipalities still lack innovative financially viable solutions, conventional cost intensive approaches.
Acts, bye-laws, rules and regulations	Key drivers how organizations work to strategize, plan, budget, and implement projects	
	Urban Design Guidelines / Volume I	Integrate urban water cycle management (drinking water, wastewater and precipitation) into city planning and design. Among the policies and strategies of water-sensitive urban design approach, which targets water-sensitive urban design, are rainwater management and green infrastructure techniques, providing natural drainage and absorption, preventing floods, improving water quality, enriching groundwater, reducing clean water consumption and ensuring biodiversity[42].
	Regulation on Rainwater harvesting, collection, storage and discharge systems, 2017	To regulate the procedures and principles regarding planning, design, project planning, construction and operation of storm water collection, storage and discharge systems[43] .
	Ankara Province Local Climate Change Action Plan 2019-2024.	AMM has taken the 'Climate Resistant Sustainable Parks Project' within the scope of adaptation to climate change. The use of rainwater and the use of less water consuming plant species adapted to Ankara climate are planned for the project, in which a self-sufficient sustainable park will be created in terms of the water needs of the city people (Ankara Metropolitan Municipality, 2020).

42 Ministry of Environment and Urbanisation. "Kentsel Tasarim Rehberleri / Cilt I: Araştırma ve Tanımlama". 2016. İncekara Matbaacılık, İstanbul.

43 Ministry of Environment and Urbanisation. Yağmursuyu Toplama, Depolama Ve Deşarj Sistemleri Hakkında Yönetmelik. Accessed 10 January, 2022. https://www.resmigazete.gov.tr/eskiler/2017/06/20170623-8.htm

	Ankara Metropolitan Municipality Strategic Plan 2020- 2024	Strategic Goal 3 states about protecting ecological balance with a nature and animal friendly management approach, support biological diversity, effective waste management and renewable energy policies, adopt sustainable environmental management, and are aware of the negative effects of climate change. However, there is no clear focus on nature based solutions for the water sector.
	Ankara Province Drinking Water, Wastewater and Stormwater Management Master Plan	The plan is signed between Ankara Water and Sewerage Administration General Directorate (ASKİ) and TEMELSU - SU-YAPI Joint Venture on 7 April 2020. This plan will focus planning of storm water collection and stream systems, the impacts of climate change on precipitation, snow melting and water resources etc.[44]
	Ankara Green city Action Plan	This plan is under plan preparation process. It is expected that the plan will provide robust actions and activities for nature-based solutions on water sector for Ankara city.
Community participation	It is needed to ensure community participation and development of active citizen's forum, platform.	Societal acceptance is highly important in this aspect.
Knowledge/Capacity	Knowledge and institutional capacity are highly needed to ensure water sensitive city management.	Lack of knowledge and institutional capacity to ensure water sensitive city management.

RECOMMENDATIONS AND CONCLUSION

Water Sensitive Cities provide multi-dimensional benefits for the city and its people. As there are still many institutional, planning and challenges that are available and inadequate in acts, plans, policies, and laws, therefore, firstly a robust policy and action should be taken for the city of Ankara. As water crisis in Ankara is enormous therefore, water and water related policy interventions should be systematically addressed so that city people can enjoy its benefits. In this

[44] suyapi.com.tr. "Ankara Province Drinking Water, Wastewater and Stormwater Management Master Plan contract was signed. Accessed 10 February, 2022. https://www.suyapi.com.tr/en/41174/Ankara-Province-Drinking-Water-Wastewater-and-Stormwater-Management-Master-Plan-contract-was-signed

respect, integrated action or polycentric approaches are needed with adequate financial support in order to achieve success in water sensitive city planning and design. As polycentric approaches move through a holistic way: through existing ground realities, cooperation between multiple sectors and stakeholder groups, adapt with urban systems to quickly changing frameworks, generate cross-sectoral perception of cities' resources, and dynamic transformation of production and consumption patterns, so necessary actions can be taken from this multidisciplinary perspective. As it is multi-stakeholder engagement between local government agencies, planners, utilities, communities, households, the private sector, and civil society, and thus it provides an indispensable prerequisite for the sustainability and long-term maintenance of implemented solutions.

City management authorities need more public awareness to work for sustainable urban development. There is a need to increase awareness of the users/citizens. The NbS practices of Ankaya Municipality and Golbaş Municipality, as well as Ankara Metropolitan Municipality, serve as a model for other cities interested in promoting a water-sensitive city approach. Therefore, it seems that strong and committed political leadership and good coordination among relevant agencies seem indispensable for making a water sensitive city. Though the Ankara Metropolitan Municipality is taking some actions and activities, municipalities in Ankara need to ensure reliable and effective water services to its citizens, and also need to establish financial availability and sustainability. A clear, citywide vision and goal of WSC should be set out for the city's resilience. Respective local government bodies must also focus on service delivery, service levels, operating performance, and incentives in this regard. As WSC measures are multifunctional, therefore, a comprehensive and integrated strategy/master plan should be developed to explore social, economic, climate, and environmental benefits. Finally, nature-based solution practices are implemented in diverse ways in Ankara, but a guideline is needed in urban planning guidelines and regulations.

Community participation from design to implementation of WSC measures is a key factor in ensuring success. A consensus of expanding water systems is needed in order to build urban resilience. Awareness of the advantages of WSC should be communicated to the public. For widespread implementation, the use of WSC should be incentivized for the private sector and urban dwellers. Again, in terms of knowledge and design, international practices should follow up, build capacity of the local consultants and contractors, and demonstrate the projects to the municipalities that will help stakeholders and developers to see and experience WSC benefits.

REFERENCES

1. Ahsan Md Moynul. "Climate Change Adaptation-Based Strategies on Water and its Security: A Study on Dhaka and Ankara", *Journal of Security Sciences,* (February 2020): 79-93. DOI:10.28956/gbd.695924
2. Ahsan Md Moynul. "Strategic decisions on urban built environment to pandemics in Turkey: Lessons from COVID-19", *Journal of Urban Management,* 9 No.3, (September 2020): 281-285. https://doi.org/10.1016/j.jum.2020.07.001
3. Ahsan Md Moynul, Özbek Nimet and Mahmood Shah S. M. "Assessment of Rainwater Harvesting in Coastal Bangladesh: A Comparative Study Between Southwest and Central Coast of Bangladesh. *E-journal of Social and Legal Studies.* 1 No. 3, 2015.
4. Almassy, Dora et al., "Urban Nature Atlas: A Database of Nature-Based Solutions Across 100 European Cities", 2018
5. Ankara Water and Sewerage Administration, Accessed 11 August, 2021. https://www.aski.gov.tr/ TR/Anasayfa.
6. Ankara Water and Swerage Administration. Ankara Büyükşehir Belediyesi ASKİ General Directorate 2020 Yılı Activity Report. Department of Strategy Development, 2021.
7. Ankara Water and Sewerage Administration, Accessed 12 February, 2022. https://www.aski.gov.tr/TR/Baraj.aspx.
8. Ankara Metropolitan Municipality. "T.C. Ankara Ili Ankara Büyükşehir Belediye Başkanliği 2020 Yılı Faaliyet Raporu". 2021.
9. Ankara Metropolitan Municipality. Ankara Ili Yerel Iklim Değişikliği Eylem Planı, 2020. Accessed 10 January, 2022. https://www.ankara.bel.tr/files/3616/3723/8519/Ankara_Yerel_Iklim_Degisikligi_Eylem_Plani.pdf
10. Brown, RR. Et al. "Urban water management in cities: Historical, current and future regimes." *Water, Science and Technology: A Journal of the International Association on Water Pollution Research*, 59(5), 847–55. 2009.
11. Centre for Science and Environment. "Water Sensitive Urban Design And Planning: A Practitioner's Guide, 2017, Centre for Science and Environment, India.
12. CRC Water Sensitive Cities. "What is a water sensitive city?". Accessed 5 December, 2021. https://watersensitivecities.org.au/what-is-a-water-sensitive-city/
13. Department of Meteorology. "Cities & Holiday Resorts: Ankara. 2022. Accessed 12 February, 2022. https://www.mgm.gov.tr/eng/forecast-cities.aspx
14. egedebirgun.com. Accessed 27 July, 2021. https://www.egedebirgun.com/belediye-atik-su-istatistikleri-aciklandi/8345/.
15. en.rayhaber.com. Dams Supplying Ankara with Drinking and Potable Water Alarms, Accessed 28 August, 2021. https://en.rayhaber.com/2021/01/ankaraya-icme-ve-kullanma-suyu-saglayan-barajlar-alarm-veriyor/ egedebirgun.com.
16. en.rayhaber.com, ankaraya yagmur suyu depose parklar yagmur suyu ile sulanacak. Accessed 12 February, 2022. https://en.rayhaber.com/2021/04/ankaraya-yagmur-suyu-deposu-parklar-yagmur-suyu-ile-sulanacak/
17. Fergusona, Briony C. et al. "A strategic program for transitioning to a Water Sensitive City", Landscape and Urban Planning 117, 2013. https://doi.org/10.1016/j.landurbplan.2013.04.016

18. Forest Stearns, Tom Montag. *The Urban ecosystem: a holistic approach.* New York: Halsted Press, 1975.
19. Fumero, Andera. '*Water Sensitive Urban Design (WSUD) as a climate adaptation strategy*'. KTH Royal Institute of Technology, School of architecture and the built environment, 2020.
20. Golbaşı Municipality. Accessed 7 February, 2022. https://www.ankaragolbasi.bel.tr/haberler/golbasi-belediyesi-su-yuna-sahip-cikiyor-39727.html.
21. IWA. "The IWA Principles Water Wise Cities 2nd Edition", International Water Association. Accessed 9 February, 2022. https://iwa-network.org/wp-content/uploads/2016/10/IWA_ Brochure_Water_Wise_Communities_SCREEN-1.pdf
22. Hoyer, Jacqueline et al. "Water Sensitive Urban Design. Principles and Inspiration for Sustainable Stormwater Management in the City of the Future". Manual. HafenCity Universität. 2011
23. Ministry of Environment and Urbanisation. Yağmursuyu Toplama, Depolama Ve Deşarj Sistemleri Hakkında Yönetmelik. Accessed 10 January, 2022. https://www.resmigazete.gov.tr/eskiler/2017/06/20170623-8.htm
24. Ministry of Environment and Urbanisation. "Kentsel Tasarim Rehberleri / Cilt I: Araştırma ve Tanımlama". 2016. İncekara Matbaacılık, İstanbul.
25. Olcay, Ömer. Başkentte 110 günlük su kaldı' uyarısı. Accessed 5 January, 2021. https://www.aa.com.tr/tr/turkiye/baskentte-110-gunluk-su-kaldi-uyarisi/2099031.
26. Pusalkar, Vandana et al. "Future city - challenges and opportunities for water-sensitive sustainable cities in India" *E3S Web of Conferences 170, 06017,* 2020, https://doi.org/10.1051/e3sconf/202017006017. https://www.e3s-conferences.org/articles/e3sconf/pdf/2020/30/e3sconf_evf2020_06017.pdf
27. Rohilla, Suresh Kumar et al. "Potential of Water-Sensitive Urban Design and Planning in Delhi: Stormwater Harvesting in Parks and Open Spaces", Centre for Science and Environment, New Delhi. 2020
28. suyapi.com.tr. "Ankara Province Drinking Water, Wastewater and Stormwater Management Master Plan contract was signed. Accessed 10 February, 2022. https://www.suyapi.com.tr/en/ 41174/Ankara-Province-Drinking-Water-Wastewater-and-Stormwater-Management-Master-Plan-contract-was-signed
29. Tanrıvermiş, Y., Canaz Sevgen, S. & Tanrıvermiş, H. (2022). Land Cover Monitoring Techniques and Spatiial Development: The Case of Capıtal of Turkey . *International Journal of Geography and Geography Education, 45*, 437-453 . DOI: 10.32003/igge.1007780
30. Türkeş, Murat. "Drought Vulnerability and Risk Analysis of Turkey with Respect to Climatic Variability and Socio-Ecological Indicators", Aegean Geographical Journal, 26(2), 2017.
31. Teoman, M.B. et al. "Assessment of slope stability in Ankara clay: a case study along E90 highway", *Env Geol 45, 2004.*
32. tehrantimes.com. "Graywater reuse a sustainable solution to water scarcity. Accessed 12 February, 2022. https://www.tehrantimes.com/news/430436/Graywater-reuse-a-sustainable- solution-to-water-scarcity
33. Wong, Tony H. F. "An Overview of Water Sensitive Urban Design Practices in Australia", *Water Practice & Technology 1(1),* 2006.

Chapter 16

DETERMINING RAINWATER HARVESTING PRIORITY REGIONS FOR METROPOLITANS WITH USER FRIENDLY COMPUTER SIMULATOR: A CASE STUDY İN IZMIR METROPOLITAN

Erman Ülker* - Hadya Taşçı**

INTRODUCTION

Technological and industrial developments are milestones for guiding the world's climate balance on uncontrolled consumption of water and growth of environmental pollution[1]. Climate change has the potential to tip out of balance in a civilization about the ability to access water, food, and energy systems[2]. The rapid growth of the population and industrialization cause natural resource depletion, particularly water resources. The negative impact of climate change and environmental pollution on water resources is increasing day by day, and the strategic importance of water leads to priority cases for authorities[3]. Recently, interest and demand for sustainable sources are constantly increasing due to climate changes and global warming. Although the most existing resources in the

* İzmir Katip Çelebi University, Civil Engineering Department, erman.ulker@ikc.edu.tr
** İzmir Katip Çelebi University, Civil Engineering Department, hadya.tasci@yahoo.com

1 Christian Amos, C., Rahman, A., & Mwangi Gathenya, J. (2016). Economic analysis and feasibility of rainwater harvesting systems in urban and peri-urban environments: A review of the global situation with a special focus on Australia and Kenya. Water, 8(4), 149.

2 Angrill, S., Farreny, R., Gasol, C. M., Gabarrell, X., Viñolas, B., Josa, A., & Rieradevall, J. (2012). Environmental analysis of rainwater harvesting infrastructures in diffuse and compact urban models of Mediterranean climate. The International Journal of Life Cycle Assessment, 17(1), 25-42.

3 Campisano, A., Butler, D., Ward, S., Burns, M. J., Friedler, E., DeBusk, K., ... & Han, M. (2017). Urban rainwater harvesting systems: Research, implementation and future perspectives. Water research, 115, 195-209.

world are water, most countries face a severe lack of sufficient water, also called water scarcity [4] [5] [6].

It is obvious to state that water resources have to be used reasonably to protect ecological stability and provide the sustainable development of civilization. Indeed, ecological regulations and research have gain momentum across the world. Due to the unplanned urbanization in metropolitan cities, municipalities search for alternative resources to meet their water needs. One study provided a comprehensive overview of governmental approaches to Rainwater Harvesting (RWH) system implementations in buildings[7]. Existing designs produce short-term solutions, and their negative effects on climate and ecological stability begin to be seen. All these concerns are combined with sustainability, RWH system comes into prominence.

Water security has become a risk in recent years, as climate change has considerably modified the dry and wet periods, leading to an imbalance in water availability for the year. Water scarcity is a problem for many developing countries, where rainwater is the main source of drinking water. Moreover, the rainwater collection systems can supply water suitable for agriculture and domestic use [8]. The harvesting of rainwater from rooftops is a simple method to reduce the demands and utilization of public water resources. Obtained rainwater can also be utilized in diverse regions such as toilet flushing, toilet sinks, and irrigation systems [9]. Furthermore, the harvested water can be used for other purposes, such as long-term storage for firefighting and groundwater beneficiation.

The governments can lead the development of sustainable cities throughout incentives and regulations of these systems. RWH system provides the chance to achieve economic and environmental goals against rising water demands and economic benefits, which leads to become self-sufficient locations for their water

---

[4] Brodie, I. M. (2008). Hydrological analysis of single and dual storage systems for stormwater harvesting. Water Science and Technology, 58(5), 1039-1046.

[5] Burns, M. J., Fletcher, T. D., Duncan, H. P., Hatt, B. E., Ladson, A. R., & Walsh, C. J. (2012). The stormwater retention performance of rainwater tanks at the landparcel scale. In WSUD 2012: Water sensitive urban design; Building the water sensitive community; 7th international conference on water sensitive urban design (p.195). Engineers Australia.

[6] Hamel, P., & Fletcher, T. D. (2014). The impact of stormwater source-control strategies on the (low) flow regime of urban catchments. Water science and technology, 69(4), 739-745

[7] Campisano, A., Butler, D., Ward, S., Burns, M. J., Friedler, E., DeBusk, K., ... & Han, M. (2017). Urban rainwater harvesting systems: Research, implementation and future perspectives. Water research, 115, 195-209.

[8] Helmreich, B., & Horn, H. (2009). Opportunities in rainwater harvesting. Desalination, 248(1-3), 118-124.

[9] GhaffarianHoseini, A., Tookey, J., GhaffarianHoseini, A., Yusoff, S. M., & Hassan, N. B. (2016). State of the art of rainwater harvesting systems towards promoting green built environments: a review. Desalination and Water Treatment, 57(1), 95-104.

needs and delay the need to construct new water infrastructures [10] [11] [12]. To maximize the harvesting potential of water, the most important parameter is optimizing the tank capacity with respect to rainfall intensity and duration projection [13] [14].

This research aimed to bring a new perspective to guide authorities to take measures or provide funds for a sustainable environment in their region. A web-based RWH simulator is developed in Java and applied on the previous study [15]. As a case study, two districts of Izmir metropolitan are chosen to investigate and show that each district needs different concentration points to start fast recovery for their water resources.

1. METHODOLOGY

Rainwater harvesting (RWH) is an effective water management model that allows rain to be kept in the area where it is falling. The application of an appropriate RWH system is necessary, especially in areas where rainfall exceeds annually 300 mm [16]. Recent RWH applications are a combination model of rain and moisture. It has been observed that the amount of water used in activities that do not require potable water, such as toilet flushing, irrigation, and domestic use, is dominant. Domestic purposes also include cleaning, fire extinguishing, laundry, toilet reservoirs, car washing, and irrigation. However, the drinking water quality is necessary for showering, cooking, and washing dishes that need some complex filtration and disinfection processes, increasing the design cost. Determining the volume of rainwater storage should be regulated according to the amount of water harvesting and monthly water consumption measurements of the building. The necessary coefficient can be selected according to the pollution rate of the surfaces in the region; therefore, various scenarios are needed to take into account.

---

10 Steffen, J., Jensen, M., Pomeroy, C. A., & Burian, S. J. (2013). Water supply and stormwater management benefits of residential rainwater harvesting in US cities. JAWRA Journal of the American Water Resources Association, 49(4), 810-824.

11 Devkota, J., Schlachter, H., & Apul, D. (2015). Life cycle-based evaluation of harvested rainwater use in toilets and for irrigation. Journal of cleaner Production, 95, 311-321.

12 Morales-Pinzón, T., Lurueña, R., Gabarrell, X., Gasol, C. M., & Rieradevall, J. (2014). Financial and environmental modelling of water hardness—Implications for utilising harvested rainwater in washing machines. Science of the Total Environment, 470, 1257-1271.

13 Domènech, L., & Saurí, D. (2011). A comparative appraisal of the use of rainwater harvesting in single and multi-family buildings of the Metropolitan Area of Barcelona (Spain): social experience, drinking water savings and economic costs. Journal of Cleaner production, 19(6-7), 598-608.

14 Gardner, T., & Vieritz, A. (2010). The role of rainwater tanks in Australia in the twenty first century. Architectural Science Review, 53(1), 107-125.

15 Hajjar, H., Kilinc, I. K., & Ulker, E. Rainwater Harvesting Potential in Public Buildings: A Case Study in Katip Celebi University. Türk Doğa ve Fen Dergisi, 9(Özel Sayı), 167-172.

16 Syed Azizul Haq, P. (2016). Harvesting rainwater from Buildings. Springer.

These scenarios vary with the design parameters: tank capacity, rainfall amount and intensity, water demand, and total surface area. The amount of water to be supplied from the network is determined monthly. So, the optimal tank size and location can be determined. In the following sub-sections, the study area, prediction of precipitation in the study area, and developed RWH Simulator are described.

1.1. Study area

The Gediz Delta was formed from anthropogenic old alluvial that accumulated over a very large area as a result of frequent displacement of the bed where the river empties into the sea. The region consists of the formation of Neogene aged volcanic. Precipitation is the basis of the groundwater feeding mechanism of Neogene Volcanics. The lateral flows of adjacent rocks can also feed them. The formations containing groundwater are similar to each other in Karsiyaka, Menemen, Foca, and Aliaga districts of Izmir, Turkey. There is an alluvial aquifer consisting of clay, silt, sand, gravel, and block-sized materials. The alluvial aquifer has a significant amount of groundwater reserves in the area. The alluvial aquifer is especially fed by the flow of the Gediz River and through rainfall, as seen in Figure 1. Drinking water in Izmir is supplied approximately 800 L/s according to IZSU (Izmir Water and Drainage Organization) by drilled wells in the alluvial aquifer. The Gediz Delta is a young alluvial fan. The characteristic of the coastal plain is a marsh. The total agricultural land covers 26% irrigated and 74% non-irrigated land. From the residential areas in Cigli region, public institutions have large roof areas.

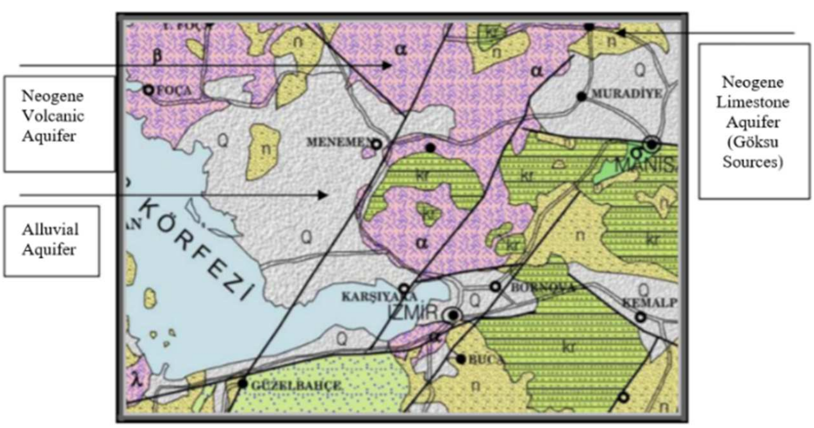


Figure 1. Aquifers in the North and northeast of Izmir [17]

[17] E. Kazanasmaz (2009). Kentimiz ve çevresinin yeraltısuyu kaynakları, yeraltısuyunu kirletici etkenler ve su kıtlığı riski. TMMOB Izmir Municapility Symposium.

The buildings that may be faulty are checked by making a parcel query from the TKGM (Turkish General Directorate of Land Registry and Cadastre) website and taking into account projections. More precise results can be obtained with the help of steep projections on the TKGM website. Building locations and shapes have been verified with 3D street images in Google Earth. Karsiyaka and Cigli districts are shown below in Figures 2 and Figure 3, respectively.

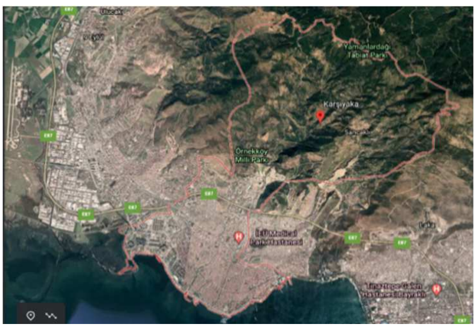


Figure 2. The district boundaries of Karsiyaka

Figure 3. The district boundaries of Cigli

1.2. Precipitation in Izmir

The region has a Mediterranean climate that contains hot, dry summers and mild, rainy winters. More than 50% of the annual rainfall occurs during the winter season. 40-45% fall in spring and autumn, and 2-4% in summer. The average annual rainfall is 710.5 mm between 1938 and 2020. The maximum and minimum monthly average precipitation is 145.7 mm in December and 4.1 mm in July, respectively. The maximum and the minimum number of rainy days are 14.4 days in December and 0.7 days in July, respectively [18]. The graphical representation of the rainfall amount and average monthly rainfall days versus months are presented in Figure 4 and Figure 5, respectively.

[18] General Directorate of Meteorology Average of Monthly precipitation; 2020. Available from: https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=IZMIR.

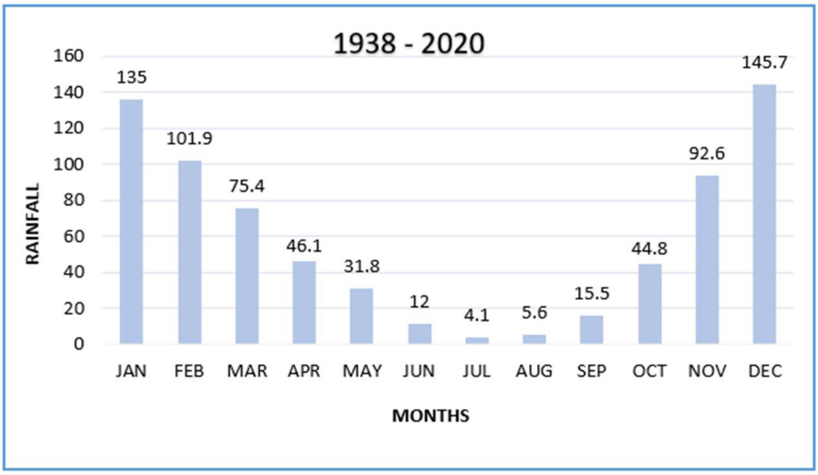


Figure 4. The average monthly precipitation (mm) in Izmir

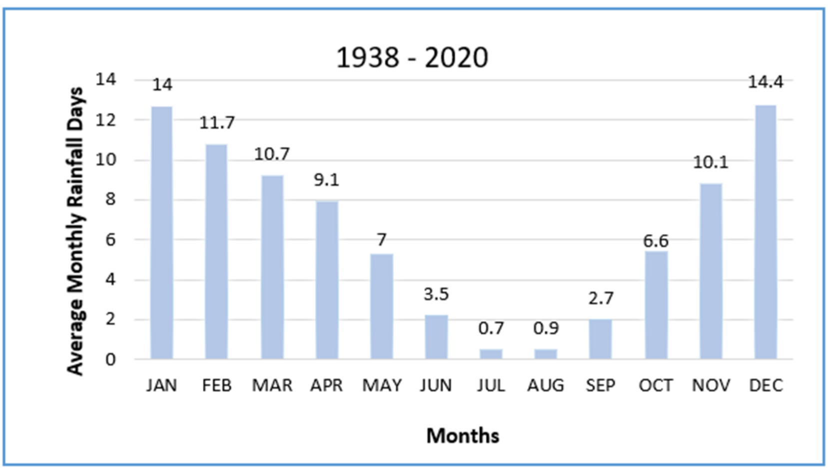


Figure 5. The average monthly rainy days in Izmir

1.3. Computer Simulation

A computer simulation imitates the operation of a system over time. The intended purpose of the simulation is to present the underlying mechanisms that control the behavior of the system. The program is developed to simulate the RWH system and assess the RWH system's potential. It is constructed web-based by adding the system's input and determining the analysis results by displaying user-friendly interfaces using Java programming languages. The simulation shows how much water is utilized in different created scenarios during the different time periods by embedding the amount and intensity of precipitation and reducing possible overflow to get the maximum tank capacity. The website's home page consists of three parts: inputs, table of results, and graphical representation of results. The inputs page, shown in Figure 6, is a list that contains a set of variables required for the simulation, such as; start date, location, catchment surface area, water demand, rainfall days calculation method, and calculation period. There are two different modes of rainfall days calculation, random mode, and continuous uniform distribution mode. The random mode is operated by dividing the amount of monthly rainfall by the number of rainy days in the same month; then, the program randomly selects the rainy days. On the other hand, the continuous uniform distribution mode is operated by dividing the monthly rainfall amount by the number of days in the month. After starting the simulation process, the volume of stored rainwater and the total savings change over the required time. The total savings value starts from a negative value that indicates the initial system cost, and by continuing the simulation process, this value starts to increase the profit. The system also presents the consumed main water volume and the overflow water volume. The total savings value changes according to the selected scenario. The second page, shown in Figure 7, contains the table of simulation results, and the last page, shown in Figure 8, has the diagrams that include; cost by scenario, rainfall days, rainfall (mm), cash flow, overflow, and payoff.

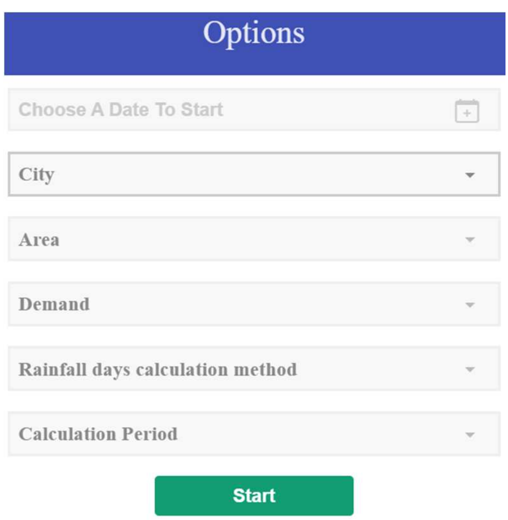


Figure 6. The inputs data

Date	rainfall amount	water collected	water used	cash flow	accumulated savings
1 - 2021 July (31) days	no rain	0.00 m³	0.000 m³	0.00 tl	-242957.00 tl
2 - 2021 August (31) days	11.40 mm	266.30 m³	266.298 m³	2556.46 tl	-240400.54 tl
3 - 2021 September (30) days	31.60 mm	738.16 m³	370.220 m³	3554.11 tl	-236846.42 tl
4 - 2021 October (31) days	33.04 mm	771.73 m³	771.729 m³	7408.60 tl	-229437.83 tl
5 - 2021 November (30) days	21.30 mm	497.45 m³	320.058 m³	3072.55 tl	-226365.28 tl
6 - 2021 December (31) days	101.46 mm	2370.08 m³	1438.499 m³	13809.59 tl	-212555.68 tl
7 - 2022 January (31) days	96.45 mm	2253.00 m³	939.992 m³	9023.92 tl	-203531.76 tl
8 - 2022 February (28) days	132.61 mm	3097.73 m³	846.039 m³	8121.97 tl	-195409.78 tl
9 - 2022 March (31) days	73.96 mm	1727.59 m³	1359.122 m³	13047.57 tl	-182362.21 tl
10 - 2022 April (30) days	58.23 mm	1360.17 m³	1168.269 m³	11215.38 tl	-171146.83 tl
11 - 2022 May (31) days	23.47 mm	548.29 m³	680.693 m³	6534.66 tl	-164612.17 tl
12 - 2022 June (30) days	5.27 mm	123.17 m³	123.168 m³	1182.42 tl	-163429.75 tl
13 - 2022 July (31) days	no rain	0.00 m³	0.000 m³	0.00 tl	-163429.75 tl
14 - 2022 August (31) days	22.80 mm	532.60 m³	295.186 m³	2833.79 tl	-160595.97 tl
15 - 2022 September (30) days	23.70 mm	553.62 m³	427.108 m³	4100.24 tl	-156495.73 tl

Figure 7. The simulation results

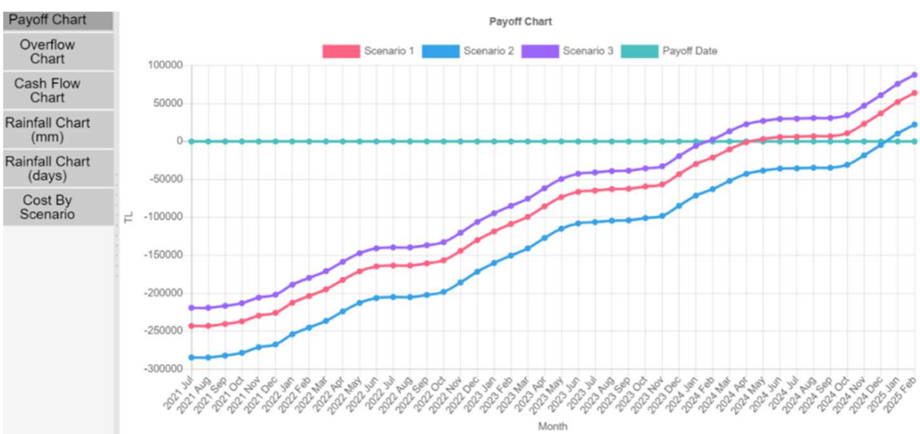


Figure 8. The simulation charts

2. RESULTS AND DİSCUSSİONS

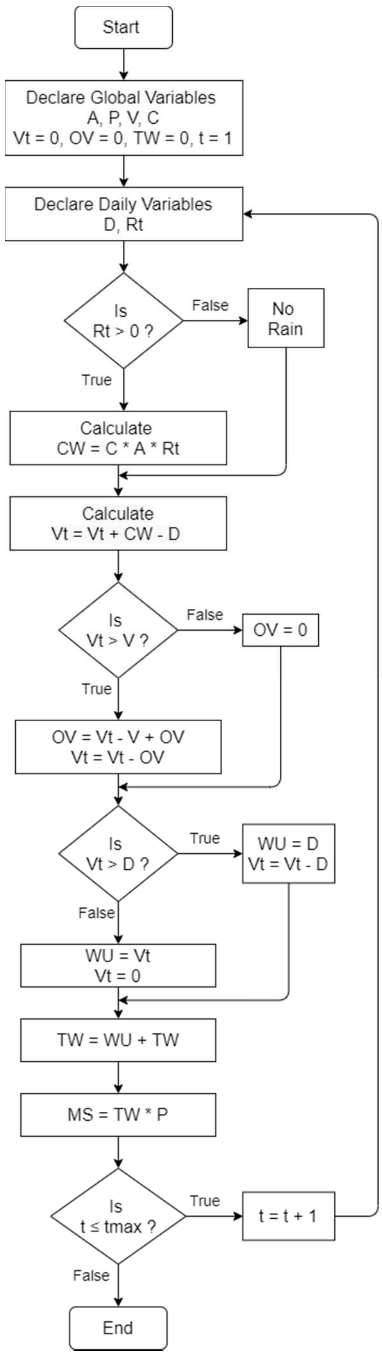
In the present study, the simulation is performed for the rainwater harvesting (RWH) systems in Karsiyaka and Cigli regions. At first, the model is implemented in Izmir Katip Celebi University, located in the Cigli region, for obtaining the performance of the RWH Simulator. In order to get clear data, the semester breaks, summer break, and public holidays take into account.

Installation of the flow meters on the supply pipes aimed to determine the consumption amount. The volume of harvested rainwater is estimated based on the rainfall data in Izmir metropolitan and the catchment area of the building, as shown in Table 1.

Table 1. Monthly amounts of harvestable rainwater in IKCU

Months	Catchment Area m^2	Average Monthly Rainfall (mm)	Runoff Coefficient	Rainwater Supply m^3
January	25,955.6	135	0.9	3,153.6
February	25,955.6	101.9	0.9	2,380.4
March	25,955.6	75.4	0.9	1,761.3
April	25,955.6	46.1	0.9	1,076.9
May	25,955.6	31.8	0.9	742.8
June	25,955.6	12	0.9	280.3
July	25,955.6	4.1	0.9	95.8
August	25,955.6	5.6	0.9	130.8
September	25,955.6	159.5	0.9	362.1
October	25,955.6	44.8	0.9	1,046.5
November	25,955.6	92.6	0.9	2,163.1
December	25,955.6	145.7	0.9	3,403.6
Total	25,955.6	710.5	0.9	16,597.3

As rainfall is an uneven phenomenon, there are wet days and dry days. Therefore, two methods were added to the simulation to determine the rainfall days. The first method is the random mode that randomly chooses the rainy days considering the number of rainy days and the average monthly precipitation. The second mode is the uniform distribution that considers the rainfall amount is uniformly in all the days. According to the daily data, all the calculations were carried out, even for the weekly and monthly periods. The cash flow of the system relies on the unit price of water and used water amount. During the simulation, the total savings start from the system's cost as a negative value, and this value increases till the breakeven point. In order to determine the optimal system, there are many scenarios applied in this simulation by considering the amount and intensity of the precipitation. The program flowchart is shown in Figure 9. According to the optimization results, the breakeven point appears in this study after three years from the starting system in Izmir Katip Celebi University as shown in Figure 10. The overflow charts show the changes in excess water and the used main water over time, and although the overflow value exceeds the used main water value, there is a need for main water because that depends on the storage volume available in the system, as shown in Figure 11. After successfully performing the developed simulation in the case study of Izmir Katip Celebi University, the study is extended to two different districts of Izmir metropolitan for analyzing the recovery amount of water resources with RWH systems. The all-public buildings, such as schools, sports centers, hospitals, are implemented in the Simulator for determining the maximum rainwater harvesting potential. It is investigated that implementing RWH systems in public buildings recover about 1% of the population water needs either for Cigli or Karsiyaka. However, there is an Organized Industrial Zone in Cigli, which is indirectly regulated by the authorities. If the Organized Industrial Zones buildings play roles in the calculation, the recovery ratio increases 13% water need of Cigli population. The monthly harvestable rainwater in Cigli and Karsiyaka are tabulated in Table 2 and Table 3, respectively.



Simulation Variables:

t = Day

V = Tank volume m^3

A = Catchment area m^2

D = Demand m^3/day

Rt = Rainfall mm

C = Runoff coefficient

P = Water price (TL)

Vt = Current tank storage volume (water) m^3

OV = Overflow m^3

WU = Water used m^3

CW = Collected water m^3

TW = Total used water m^3

MS = Money saved (TL)

Outputs:

Total savings

Total used water

Figure 9. The simulation flowchart

Date	rainfall amount	water collected	water used	cash flow	accumulated savings
1 - 2021 January (31) days	150.03 mm	3504.66 m^3	1101.595 m^3	10575.31 tl	-232381.69 tl
2 - 2021 February (28) days	123.14 mm	2876.46 m^3	778.318 m^3	7471.85 tl	-224909.84 tl
3 - 2021 March (31) days	90.39 mm	2111.50 m^3	1432.978 m^3	13756.59 tl	-211153.25 tl
4 - 2021 April (30) days	69.87 mm	1632.21 m^3	1514.671 m^3	14540.85 tl	-196612.40 tl
5 - 2021 May (31) days	35.21 mm	822.43 m^3	763.913 m^3	7333.56 tl	-189278.84 tl
6 - 2021 June (30) days	10.55 mm	246.34 m^3	304.854 m^3	2926.60 tl	-186352.24 tl
7 - 2021 July (31) days	no rain	0.00 m^3	0.000 m^3	0.00 tl	-186352.24 tl
8 - 2021 August (31) days	no rain	0.00 m^3	0.000 m^3	0.00 tl	-186352.24 tl
9 - 2021 September (30) days	15.80 mm	369.08 m^3	280.833 m^3	2696.00 tl	-183656.24 tl
10 - 2021 October (31) days	41.30 mm	964.66 m^3	759.093 m^3	7287.29 tl	-176368.94 tl
11 - 2021 November (30) days	85.18 mm	1989.80 m^3	1403.206 m^3	13470.78 tl	-162898.17 tl
12 - 2021 December (31) days	169.10 mm	3950.13 m^3	1654.196 m^3	15880.28 tl	-147017.89 tl
13 - 2022 January (31) days	85.73 mm	2002.66 m^3	1015.819 m^3	9751.86 tl	-137266.02 tl
14 - 2022 February (28) days	104.19 mm	2433.93 m^3	744.935 m^3	7151.38 tl	-130114.65 tl
15 - 2022 March (31) days	65.74 mm	1535.63 m^3	1529.035 m^3	14678.73 tl	-115435.91 tl
16 - 2022 April (30) days	17.47 mm	408.05 m^3	210.960 m^3	2025.22 tl	-113410.70 tl
17 - 2022 May (31) days	17.60 mm	411.22 m^3	478.404 m^3	4592.68 tl	-108818.02 tl
18 - 2022 June (30) days	5.27 mm	123.17 m^3	188.908 m^3	1813.52 tl	-107004.50 tl

Date	rainfall amount	water collected	water used	cash flow	accumulated savings
19 - 2022 July (31) days	no rain	0.00 m^3	0.000 m^3	0.00 tl	-107004.50 tl
20 - 2022 August (31) days	11.40 mm	266.30 m^3	3.611 m^3	34.67 tl	-106969.84 tl
21 - 2022 September (30) days	15.80 mm	369.08 m^3	477.662 m^3	4585.56 tl	-102384.28 tl
22 - 2022 October (31) days	41.30 mm	964.66 m^3	877.082 m^3	8419.99 tl	-93964.29 tl
23 - 2022 November (30) days	117.12 mm	2735.98 m^3	1481.760 m^3	14224.90 tl	-79739.39 tl
24 - 2022 December (31) days	169.10 mm	3950.13 m^3	1571.147 m^3	15083.01 tl	-64656.38 tl
25 - 2023 January (31) days	150.03 mm	3504.66 m^3	1127.756 m^3	10826.46 tl	-53829.93 tl
26 - 2023 February (28) days	104.19 mm	2433.93 m^3	894.821 m^3	8590.28 tl	-45239.64 tl
27 - 2023 March (31) days	90.39 mm	2111.50 m^3	1478.657 m^3	14195.11 tl	-31044.54 tl
28 - 2023 April (30) days	29.11 mm	680.09 m^3	613.942 m^3	5893.84 tl	-25150.69 tl
29 - 2023 May (31) days	29.34 mm	685.36 m^3	761.751 m^3	7312.81 tl	-17837.89 tl
30 - 2023 June (30) days	15.82 mm	369.50 m^3	226.648 m^3	2175.82 tl	-15662.07 tl
31 - 2023 July (31) days	no rain	0.00 m^3	203.005 m^3	1948.84 tl	-13713.22 tl
32 - 2023 August (31) days	no rain	0.00 m^3	0.000 m^3	0.00 tl	-13713.22 tl
33 - 2023 September (30) days	15.80 mm	369.08 m^3	369.080 m^3	3543.17 tl	-10170.05 tl
34 - 2023 October (31) days	16.52 mm	385.86 m^3	335.596 m^3	3221.72 tl	-6948.33 tl
35 - 2023 November (30) days	74.53 mm	1741.08 m^3	1256.544 m^3	12062.83 tl	5114.49 tl
36 - 2023 December (31) days	124.01 mm	2896.76 m^3	1428.483 m^3	13713.44 tl	18827.93 tl

Figure 10. The breakeven point

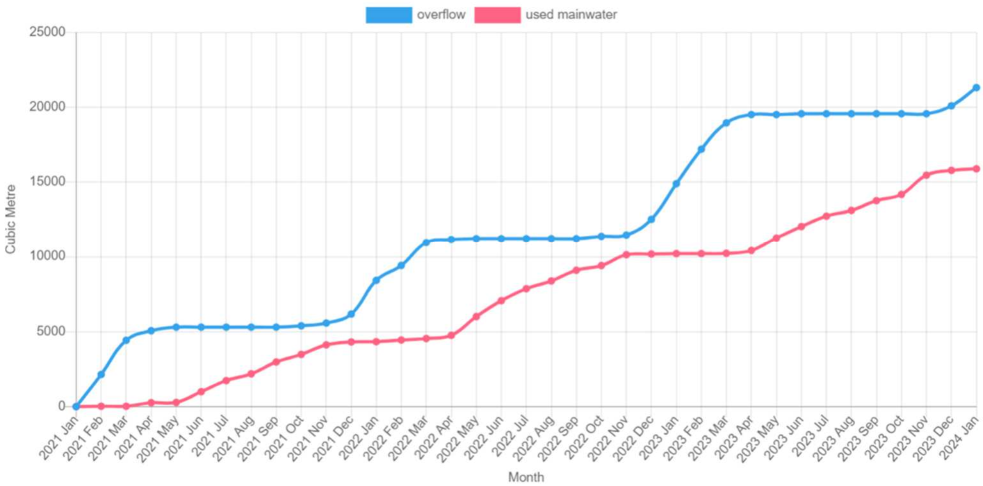


Figure 11. The overflow charts

Table 2. Monthly amounts of harvestable rainwater in Cigli

Months	Total Rooftop Area, m^2	Runoff Coefficient of Rooftop	Average Monthly Rainfall, mm	Total Concrete Surfaces Area, m^2	Runoff Coefficient of Concrete surfaces	Total Rainwater Harvesting, m^3
January	73528.8	0.9	135.0	4,308,061.7	0.7	416,045.6
February	73528.8	0.9	101.9	4,308,061.7	0.7	314,037.4
March	73528.8	0.9	75.4	4,308,061.7	0.7	232,369.2
April	73528.8	0.9	46.1	4,308,061.7	0.7	142,071.9
May	73528.8	0.9	31.8	4,308,061.7	0.7	98,001.8
June	73528.8	0.9	12.0	4,308,061.7	0.7	36,981.8
July	73528.8	0.9	4.1	4,308,061.7	0.7	12,635.5
August	73528.8	0.9	5.6	4,308,061.7	0.7	17,258.2
September	73528.8	0.9	15.5	4,308,061.7	0.7	47,768.2
October	73528.8	0.9	44.8	4,308,061.7	0.7	138,065.5
November	73528.8	0.9	92.6	4,308,061.7	0.7	285,376.4
December	73528.8	0.9	145.7	4,308,061.7	0.7	449,021.1
Total	73528.8	0.9	710.5	4,308,061.7	0.7	2,189,632.5

Table 3. Monthly amounts of harvestable rainwater in Karsiyaka

Months	Total Rooftop Area, m^2	Runoff Coefficient of Rooftop	Average Monthly Rainfall, mm	Total Concrete Surfaces Area, m^2	Runoff Coefficient of Concrete surfaces	Total Rainwater Harvesting, m^3
January	183,696.2	0.9	135.0	326,125.5	0.7	53,137.9
February	183,696.2	0.9	101.9	326,125.5	0.7	40,109.3
March	183,696.2	0.9	75.4	326,125.5	0.7	29,678.5
April	183,696.2	0.9	46.1	326,125.5	0.7	18,145.6
May	183,696.2	0.9	31.8	326,125.5	0.7	12,516.9
June	183,696.2	0.9	12.0	326,125.5	0.7	4,723.4
July	183,696.2	0.9	4.1	326,125.5	0.7	1,613.8
August	183,696.2	0.9	5.6	326,125.5	0.7	2,204.2
September	183,696.2	0.9	15.5	326,125.5	0.7	6,101.1
October	183,696.2	0.9	44.8	326,125.5	0.7	17,633.9
November	183,696.2	0.9	92.6	326,125.5	0.7	36,448.7
December	183,696.2	0.9	145.7	326,125.5	0.7	57,349.6
Total	183,696.2	0.9	710.5	326,125.5	0.7	279,663.1

Total rainwater harvesting in Karsiyaka region is estimated at 279,663.1m3/year, and total rainwater harvesting in Cigli region was estimated at 2,189,632.5 m3/year. The consumption rates of the public buildings in Karsiyaka and Cigli regions from collected rainwater are shown in Figure 12 and Figure 13. Total rainwater harvesting potential in Cigli is estimated at 2.194.856,7 m3/year. It corresponds to 13.1% of the total water consumption of Cigli according to the 2020 population. On the other hand, the total rainwater harvesting potential in Karşıyaka is estimated at 292.714,7 m3/year. It corresponds to 1.02% of the total water consumption of Karşıyaka according to the 2020 population. As a result, the authorities should take priority for RWH projects in locations where it has concentrated large buildings such as industrial zones, airports, military zones, stadiums, mass housing projects, touristic facilities. However, authorities' efforts in public buildings are not sufficient as it is seen that about 13% of the recovery rate is obtained. The main task for authorities is spreading RWH systems among the public as much as possible, irrigation and agriculture in particular. The cumbersome of this task is the economic perspective of the system. The developed RWH simulator carries out both water savings and economic analysis of any kind of building in any location in a user-friendly way. It is keen believed that these kinds of simulators are going to encourage the communities to harvest rainwater by showing them how cost-effective their design can be done by manipulating their inputs.

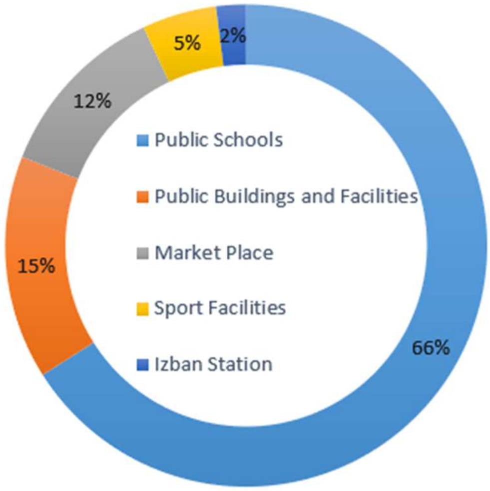


Figure 12. The consumption rates of the publ buildings in Karsiyaka from collected rainwater

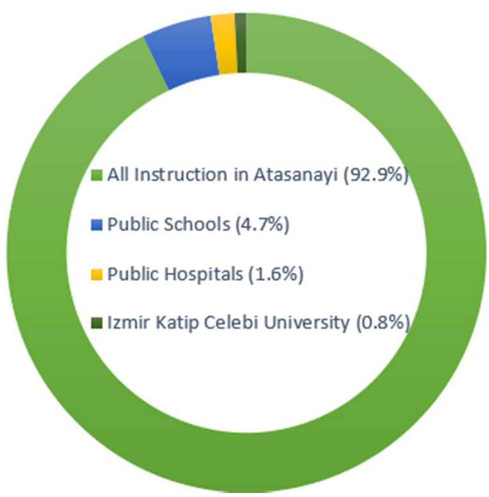


Figure 13. The consumption rates of the public buildings in Cigli from collected rainwater

CONCLUSIONS

Rainwater is a natural resource that needs to be investigated regarding the potential of benefit. This natural resource needs to be evaluated both economically and in terms of creating a sustainable resource. For this reason, authorities are searching for effective policies and collaborative strategies, including community participation in decision-making in order to solve water stress issues. In the present study, a web-based user-friendly rainwater harvesting simulator is developed in Java to determine the most efficient rainwater harvesting design among given scenarios. The simulator is experienced in the previous study of Izmir Katip Celebi University's rainwater harvesting potential. Then, the analysis is extended into all public buildings in two districts of Izmir Metropolitan, namely Karsiyaka and Cigli. The results show that public buildings only provide around 1% of public water needs. If the independent zones, such as Organized Industrial Zones, airports, stadiums, military zones, are taken into account, the recovery ratio increases about 13 % of public water needs. It is still a small portion of the public's water needs, therefore spreading rainwater harvesting in the communities is necessary. It is a keen belief that accurate and user-friendly rainwater harvesting simulators are going to encourage the communities to harvest rainwater.

REFERENCES

1. Angrill, S., Farreny, R., Gasol, C. M., Gabarrell, X., Viňolas, B., Josa, A., & Rieradevall, J. (2012). Environmental analysis of rainwater harvesting infrastructures in diffuse and compact urban models of Mediterranean climate. The International Journal of Life Cycle Assessment, 17(1), 25-42.
2. Brodie, I. M. (2008). Hydrological analysis of single and dual storage systems for stormwater harvesting. Water Science and Technology, 58(5), 1039-1046.
3. Burns, M. J., Fletcher, T. D., Duncan, H. P., Hatt, B. E., Ladson, A. R., & Walsh, C. J. (2012). The stormwater retention performance of rainwater tanks at the landparcel scale. In WSUD 2012: Water sensitive urban design; Building the water sensitive community; 7th international conference on water sensitive urban design (p.195). Engineers Australia.
4. Campisano, A., Butler, D., Ward, S., Burns, M. J., Friedler, E., DeBusk, K., ... & Han, M. (2017). Urban rainwater harvesting systems: Research, implementation and future perspectives. Water research, 115, 195-209.

5. Christian Amos, C., Rahman, A., & Mwangi Gathenya, J. (2016). Economic analysis and feasibility of rainwater harvesting systems in urban and peri-urban environments: A review of the global situation with a special focus on Australia and Kenya. Water, 8(4), 149.
6. Devkota, J., Schlachter, H., & Apul, D. (2015). Life cycle-based evaluation of harvested rainwater use in toilets and for irrigation. Journal of cleaner Production, 95, 311-321.
7. Domènech, L., & Saurí, D. (2011). A comparative appraisal of the use of rainwater harvesting in single and multi-family buildings of the Metropolitan Area of Barcelona (Spain): social experience, drinking water savings and economic costs. Journal of Cleaner production, 19(6-7), 598-608.
8. Gardner, T., & Vieritz, A. (2010). The role of rainwater tanks in Australia in the twenty first century. Architectural Science Review, 53(1), 107-125.
9. General Directorate of Meteorology Average of Monthly precipitation; 2020. Available from: https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=IZMIR.
10. GhaffarianHoseini, A., Tookey, J., GhaffarianHoseini, A., Yusoff, S. M., & Hassan, N. B. (2016). State of the art of rainwater harvesting systems towards promoting green built environments: a review. Desalination and Water Treatment, 57(1), 95-104.
11. Hajjar, H., Kilinc, I. K., & Ulker, E. Rainwater Harvesting Potential in Public Buildings: A Case Study in Katip Celebi University. Türk Doğa ve Fen Dergisi, 9(Özel Sayı), 167-172.
12. Hamel, P., & Fletcher, T. D. (2014). The impact of stormwater source-control strategies on the (low) flow regime of urban catchments. Water science and technology, 69(4), 739-745.
13. Helmreich, B., & Horn, H. (2009). Opportunities in rainwater harvesting. Desalination, 248(1-3), 118-124.
14. Kazanasmaz E.(2009). Kentimiz ve çevresinin yeraltısuyu kaynakları, yeraltısuyunu kirletici etkenler ve su kıtlığı riski. TMMOB Izmir Municapility Symposium.
15. Morales-Pinzón, T., Lurueña, R., Gabarrell, X., Gasol, C. M., & Rieradevall, J. (2014). Financial and environmental modelling of water hardness—Implications for utilising harvested rainwater in washing machines. Science of the Total Environment, 470, 1257-1271.
16. Steffen, J., Jensen, M., Pomeroy, C. A., & Burian, S. J. (2013). Water supply and stormwater management benefits of residential rainwater harvesting in US cities. JAWRA Journal of the American Water Resources Association, 49(4), 810-824.
17. Syed Azizul Haq, P. (2016). Harvesting rainwater from Buildings. Springer.

Chapter 17

RESILIENT AND SMART CITY APPLICATIONS

Pelin Okutan* - Atilla Akkoyunlu**

INTRODUCTION

The urbanization process has impacts on the economy of the city, utilization of the resources, quality of life and sustainable development[1]. The urbanization also creates an attraction point for the people who live in the rural areas. Majority of the world population live in cities, therefore, the population in the cities increases with creating the problems such as energy shortages, air pollution and waste management as well as poverty, inequality and health crises. Some cities seek to improve their management strategies to overcome these problems by implementing visions related to the innovation, success and wellbeing to their citizens. These city planning visions include sustainable city, the resilient city and the smart city.

Increasing urban issues have encouraged the frequent use of technology to provide growth in handling urban services to increase quality of life and wellbeing of people[2]. As a result, technology increased the possible urban advantages via smart cities while creating latest urban development and planning concept[3]. Hence, cities around the world are becoming increasingly reliant on information and communication technologies (ICTs) to develop smart solutions that improve

* Boğaziçi University Civil Engineering Department, 34342 Bebek, Istanbul, Turkey

** Boğaziçi University Civil Engineering Department, 34342 Bebek, Istanbul, Turkey

1 Macke, Janaina, Rodrigo M. Casagrande, João Alberto R. Sarate, and Kelin A. Silva. "Smart city and quality of life: Citizens' perception in a Brazilian case study." *Journal of Cleaner Production* 182 (2018): 717-726.

2 Parmar, Bidhan L., R. Edward Freeman, Jeffrey S. Harrison, Andrew C. Wicks, Lauren Purnell, and Simone De Colle. "Stakeholder theory: The state of the art." *Academy of Management Annals* 4, no. 1 (2010): 403-445.

3 Angelidou, Margarita. "Smart city policies: A spatial approach." *Cities* 41 (2014): S3-S11.

the efficiency and effectiveness of services and management[4]. Furthermore, smart cities guide resilience concepts[5], more than 2100 cities joined the “Making Cities Resilient” initiative which was launched in 2010[6].

One of the important highlights in order to improve wellbeing of the people and increase quality of life is that World Health Organization (WHO) initiated “Healthy Cities approach” acknowledges health determinants and the need for collaboration among public, private, non-profit, and community sector organizations[7]. This approach involves local people in decision-making process, necessitating political commitment while improving organizational and community development[8]. The WHO European Health for All strategy and the Health21 targets inspired and supported the Healthy Cities concept while being in line with the United Nation’s 2030 Agenda for Sustainable Development[9].

Another important highlight to improve wellbeing of the people and increase quality of life is that building urban green spaces encouraged and initiated by WHO[10]. The “Urban Green Spaces” initiative benefit cities in terms of upgrading social and environmental quality, improving disadvantaged areas, contributing positive image of the city and branding. The benefits can be maximized via detailed planning and management as well as implementing them in a resilient smart city concept[11].

The concept of resilient city is a framework developed by leading bodies such as the United Nations Office for Disaster Risk Reduction in the early 21st century.

---

4 Theoharides, Theoharis C., Bodi Zhang, Duraisamy Kempuraj, Michael Tagen, Magdalini Vasiadi, Asimenia Angelidou, Konstantinos-Dionysios Alysandratos et al. "IL-33 augments substance P–induced VEGF secretion from human mast cells and is increased in psoriatic skin." *Proceedings of the National Academy of Sciences* 107, no. 9 (2010): 4448-4453.

5 Sweya, Lukuba N., Suzanne Wilkinson, Joseph Mayunga, Aron Joseph, George Lugomela, and John Victor. "Development of a tool to measure resilience against floods for water supply systems in Tanzania." *Journal of Management in Engineering* 36, no. 4 (2020): 05020007.

6 UNISDR, WMO. "Disaster risk and resilience." *Thematic Think Piece, UN System Task Force on the Post-2015 UN Development Agenda* (2012).

7 Davies, John K., and Michael Kelly. *Healthy cities: research and practice*. Routledge, 2014.

8 Hancock, Trevor. "The evolution, impact and significance of the health cities/healthy communities movement." *Journal of public health policy* 14, no. 1 (1993): 5-18

9 De Leeuw, Evelyne. "Global and local (glocal) health: the WHO healthy cities programme." *Global Change and Human Health* 2, no. 1 (2001): 34-45.

10 World Health Organization. *Urban green spaces and health*. No. WHO/EURO: 2016-3352-43111-60341. World Health Organization. Regional Office for Europe, 2016.

11 World Health Organization. *Urban green spaces and health*. No. WHO/EURO: 2016-3352-43111-60341. World Health Organization. Regional Office for Europe, 2016.

According to Beck (1992)[12], the concept of resilient city is based on the idea of a risk society. The city is an entity with a capability of withstanding and rebounding from natural hazards, human threats, and challenges such as economic crises, and pandemics[13].

The concept of smart city is also known as the intelligent, information or virtual city[14]. It is based on the understanding of a city as it uses information and communication technologies, big data analyses and cyber systems to connect all its constituents such as its residents, urban infrastructure and city services.

Although concept of smart city depends on the technology to enhance the urban standards, the concept of resilience adjusts city to any disastrous events by absorbing adapting and transforming external pressures[15]. Moreover, a smart city is prepared to prevail resilient interminable to work with unpredicted events, like disasters[16].

1. RESILIENT AND SMART CITIES

Resilient cities can also be thought as cities that can last, withstand crisis, process inner strength in an appropriate built form and physical infrastructure. There is a need for planning resiliency in a city as a response for depleting natural resources and mitigating climate change. Newman, Beatley and Boyer (2009)[17] defines seven significant elements for a city to become resilient:

1. Renewable Energy City: Urban areas will use renewable energy technologies from the top to the bottom.
2. Carbon Neutral City: Every component of a city will be carbon neutral.
3. Distributed City: Cities will use small-scale and neighborhood-based systems rather than large, centralized power, water and waste systems.

---

12 Beck, Ulrich. "From industrial society to the risk society: Questions of survival, social structure and ecological enlightenment." *Theory, culture & society* 9, no. 1 (1992): 97-123.

13 Coaffee, Jon. "Policy transfer, regeneration legacy and the summer Olympic Games: lessons for London 2012 and beyond." *International journal of sport policy and politics* 5, no. 2 (2013): 295-311.

14 Batty, Michael. "Big data, smart cities and city planning." *Dialogues in human geography* 3, no. 3 (2013): 274-279.

15 Schwarting, Wilko, Javier Alonso-Mora, and Daniela Rus. "Planning and decision-making for autonomous vehicles." *Annual Review of Control, Robotics, and Autonomous Systems* 1 (2018): 187-210

16 Arav, N., C. Chamberlain, G. A. Kriss, J. S. Kaastra, M. A. S. S. I. M. O. Cappi, M. Mehdipour, P-O. Petrucci et al. "Anatomy of the AGN in NGC 5548-II. The spatial, temporal, and physical nature of the outflow from HST/COS Observations." *Astronomy & Astrophysics* 577 (2015): A37.

17 Newman, P., T. Beatley, and H. Boyer. "A vision for resilient cities." *Resilient cities. Responding to peak oil and climate change* (2009): 55-85.

4. Satellite City: Cities are "smaller municipalities located adjacent to a major city that serves as the core of a metropolitan area"[18].
5. Photosynthetic City: Urban green infrastructure will have the potential to harness renewable energy, food and fiber locally.
6. Eco-Efficient City: "Cities and regions will move from linear to circular or closed-loop systems, where substantial amounts of their energy and material needs are provided from waste streams."
7. Place-Based City: "Cities and regions will understand renewable energy more generally as a way to build the local economy and nurture a unique and special sense of place."
8. Sustainable Transport City: "Cities, neighborhoods, and regions will be designed to use energy sparing by offering walkable, transit-oriented options for all supplemented by electric vehicles."

The authors also mention that there is no city that contains all the elements at the moment. Yet, there are a few cities that has some of the elements.

A smart city integrates information and communication technologies with its conventional infrastructures as well as using emerged digital techniques for coordination. Smart city solutions benefit economies and public by monitoring and analyzing data for real-time decisions. Examples of these applications include smart agriculture, smart logistics, smart building and smart medicine.

Applying smart city solutions will help cities to deal with challenges by improving urban resilience. This paper discusses the structures, tools, and action plans to strengthen resilience by increasing their ability to absorb and withstand from shocks, preserve their functions and adapt to the change. This study also covers smart city solutions by examining the role of innovative technologies in promoting resilience.

Integrating smart systems into resilient cities are encouraging to overcome the issues and support social, ecological and engineering resilience[19]. A smart resilient city is the city that uses big data, Internet of Things (IoT) and other ICT to manage cities. These management strategies to achieve urban resilience include enhancing the capability of resisting, being ready for the external and internal changes by

---

[18] Shao, Zisheng. *The new urban area development: a case study in China*. Springer, 2015.

[19] Godschalk, David R. "Urban hazard mitigation: creating resilient cities." *Natural hazards review* 4, no. 3 (2003): 136-143.

absorbing and adapting. Furthermore, building smart and resilient cities will ease the vulnerabilities such as natural disasters and pandemics such as COVID-19 or earthquakes.

As part of this transition to sustainability and resilience, the development of future smart cities includes the creation of circular cities with a focus on the overall ecosystem's well-being[20]. Circular economy principles (recycling, reusing, repairing, refurbishing, and remanufacturing to reduce waste and environmental impact) are centralized with the idea that urban systems should be smart and sustainable[21]. The concept of circular economy is linked to the concept of sustainability.

Cities provide a large reservoir of knowledge that can be used to improve their sustainability. Cities and metropolitan areas have the potential to drive circular economies while also promoting renewable energy, energy savings, sustainable consumption and production, sustainable transportation, natural resource conservation, and sustainable waste management[22]. Policies to achieve these goals are also encouraged by the United Nation's 2030 Agenda: "Make cities and human settlements inclusive, safe, resilient, and sustainable[23]." Furthermore, the principles of the circular economy promote sustainable urban development. Furthermore, the principles of the circular economy inspire resilient smart cities to ensure economic growth while also reducing resource exploitation and waste production, resulting in reducing CO_2 emissions[24].

Another way of improving resilience and sustainability in a smart city is introducing the "Healthy Cities approach" initiated by WHO and in line with the

---

20 Levoso, Ana Sánchez, Carles M. Gasol, Julia Martínez-Blanco, Xavier Gabarell Durany, Martin Lehmann, and Ramon Farreny Gaya. "Methodological framework for the implementation of circular economy in urban systems." *Journal of Cleaner Production* 248 (2020): 119227.

21 Mont, Oksana, and Eva Heiskanen. "Breaking the stalemate of sustainable consumption with industrial ecology and a circular economy." In *Handbook of research on sustainable consumption*. Edward Elgar Publishing, 2015.

22 Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati. "A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems." *Journal of Cleaner production* 114 (2016): 11-32.

23 Rosa, William. "Goal 11: Make cities and human settlements inclusive, safe, resilient, and sustainable." *A New Era in Global Health: Nursing and the United Nations* 2030 (2017): 339-44.

24 Sharma, Hari Bhakta, Kumar Raja Vanapalli, Biswajit Samal, VR Sankar Cheela, Brajesh K. Dubey, and Jayanta Bhattacharya. "Circular economy approach in solid waste management system to achieve UN-SDGs: Solutions for post-COVID recovery." *Science of The Total Environment* 800 (2021): 149605.

United Nation's 2030 Agenda for Sustainable Development[25] . The approach simply acknowledges health contributors and the need for collaboration among public, private, non-profit, and community sector organizations[26]. This approach also includes local people in decision-making process as well as policy makers to improve organizational and community development[27].

Moreover, the "Urban Green Spaces" initiative is also efficient to reach resilience and sustainability goals. Cities benefit from the initiative in terms of imroving social and environmental quality, retrofitting disadvantaged areas, contributing positive image of the city and branding[28]. The benefits can be maximized via implementing them in a resilient smart city concept.

Smart technologies increase the capability of a city to recover from the disasters as well as ensuring the efficient use of resources, eliminating harms caused by disasters. Furthermore, a smart resilient city aims to improve urban infrastructure. Although most of the existing studies considered resilient city and smart city relatively independent realms, connections between them can be considered in two forms. To begin with, both resilient city and smart city supplies sustainable development of cities. The former plans and acts as feedback to hazards including climate change and emergencies as well as increasing ability of the city to "resist, absorb and recover". The latter, however, uses ICT to sense, analyze and consolidate different key data including traffic blockage and environmental pollution. For example, during the COVID-19 pandemics, cities benefited ICT and big data to integrate geographic, spatial, and temporal information to further give a timely response to reduce the rate of spread and minimize negative effects as well as improving urban resilience. Moreover, resilient city and smart city are in a application-feedback mechanism such that smart technologies provide tools for management to intervene resilient city in practice. Also, development of resilient city provides technical background to adapt smart city technologies (Figure 1).

---

[25] De Leeuw, Evelyne. "Global and local (glocal) health: the WHO healthy cities programme." *Global Change and Human Health* 2, no. 1 (2001): 34-45.

[26] Davies, John K., and Michael Kelly. *Healthy cities: research and practice*. Routledge, 2014.

[27] Hancock, Trevor. "The evolution, impact and significance of the health cities/healthy communities movement." *Journal of public health policy* 14, no. 1 (1993): 5-18

[28] World Health Organization. *Urban green spaces and health*. No. WHO/EURO: 2016-3352-43111-60341. World Health Organization. Regional Office for Europe, 2016.

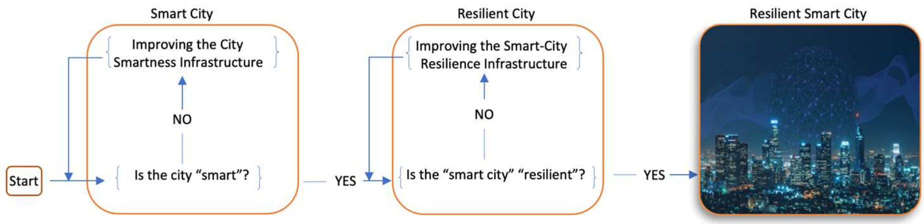


Figure 1. Resilient Smart City Framework (Adapted from Khatibi et al, 2021[29])

Building smart resilient city provides many opportunities as well as many challenges. Establishment of smart cities is highly dependent on the availability of data; however, data centers may have some negative impacts on resilient city. For example, if data centers suffer from security threats, there will be serious blockades for a city to operate, therefore, this will result in the reduction of resilience. Secondly, smart technologies are considered for their negative environmental impacts and lack of social justice and public equality, therefore implementing smart city solutions may create social instability and hinder security that will threaten development of resilient cities.

For example, the health codes applied to monitor and generate early response to the COVID-19 pandemic prevention and control and challenged with public privacy data leakage. Hence, technical and social risks with the smart city should be addressed to promote opportunities for smart resilient cities to address urban threats.

2. RESILIENT AND SMART CITY APPLICATIONS

Urbanization can be a powerful economic driver, but if not properly managed, it can also lead to unsustainable poverty. The concentration of people and activities are prone to pollution, disasters and impacts of climate change unless properly managed via smart city applications. These applications aim to enhance the integrity of sustainable technologies including the ones aiming to decrease the emissions. Moreover, they aim to improve the resource efficiency, waste reduction,

[29] Khatibi, Hamed, Suzanne Wilkinson, Mostafa Baghersad, Heiman Dianat, Hidayati Ramli, Meldi Suhatril, Ahad Javanmardi, and Khaled Ghaedi. "The resilient-smart city development: a literature review and novel frameworks exploration." *Built Environment Project and Asset Management* (2021).

enhance social inclusion, enhance ability to recover and use of renewable resources.

Nature-based solutions are also significant when establishing smart resilient cities. These solutions can be categorized in three groups: solutions within the cities, solutions around the cities and solutions away from the cities. Solution within the cities can provide natural shading, reduce pollution and urban heat island effects, provide cooling needs, manage run-off water; solutions around the cities forms part of city-region connection related to watershed management, wildfire management, reduce and capture greenhouse gasses (GHG) and measures for sand/dust storm; whereas solutions away from cities provide solutions for goods and infrastructures to improve urban supply chains[30].

Examples of solutions to smart resilient cities are:

- Catchments that are forested and provide clean water while also storing carbon.
- Wetlands in urban areas that improve water infiltration and reduce flood risk[31].
- Farms in and around cities that reduce food miles and connect people to the food they eat.
- Parks, tree-lined streets, green roofs, and building facades that reduce noise pollution, air pollution, and energy demand for cooling while mitigating the urban heat effect and accelerating water drainage[32].
- City parks that connect people to nature while also providing recreational space and biodiversity islands.
- Storm surges are mitigated by mangroves, dunes, and healthy reef systems[33].

---

30 Wendling, Laura A., Aapo Huovila, Malin zu Castell-Rüdenhausen, Mari Hukkalainen, and Miimu Airaksinen. "Benchmarking nature-based solution and smart city assessment schemes against the sustainable development goal indicator framework." *Frontiers in Environmental Science* 6 (2018): 69.

31 Chan, Faith Ka Shun, James A. Griffiths, David Higgitt, Shuyang Xu, Fangfang Zhu, Yu-Ting Tang, Yuyao Xu, and Colin R. Thorne. ""Sponge City" in China—a breakthrough of planning and flood risk management in the urban context." *Land Use Policy* 76 (2018): 772-778.

32 Wendling, Laura A., Aapo Huovila, Malin zu Castell-Rüdenhausen, Mari Hukkalainen, and Miimu Airaksinen. "Benchmarking nature-based solution and smart city assessment schemes against the sustainable development goal indicator framework." *Frontiers in Environmental Science* 6 (2018): 69.

33 Zhongming, Zhu, Lu Linong, Yao Xiaona, Zhang Wangqiang, and Liu Wei. ""Sponge City": San Salvador uses nature to fight floods." (2020).

- Walking and cycling paths shaded by trees that serve as both ecosystem and mobility corridors, especially when linked to citywide public space networks[34].
- Identifying greenhouse gas emission sources and replacing with greener options.
- Identifying carbon and water footprints by collecting data and taking precautions on decreasing.
- Identifying risks due to climate change and preparing action plan.
- Eliminating waste at the resource to decrease environmental pollution.

3. RESILIENT AND SMART CITY APPLICATIONS IN THE WORLD

The United Nations developed a guide to urban resilience in 2016 for its member countries while introducing new risk concepts with additional variables[35]. The terms "hazard", "exposure" and "vulnerability" started to use more frequently to define communities susceptible to hazards[36]. For this reason, the guide to resilient cities categorized phenomena by the type of disorder: (i) geological, (ii) hydro-meteorological, (iii) sanitary-ecological, (iv) socio-organizational[37].

Resilience applications in the smart cities as follow:

- To improve air quality, Jakarta and Mexico City are investing in massive tree-planting campaigns[38].
- Rotterdam aspires to be climate-proof by 2025. The authorities hope to build a waterproof city by combining grey and green infrastructure and focusing on adaptive measures to capture rainwater and slow drainage[39].
- In Tanzania, a combination of grey infrastructure (sea walls) and green infrastructure (mangrove, coral reef, and vegetation-stabilized shoreline rehabilitation) is strengthening disaster resilience in Dar es Salaam, directly benefiting 430,000 people[40].

---

34 UN Habtitat. City-wide public space strategies : A guidebook for city leaders. www.unhabitat.org/city-wide-public-space-strategies- a-guidebook-for-city-leaders. (2020).

35 Guia de Resiliencia Urbana. ONU-HABITAT: Mexico City, Mexico. (2016).

36 Arango, L. A. "Subgerencia Cultural del Banco de la República." (2015).

37 Guia de Resiliencia Urbana. ONU-HABITAT: Mexico City, Mexico. (2016).

38 Cook, Jonathan, and Rod Taylor. "Nature is an economic winner for Covid-19 recovery." (2020).

39 Oppla. Rotterdam – NBS for building a waterproof city. www.oppla.eu/casestudy/19457. (not dated).

40 Zhongming, Zhu, Lu Linong, Yao Xiaona, Zhang Wangqiang, and Liu Wei. "Nature-Based Solutions in Europe: Policy, Knowledge and Practice for Climate Change Adaptation and Disaster Risk Reduction." (2021).

- Singapore has had a Landscaping for Urban Spaces and High-Rise (LUSH) program for the last decade, with the goal of encouraging more greenery in the built environment, supporting rooftop urban farming, establishing Green Plot Ratio standards for private developments, and counting vertical greenery and green roofs towards Landscape Replacement Area requirements[41].
- Lisbon is developing the Main Green Corridor project to improve air quality, reduce traffic, and support non-motorized transportation options[42].
- In San Salvador, the "CityAdapt" project is restoring coffee plantations and digging infiltration ditches in order to reduce flood risks for 115,000 people by 2022[43].
- The UK government has stated that future flood defense efforts will include nature-based approaches such as grassland restoration, buffer strip creation, and allowing rivers to flow more freely across the landscape[44].
- Food price inflation affects the urban poor in Kathmandu on a regular basis due to poor transportation, a reliance on imported food, and rising climate instability. In response, the city experimented with rooftop gardens outfitted with rainwater-harvesting systems, thereby increasing residents' food and water security[45].

CONCLUSION

Smart city and resilient city integrate one another via decision-practice and application-feedback mechanisms. Smart city evidence-based decisions support resilient city, and smart city development requires feedback from resilient city practice. Nonetheless, when it comes to improving urban resilience, smart cities may face some challenges such as data insecurity and social injustice. Overall, this essay provides people with an innovative idea of a smart resilient city as

41 Urban Redevelopment Authority. Updates to the Landscaping for Urban Spaces and High-rises (LUSH) Programme: LUSH 3.0. https://www.ura.gov.sg/Corporate/Guidelines/Circulars/ dc17-06. (not dated).

42 Oppla.Lison: Masterplan Vale de Alcantara: A green corridor. www.oppla.eu/casestudy/17624. (not dated).

43 Zhongming, Zhu, Lu Linong, Yao Xiaona, Zhang Wangqiang, and Liu Wei. ""Sponge City": San Salvador uses nature to fight floods." (2020).

44 Cook, Jonathan, and Rod Taylor. "Nature is an economic winner for Covid-19 recovery." (2020).

45 Zhongming, Zhu, Lu Linong, Yao Xiaona, Zhang Wangqiang, and Liu Wei. ""Sponge City": San Salvador uses nature to fight floods." (2020).

well as an understanding of the opportunities and challenges of a smart resilient city. This research is important for future studies and practices in smart resilient cities, as well as for promoting the development of sustainable cities and communities.

It is important to highlight that such circumstances should have been created to allow land use concepts to mature, focusing on a common goal that ensures the well-being of the ecosystem, removing the perception of land from an anthropocentric perspective, and, in turn, offering tools that allow us to apply the concept of sustainable development and sustainability.

It is also important to recognize the importance of public involvement in the creation of region, which entails identifying and engaging groups that may be affected by regional transitions, allowing for free expression and emphasizing debate and cooperation, thereby awakening understanding of the region as a bioregion and enabling citizen participation in the seek for governance compliance.

Cooperation with the Sustainable Development Goals is impossible if many obstacles to the conservation of physical, chemical, and biological components of ecosystems must be overcome. The ability to achieve sustainable urban development is dependent on the quality of the environment that provides key ecological services. Even so, the harmonious relationship between technology and planning provides a clear path to intelligent environmental planning innovation, resulting in synergy in favor of the efficiency of complex systems in the face of hidden risks.

REFERENCES

1. Angelidou, Margarita. "Smart city policies: A spatial approach." Cities 41 (2014): S3-S11.
2. Arango, L. A. "Subgerencia Cultural del Banco de la República." (2015).
3. Arav, N., C. Chamberlain, G. A. Kriss, J. S. Kaastra, M. A. S. S. I. M. O. Cappi, M. Mehdipour, P-O. Petrucci et al. "Anatomy of the AGN in NGC 5548-II. The spatial, temporal, and physical nature of the outflow from HST/COS Observations." Astronomy & Astrophysics 577 (2015):A37.
4. Batty, Michael. "Big data, smart cities and city planning." Dialogues in human geography 3, no. 3 (2013): 274-279.

5. Beck, Ulrich. "From industrial society to the risk society: Questions of survival, social structure and ecological enlightenment." Theory, culture & society 9, no. 1 (1992): 97-123.
6. Chan, Faith Ka Shun, James A. Griffiths, David Higgitt, Shuyang Xu, Fangfang Zhu, Yu-Ting Tang, Yuyao Xu, and Colin R. Thorne. "“Sponge City” in China—a breakthrough of planning and flood risk management in the urban context." Land Use Policy 76 (2018): 772-778.
7. Coaffee, Jon. "Policy transfer, regeneration legacy and the summer Olympic Games: lessons for London 2012 and beyond." International journal of sport policy and politics 5, no. 2 (2013): 295-311.
8. Cook, Jonathan, and Rod Taylor. "Nature is an economic winner for Covid-19 recovery." (2020).
9. Davies, John K., and Michael Kelly. Healthy cities: research and practice. Routledge, (2014).
10. De Leeuw, Evelyne. "Global and local (glocal) health: the WHO healthy cities programme." Global Change and Human Health 2, no. 1 (2001): 34-45.
11. Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati. "A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems." Journal of Cleaner production 114 (2016): 11-32.
12. Godschalk, David R. "Urban hazard mitigation: creating resilient cities." Natural hazards review 4, no. 3 (2003): 136-143.
13. Guia de Resiliencia Urbana. ONU-HABITAT: Mexico City, Mexico. (2016).
14. Hancock, Trevor. "The evolution, impact and significance of the health cities/healthy communities movement." Journal of public health policy 14, no. 1 (1993): 5-18
15. Khatibi, Hamed, Suzanne Wilkinson, Mostafa Baghersad, Heiman Dianat, Hidayati Ramli, Meldi Suhatril, Ahad Javanmardi, and Khaled Ghaedi. "The resilient–smart city development: a literature review and novel frameworks exploration." Built Environment Project and Asset Management (2021).
16. Levoso, Ana Sánchez, Carles M. Gasol, Julia Martínez-Blanco, Xavier Gabarell Durany, Martin Lehmann, and Ramon Farreny Gaya. "Methodological framework for the implementation of circular economy in urban systems." Journal of Cleaner Production 248 (2020): 119227.
17. Macke, Janaina, Rodrigo M. Casagrande, João Alberto R. Sarate, and Kelin A. Silva. "Smart city and quality of life: Citizens' perception in a Brazilian case study." Journal of Cleaner Production 182 (2018): 717-726.
18. Mont, Oksana, and Eva Heiskanen. "Breaking the stalemate of sustainable consumption with industrial ecology and a circular economy." In Handbook of research on sustainable consumption. Edward Elgar Publishing, (2015).
19. Newman, P., T. Beatley, and H. Boyer. "A vision for resilient cities." Resilient cities. Responding to peak oil and climate change (2009): 55-85.
20. Oppla.Rotterdam – NBS for building a waterproof city. www.oppla.eu/casestudy/19457. (not dated).

21. Oppla.Lison: Masterplan Vale de Alcantara: A green corridor. www.oppla.eu/casestudy/17624. (not dated).
22. Parmar, Bidhan L., R. Edward Freeman, Jeffrey S. Harrison, Andrew C. Wicks, Lauren Purnell, and Simone De Colle. "Stakeholder theory: The state of the art." Academy of Management Annals 4, no. 1 (2010): 403-445.
23. Rosa, William. "Goal 11: Make cities and human settlements inclusive, safe, resilient, and sustainable." A New Era in Global Health: Nursing and the United Nations 2030 (2017): 339-44.
24. Schwarting, Wilko, Javier Alonso-Mora, and Daniela Rus. "Planning and decision-making for autonomous vehicles." Annual Review of Control, Robotics, and Autonomous Systems 1 (2018): 187-210.
25. Shao, Zisheng. The new urban area development: a case study in China. Springer, (2015).
26. Sharma, Hari Bhakta, Kumar Raja Vanapalli, Biswajit Samal, VR Sankar Cheela, Brajesh K. Dubey, and Jayanta Bhattacharya. "Circular economy approach in solid waste management system to achieve UN-SDGs: Solutions for post-COVID recovery." Science of The Total Environment 800(2021): 149605.
27. Sweya, Lukuba N., Suzanne Wilkinson, Joseph Mayunga, Aron Joseph, George Lugomela, and John Victor. "Development of a tool to measure resilience against floods for water supply systems in Tanzania." Journal of Management in Engineering 36, no. 4 (2020): 05020007.
28. Theoharides, Theoharis C., Bodi Zhang, Duraisamy Kempuraj, Michael Tagen, Magdalini Vasiadi, Asimenia Angelidou, Konstantinos-Dionysios Alysandratos et al. "IL-33 augments substance P–induced VEGF secretion from human mast cells and is increased in psoriatic skin." Proceedings of the National Academy of Sciences 107, no. 9 (2010): 4448-4453.
29. UN Habtitat. City-wide public space strategies: A guidebook for city leaders. www.unhabitat.org/city-wide-public-space-strategies- a-guidebook-for-city-leaders. (2020).
30. UNISDR, WMO. "Disaster risk and resilience." Thematic Think Piece, UN System Task Force on the Post-2015 UN Development Agenda (2012).
31. Urban Redevelopment Authority. Updates to the Landscaping for Urban Spaces and High-rises (LUSH) Programme: LUSH 3.0. https://www.ura.gov.sg/Corporate/Guidelines/Circulars/dc17-06. (not dated).
32. Wendling, Laura A., Aapo Huovila, Malin zu Castell-Rüdenhausen, Mari Hukkalainen, and Miimu Airaksinen. "Benchmarking nature-based solution and smart city assessment schemes against the sustainable development goal indicator framework." Frontiers in Environmental Science 6 (2018): 69.
33. World Health Organization. Urban green spaces and health. No. WHO/EURO: 2016-3352-43111-60341. World Health Organization. Regional Office for Europe, (2016).
34. Zhongming, Zhu, Lu Linong, Yao Xiaona, Zhang Wangqiang, and Liu Wei. ""Sponge City": San Salvador uses nature to fight floods." (2020).

35. Davies, John K., and Michael Kelly. Healthy cities: research and practice. Routledge, (2014).
36. De Leeuw, Evelyne. "Global and local (glocal) health: the WHO healthy cities programme." Global Change and Human Health 2, no. 1 (2001): 34-45.
37. Hancock, Trevor. "The evolution, impact and significance of the health cities/healthy communities movement." Journal of public health policy 14, no. 1 (1993): 5-18
38. World Health Organization. Urban green spaces and health. No. WHO/EURO: 2016-3352-43111-60341. World Health Organization. Regional Office for Europe, (2016).

Chapter 18

COPING WITH GLOBAL PERIL, PANDEMICS, AND POLITICS: TRENDS IN URBAN INNOVATION, SUSTAINABILITY, AND RESILIENCE FOR THE 21ST CENTURY

Gary M. Grossman*

INTRODUCTION

The 21st Century has introduced enormous challenges. Demographic trends have shown rapidly increasing urbanization in all countries of the world. Cities are crowded, while the countryside struggles to retain viability. Urban areas are choked with traffic and pollution, exacerbating sustainability challenges and providing a fertile ground for social problems and disease. Likewise, national governments, regardless of their political nature or the level of development of the societies in which they exist, have all, to varying degrees, shown impotence in efforts to address them. It is in this environment that COVID-19 emerged and they are major factors for its spread and in our collective inability to combat it adequately.

This paper examines the evidence associated with each of these trends and suggests that they are not separate and isolated phenomena. Indeed, they are linked and actions toward addressing these challenges can be engaged effectively. What is required is a reconceptualization of these phenomena and considers available innovative social, political, and technological options that can be pursued in resolving them. The paper will provide strong initial steps that cities, nations, and the world can take toward a better future for all.

---

* Associate Director and Associate Professor, School for the Future of Innovation in Society, College of Global Futures, Arizona State University

A variety of causes has led to more than 55% of the world's population living in cites. By 2050, this number is expected to grow to 70%, representing about 6 billion human beings. This is no cause for panic, the World Bank (2022) seems to assure us, as "urbanization can contribute to sustainable growth if managed well by increasing productivity, allowing innovation and new ideas to emerge." No problem, then. We simply live sustainably in our cities and the issue is resolved. All we need is good management!

To be fair, the World Bank is not quite so naïve as this, suggesting to us that there may be a few barriers to getting us there, such as the speed of urbanization, poor infrastructure, the lack of affordable housing, basic services, and jobs, the presence of the resident poor, the physical landscape, etc. But if we can manage those things, the cities can, presumably, be saved.

This paper argues that the issue is both broader and more complex than the Bank, and many urban planners, seem to suggest. Cites are growing at a rapid rate for many reasons and urbanization is the effect, not the cause, of these issues. Cities have problems because the societies in which they reside have problems, and given the fact that rapid urbanization is occurring across all societies, it suggests that the planet has problems. As such, dealing with these issues city by city by city across the entire world is a road map to nowhere, which is what the 6 billion souls expected to live in cities are sure to be if we misunderstand the causes and their effects. In analyzing this phenomenon, it will be useful to look at some of the major global trends that contribute to the urban problems we seek to resolve. Perhaps somewhere in there may be some ways to more effectively address the challenges of cities in the future.

1. "MEGATRENDS" IMPACTING HUMAN EXISTENCE ON PLANET EARTH

The term "Megatrends" is a popularized, and as such, overused description of what might more usefully be termed Global Challenges. Coming to public notice in the early 1980s, the worldwide best-seller with that title offered us the shocking "Ten New Directions Transforming Our Lives" (!-emphasis added) (Naisbitt, 1982). This extremely popular book suggested ten trends that will transform the lives of everyone on the planet. Including such things as evolving from an industrial society to an information age; transformation from a national economy into a global marketplace; movement toward a participatory democracy from a representative one; and so forth, this book helped popularize futures studies and set off a movement seeking to determine "Megatrends" in real estate, advertising, business communications, and dozens of other iterations on the idea. It joined other books on the popularized views of the future, like Toeffler's *The Third Wave* (1970) and *Future Shock* (1980), and many other authors. Indeed, the notion of the future in the latter part of the 20th century had so captured the imagination of many and became so salient, President Bill Clinton chose to theme his 1996 re-election campaign as "The Bridge to the 21st Century". The future was everywhere and the future was-is-now, in 2022.

But was Naisbitt wrong? Simply because an idea becomes popularized does not mean it is incorrect. Indeed, upon his death in 2021, the New York Times (14 April 2021) anointed Naisbitt as "half right". As well, Futurism and Future Studies are well-ensconced in academic curricula and even appears in names of academic units in major universities. But the fact of the matter that predicting the future and identifying the causes is neither new nor rare, at least since Copernicus (Gott, 1993). The accuracy or inaccuracy of those predictions are less relevant than the fact that there are forces larger than human activity that determine human outcomes. As such, while urban planning is important, it becomes most useful in the context of an understanding of those trends which will impact cities over the next several decades. With this purpose in mind, let us consider those "megatrends" with specific application to life in cities.

2. URBAN MEGATRENDS

Fortunately, some of our work is already done for us. According to the Project Management Institute (2022), the "Megatrends" concept has been updated. Utilizing their six broadly identified categories, we will now venture to assess the impacts of each on urban life, particularly in the context of the ongoing COVID crisis.

Digital Disruption: According to PMI, "There is almost no field of endeavor that is free from the constant drive of technological change. Even before we get used to the latest collaboration tool or smart home appliance, newer technology arrives with up-to-date features. While these solutions can save time, improve productivity and support innovation, they can also present risks, such as data breaches and loss of privacy." As the authors correctly point out, this was a trend in process before COVID-19. "The pandemic greatly accelerated an expansion of digital technologies, especially tools to enable online collaboration and remote work. The trend toward remote work had been gaining speed, facilitated by digitization and improved connectivity. But any barriers or hesitation about adopting a remote model were swept aside as the ability to work from home became necessary to carry on normal business." Interestingly, this effect mitigated to some degree the heavy migration to cities during the past two years. (UN Population Division, 2021). While this process may have provided a respite of sorts for cities, it is by no means sustainable. Once COVID is either gone or fully moves into its endemic phase, this temporary disruption promises to return full force.

Demographic Shifts: PMI state, "With declining fertility rates and an increasing percentage of workers aging out of the workforce, organizations will need to find new ways to alleviate worker shortages and close the talent gap." Indeed, and virtually all of the jobs the worker shortages and talent gap combine to impact are in cities. Hence, cities are caught in an ironic dilemma. While people are streaming into cities from rural parts of their nation plus absorbing refugees from outside of their nation, skilled jobs are left vacant because of the talent gap. This puts extreme pressures on urban administrations which will have to deal with these stresses largely by themselves.

Economic Shifts: As PMI argues "The stresses created by the pandemic have led to supply chain disorder and the rethinking of globalization. The issue is complex, however. Rebuilding domestic supply chains is a long-term undertaking, and permanent pullbacks are not certain. However, there are strategies that can be applied to mitigate global supply chain risks and facilitate cross-border collaboration. **The COVID-19 pandemic has exposed long-standing supply chain vulnerabilities, particularly overreliance on single-source vendors and suppliers. These vulnerabilities — combined with demand spikes, labor shortages, weather events and other factors — have decimated port and shipping capacity, pushed transport costs to new highs, created massive shortages of goods and components, raised consumer prices and increased inflation."** (Emphasis added) Increasing economic (as well as social and political) disparities have long been a noted consequence of the global economy and the neo-liberal policies that fanned its flames (Escobar, 2012). This impacts cities the most in no small measure because that is where most people live and where most businesses locate. It, therefore, stands to reason that cities will absorb these impacts and the distortions they present.

Climate Crisis: PMI reports, "World leaders attending the 2021 United Nations Climate Change Conference (COP26) proclaimed the need for urgent action. However, progress to address climate change has been elusive". Climate, inarguably, is the defining crisis of our time and, without exception, exacerbates every problem area. This is especially true for cities already dealing with infrastructure challenges. It also adds the factor of climate migration to the list of migration issues cities already deal with. (Brookings, 2019)

Labor Shortages: There is an exodus of employees and a loss of institutional knowledge happening at organizations around the globe — and it's shaking up the workplace in ways we haven't seen or prepared for. How organizations react will determine whether this is a long-term trend or just a reset. Over the last year, many companies have faced a reckoning as large numbers of employees quit their jobs, launching a movement of sorts that Anthony Klotz, professor at Texas A&M University, Texas, USA, named the 'Great Resignation.'" In the United States, 4.5 million workers left their jobs in one month. (USDOL, 2022). This trend is now global (Washington Post, 2021). As with other trends, problems go where the people live: cities. Consequently, the problems resulting from this will emerge most strongly in cities.

Civil, Civic and Equality Movments: According to PMI, "Despite ongoing restrictions due to the COVID-19 pandemic, social protests continued to spill into the streets in 2021. We expect these protests to endure as the economic effects and rising inequalities intensified by the pandemic contribute to the drivers for social unrest. But increasingly, we will also see boardrooms, office suites and project sites become the setting for real change and collaboration in response to civil, civic and equality movements. While organizations have increased diversity, equity and inclusion (DE&I) efforts, it's been a challenge to make them effective because of the all-encompassing changes required. The appointment of chief diversity officers (CDOs) — which has risen over the past five years and saw a massive spike in 2020 — will certainly help achieve this. The need to blunt the effects of labor shortages will be a strong motivator for companies to build more inclusive cultures. At the same time, the impacts of the pandemic have fallen more heavily on communities of color and globally have hit the hardest in emerging markets and developing economies." Put another way, people are taking their grievances increasingly to the streets. Where are the streets? In cities.

We will now turn to an analysis of these trends as it impacts issues of urban change, development, and resilience.

3. DISCUSSION

A number of issues emerge from our adaptation of the notion of "Megatrends" in cities. First, and most fundamentally, trends in urban environments are not different from trends in the rest of society nor are they immune from global effects. Indeed, it can fairly be stated that whatever is happening in the rest of the nation or the world comes to the city in intensified form, whether the issue is climate change, economic trends, migration, or civil unrest. The city is Ground Zero for all social, economic, political, and environmental trends, wherever they may come from. As well, there is little that cities, by themselves, can do to entirely resist those forces that originate from outside of their urban limits. "Smart Cities", a movement that has a cache in the popular literature similar to that which "Megatrends" had in the 1980s, (e.g., Gassman, Bohm, and Palmie, 2019), can certainly contribute to the urban planning process by effective management and sustainability strategies, but these are reactive approaches by definition. Cities, by themselves, did not "cause" the stresses outlined by the trends they experience. They are clearly at their effect. So, the notion of "solutions" to these problems are not a terribly useful concept.

We also noticed the impact of COVID-19 on these broader trends and, therefore, life in cities. COVID-19 did not "cause" any of them. Indeed, all of the items in the PMI analysis-and we can extend this to the Naisbitt and Toffler sets of trends as well-were in process anyway, pandemic or not. What it did do is at least speed up, even exacerbated, the impacts of these trends, and it has not been helpful to cities that the profound lack of success of modern nation-states in dealing with COVID would certainly deliver national and global failure to their streets and cities. (Grossman, 2022).

Finally, and most importantly, we all must answer some questions. If all of the problems that beset cities did not originate there, and cannot be solved by them, what does the future hold? How can cities move forward in a way that best ensures that its citizens can survive and thrive in the future?

CONCLUSION

This paper has examined the challenges that cities across the globe face, utilizing the "Megatrends" conceptualization as a framework to understand and address those challenges. In looking at the widely disseminated "Megatrends 2020" analysis, the cities of the world are faced with a daunting set of problems that it seems they cannot solve.

Having said this, we have to recognize that resilience itself is a solution. Beyond that, COVID itself has opened the way toward solutions, in that it affords the opportunity to "Build Back Different" (Carnegie Endowment for Peace, 2021). Among the things that the COVID-19 pandemic may have intensified is the movement across the world toward enhanced civil society and democratization. While this topic is well beyond the scope of this paper and may be difficult to see amid a war in Eastern Europe occurring at the time of this writing, there is strong evidence that this may be in process.

Finally, the movement toward the United Nations Sustainable Development Goals (SDGs) offers all of us perhaps the best chance to address the serious needs both globally and locally. Progress has been slow worldwide, too slow to achieve the 17 goals by the imagined 2030 date. However, as Secretary-General Antonio Guterres points out "The Sustainable Development Goals are now more important than ever. Now is the time to secure the well-being of people, economies, societies, and our planet." But even slow progress means that lives where people are-our cities-will be improved. Enhanced progress will substantially ease all of the challenges that people face where they live-our cities.

REFERENCES

1. Carnegie Endowment for Peace, *Civil Society and the Global Pandemic: Building Back Different?",* 2021. (https://carnegieendowment.org/2021/09/30/civil-society-and-global-pandemic-building-back-different-pub-85446)
2. Escobar, Arturo. *Encountering Development.* (Princeton, NJ: Princeton University Press, 2012)
3. Gassman, Oliver; Jonas Bohm; Maximillian Plame. *Smart Cities: Digital Innovation to Cities.* (London, Emerald Publishing, 2019)
4. Gott III, J. Richard. "Implications of the Copernican principle for our future prospects". *Nature*, 27 May 1993, pp. 315-319.

5. Grossman, Gary M. "The Global Consequences of 'Knowing': Information Dissemination and Disparity in the COVID-19 Pandemic" in Gulsecen, Sevinc; Sushil. Sharma; F.Kocaoglu. *Pandemics and the Critical Role of Knowledge Management* (Istanbul: Istanbul University Press, 2022-Forthcoming)
6. Naisbitt, John*. Megatrends: Ten New Directions Transforming Our Lives.* (New York: Warner, 1982)
7. New York Times, "John Naisbitt, Business Guru and Author Dies at 92" (https://www.nytimes.com/2021/04/14/books/john-naisbitt-dead.html
8. Toffler, Alvin. *Future Shock.* (New York: Random House, 1970)
9. Toffler, Alvin. *The Third Wave.* (New York: William Morrow, 1980)
10. United Nations Statistics, The *Sustainable Development Goals Report, 2021.*
11. United States Department of Labor. *Number of Quits at an All-Time High in November 2021.* (https://www.bls.gov/opub/ted/2022/number-of-quits-at-all-time-high-in-november-2021.htm)
12. Washington Post "The Great Resignation Goes Global", 18 October 1992 (https://www.washingtonpost.com/world/2021/10/18/labor-great-resignation-global/)
13. World Bank, 2021 *New World Bank Report Covering 10,000 Cities Shows Shape of Urban Growth Underpins Livability and Sustainable Growth* (https://www.worldbank.org/en/news/press-release/2021/06/01/new-world-bank-report-covering-10-000-cities-shows-shape-of-urban-growth-underpins-livability-and-sustainable-growth#:~:text=Today%2C%20around%2055%20percent%20of,Saharan%20Africa%20and%20South%20Asia.))