Agent-Based Modelling for Enhancing Liveability: Addressing Overcrowded Living Conditions among Urban Migrants

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Abstract

The migration started 60000 years ago out of Africa; the homo sapiens dispersed across Eurasia. Migration is an everyday act; millions of people migrate to places yearly for a good life, well-being, escape from natural calamities and so on. Cities and Urban areas face a massive influx of population from migration; cities sometimes find it hard to accommodate these migrating people. Millions of people in big cities live without enough space and have a low quality of life. Climate change and urban sprawling make the living conditions worse in cities. This article contains the internal migration data of people from 10 rural areas to a city from 2017-2022. Using this data by using regression, we find out the migration rate of the last five years and also the number of people expected to arrive in the city from the ten rural areas by 2023.Using Agent-based modelling, what kind of accommodation they choose is found out .The result from the study can be used for the city authorities to plan buildings in such a way that buildings are designed which is affordable does not consume green fields present in the cities and also in a sustainable way to promote climate resilience.

Keywords: *Migration, People, Climate change, Urban, Sustainable, Accommodation*

1. Introduction

The proportion of the world's population living in large towns or cities has grown from around 5% to 50% over the past two centuries (1). Urban areas are facing a massive influx of migrants from rural areas who are seeking a better lifestyle or to escape from dangerous, life-threatening situations, war, or climate change. This influx of people can make the functioning of the city more complicated. Although most people migrate within their own country, there has been an increase in international migration, with Europe and Asia hosting around 87 and 86 million people, comprising 61% of the global international migrant stock (2).

Migration has positive and negative implications for both the host and guest of the countries. Residential immigration triggered by higher immigration results in a lack of housing, rising housing costs, city congestion and population distribution, higher resource consumption, and a need for improved service(3,4). The increasing role of migration is creating problems in the social, economic and demographic development of countries and regions, stimulating interest in the mathematical modelling of migration to design more efficient cities. The goal is to create a city that offers a high quality of life for all species, is efficient in all stages, and has less or zero climate-related problems.

Over-migration results in a population explosion, and it causes several social and economic problems: growth of slum areas, traffic disorganisation, under-functioning of drainages and sewers, lack of resources and exploitation of resources, and related issues. As the number of people in cities increases, problems start to appear, and poor people are the first to be impacted. For example, many rural migrants who settle in an urban slum area bring their families and domesticated animals, pets, and livestock with them, which expands the urban crawling of slums. Further, most poor people in urban areas live in unregulated slums, have congested conditions, are overcrowded, are positioned near open sewers, and are restricted to geographically dangerous places such as hillsides, riverbanks, and water basins subject to landslides, flooding, or industrial hazards (5). Unhygienic, unsanitary, unemployment, and poverty can lead to frustration and anger among educated youth(6). There are specific challenges that arise with an increase in the temperature, the poverty rates, the poor lower-income people vulnerable to weather extremes, scarcity of water and challenges High poverty rates and social inequality leave many low-income populations susceptible to weather extremes, water stresses, and food production challenges associated with a warming climate (7). The increase in population number results in more consumption of resources, water, energy, food, and the emission of more combustion fuel, which can act as catalysts to increase climate change.

Long-lasting Solutions to the Problem of Migration in Europe: There are several solutions, such as guidelines and rules already in action, adequate border controls, rapid relocation such as the Malta and Dublin agreements, and measures in the countries of destination. Developed countries having trouble coping with immigration are considered third-world nations facing the problems; Colombia faces a surge in Venezuelan refugees. 2.5 million Venezuelan refugees arrived in Colombia and started living in Colombia after the economic and political crisis that happened in 2018 (8). Similar situations are from the people of Niger who are fleeing from there to bordering Mali due to terror and fear for life(9). These uncontrolled migrations result in unemployment and further problems, increasing ghetto creation and living a life below the usual standards of lifestyle. We have a lot of information globally on the dangers of how climate change impacts people's health and lives, and the impacts of climate vary depending on the region(10). Many cities across the world experience extreme weather events and high temperatures, but how they impact people can vary. This variation is based on local factors, poorly designed cities, health problems, and the most vulnerable people, which could be Indigenous people or older people. (11,12)

Former research articles based on this kind of migration management are International Migration Management in the Age of Artificial Intelligence (13). In certain countries like Canada, algorithmic decision-making is already integrated into immigration and asylum determination processes, while in Germany, they have experimented with projects that employ technologies like facial and dialect

recognition for decision-making in asylum determination procedures.

Controlling the population is time-consuming, but improving the living conditions of the people who live in unhygienic, overcrowded areas is possible. Creating housing for them, sustainable, affordable houses that have climate-resilient efficiencies through nature-based or technical solutions implemented on these houses and surroundings. These houses are built on brownfield areas or deteriorated areas in the city; thereby, green space is not consumed, and it is possible to preserve the green space as it is.

For housing design and numbers, predicting the percentage of migration is essential. This article will analyse the internal migration of 10 rural areas of a country to the largest city, Bansoff, in that country. The data will show the number of people migrating from rural areas to urban areas from 2017 to 2022, according to the data collected by city officials. From that migration constant, which is found from 2017 to 2022, the 2023 expected migration is found out.

This data contains the number of migrants in the city and the expected number of migrants arriving in 2023; this number is analysed by agent-based modelling, and the result is the type of accommodation chosen by the people. The number of people considered in the agent-based modelling is not only the expected people in the year 2023 but also people in Bansoff who need housing and suffer problems due to poor living conditions.

This includes housing, single rooms, shared rooms, single houses, dorm houses, and shared houses. Based on the result derived from the agent-based modelling, the government can develop an urban plan for what kind of accommodation these people will choose, and based on that, the construction of these housing models could be started.

The focus is on sustainable housing options to help solve climate-related and overpopulated housing issues. The study's results can be used by city authorities to plan and build the required accommodation options that meet the needs of the migrating population.

The limitations of the study are as follows.

Finding an area for the building, as it is hard to find places in the Urban areas of the city

This modelling is only possible with immigrant details.

This is not possible in poor countries as the investment is higher.

2. A metaphor, Bansoff

It is an imaginary city, but it has all the problems of an overcrowded city we see around the world: people outnumber the city's accommodation capacity, high traffic, climate change problems, heat islands, and bad air quality.

Bansoff is not only the capital but also an economic centre. The industry has expanded its Cobalt mines, the most significant textile industry, and the biggest port in the country, Port Bansoff; tourism is booming. These things create many job opportunities that attract people from rural areas. The wages are high compared to the rural areas, and the modern city lifestyle attracts people from around the country. These are the main reasons for the exponential migration from the rural area to the Urban Bansoff region.

Bansoff is a city of 410.83 sq. km with a current population of 2.9 million people and is expected to increase by 4 million in the next ten years. Currently, the infrastructure and associated buildings to accommodate people are starting to get overcrowded, and there is not enough space for people to have leisure, car parking, problems like crowded streets, illegal accommodation instead for three people flats nine people or more are living due high rents, ghetto creation and not the availability of flats.

Table 1 shows data on migration from ten rural areas and the number of people moving to the capital, Bansoff, from 2017 to 2022. Most of the villagers' ultimate destination is Bansoff due to its vast opportunities; very few are choosing other cities, and eventually, they would like to move to Bansoff.

Climate change in Bansoff has caused heat waves and urban flooding, which occurs regularly during the rainy season, even with the slightest rainfall due to the flooding of the river Mara. The increased population and urban floods resulted in an overflow of the sewer because the sewer could not accommodate that much water as it became underdesigned for the current number of people in Bansoff.

$$\textit{The population density according to } 2022 = \textit{Number of people/Land area in sq km}$$
$$= 2900000/410.83 = 7058 \textit{ people per sq km}$$

The population per square kilometre for Prague is 495 sq. km with a population density of 4600 residents per sq. km (14), so we can imagine how Bansoff is congested Bansoff; it has almost double the population per sq km with a smaller area of nearly 100 sq km lesser than Prague.

The research aims to increase the quality of life of people in urban areas by providing affordable, climate-resilient housing options.

3. Related works and contributions

Housing supply and affordability: Evidence from rents, housing consumption and household location. Do housing prices promote total factor productivity? Evidence from spatial panel data models in explaining the mediating role of population density ((15).Effect of zoning plans on urban land-use change: A multi-scenario simulation supporting sustainable urban growth (16). Mathematical modelling as a tool for policy decision making: Applications to the COVID-19 pandemic (17)

4.Methodology

4.1Mathematical modelling for solving the problem

Mathematical modelling offers a structured approach that, when coupled with data, enables an understanding of how alterations within the model can influence results. Through this combination of modelling and data analysis, we can elucidate historical patterns, make projections about future trends, and assess the potential impact of changes on these forecasts((18).

Two mathematical models used for this research are regression analysis and agent-based modelling.

Regression analysis is a robust statistical technique that enables the exploration of connections between two or more variables under investigation. Although various forms of regression analysis exist, they all share a common objective: assessing the impact of one or many autonomous variables on a reliant variable((19).

Agent-based modelling (ABM) involves representing a system as a group of self-governing entities known as agents. These agents independently evaluate their circumstances and act according to a predefined set of rules. Depending on the system they represent, agents may engage in various activities, such as production, consumption, or sales. Agent-based modelling is characterised by recurring competitive interactions between agents, leveraging the computational capabilities of computers to

investigate dynamics that may be beyond the scope of purely mathematical approaches(20)

4.2 Study and analysis of data

From the data (artificial benchmark), living conditions are analysed from certain housing agencies and other government records to get a clear idea of how many people live under those conditions.

The below table shows the data of migration numbers of people from a particular age group of16-35 years from a rural area to the capital city of that country in the year 2017-2022 (Internal migration)

Tab. 1. Migration of people from rural areas to Bansoff

Sl number	**Rural areas**	**Migration: number of people between16-35 migrating every year**							
		2017	**2018**	**2019**	**2020**	**2021**	**2022**		
1	**Ulnas**	**23300**	**28355**	**40483**	**42345**	**47567**	**55663**		
2	**Maru**	**17800**	**21106**	**42156**	**32456**	**33775**	**39885**		
3	**Senj**	**31344**	**40464**	**55776**	**61567**	**77785**	**80365**		
4	**Azor**	**10224**	**12647**	**16975**	**21954**	**26574**	**29773**		
5	**Mezo**	**7687**	**14464**	**45565**	**50348**	**63556**	**78857**		
6	**Fatul**	**21779**	**25466**	**29454**	**30453**	**35358**	**39467**		
7	**Casar**	**25354**	**33558**	**41666**	**60577**	**91353**	**100567**		
8	**Garu**	**45567**	**70397**	**90363**	**100739**	**120167**	**140677**		
9	**Ranca**	**30678**	**37585**	**44397**	**51694**	**55155**	**58687**		
10	**Bengue**	**27789**	**33298**	**41392**	**45358**	**40566**	**43378**		

Three main steps are in the methodology

1. Calculate the migration rate from 2017 to 2022 using the regression method. GNU Octave and Python are used.
2. The number of people arriving in 2023 is calculated using Python and the regression method. It is calculated from the 2017-2022 migration rate.
3. Using Agent-Based modelling, sustainable accommodation choices were chosen from the data (total number of people arriving in the city in the year 2023, which is derived from Python at “step 2”) of the total number of people who arrived in the town in 2023 and people who are already in the city and suffering from the lack of proper accommodation.

Given below are tables that contain individual population lists of each city from 2017- 2022 and their population regression graphs

Tab. 2. Migration from ulnas to Bansoff

Sl number	Year	Migration, number of people migrating16-35 every year
1	2017	23300
2	2018	28355
3	2019	40483
4	2020	42345
5	2021	47567
6	2022	55663

Regression graphs are made using the software’s octave Gnu and Python.

Coding is in GitHub for Octave and Python.

Graph of the exponential regression of population migration in the Ulnas region

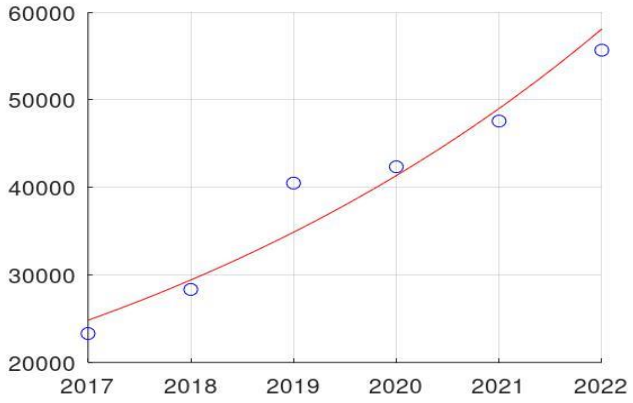

Fig 1. Regression graph Ulnas region

Similarly for the 10 regions are calculated

Tab. 4. The most Optimised Migration rate of each state from 2017-2022

Ulnas	1004
Maru	4.2622e+02
Senj	576.14
Azor	263.44
Mezo	1070.5
Fatul	51.01
Cesar	3.825e+02
Garu	8.5387e+02
Ranca	4.4321e+04
Bengue	330.91

The table aboveshows the rural areas with the most optimised migration growth of each city from 2017-2022.

These are the most optimised values found in the exponential regression curve.

The table shows that Garu has the most increased migratory rate from the past six years 2017-2022. The growth constant is 8.5387e+02 in Garu, where the least is from Fatul 51.01.

In rural areas like Mezo, Fatul and Bengue specific government initiatives helped the people stay there in their home areas. Monthly allowances, subsidies for agriculture insurance, and daily wage plans from the central authority (Bansoff) helped the migration grow at a controllable level.

Bansoff can still expect a massive increase in population from all seven rural areas which will make the city overpopulated, particular measures have to be taken to solve the crisis due to overpopulation and related problems. The primary how the city accommodates them is that no city wants homeless people who cannot afford a house.

Some estimations and predictions are made based on what kind of buildings people choose based on economic, social, and age factors. The city is planning to build it sustainably, and affordable and nature-based solutions are used to mitigate certain climate and air-related problems.

By using agent-based modelling to determine what kind of accommodation will be chosen by future arriving peoples (21).

For finding the number of people who will be arriving in the city in 2023, a regression was done by using Python and the data is as follows: hyperlink for the coding is also highlighted

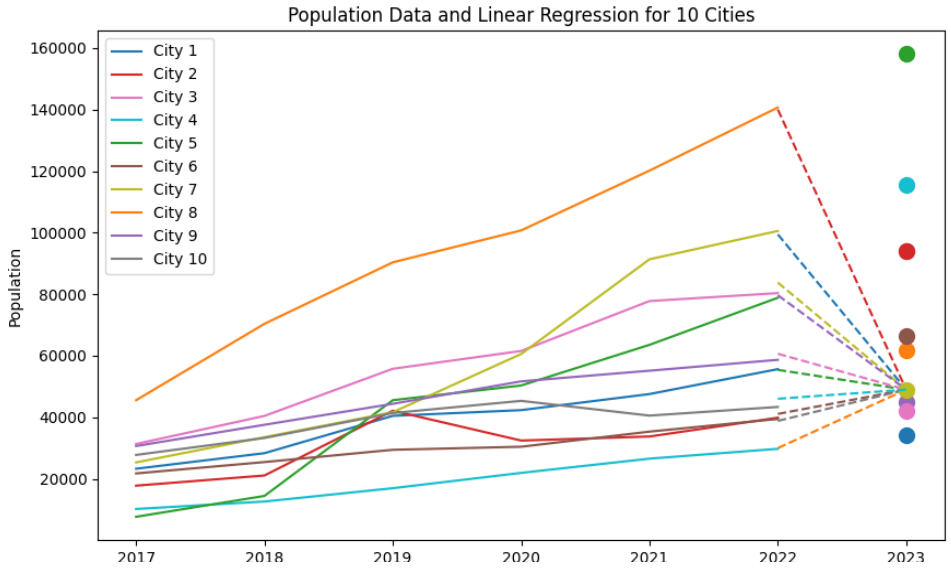

Fig. 2. Graph showing the number of people expected to arrive in Bansoff in 2023 by using PHYTHON regression

Tab. 13. Number of people arriving in 2023 in each city

Ulnas(city 1)-61750
Maru(city 2)-45070
Senj(city 3)-94169
Azor(city 4)-34142
Mezo(city 5)-94204
Fatul(city 6)-42241
Cesar(city 7)-115682
Garu(city 8)-158175
Ranca(city 9)-66371
Bengue(city 10)-49002

Agent-based modelling will give a result of what kind of accommodation should be chosen by the 600000 people who are expected to be in need of housing in the Bansoff municipality in the year 2023-2024. This number of 600000 who is in need of housing, the number is estimated as the number of people will be expected to arrive in 2023 is calculated by using Python Regression, from the 10 cities the number of people 431471,around its 150000 people is estimated who are already residing in

Bansoff in need of housing, adding those two population numbers so it's estimated as around 600000 altogether. The new buildings which will serve as accommodation are sustainable buildings using nature-based solutions like green roofs, green walls, Bioswales, Sustainable urban drainage and several Nature-based solutions to tackle climate change. This nature-based solution can mitigate the problems of climate change and the agent-based modelling solutions help to reduce the overcrowded problems of the migrants by helping the city to see what kind of accommodation they chosen by the people in the city there by design city according to that

4.3 Various agents used for this agent-based modelling are given below

The agents are chosen based on economic, education and social status

Number of people -600000,Social status-single majority,Married-7%(estimated as majority of migrants are young people)
Economic status
Salary ranges from 200-300 dollars,
Education status
High schools above 90 %,Graduated less than 10%
Property types
Single room, Shared room, Single house, Dorm houses, Shared house
Rent in dollar
Single room-70,Shared room-25,Single house-350,Dorm house-15,Shared house-300
By using these as the agents and coding in PYTHON
The coding is in GitHub
From the coding, the result is as follows: What kind of accommodation do people choose.
Single room 101704, Shared room 223638, Single house 25964, Dorm house-148624, Shared House 100695

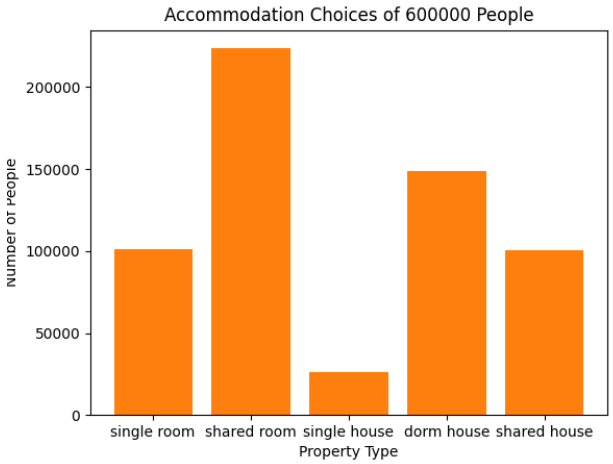

Fig. 12. The bar chart shows accommodation chosen by the people by agent-based modelling

5. Result

By using the GNU octave, the state has the highest number migration rate from Garu and the least from Fatul. Using regression in PYTHON, the expected number of people arriving in Bansoff in 2023 from the ten rural areas is calculated. From the expected number of people arriving in the city and the people who are suffering from low-quality lifestyles estimated (600000 people), this data is used, and agent-based modelling is done to find out what kind of accommodation they choose the result follows Single room 101704, Shared room 223638, Single house 25964, Dorm house-148624 shared house 100695.

6. Conclusion

Cities can use this strategy to mitigate the population rise issues and climate-related problems, predicting the population of cities in the coming years and predicting the potential housing option they will choose on certain basis (social, economic and education). From that number after analysed by the agent based modelling they can build housing in such a manner that it is sustainable, cheap to afford and mitigates the effects of climate change and problems related to overcrowding.

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