

Characteristics of recent urbanisation in India in light of the divergent development paths of metropolises

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Keywords:

India, urbanisation,
metropolisation,
agglomeration,
urban statistics,
city clusters

India is one of the fastest growing and developing economies as well as societies of the world. An evident consequence of this trend is urbanisation, which poses an immense challenge for the population and political decision-makers of the country, and it is one of the most important social geographical topical research trends concerning India. First, this paper introduces the general urbanisation trends experienced in sovereign India in the 1951–2011 period, in the framework of an analysis of statistical data recorded in censuses, indicating the volume and trends of urbanisation. This step is followed by the demonstration of the structural features and diverse development paths of the million-plus agglomerations (i.e. agglomerations with at least a million inhabitants), connected to one of its main characteristics depicted by this introductory summary: metropolisation. This also allows the demonstration of the differences between the statistical and functional interpretation of metropolitan areas. Using the quantitative categories defined during the analysis, the authors classify the metropolises of India in terms of types of urbanisation through cluster analysis.

Introduction: General urbanisation trends in India in the second half of the 20th century and the beginning of the 21st century

Urbanisation in India, a country with a past of almost four and a half millennium (Ramachandran 2001, Tirtha 2002), experienced a radical direction change after the country gained its sovereignty in 1947 (Wilhelm 2008, 2015, Wilhelm–Zagyi 2018). The new socio-economic factors of this time, similar to the impact of refugees from Pakistan on urbanisation, the building out of new administrative centres generated by the indigenous process of state creation, the birth of more industrial cities and districts, and the natural increase in population as well as the continuously accelerating pace of migration into cities led to a growth in the number of cities and the proportion of urban inhabitants in a way that had never been experienced

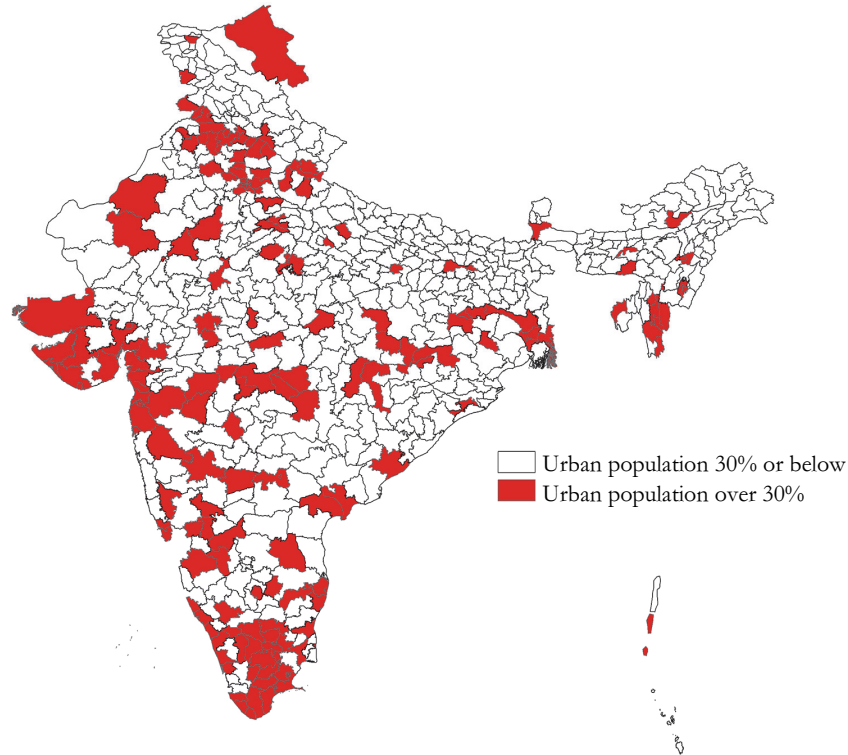
before. In addition, a significant phenomenon of the period from the mid-20th century until now is the rapid strengthening of the weight of cities with populations of hundreds of thousands or millions. This process is in sharp contrast with characteristics of urbanisation experienced in developed, ageing economies where the birth of small new towns from villages through legal interventions results in an increasing number of urban settlements (Konecka-Szydłowska et al. 2018, Atkinson 2019, Rechnitzer et al. 2019). At the time of the first census in sovereign India in 1951, only 45% of urban citizens lived in settlements with more than 100,000 inhabitants, while cities in this size category gave home to more than 60% of India's population, parallel to a six and a half-fold increase in their population; further, their number grew from 76 to 423 cities by the time of the 2001 census. The growth in the number of million-plus cities (metropolises) was also dynamic: as opposed to five such cities in the mid-20th century, India had 35 of them by the dawn of the new millennium. This evidently led to the stagnation or decline in settlements with less than 100,000 inhabitants, considered as small towns in India: their share from the urban population fell from 55% to less than 40%, within this, that of towns with less than 20,000 inhabitants from 30% to 11%, and they were less than twice their number of the 1951 census (Census India 2001).

The concentration of urban citizens in settlements with more than 100,000 inhabitants experienced a new momentum in the first decade of the 21st century. Their population further increased, due, on one hand, to the recent expansion in the number of cities of this magnitude (Class-I category), and on the other hand, to the surplus population coming from a natural increase and in-migration. In 2011 already 70% of all urban citizens lived in such settlements. With the rapid progress of mid-size cities with populations of over 100,000, and of metropolises, urbanisation now shows a high degree of concentration: in extended regions void of urban settlements or having only small towns, urban spaces are represented by agglomerations that are few, usually sparse, but consist of a concentration of a large population number.

An examination of the spatial concentration of urban population at the district level, which refers to the lower administrative units of states and union territories, reveals that urban agglomerations, which sometimes grow into megapolises, are being born, with tight correlation with the SENTIENT index featuring their social, economic, and infrastructural development level (Wilhelm 2011, Wilhelm et al. 2011, 2013, 2014). These formations were even more striking by 2011 than ten years before (Figure 1).

For the statistical interpretation of urbanisation in India, one must know that settlements with central functions, having different names depending on the size of their population – Municipal Corporation, Municipal Council, City Council – having accordingly administrative independence at different levels, but all with urban self-governments (statutory towns), are home to only one part of the urban population, although definitely the larger part.

Figure 1

Districts with over 30% urban population in 2011

Source of data: Census India (2011).

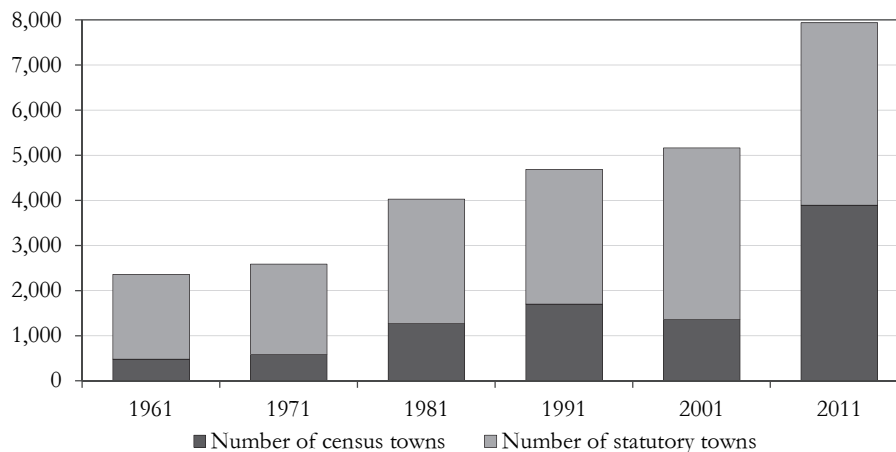
The number of cities, according to the size and proportion of urban population, is further increased by the so-called census towns that are registered among the urban settlements only for the manipulation of the pace of urbanisation, sometimes by a plastically interpreted urban definition, in the absence of real central functions and self-governments. In this definition, all settlements with more than 5,000 inhabitants – in reality, many settlements with fewer population – are considered as towns if they meet the following criteria: at least 75% of their full-time male employees work in the secondary or tertiary sector and the population density is at least 400 persons/km². The group of census towns is newly designated before each census in accordance with this set of criteria, and the size of the urban population is defined taking this aspect into consideration. The number of census towns at the time of the 2011 census was 3,894, as opposed to 1,362 a decade earlier, while that of functional towns increased from 3,799 to 4,041 (Singh 2014), which means a more than one-and-a-half-fold growth in the number of urban settlements, from 5,161 to 7,935. According to our computation, a strong (Pearson method) correlation ($r=+0.89$) exists between the change in the number of census towns

(Figure 2) and in rates of urban population from 1961 until 2011 (Census Newsletter 2001, Census India 2011) verifying the definite role of census towns in Indian urbanisation.

Urban areas registered during the census consist of cities in themselves or urban agglomerations (UAs). In a statistical sense, agglomerations include the central city, the real and census towns coalesced with it, and other units integrated into this agglomeration but outside its administrative borders and without self-governance, possessing an urbanised infrastructure. In the settlement statistical nomenclature, these settlement parts are collectively defined as an outgrowth, they may be railway colonies, university campuses, harbour districts, military bases, and so forth.

Figure 2

**Change in numbers of census and statutory towns by censuses
between 1961 and 2011**



Source of data: Duijne–Nijman (2019), Singh (2014).

Looking at the growth in the number of cities and UAs from 2001 to 2011, we can see that the number of small towns (small town areas) with less than 100,000 inhabitants grew one-and-a-half-fold, from 4,738 to 7,467, due to the sudden increase in the number of census towns; their share in the urban population, however, fell from 38% to 30%. The number of middle towns and agglomerations in the 100,000–1,000,000 population category grew by 7%, from 388 to 416, while the increase in the size of their population was twice as much, 14%. On the whole the most dynamic growth could be observed in the million-plus cities and agglomerations, with an increase in their number from 35 to 52 in ten years (Table A1 – see [Internet Appendix](#)). The number of their inhabitants showed a similar growth, approximately 50%, as a consequence of which it grew from 107.9 million to 160.7 million. However, the average population of these settlements increased only slightly, due to the growth in the proportion of metropolises with a population

of just over a million people; still, it exceeds three million people. As a result of these processes, with the exception of Odisha and the states with small territories and low population numbers, by 2011 there was at least one million-plus city in all federal states, in addition to the Delhi union territory (Figure 3).

The metropolises, giving home to 43% of India's urban population by 2011, already showed tremendous growth both in regard to their number and their population, although the growth of the latter showed significant extremes between the last two censuses: whereas the population of Kolkata or Kanpur only grew by 6.5% and 7.5%, respectively, that of Thrissur increased to over a five-and-a-half-fold, and that of Malappuram to almost tenfold. Leaving Vasai-Virar City – detached from the territory of Greater Mumbai in 2009 and becoming a sovereign metropolitan area by now, but actually being a part of the agglomeration of Mumbai – out of consideration, the growth of the population in the remaining 51 cities or agglomerations was 67% on average, in the respective decade.

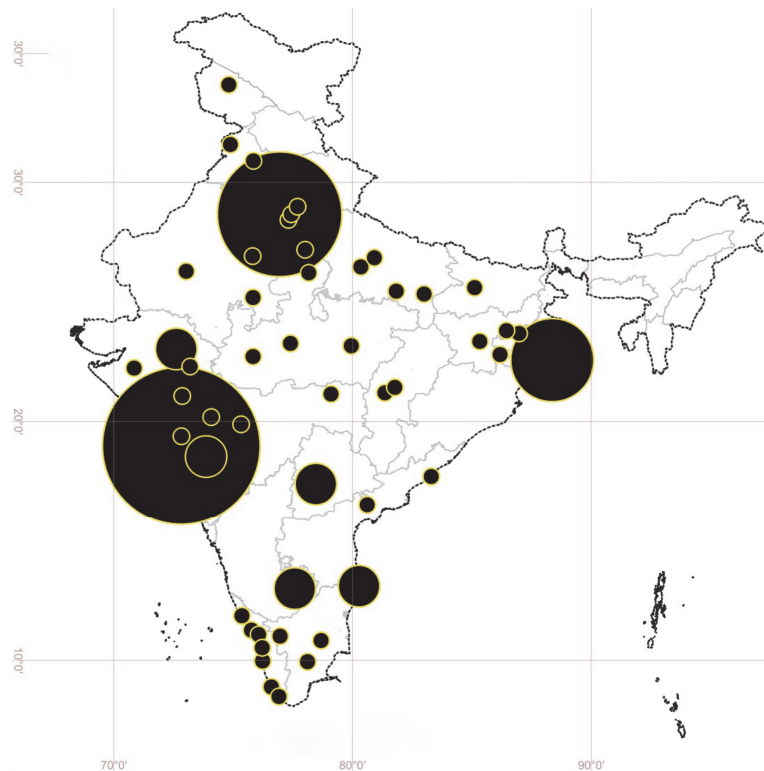
Cities and agglomerations showing outstanding growth, with the exception of Ghaziabad, can all be found in Kerala state, far above the average Indian urbanisation and socio-economic development level, with a 47.7% share of urban population, where the proportion of urban population grew by 98.2% in ten years, advancing all union territories and states with at least one million-plus city (agglomeration). A considerable part of this growth was due to the intensive, often tenfold population growth in cities which have grown into metropolises, being in the category of middle cities in the previous decade, except for Kochi. As a consequence the first, approximately 500-kilometre-long metropolitan axis of India was born in the south part of the Western Coast, in the Kerala territories of the Malabar Coast in the foreground of the Western Ghats, stretching from Kasaragod to Thiruvananthapuram (Figure 3).

In the approximately 4,500-year-long history of Indian urbanisation, from the flourishing of the Harappa culture to the birth of the Kerala megalopolis¹, the latter phenomenon is a significant milestone even if we consider the fact that it is largely the result of statistical manipulation. Of all the 2,352 Indian settlements declared census towns in 2011, almost 13%, that is 320 settlements, can be found in the federal state that makes just over 1% of the territory and approximately 3% of the population of the country, with 33.4 million inhabitants in 2011 (Pradhan 2017). Further, the 8.8 million population surplus of the new Kerala census towns is more than 40% of the 16 million urban population of the state, and almost 90% of the 7.7% growth of urban population.

¹ In our interpretation, megalopolises are extended and continuous urban areas having more than 10 million inhabitants.

Figure 3

Location of cities (urban agglomerations) with a population of at least a million people in 2011



Source of data: Census India (2011). The largest circle representing Greater Mumbai measures up to 18.4 million people; the other ones are proportionally smaller.

Functional interpretation possibilities of metropolitan areas different from the statistical one

In this case – in connection with the situation of the above-mentioned Vasai-Virar City or the Kerala megalopolis – it is worth examining how the settlements exceeding the population threshold of one million can be interpreted as independent metropolitan regions.

There are several million-plus cities and agglomerations which, due to either local interests or the constraint to adapt to administrative boundaries, are independent in the statistical-administrative sense, but in reality make a functional unit with the neighbouring agglomeration at a higher hierarchy level, with which they are coalesced. In addition to Vasai-Virar City that is actually part of Greater Mumbai, cities that must be mentioned are Ghaziabad that is part of the

agglomeration of the capital city, but situated in the territory of Uttar Pradesh, and Faridabad which belongs to the state of Haryana. If, apart from the smaller towns coalesced with Mumbai or Delhi, in addition to these million-plus settlements, we also calculated the Bhiwandi agglomeration with almost 750,000 inhabitants, being an organic part of Greater Mumbai, and Gurgaon with its 900,000 inhabitants, making a common settlement space with the agglomeration of the capital city, and Noida census town that more than doubled its population in a decade, reaching almost 650,000 by 2011, to the agglomeration of Mumbai and Delhi, respectively, the population of the former would be almost twenty million, and that of the latter would grow to twenty-two million. This means that the Delhi agglomeration, growing at a fast pace, is actually the most populated urban area in India, exceeding even Mumbai.

Among the metropolises of India, as a perfect example of classic conurbations, there is a more and more apparent city pair growing into a twin city, located only 30 kilometres away from each other and being continuously built up along the communication corridor between them that now makes a contiguous urban space. These cities are Bhilainagar and Raipur, making now one agglomeration and having by and large the same weights, with a combined population in excess of two million people.

Due to the more than 300 Kerala census towns appointed in 2011, that will – probably – be functional towns by the time of the next census, as it has already been mentioned, a contiguous urban axis, hundreds of kilometres long and growing into a megalopolis, has been born in the recent years along the south part of the Malabar Coast. The population of this agglomeration, made by independent agglomerations in the statistical sense, stretching from Kasaragod to Thiruvananthapuram, if handled as one single mega-agglomeration, is at least ten and a half million people, which makes it the fourth largest agglomeration in India, even if only the partial agglomerations with a population of over a million people are taken into consideration.

In case of the flexible designation of agglomerations, leading to a growth in size of functional urban agglomerations, the actual number of metropolitan areas will decrease, if a part of settlement spaces now handled as separate cities or agglomerations are united. If, however, the range of examination includes urban areas with less than one million but more than 500,000 inhabitants, the number of metropolises may even increase, as the population of these and the other settlements forming an organic unit with them is over one million in some cases. Therefore, the range of real agglomerations (making functional units) is somewhat different from those of the metropolises in the statistical registers.

Indeed, there are a few examples of this in the settlement network of India. Similar to the enlargement of the urban network around Delhi, the population of the Chandigarh agglomeration can also be increased. In this case, the population will

increase to 1.3 million, along with the population of S.A.S. Nagar and Panchkula coalesced with that of Chandigarh, in the territory of Punjab and Haryana states, respectively, surrounding the city that is a separate administrative unit, as Delhi is. The combined population of Bhubaneswar (885,000 people) and Cuttack (663,000 people), interpretable as a conurbation, is over a million and a half, which also means that according to this interpretation of agglomerations, Odisha state has a settlement with a population in excess of one million as well. Finally, attention must be called to the triple city group located in the southern edge of Maharashtra state: Kolhapur (562,000 people), Sangli (512,000 people), and Ichalkaranji (325,000 people), the total population of which reaches 1.4 million, even if only the pole settlements in the Class-I category are taken into consideration.

A certain transfer among cities and agglomeration is also possible. If more settlements can be annexed to sovereign towns (statutory towns), they may turn into agglomerations. The authors' examinations found no example of this possibility among the metropolises. However, some of the regions considered as agglomerations by statistics are actually not agglomerations. Such a *quasi agglomeration* is Bengaluru (8,520,000 people); in this case, Bengaluru M. Corp. (8,495,000 people), that is Bengaluru, making the core of the settlement cluster, is home to 99.7% of the population; besides this, there is a negligible number of inhabitants, approximately 25,000 people, in two small census towns that are parts of the agglomeration. There are settlements which are considered agglomerations due to the presence of a cantonment² with a limited number of people: in the case of Aurangabad, the central settlement with a population of 1,175,000, Aurangabad M. Corp. makes 98.5% of the total population of the agglomeration with 1,193,000 inhabitants, that is with only an extra population of 18,000 people.

The restructuring of the Indian metropolises by the considerations mentioned above results in a range of cities and agglomerations with populations of more than a million people, and their order by size of population as featured in Table A2 (see [Internet Appendix](#)). This was compiled by the application of those methodology criteria according to which only the inhabitants of cities and agglomerations in Class-I group, that is with more than 100,000 inhabitants, from among the settlements in the coalesced, functionally single urban areas, were considered; this method seems to be appropriate for the calculation of a population size in line with reality. On the other hand, those single-centred agglomerations where the proportion of the eponymous core city within that of the total agglomeration reaches 97.5% or at least 95%, and concurrently the administrative territories of the towns in the hinterland of the core make less than 5% of the territory of the total urban area, are not taken into account as agglomerations. From among the total of 52 settlements with population in excess of a million inhabitants, created by the

² Permanent military base, garrison.

designation of the census in 2011, only the first condition is met, in addition to the already mentioned Bengaluru and Aurangabad, by Surat and Amritsar, the second one by Nagpur and Gwalior. By the accession of Hosur, now coalesced with Bengaluru and Nagpur (part of the neighbouring federal state, Tamil Nadu, already), and Kamthi; however, these two settlements are among the agglomerations in a functional sense.

Characteristics of metropolisation on the ground of the structural features and development processes of agglomerations and cities registered in statistics

Survey methods

In this paper, the structural and growth characteristics of settlements are analysed based on the authors' own database compiled from the data registered during the censuses for the population of 52 cities with more than a million inhabitants, and the population of agglomerations as well as the size of their administrative territories (Towns and urban agglomerations 2011). On this ground, an attempt is also made to identify certain types of settlements.

In addition to the time series values of the size of population in the cities, the database generated by the authors contains data for the agglomerations: the number of inhabitants in the core settlements and satellite towns, and within this, separately, the population of the real and census towns, the proportions of the centre and census towns in relation to the total population of the agglomeration, and the proportions of the census towns within the total population of all real and census towns in the hinterlands. In addition, the authors made separate calculations for the volume of the change in population in the sub-settlement categories (total of the agglomeration, centre, hinterland, real and census towns of the hinterland), by decades, for the period 1951–2011.

In a breakdown similar to this, aggregate data for the towns and agglomerations were collected: size of the administrative territory of the whole agglomeration, of the central settlement, and of the hinterland; further, proportions of the territories of the centres and the adjoining towns within the agglomerations were calculated, and the volumes of the changes in these in time series. Finally, population density values were calculated for the total of the respective settlements, in the case of agglomerations separately for the central settlement and the hinterland, as were the data indicating the changes of these by decades.

Based on these population, territory, and population density data, different examination goals were set for the time of the 2011 census and for the period from 1951 to 2011, and the metropolises were analysed, assessed, and grouped based on these aspects and using the relevant data.

To identify the urbanisation categories of million-plus agglomerations, classified into static and dynamic (time series) categories (ordered to variables), after the analysis of the data set mentioned above, a cluster analysis was implemented, the results of which, as the abstraction of the urban statistics examinations of the authors described below, are seen as the summary of the work.

During this, analysis variables were created – in a statistical approach – each of them with a numerical value, as were the categories belonging to these, which are essentially the textual data (factor). Data were processed with the R programming language (R Core Team 2020). In the first step, the extent to which the respective variables support the cluster analysis and how much they are independent of each other was analysed. The majority of the procedures applied require that each variable included in the survey has a value for all cases (locations). Thus, it is more reasonable to have variables in the data series of which there are less <NA> values.

During the one-by-one examination of variables, the plot of the estimated density function was visually evaluated. The R language integrated density function was used with default parameters (Becker et al. 1988). The factors that had stronger ($|r| > 0.3$, Pearson method) correlations were also examined. Through this, variables were evaluated on the ground of how many other variables they correlated with. This means that variables indicated with larger correlation numbers derived this way (Table 1, column ‘ $|r| > 0.3$ corr. number’) can be neglected, if necessary. This kind of selection is based on the scholar’s decision, however, not without examples as a checkup (Alpek–Tésits 2019) in the field of cluster analysis preparations. The definitive capacity of the respective variables for the sample were evaluated with K means clustering, where groups sum of squares (WSS) were calculated for 2–15 clusters. Demonstrating this by the number of clusters, with the *elbow* method frequently used in practice, the practical number of clusters for the given variable was defined (Table 1, column ‘K-means WSS based number of clusters’). To counterbalance subjectivity, a model-based clustering was also implemented. The chosen procedure was model-based clustering based on parameterised finite Gaussian mixture models, where the number of clusters is defined by the algorithm itself. In the process, default settings of the system were used (Scrucca et al. 2016). Cluster numbers gained as a result are included in the column ‘Model-based clustering number of clusters’ in Table 1.

As the respective quantifiable values had already been ordered into categories, the actual multi-variable clustering was practically continued with these categories (according to the R terminology: factor) of values. The shift from the set of real numbers to discrete factor values will definitely change the ideal number of clusters but will still carry the definitive characteristics of the numerical variable used as the basis of the category.

Table 1

Key characteristics of each variable
(Those involved in cluster analyses are in bold)

Variable description	Numerical variable name (Category variable name)	Number of <NA> occurrences	Single variable k-means WSS based optimal number of clusters	Model-based clustering ideal number of clusters	Number of $ r > 0.3$ correlations computed against all other variables
Static					
Name of location	(loc)				
Population density	Popdens (popdens_c)	0	4	1	8
Population density of centre	centdens (centdens_c)	0	3	2	5
Centre and agglomeration population density ratio	centaggl densrat (centaggl densrat_c)	12	3	2	3
Size of administrative area	adminarea (adminarea_c)	0	2	2	4
Centre and agglomeration area size ratio	centaggl arearat (centaggl arearat_c)	12	3	3	5
Weight of census towns	cenzcitwei (cenzcitwei_c)	12	2	3	7
Centre and agglomeration population ratio	centaggl poprat (centaggl poprat_c)	12	3	2	6
Dynamic					
Population growth rate (1951–2011)	growth19512011 (growth19512011_c)	0	3	3	2
Population change of census towns (2001–2011)	Cenzpopchange 20012011 (cenzpopchange 20012011_c)	26	3	3	0
Population density change of metropolises (1961–2011)	Metropopchange 19612011 (metropopchange 19612011_c)	2	3	3	6
Population density change of metropolises (2001–2011)	Metropopchange 20012011 (metropopchange 20012011_c)	0	4	3	5
Agglomeration population density change (2001–2011)	Agglpopdenschange 20012011 (agglpopchange 20012011_c)	14	3	3	4

Values of dissimilarities among the factors as ‘distances’ were calculated with the R daisy function. In this case, taking factors into consideration, Gower’s procedure (1971) was used. For multi-variable clustering, agglomerative hierarchical clustering was chosen and implemented with the hclust function. Within this, ward.D2 was selected as the agglomeration method (Murtagh–Legendre 2014), meanwhile, other options were left at their defaults.

Further, during this procedure, the ideal number of clusters is not obvious; therefore, from the static and dynamic variables, what would give ideal results by several indices was preliminarily evaluated. The results of Table 1 on the characteristics of the variables were also used for compiling the series of variables. Such selective reduction of variables and samples is an omnipresent issue with working examples in relevant publications (Bodnár–Csomós 2018) targeting the same kind of hierarchical analysis. As the calculation of optimum variable combinations is not a goal of this paper, what is given here is only the final set of variables used for the two analyses (Table 2).

Table 2

Lists of involved variables in each cluster analysis

Cluster analysis	Involved variables
On static variables	adminarea, centdens, centagglarearat, centaggl densrat, centagglpoprat
On dynamic variables	popgrowth19512011, metropopchange20012011, metropopchange19612011

For the definition of the cluster number, a routine that calculates multiple variables was used, run for 1–8 clusters. Cluster analysis was finalised with the ideal number of clusters defined this way. Values taken into consideration were the application of the elbow method also used during the single-variable analysis at the WSS chart, the search for the maximum of the silhouette values (Rousseeuw 1987) and dunn2 index (Halkidi et al. 2001). The results of clustering are presented in a dendrogram. For the examination of the regularities of spatial appearances, settlements ordered into clusters were also presented in a map using the QGIS geographical information system. To assist in the interpretation of the spatial distribution, the maps also contain the standard deviational ellipses and their centres (Yuill 1971) for each respective cluster.

Findings of the (static) settlement surveys based on data from the 2011 census

In this subject, the most obvious way of examination can be typifying based on the relative weights of the populations of the agglomerations’ central settlements and of the towns in their hinterlands. At this place and hereinafter, the starting point of the examinations is the range of agglomerations as they are defined in the official statistical registry based on the data of the 2011 census. Accordingly, statements concerning the strength of the dominance of the centre can be made about 46

agglomerations, as six additional settlements (Jaipur, Visakhapatnam, Ludhiana, Faridabad, Vasai-Virar, and Kota) are considered independent cities. In addition, however, six other settlements not taken as real agglomerations are referred to as quasi agglomerations, starting from the interpretation of agglomerations as defined above – Bengaluru, Aurangabad, Surat, Amritsar, Nagpur, and Gwalior – and these are classified into a separate category.

In accordance with the authors' preliminary expectations – and information – in the majority of cases, classic single-centred agglomerations with a dominant centre could be identified. The criterion set for this by the authors is that the population ratio of the central city to the total population of the agglomeration is at least 60%. Further, there are agglomerations with a relative balance of the size of population in the centre and hinterland. In these cases, neither the centre nor the adjoining settlements have population shares below 40% of the total agglomeration's; however, this figure does not exceed 60%, either. The third group involves those agglomerations where the central city has less than 40% of the total population. This group may be further broken down into two sub-categories: in one case, the centre, despite its relatively low share in terms of the population, has a dominance over the other settlements due to the fragmented hinterland; finally – starting from the example of the Kerala agglomerations – there are agglomerations whose eponymous settlement is actually not more than a pole in a multi-polar cluster of cities, which, however, has an outstanding significance due to its role in culture, economy or urban hierarchy. On the ground of these considerations and the previously defined set of criteria, the 46 million-plus agglomerations in India can be typified as follows (Table A3 – see [Internet Appendix](#)).

The population ratios of census towns to the total of the agglomeration and hinterland of the central settlement allows us to draw further conclusions. The authors believe that a higher share of population living in census towns refers to the fact that the scale of urban growth apparent in physical form and in quantitative indices is bigger on the whole than in those agglomerations that consist exclusively or predominantly of settlements with urban status and consequently, shorter or longer historical past. In the former case, urban growth reflects economic prosperity and higher employment level; in the latter, it reflects the agglomeration process as a result of organic urban development.

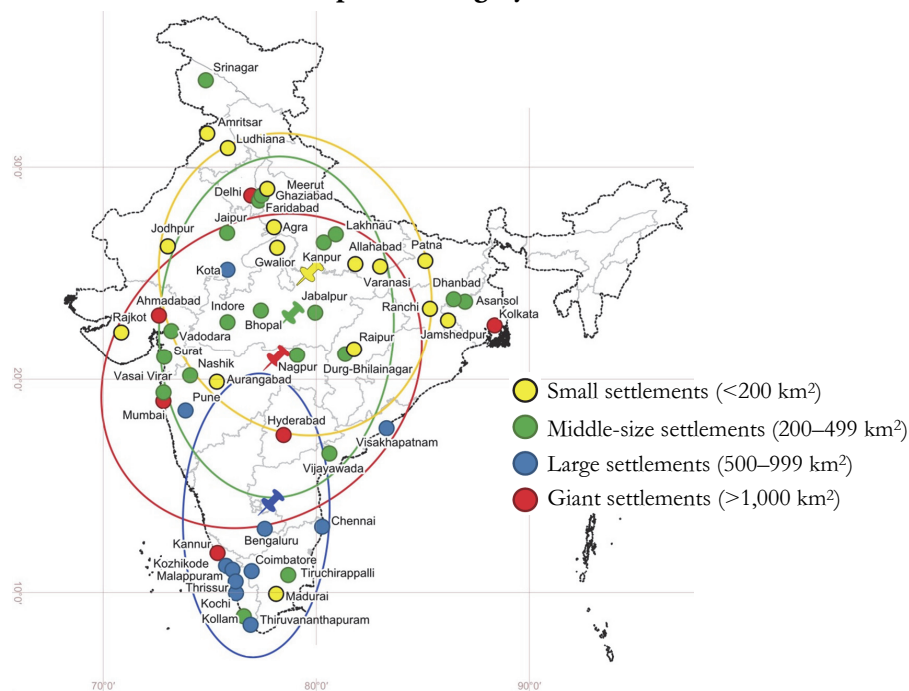
It only makes sense, however, to typify agglomerations based on the above criteria for settlement clusters with real hinterlands. Adjusted to the threshold values set in accordance with the authors' interpretation of agglomerations, 40 out of the 46 settlements with a population in excess of a million are taken into consideration as the assessment of the six settlements formerly qualified as quasi agglomerations is omitted in this respect.

Clearly, the agglomerations without census towns are also seen as a separate category. The role of census towns in urban development is considered as limited or

negligible if the share of their population in the total of the agglomeration is from 5 to 9.9%, or less than 5% and concurrently, less than half of the population of all settlements in the hinterland. Depending on the share of population of census towns, their role is considered as palpable (10–29.9% or less than 10%, but making more than half of the population of the hinterland), dominant (30–49.9%) or decisive (at least 50%). On this ground, the metropolises of India can be categorised as follows (Table A4 – see [Internet Appendix](#)).

Figure 4

Cities and agglomerations with a population of at least a million people, grouped by the size of their administrative territories and featuring the standard deviational ellipses and their topographical centres for each respective category in 2011



Source of data: Towns and urban agglomerations (2011).

With regard to the administrative sizes of the 52 cities and agglomerations with populations in excess of 1 million in 2011 by the official statistics, and their differences, the following statements can be made. The size of the largest settlements exceeds 1,000 km², whereas that of the smallest ones does not even reach 150 km². The largest administrative territory, larger than that of Delhi, belongs to Hyderabad; the smallest one is that of Allahabad. The largest million-plus agglomerations can be found, in addition to the most populated metropolises of

India, almost exclusively in the Kerala megalopolis, typically enlarged with census towns (Kannur, Thrissur, Kozhikode, Kochi, Malappuram), while the smallest ones can usually be found in the Northern Plains with high agricultural potential and on the whole below-average urbanisation level (Allahabad, Varanasi, Amritsar, Patna, Aurangabad, Ludhiana, Agra). Classifying the examined settlements into at least 1,000 km² territory (giant), 500–999 km² (large), 200–499 km² (medium), and smaller than 200 km² (small) size categories, the following results can be seen (Figure 4).

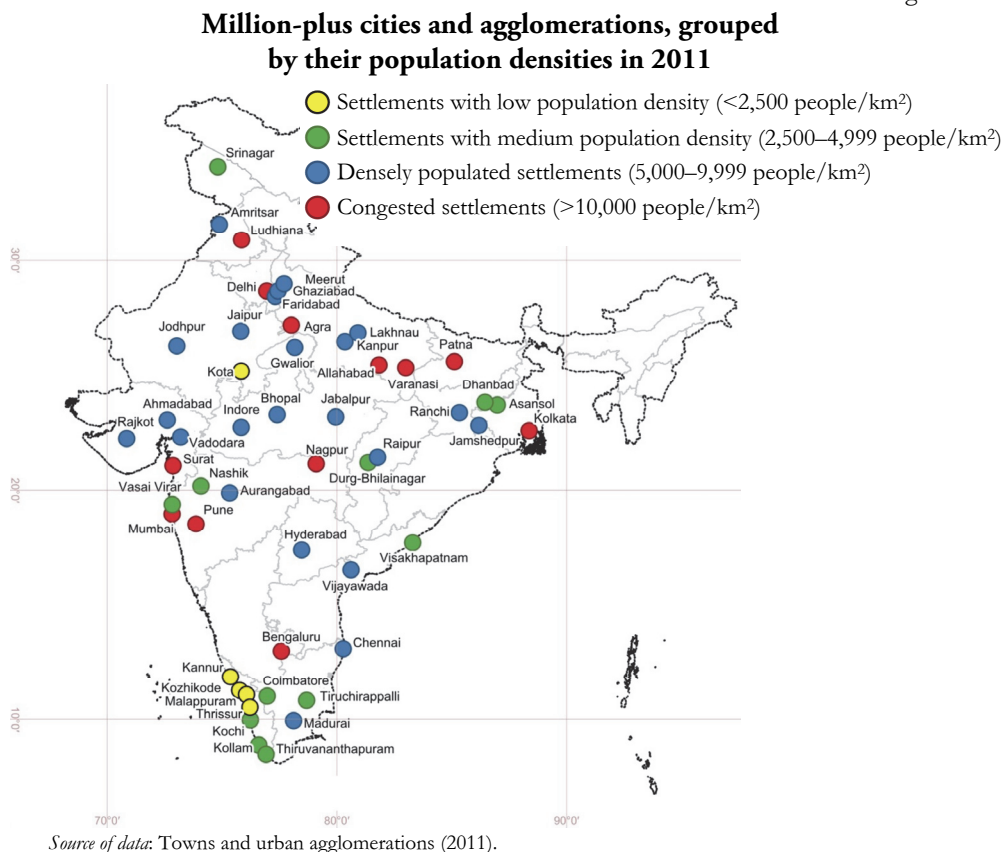
It is also worth looking at and categorising million-plus agglomerations on the ground of the administrative territory ratios of the centre and hinterland. In this respect, the 2011 data of the 46 agglomerations are analysed, still reserving the concept that the six agglomerations where the central settlement – with its population and territory – almost fully covers the respective agglomerations that are not considered as real agglomerations. As a reminder: the authors defined cases where the share of the population of the eponymous central city within the total of the agglomeration reaches 97.5%, or it is at least 95%; in the latter case, however, the administrative territory of the towns making the hinterland of the centre is not more than 5% of the territory of the whole agglomeration.

Besides the so-called quasi agglomerations, the following categories were defined: agglomerations with centres of dominant territories in which the administrative territory of the centre is at least 60% but does not amount to 95%; agglomerations with balanced centre-hinterland proportions where the administrative territory of both the eponymous central settlement and the towns in its hinterland makes 40–59.9% of the territory of the whole agglomeration; agglomeration where the territorial weight of the centre is 15–39.9%, still, it has a decisive role and significance in comparison with the settlements in its definite fragmented hinterland; and finally, agglomerations in which the territorial weight of the eponymous centre is negligible (less than 15%). It is only one pole of outstanding significance due to its role in culture, economy or the urban hierarchy (Table A5 – see [Internet Appendix](#)).

A great deal is revealed by the population density figures of cities and agglomerations with regards to the settlement structural features of urban areas, the quality of living space they provide, and the relation of the centre and hinterland. In the case of India, a country with a developing economy, overpopulated, and still growing, it is not particularly surprising that the million-plus cities and agglomerations are mostly densely populated congested areas as the population density of the country as a whole is also well above the world average. The settlements with the largest population density among the 52 metropolises – typically the most populous agglomerations (Mumbai, Delhi, Kolkata, Bengaluru) and the ones with the smallest territories, mostly in the Ganges Plain experiencing the challenge of a shortage of land (Patna, Agra, Varanasi, Allahabad) – have population numbers in excess of 10,000 per km². On the contrary, population

density in the developed Kerala megalopolis is enlarged by its less densely populated census towns (Kannur, Malappuram, Thrissur, Kozhikode, Kochi) which have population densities typically only making one-fourth or one-fifth of the previous ones. The latter figures do not even amount to those of European metropolises with lower population densities (e.g. Hamburg, Prague, Budapest, or Vienna) (Páthy 2017, Zdanowska et. al. 2020). On the whole, a more than ten times difference can be seen between the relevant values of settlements with the highest and lowest population densities. Evaluating agglomerations and cities together, they can be classified into the following categories: congested settlements with a population density of above 10,000 people/km², densely populated settlements (5,000–9,999 people/km²), and settlements with medium (2,500–4,999 people/km²) and low (< 2,500 people/km²) population density (Figure 5).

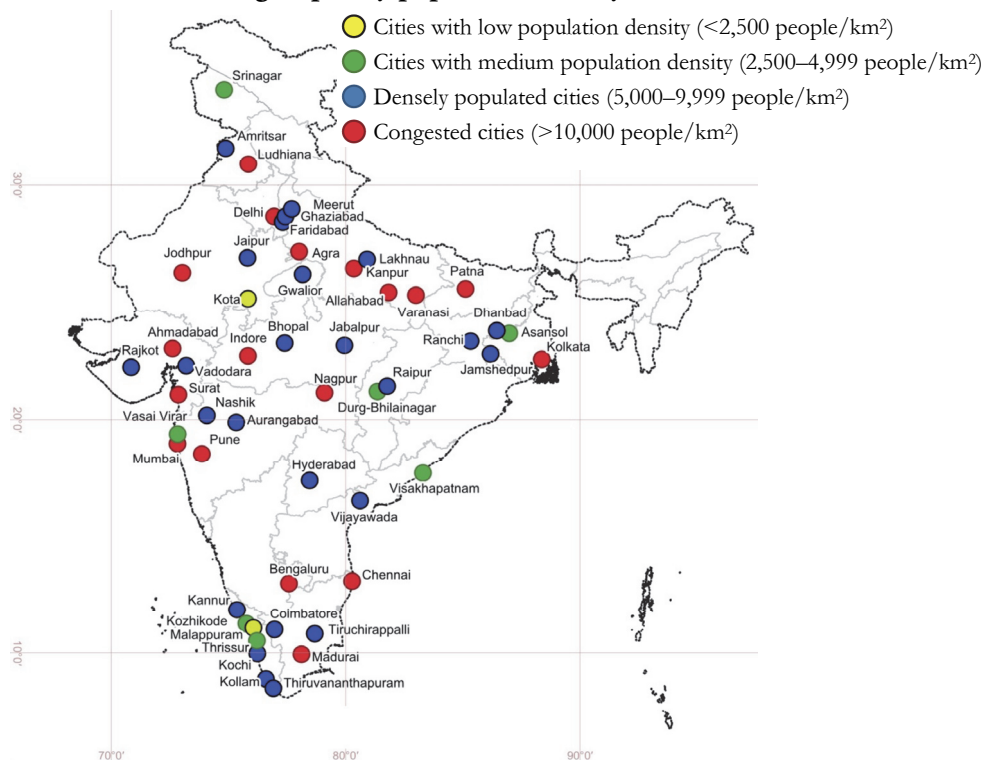
Figure 5



To decrease the distortion of data obtained from the comparison of population density values of agglomerations, lower on the whole, and of sovereign cities, higher on the whole, it is worth comparing population densities of settlements consisting of one single city and the eponymous settlements of agglomerations, despite the fact that in a statistical sense, these two settlement types are equal in rank, and the fact that the number of inhabitants in a few million-plus agglomerations is way below the one million threshold. Examining the range of cities interpreted this way, the composition of the settlements in the above-created types and size categories is as follows (Figure 6). Contrary to the distribution of agglomerations among these categories, a well-marked difference is that much fewer cities have low or medium population density. It is most conspicuous in the Kerala megalopolis usually consisting of more sparsely inhabited agglomerations with much more densely populated central settlements. In turn, on the Northern Plains, there is no significant difference between population densities of agglomerations and those of their centres.

Figure 6

**Million-plus cities and centre settlements of agglomerations,
grouped by population density in 2011**



Information on the differences between the relative positions of the centres and hinterlands in the agglomerations can be obtained, and concurrently on the classic or non-typical development paths of these clusters of settlements by the deviations of population density values in the centres and adjoining settlements, as well as the magnitudes of these deviations. To demonstrate this, those 40 settlements among the 46 agglomerations that were defined as real agglomerations are analysed below. As expected, at the overwhelming majority of the agglomerations it can be seen that the population density of the centre or the eponymous pole settlement is above that of the hinterland (Table A6 – see [Internet Appendix](#)). As for the irregular exceptions, it is partly a consequence of residential developments implemented in the hinterland, or due to enclaves that are unable to expand, residential areas of high population density were born (Dubey 2017), increasing the population density of the respective hinterland so much that it exceeds that of the central settlement or the whole agglomeration (Jamshedpur, Ghaziabad), and partly that in a polycentric agglomeration, the eponymous city, whose weight in population and its mathematical weight in shaping the population density figures of the agglomeration as a whole is negligible, has population density figures per territorial unit that might be lower than those of other pole cities with a similar size (Malappuram). Agglomerations showing a regular picture in this respect may be categorised by the magnitude of difference between the population density in the centre and hinterland. In case of deviation not more than twofold, the population and settlement ratios of the agglomerations can be considered almost homogeneous, which raises the issue whether these statistical agglomerations should be handled as one single city in the functional sense. In case of a difference bigger than twofold but not more than fourfold, there is a regular centre-hinterland relation, or we can see settlements born as a result of classic agglomeration development. Finally, if population density in the centre is more than four times that of the settlements in the hinterland, we can talk about irregular agglomerations. The basic reason for the birth of the latter category is the appearance of settlement clusters created in the agglomeration by the involvement of census towns with much lower population density compared with the typically congested or densely populated central settlement.

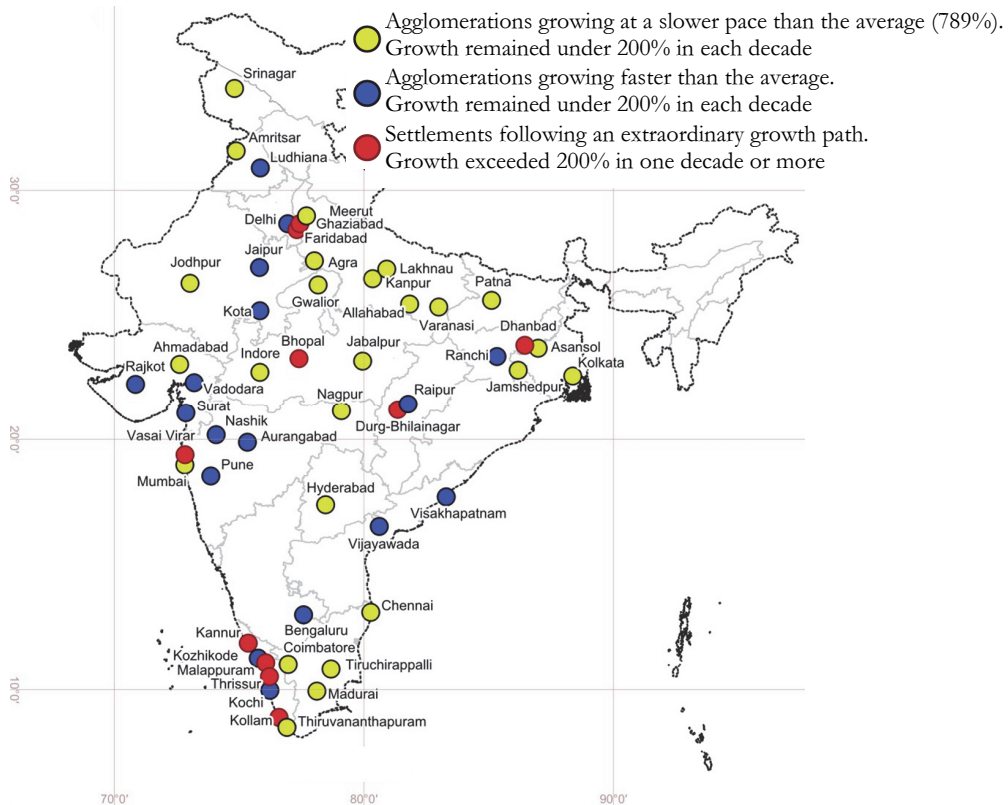
Findings of the examination of the growth characteristics of metropolises

In the following paragraphs, surveying the processes of the changes of population relations in million-plus metropolises (agglomerations and cities) over time, how, to what extent, and at what pace the population numbers of the respective settlements changed in the 60 years between the censuses of 1951 and 2011 is examined. In the case of those where the population growth did not double in one decade between the censuses were classified as settlements with regular but different development paths, and divided into agglomerations growing at a slower or faster pace than the

average (789%). Every other settlement is taken as irregular in this sense. The 52 metropolises of India are divided on this ground as follows (Figure 7).

Figure 7

Metropolises (cities and agglomerations) in India, grouped by the pace of their population growth from 1951 to 2011



Agglomerations showing a regular growth, and their centres, were usually members of the most privileged group as per India's settlement hierarchy at the time of the 1951 census, apart from a few exceptions with a long and rich historical past, and significant cultural and administrative functions, born as a result of autochthonous development. Practically all these were already in the Class-I category in the mid-20th century, that is, their population exceeded 100,000 people. The volume of population growth from 1951 to 2011 can be correlated to the size of the population registered at the beginning of the examined period. The size of the population in an agglomeration with a relatively moderate growth was 720,000 in 1951, on average, and even the smallest one had a population in excess of 180,000, while the average population of settlements showing the most intensive

growth was just over 300,000 at that time, with only three of them being in the 65,000–90,000 category (Aurangabad, Raipur, and Kota).

The differences and parallels are even more striking among the metropolises described above, born as a result of organic development, and agglomerations or towns qualified as irregular by the authors. The largest part of the latter is the latest formations of the urban network of India: with the exception of a few settlements with longer (Kollam, Thrissur, Kannur) or shorter (Bhopal), but in each case real historical development. They are industrial centres founded in the 20th century, which became urban areas in the second half of the century, and are now satellite towns with residential functions. Examples are Dhanbad, Durg-Bhilainagar, Ghaziabad, Vasai-Virar or Faridabad. The mean value of their population in 1951 was only 64,000 people, while their population grew to 31-fold, on average, until 2011; therefore, in their case, the regularity between the original size of the population and the pace of growth is even more valid.

If the examinations concerning the population increase in the settlements are extended specifically to the agglomerations, a much more articulated picture is gained about the temporal processes of their development. In this framework, differences and anomalies in the development pace of centres and their hinterlands are enumerated. In the majority of agglomerations, the pace of growth of the centre settlement is exceeded, although at different scales, by the population increase of the total of acceding towns. In a statistical sense, the dominant development path within this is represented by those settlements that already had a hinterland and a centre at the time of the 1951 census, and the volume of their increase can be continuously traced until 2011, that is, in their case, the growth characteristics of the constituents of the agglomerations can be meaningfully compared. Most of these are settlements where the population of the centre continuously grew until the time of the latest census, although more slowly on the whole.

An exception in this respect is, on one hand, the Kolkata agglomeration with the slowest growth and now with a hinterland several times more populous than its centre, which was the only one of the present metropolises with more than a million inhabitants in 1951 in the acceding settlements (almost 1.8 million at that time). It must be remarked here that in the mid-20th century, the relevant size of the population in the agglomeration of Delhi, with the second largest cluster of settlements in its hinterland, was 317,000. Irregularities are shown in this respect, on the other hand, by the Kerala metropolises where, as in the case of Kolkata, the population of the centre already decreased from 2001 to 2011, that is, the agglomeration process switched to a new direction in the first decade of the new millennium.

Considering this methodology, the examination of the so-called quasi agglomerations is still neglected. The fact that these cannot be considered real agglomerations is underlined not only by the static population and territory figures

of 2011 but also by the time of birth and temporal development processes of their hinterland: except for Aurangabad, the urban settlement clusters acceding to the centre, with low population numbers anyway, emerged quite late (in the case of Amritsar, first data for this trend were registered in 2011), and the pace of growth of these was definitely low, below 300%, until the time of the latest census (with the exception of Bengaluru).

Another frequent but atypical agglomeration path is followed by those settlements where the growth of population in the central city from 1951 to 2011 exceeded that of the hinterland. These are usually agglomerations in the Northern Great Plains, with high population densities and relatively small territories, incapable of further expansion in the surrounding agricultural areas. The directions of their population growth, however, were divergent in the period between the last two censuses. In some of them, the more intensive growth of the centre remained in the 2001–2011 period, in fact, in the case of Kanpur – as an exception – the number of inhabitants in the hinterland even decreased. In all other cases, the trend of several decades seems to be in reverse, inasmuch as the pace of growth was higher in the latest census decade in the hinterlands than in the centres. The former are, presumably, as a result of the shrinking of the hinterland, on the way to becoming separate towns from an agglomeration settlement, at least in the functional sense, as opposed to the latter where an opposite tendency seems to unfurl: a tendency towards an accelerating agglomeration process.

The other agglomerations, as opposed to the ones above, are settlements whose hinterlands, or – as seen in the case of Malappuram and Bhilainagar – centres were born, or became part of the urban area only later, and so there are no comparable data series for these, related to the same period. Further, two cities, Bhopal and Jodhpur, only became agglomerations with hinterlands in the census decade between 2001 and 2011, and so no statements can be made about their agglomeration processes.

Agglomerations are divided into the following types described above based on the volume and direction of growth of their centres and hinterlands (Table A7 – see [Internet Appendix](#)).

For the majority of the metropolises that transformed into agglomerations from 1951 to 2011, only the narrowest period from 2001 to 2011 allows a comparison of the changes in the size of the population. Among these agglomerations, the above-mentioned Bhopal and Jodhpur are necessarily excluded because information concerning their hinterlands is only available since the last census; therefore, a total of 11 agglomerations are examined from the aspect of the change in the population of the centres and hinterlands between the dates of the last two censuses. For these agglomerations and even for this narrow interval, a trend was valid: the extent of population growth in the hinterlands is typically above that of the centres, parallel to the advancing growth of the population in the central city, with the exception of

Kollam. Only two agglomerations show opposite processes: there was an increase in the size of the population in the centre cities of Vadodara and Dhanbad parallel to a decrease in the population of the acceding settlements (Table A8 – see [Internet Appendix](#)).

Looking at the temporal processes of the development of population numbers in the agglomerations, the last thing to be examined, also for the 2001–2011 period, is the role of census towns in the growth of their hinterlands. For this purpose, out of the 46 statistical agglomerations – excluding the formerly specified six quasi agglomerations and those two settlements (Bhopal and Jodhpur) for whose hinterland the first data are from 2011 – 38 can be analysed. The designation of this narrow interval of time was justified, on one hand, by the need to compare as many settlements as possible, and on the other hand, by the fact that the urbanisation effects of census towns were dominant in the development of the settlement relations in the period between the last two censuses, as it has already been mentioned in the first part of the paper. This latter fact is partly proven by the presence of ten agglomerations among the ones in the survey in which there were no census towns in 2001 but there were in 2011. Another indirect proof is that in the case of another 15 agglomerations, the pace of growth of census towns exceeds that of the extent of the increase of the functional settlements with town status in the hinterland. In addition, the size of the population in two census towns increased parallel to a decrease in the other acceding settlements; further, in two other agglomerations, hinterlands were made by census towns only in both 2001 and 2011.

The atypical urbanisation trend of census towns, opposite to their role of dynamising the agglomeration process, is only indicated by two facts: in one single metropolis, Raipur, the population that had lived in a census town in 2001 was the population – increased in number – in a town with a municipal self-government in 2011, as a result of an administrative change, in two other agglomerations, there are no census towns at all.

Among those agglomerations where the pace of growth of the population of census towns is interpretable, that is, it had census town population both in 2001 and 2011, there is an overwhelming majority of those where the size of the respective population increased, typically in a way that this population increase exceeded the growth rate of the other, including growing towns in the hinterlands; in a few cases, however, the population of the latter even decreased. It was less typical that the functional towns in the hinterland grew faster than the census towns. In two of the agglomerations with census towns with growing populations, there was no functional town at the time of either census. Among the four groups described above, the breakdown of agglomerations is as follows (Table A9 – see [Internet Appendix](#)).

At a small proportion of agglomerations, the population of the census towns decreased in the census decade 2001 to 2011, partly parallel to a decline in the population of functional towns, and partly simultaneously with a population increase in the latter. Finally, in only one case, there were no real towns in the agglomeration (Table A10 – see [Internet Appendix](#)).

The Indian agglomerations where the pace of increase or decrease in the population of the census towns cannot be quantified, can be grouped as follows (Table A11 – see [Internet Appendix](#)).

Finally, the change of the population density in million-plus settlements, then separately in the statistical agglomerations among them, is analysed. It is possible to do so for 50 settlements for the period between 1961 and 2011, excluding Hyderabad and Rajkot for which no data exist for the whole period, as the change of their administrative territory can only be traced from 2001 and 1971. There was a typical growth in the population density of the agglomerations during the 50 years prior to the latest census, but several counter-examples can also be seen (Table A12 – see [Internet Appendix](#)). As population did not decrease in one of the settlements, a decrease in the population density is as a result of an increase in the rate of the administrative territory above that of the size of the population. Settlements where the increase in population density was no more than twofold can be considered as cities or agglomerations demonstrating growth in the normal way, whereas metropolises producing values higher than this have become less and less liveable, congested urban living spaces, although to varying degrees, depending on the absolute value of population density. In only one agglomeration, Amritsar, the population density figure was the same in 2011 as it had been in 1961, as a result of changes within the examination period.

In part, to be able to include all metropolises in the examination of the change in population density, and partly, to detect recent processes as well and compare them to data showing the average changes over a longer period, the direction and extent of the change in population density in all 52 cities and towns with more than a million inhabitants from 2001 to 2011 are examined (Table A13 – see [Internet Appendix](#)). The relative proportions of settlements with growing or stagnating, or declining population density in the period between the last two censuses are by and large the same as the values typical for the 1961–2011 period, and the cities making the respective groups are mostly the same as well. Among the settlements with growing population density, the increase in the size of the population in the same territorial unit did not amount to one and a half times compared with the values of ten years before – with the exception of the outstanding 180% increase in Pune where this phenomenon is dominantly due to the loss of a quarter of the city's administrative territory.

The size of the population per square kilometre in the cities and agglomerations with decreasing population density in the previous census decade, from 1991 to

2001, increased to a smaller or lesser extent, with the exception of Ahmedabad. No relevant information is available for Hyderabad and Vadodara. The main reason behind the decline in the population density of the respective Indian million-plus cities and agglomerations is the significant increase in their administrative territories between 2001 and 2011. This is in line with the fact that the settlements of the Kerala megalopolis, considerably enlarged with census towns recently, are all in this category, with the exception of Malappuram whose population density slightly increased in the 2001–2011 period, but it was rather a stagnation, actually (102%); in the previous period, growth was evident (115%).

The final issue to be examined is the change in population density separately in the centre settlements of the statistical agglomerations and in their hinterlands from 2001 to 2011. So far this range, due to the applied methodology does not include the six cities defined as quasi agglomerations; further, Bhopal and Jodhpur are evidently omitted as they were not registered as agglomerations in 2001. In most agglomerations the population density of the hinterland increased slower or faster than that of the centre, but typically to the same extent, or in a few cases, opposite to them. Hinterlands with a decreasing population density partly acceded to centre towns following the same trend, and partly to others that were more densely populated than they had been a decade earlier. The fact that the reason for the decline in the population density of megalopolises is the decline in the size of the population per area unit in their hinterlands is justified by the fact that the decreasing population density of the respective hinterlands – with two exceptions: Vijayawada and Vadodara – was parallel to the increase in the population density of the centres or the slower decrease compared with the total of settlements in the hinterlands (Table A14 – see [Internet Appendix](#)).

Summary: Findings of the cluster analysis

The cluster analysis performed for the designation of types of urbanisation was extended to those settlements that were defined as real agglomerations in the framework of the statistical data analysis above, meaning that the six metropolises that are registered as *statutory towns* (Jaipur, Visakhapatnam, Ludhiana, Faridabad, Vasai-Virar, and Kota) were excluded, as were cities that were considered by the authors as *quasi* (i.e. not real) *agglomerations* (Bengaluru, Aurangabad, Surat, Amritsar, Nagpur, and Gwalior). This analysis was performed for technical reasons explained in the section on the methodology of cluster analysis, on one hand, and because these settlement clusters are significantly different due to their own classification features from the real agglomeration, on the other hand.

As a result of the *static analysis*, that is, an analysis built on the data of the 2011 census, the 40 agglomerations included in the research can be best classified into five clusters (Figure 8). Their classifying factors are given by different

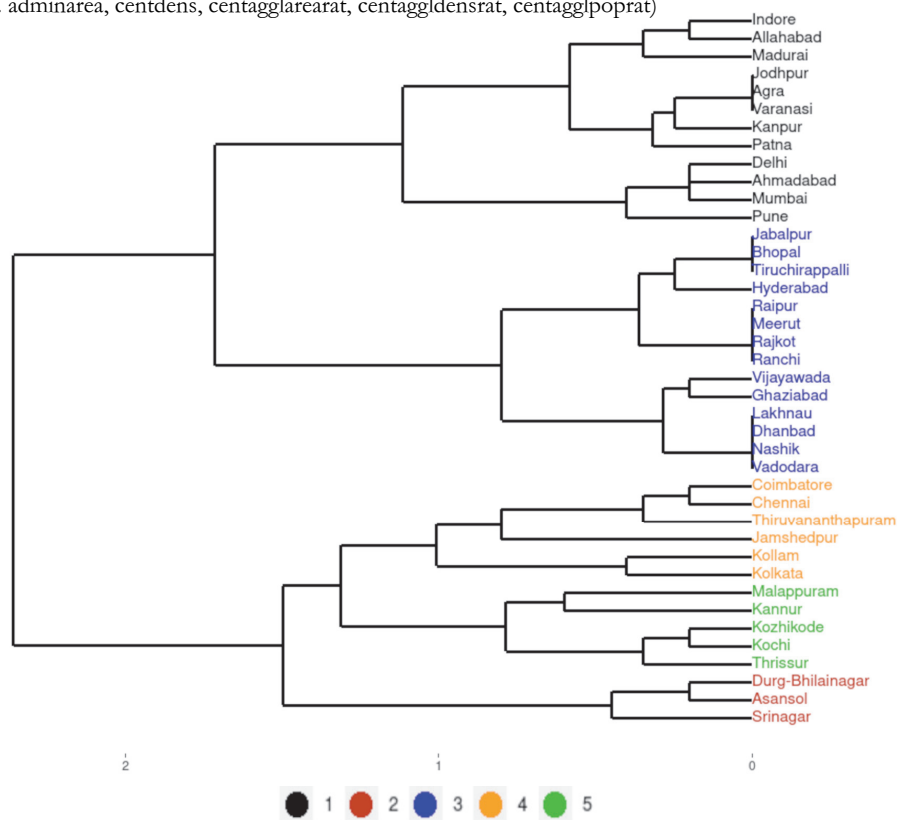
combinations of also five relevant variables indicated in Tables 1 and 2 (size of administrative area; population density of centre; centre and agglomeration area size ratio; centre and agglomeration population density ratio; centre and agglomeration population ratio). This makes it evident that the size of the population of the agglomerations is not a clustering factor in the absolute sense.

Figure 8

Clusters of the static analysis in 2011

Agglomerative hierarchical clustering

(2. adminarea, centdens, centagglarearat, centagglpoprat)



Cluster 1, the second largest one consisting of 12 elements, is definitely heterogeneous with regards to the size of the administrative area but shows a relatively homogeneous picture with regards to the other categories. Agglomerations listed here are all densely populated, congested ($>10,000$ people/km²), have central settlements that are mainly dominant ($>60\%$) – with only one exception – and have balanced territories (40–59.9%) in which the population density is significantly – typically 2–4 times or more than 4 times – higher than that of the hinterland. All the agglomerations ordered into this cluster have single-centred cores dominant in the size of the population ($>60\%$). The research findings show that these settlement

clusters make the type of *agglomerations definitely prevailed by congested centres (top-heavy UAs)*. In a topographic sense, these 12 settlements are partly scattered; half of them, however, are clearly concentrated in the Great Plains, along the rivers of the Yamuna (Delhi and Agra) and the Ganges (Kanpur, Allahabad, Varanasi, and Patna) (Figure 9).

In the definition of the largest cluster, *Cluster 3* with 14 members, the size of the territory of the settlements already plays a role: with one exception, there are middle-sized (200–499 km²), and small agglomerations (<200 km²). The centres are densely populated (5,000–9,999 people/km²) in each case. With no exception, they have one single centre dominant in territory and population whose population density, apart from one single case (Ghaziabad), exceeds that of the rest of the settlements in the hinterland at least 2–4 times, in some cases, more than 4 times. Taking all these facts into consideration, settlements in this cluster are *agglomerations with small-medium sized areas definitely prevailed by densely populated centres (centralised UAs)*. Their geographical location shows no regularity at all: they can be found scattered all over the country, from Tiruchirappalli in Tamil Nadu to Ghaziabad adjacent to Delhi, from Rajkot in Gujarat to Dhanbad in Jharkhand.

Cluster 2, with only 3 elements, features settlements with medium-sized territories, with centres that have medium population density (2,500–4,999 people/km²). The ratio of the territory of the centre and hinterland proved to be irrelevant in this case. The position of the centre within the agglomeration, with regards to population density and size of the population, is much less definite: population density of the central settlements is maximum 2 times that of the hinterland, and its share in terms of the size of the population is even more balanced. Considering these facts, these three clusters of settlements are seen as *homogeneous agglomerations with medium-sized areas and moderately populated centres (balanced UAs)*. Similar to the settlements in Cluster 3, these three agglomerations are situated far from each other, with no topographical connection detectable among them.

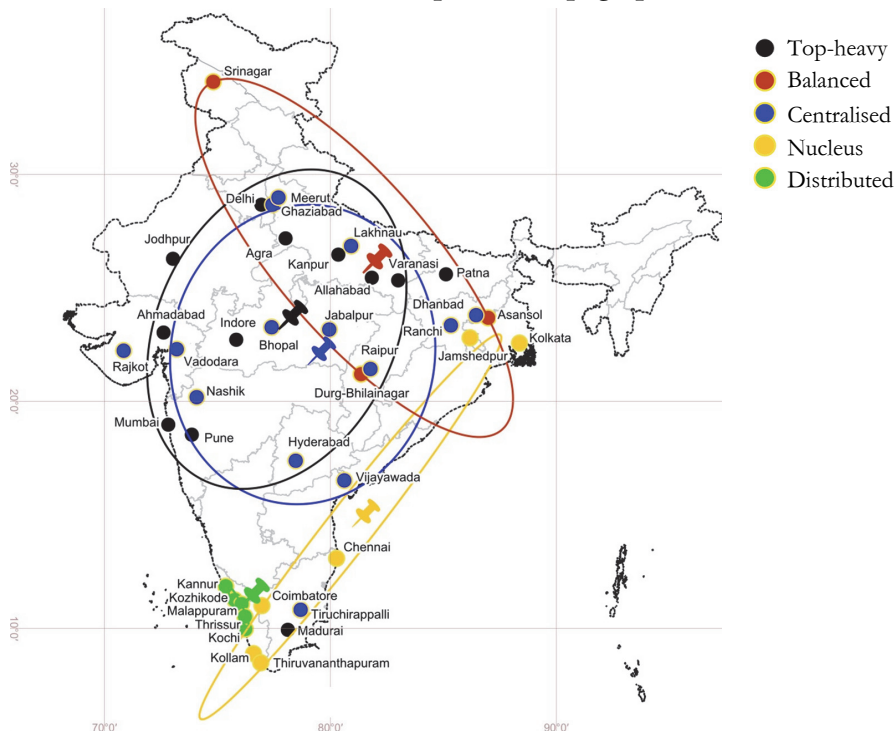
In *Cluster 4*, consisting of 6 members, settlement size shows a significant standard deviation as in Cluster 1, that is, it has no clustering role. Most of the centres are densely populated; in two agglomerations, they are congested. With regards to the territories of the centres, they are, with the exception of one agglomeration with a balanced centre, smaller (15–39.9%) than the hinterlands, but with decisive significance in each case. Their population density, with the same one exception (Jamshedpur) exceeds that of the settlements in the hinterland 2–4 times or more than 4 times. With regards to the size of the population in the central cities, agglomerations in this cluster have typically balanced, in a smaller part, low (<40%) weight but dominant centres. Accordingly, settlements in this cluster are categorised as *agglomerations with nucleus-type centres drawing widespread and populous urban areas (nucleus UAs)*. The cluster is also hard to grasp in a territorial sense. Four settlements (Chennai, Coimbatore, Kollam, and Thiruvananthapuram) can be found in the Dravidian South; however, no other closer geographical relation among them seems

to exist. The other two agglomerations (Kolkata and Jamshedpur) are far from these in the north-eastern part of the country, although their standard deviation seems to stand out along the south-eastern coast of the country.

Cluster 5, with 5 elements, consists predominantly of large territory agglomerations; however, the population density of the centres shows considerable differences, and thus has no clustering effect in this case, either. The sizes of the administrative area of the centres are negligible in proportion to the hinterlands, but their population density is significantly higher (in three out of the five cases, 2–4 times higher than that of the adjoining settlements). The centres of the agglomerations in this cluster typically have low weight in the population but dominant roles otherwise; in a smaller number of cases, however, the share of the centre from the total population is negligible. This made the authors identify these settlements as *large-sized decentralised agglomerations (distributed UAs)*. As opposed to the clusters described above, members of these settlement clusters are in a visibly same geographical environment: each is part of the so-called Kerala Megalopolis, located next to each other from Kannur to Kochi in the northern part of the Malabar Coast (Figure 9).

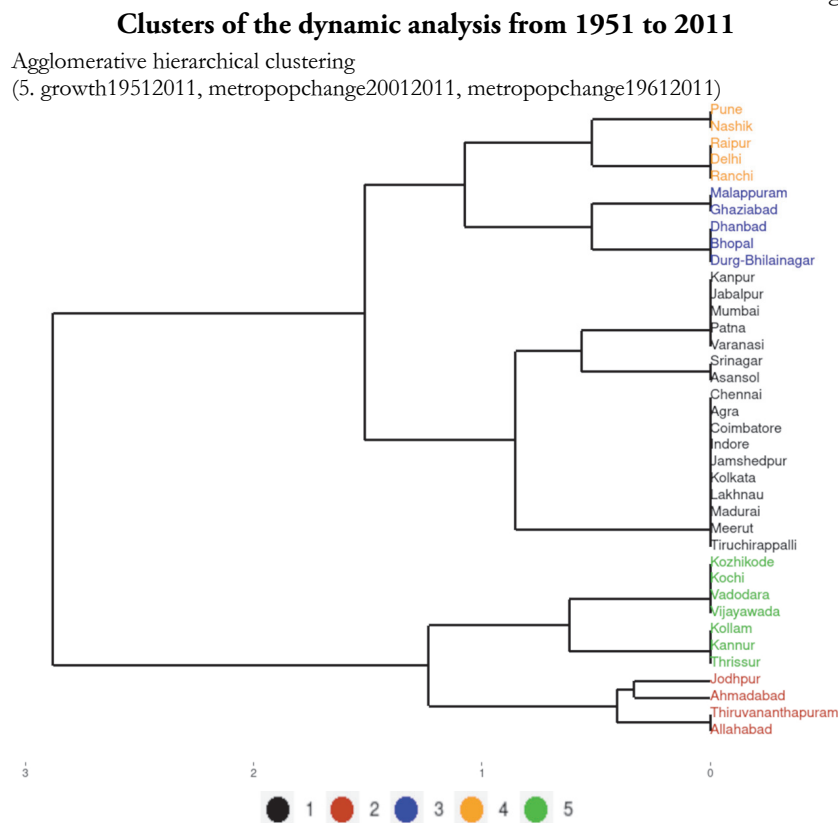
Figure 9

Geographical distribution of static urban clusters featuring their standard deviational ellipses and topographical centres in 2011



The set of *dynamic cluster analysis*, based on the changes in urban statistical data of metropolises from the mid-20th century until the time of the latest census in 2011, was made based on 38 agglomerations. In this case, on the ground of the reasons already mentioned above, analysis was not extended to the six cities with no hinterlands and the six quasi agglomerations; Hyderabad and Rajkot were also not included due to the deficient data concerning their administrative areas. The best grouping of agglomerations resulted in five clusters again (Figure 10), where clustering factors are defined by the combinations of the value ranges of the three relevant variables featured in Tables 3 and 4 (population growth rate 1951–2011, population density change of metropolises 1961–2011, population density change of metropolises 2001–2011).

Figure 10



The largest cluster (*Cluster 1*), consisting of 17 elements, represents almost half of all settlements examined. All these are characterised by a slower population growth from 1951 to 2011 than the average (789%), and a regular growth rate by decades (not exceeding 200% in one decade). As a reminder, these settlements were the most privileged members of the Indian urban hierarchy at the time of the 1951

census, all but a few with a long and rich historical past, significant cultural and administrative functions, and born as a result of organic development, with population numbers already typically in excess of 100,000 in the middle of the last century. Population density in most settlements in this cluster, on the maximum, doubled from 1961 to 2011, and in some of them more than doubled. In two of the 17 cases it decreased, whereas in the 2001–2011 period, it also grew or stagnated (which means a small per cent increase). On this ground, these settlements are considered as *moderately growing and densifying autochthonous (regular) agglomerations (conformist UAs)*. With regards to the geographical distribution of these settlements, no clear-cut spatial concentration can be identified. The only connection in terms of physical and regional geographical character seems to be justifiable among the six agglomerations in the plains of the Ganges and Yamuna rivers (Meerut, Agra, Kanpur, Lakhnau, Varanasi, and Patna) (Figure 11). In addition, two other smaller settlement clusters, not showing much similarity apart from the relative geographical proximity, can be detected in the southern (Coimbatore, Tiruchirappalli, and Madurai) and north-eastern part of the Peninsula (Kolkata, Asansol, and Jamshedpur).

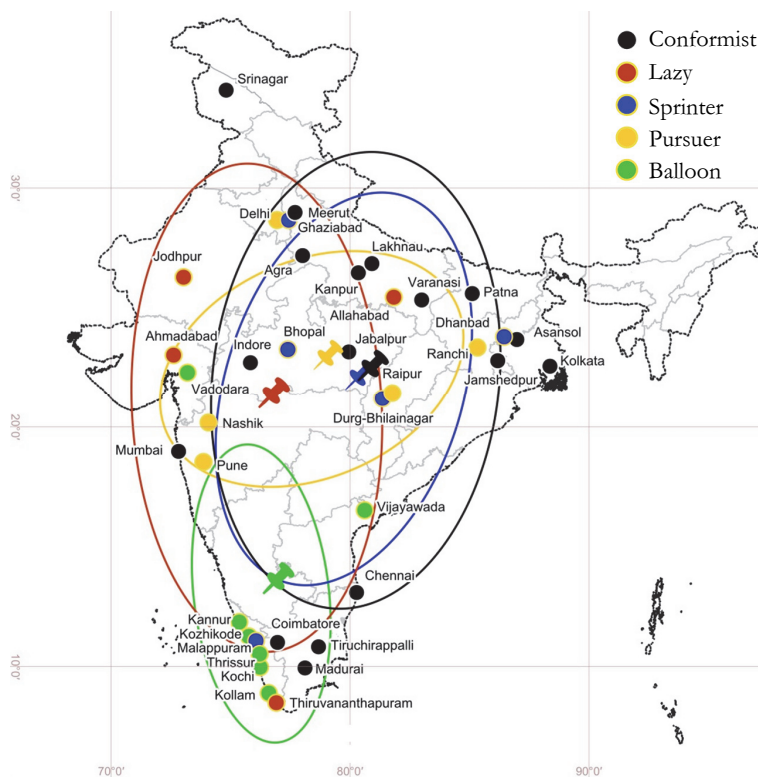
The population of settlements in *Cluster 2*, with only four members, grew similarly to that of the agglomerations in the previous type of urbanisation, slower than the average, and at a balanced pace from 1951 to 2011. The volume and direction of the change in their population density in the 1961–2011 period vary, so it has no clustering effect in this case, either, but the tendency from 2001 to 2011 is declining in each case. This latter fact, as it has already been mentioned, indicates the growth in the administrative area exceeding that of the size of the population. Taking the above-said into consideration, these settlements are referred to as *moderately growing, recently sparsifying autochthonous (regular) agglomerations (lazy UAs)*. They cannot be related to each other in a topographical sense.

The common feature of the agglomerations in *Cluster 3*, with five elements, is that the size of the population in the 60 years up until 2011 grew in an extraordinary way, in some decades in excess of 200%, definitely fast. Most of these have been described above as settlements among the latest creations of the urban network of India, with a short historical past in almost all cases; they are typically industrial centres and satellite towns with residential functions, founded in the 20th century or became urban areas in the second half of the century. The increase in their population density from 1961 to 2011 was intense – more than twofold in most cases, less than twofold in fewer cases – and continued to grow in the 2001–2011 period with no exception. These settlements, on the basis of their population trends outlined above, are *intensively growing and densifying, being newly developed (irregular) agglomerations (sprinter UAs)*. With regards to their geographical situation, they are not related to each other.

The population of the five settlements in *Cluster 4* grew regularly from 1951 to 2011, but faster than the average. Population density in the half century before 2001 grew to a maximum of double in most cases, and it more than doubled in fewer cases; further, there was a growth tendency in the 2001–2011 period. Accordingly, these agglomerations are seen as *rapidly growing and densifying autochthonous (regular) agglomerations (pursuer UAs)*. No spatial relation can be traced among them.

Figure 11

Geographical distribution of dynamic urban clusters featuring their standard deviational ellipses and topographical centres from 1951 to 2011



The most considerable common feature of the seven-member *Cluster 5* is the decrease in the population density both in the period from 1961 to 2011 and in the last census decade (2001–2011), with no exception. The reason for this is the significant increase in their administrative territories from 2001 to 2011. This is in line with the fact that settlements of the Kerala megalopolis, significantly enlarged with census towns recently, are all in this group, with the exception of Malappuram and Thiruvananthapuram. The characteristic of the growth in the size of their population, however, is mostly regular but faster than the average; in fewer cases, it is irregular and

definitely intensive. On this ground, these settlements are considered as *rapidly growing but sparsifying, newly developed (irregular) agglomerations (balloon UAs)*. As mentioned before, most of these settlements are in the so-called Kerala Megalopolis; therefore, they are located next to each other along the Malabar Coast (Figure 11).

Table 3

UAs ordered in complex (static–dynamic) urban types

	(1) agglomerations definitely prevailed by congested centre (top-heavy)	(2) homogeneous agglomerations with medium sized area and moderately populated centre (balanced)	(3) agglomerations with small- medium sized area definitely prevailed by densely populated centre (centralized)	(4) agglomerations with nucleus type centre drawing widespread and populous urban area (nucleus)	(5) large-sized decentralized agglomerations (distributed)
(1) moderately growing and densifying autochthonous (regular) agglom- erations (conformist)	[Agra] [Indore] [Kanpur] [Madurai] [Mumbai] [Patna] [Varanasi]	[Asansol] [Srinagar]	[Jabalpur] [Lakhnau] [Meerut] [Tiruchirappalli]	[Chennai] [Coimbatore] [Jamshedpur] [Kolkata]	
(2) moderately growing, recently sparsifying autochthonous (regular) agglomerations (lazy)	[Ahmadabad] [Allahabad] [Jodhpur]			[Thiruvananthapuram]	
(3) intensively growing and densifying, newly developped (irreg- ular) agglomera- tions (sprinter)		[Durg- Bhilainagar]	[Bhopal] [Dhanbad] [Ghaziabad]		[Malappuram]
(4) rapidly grow- ing and densifying autochthonous (regular) agglome- rations (pursuer)	[Delhi] [Pune]		[Nashik] [Raipur] [Ranchi]		
(5) rapidly grow- ing but sparsi- fying, newly deve- lopped (irregular) agglomerations (balloon)			[Vadodara] [Vijayawada]	[Kollam]	[Kannur] [Kochi] [Kozhikode] [Thrissur]

For the joint visualisation of the clusters identified and described above, that is, for the sake of the demonstrability of complex urbanisation types, static–dynamic pairs were generated by placing the examined agglomerations in a 5x5 matrix, in accordance with the number of clusters. It must be remarked that only those 38 agglomerations are visualised in the matrix as parts of the domains of both the static and dynamic cluster analysis; accordingly, Hyderabad and Rajkot were omitted. Linking the two dendrograms and visualising the results of the cluster analyses, somewhat overlapping them, how much a respective static cluster attracts a respective dynamic agglomeration type is seen, whether settlements making the cluster pairs are concentrated into certain complex types or are scattered in the most diverse combinations.

The results show the presence of a few complex types with a relatively large number of elements; however, 11 of the possible 25 cluster pairings do not have one agglomeration. With regards to pairs of urbanisation containing at least 10% of the presentable 38 settlement clusters, that is, a minimum of four members, the biggest one is the classic type with at least seven agglomerations: the *top-heavy and conformist* type. In addition, three more complex types of urbanisation with four elements can be identified: *centralised and conformist*, *nucleus and conformist*, and *distributed and balloon* (Table 3).

Besides agglomerations that can be categorised into complex types, agglomerations interpretable only in the static cluster, the quasi agglomerations, and the city metropolises consisting of only one city are also summarised by types of urbanisation in Table A15 (see [Internet Appendix](#)).

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