



An Analysis of Metropolization and High-Capacity Transportation of Brazil Via Clustering Methods

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Abstract:

High-speed systems and networks are the most important elements of transportation infrastructure and city. It is an infrastructural concept that is related to high standard and high technology services. This systematic has a critic role for tourism attractiveness. In this paper, a cluster-based analysis was conducted for Brazil, which is on a strong point about big metropolitans by using population, gross domestic product, livability through cluster statistical methods. Metropolization trends were presented by taking into account the agglomerations between cities. Lastly results and suggestions were given in this context.

Keywords: Clustering analysis, urban, high speed, tourism, economy

1. Introduction

Brazil is the largest country in Latin America in terms of population and area. The country is the second largest in terms of population and the third largest in terms of area on the entire American continent. The country covers approximately half of the South American continent with its 8.514 million km² of land. Brazil encompasses almost the entire eastern part of the South American continent. In addition, its territory especially expands to the north. The country shares borders with all countries in the Americas except Chile and Ecuador. Brazil is the 7th largest country in the world by population and the 5th largest by land area. Brazil's population is projected to be 218.56 million by 2025 (Trading Economics, 2025). São Paulo and Rio de Janeiro are the major cities, and the country has more than 13 cities with populations of over 1 million. Although the country has vast metropolitan areas, it also contains the great pristine Amazon forests. In addition to its rich and powerful nature, it also has great tourist potential. In Brazil, where Catholic religious culture is predominant, Portuguese is the official language. In Brazil's ethnic distribution, Europeans (42-47%) and mestizos (43-45%) form the largest groups. There is a significant population of African descent (7-10%). In the country, the population of the group believed to have Arab and Ottoman origins, referred to as El Turco, is estimated to be between 6-20 million. The mestizos, who constitute one of the two largest ethnic groups in the country, are referred to as Pardo. Pardos are predominantly composed of a significant mix of Europeans, Native Americans (Indigenous people), and Africans, with Europeans being the largest group.

One of the two largest ethnic groups in the country, the European descendants, is composed of half Portuguese (42-47%), 17-20% Italian, 5-10% Spanish, 5-7% German, and 13-23% European mestizos. One of the two largest ethnic groups in the country, the Pardolar, are in the majority throughout the northern expanse of the country. This area includes the sparsely populated, forested, and pristine regions in the northeast, as well as one of the most densely populated and developed clusters in the country's northeast. Brazil's European descendants, on the other hand, are either the majority or a significant presence in almost all of the country's densely populated and developed areas. However, they constitute the majority especially in the developed regions of the country, such as the Middle East, Southeast, South, and Midwest. Portuguese, in addition to being the official language in Brazil, is quite widespread and inclusive. In addition, Spanish and English also have a certain prevalence. In summary, while Brazil is a country of cultural richness, it has largely achieved national unity through the Portuguese language and the European and Pardos ethnic cultures. All these features of Brazil hold an important position in the political, commercial, and economic integration of Latin America.

With its significant cultural affinities and connections, Brazil distinctly stands out from other countries on the South American map in terms of its official language. The official language of almost all the other countries in South America is Spanish. However, Spanish and Portuguese are mutually intelligible to a considerable extent.

The country's population density increases in the eastern regions, especially in the northeastern and southeastern regions. The northwestern region of the country is covered with large forests. A

large part of Brazil is far from the risk of earthquakes. Brazil is the most important center of political integration in the South American continent and the Latin American world, and this centrality is so evident that after Brazil, Mexico and Argentina can be mentioned to some extent in this regard.

Although countries like Venezuela, Colombia, and Peru have significant strategic positions, Brazil is exceptional in terms of its strategic location, population, land area, and the geography it covers. Therefore, Brazil is at the center of the political and social integration of the Latin American world. At the center of this is having effective transportation and infrastructure systems. In addition, regular urbanization is quite important. Therefore, accurately identifying the metropolitanization trends of important countries like Brazil is a necessity. However, Brazil's priority is to be woven with a high-speed train network that has high speed, high capacity, and high comfort. In this context, this study first lists Brazil's leading cities according to parameters such as population, economic development, and levels of progressivism. Subsequently, the listed cities were clustered using statistical methods in the R Studio program. For the aforementioned cluster analysis, the K-means, Pam, and Clara methods were used in this program.

Then, the method that provides the most suitable number of clusters and the best cluster distribution was determined. Accordingly, the clustered list of Brazilian cities has been determined, and then the clusters containing the priority cities in the said clustered list have been identified. Accordingly, a comparative evaluation of these priority cities was conducted, taking distance into account, and based on this, a high-speed train network proposal and clustering trend calculations were presented.



Fig. 1. Big Urbans of Brazil (Worldometer, 2025)

Brazil has a very large land area. The country has a variable climate system. Brazil has various ver big urbans on all over the world. The infrastructure development process is ongoing. Transport and traffic-related problems has local similarities with developed countries. Below on Figure 1, there are the regions of Brazil

(Worldometer, 2025).

In Figure 2 Brazil state map is presented (Worldometer Politic, 2025). Figure 3 shows Brazil Geographical Map (Worldometer Info, 2025). Table 1 shows Brazil cities' populations and liveabilities (OECD, 2020).



Fig. 2. Brazil State Map (Worldometer Politic, 2025)



Fig. 3. Brazil Geographical Map (Worldometer Info, 2025)

Table 1: Brazil Cities Populations And Related Parameters (OECD, 2020)

City	Livability	Population
Sao Paulo	66	12300000
Rio de Janeiro	64	6750000
Belo Horizonte	60	2510000
Brasilia	59	3020000
Manaus	59	2220000
Porto Alegre	59	1480000
Campinas	58	1210000
Recife	58	1650000
Curitiba	58	1880000
Santos	57	434000
Sao Jose dos Campos	56	730000
Florianopolis	56	478000
Fortaleza	55	2450000
Joao Pessoa	53	818000
Goiania	52	1390000
Natal	52	878000
Maringa	50	436000
Niteroi	49	497000
Sao Caetano do Sul	49	162000
Vitoria	49	356000
Santo Andre	49	721000
Joinville	49	598000
Nova Iguacu	48	823000
Guarulhos	47	1320000
Barueri	46	262000
Sao Joao de Meritis	46	473000
Maua	46	453000
Diadema	46	427000
Sao Bernardo do Campo	46	844000
Jundiai	46	402000
Itaquaquecetuba	45	353000
Osasco	45	695000
Duque de Caxias	45	887000
Taboao da Serra	45	294000
Sao Vicente	45	356000
Belford Roxo	45	513000
Mogi das Cruzes	44	451000
Embu das Artes	44	277000
Belem	44	1500000
Francisco Morato	44	168000

Poa	44	114000
Atibaia	44	137000
Mairipora	44	100000
Franco da Rocha	44	146000
Ribeirao Pires	44	120000
Petropolis	44	298000
Carapicuiaba	43	403000
Caieiras	43	95800
Ferraz de Vasconceloz	43	185000
Aruja	43	83900
Salvador	43	2890000
Cotia	43	230000
Itapevi	43	223000
Itapecerica da Serra	42	167000
Canosa	42	348000
Vespasiano	42	130000
Jandira	42	126000
Varzea Paulista	42	117000
Santana de Parnaiba	42	127000
Cajamar	42	71800
Campo Limpo Paulista	42	80800
Cubatao	42	132000
Contagem	42	649000
Ananindeua	42	540000
Viamao	42	256000
Itanhaem	42	96200
Guaruja	41	311000
Nova Lima	41	96200
Jaboatao dos Guararapes	41	707000
Caxias do Sul	41	517000
Olinda	41	393000
Indaiatuba	41	256000
Cachoeirinha	41	118000
Sete Lagoas	41	242000
Teresopolis	41	184000
Embu-Guacu	41	67300
Novo Hamburgo	40	247000
Praia Grande	40	299000
Itatiba	40	123000
Jacarei	40	235000
Caucaia	40	369000
Sao Roque	40	86500
Camargibe	40	155000

Braganca Paulista	40	161000
Sao Jose dos Pinhais	40	335000
Vinhedo	39	72600
Bertioga	39	64700
Valinhos	39	120000
Colombo	39	247000
Rio Claro	39	200000
Cabo de Santo Agostinho	39	209000
Ibiuna	38	76400
Campina Grande	38	405000
Salto	38	114000
Sorocaba	38	645000
Saquarema	38	90600
Piracicaba	38	391000
Blumenau	38	362000
Sumare	38	266000
Hortoloandia	38	216000

This study gives a strong relationship and solves the connection between development, economy, urbanization and national integration and highlights the role of transportation on this case. Because of all of this, the study gives an original approach and understanding between all of these disciplines via robust calculation methods and actual R studio software.

2. Literature Review

The mobility phenomena of the 21st century are sustainability, urbanization, and digitalization. Digitalization is the result of significant advancements over the past 30 years, leading to the emergence of advanced and new technology products. Its most prominent current position can be seen through intelligent transportation systems and human technologies. Perhaps the pandemic was the final and greatest challenge of digitalization. Sustainability has been a growing topic of discussion for over half a century, particularly in developed countries around the world.

Currently, the European Union's transportation policies and many other policies are heavily shaped directly around sustainability or take it into account, and these have been included in medium-term programs. It is known that many countries and states from Latin America to East Asia and from Australia to North America are engaged in sustainability practices, particularly in areas such as energy transportation and infrastructure. Sustainability cannot be considered separately from urbanization.

In the 21st century, these two are integrated and mutually supportive elements. Urbanization made a significant leap with the industrial revolution, and there began to be important transitions from rural to urban populations. Today, in developed and developing countries, a very large portion of the national population lives in cities. It cannot be said that the population living in the city is exactly the same as the city's population, especially since the difference between the two is even greater in developing and underdeveloped countries. In developed countries, it can be said that a large proportion of the urban population has assimilated

urban culture.

In the last quarter of the 20th century and the 21st century, urbanization trends have become apparent. The increasing trend in urbanization continues. Globally, urban populations, especially in developed and developing countries, are constantly increasing in terms of urban population ratio, the number of large cities, and similar factors. At this point, it is of great importance to correctly understand and direct the trends of metropolitanization and to plan them in the best possible way. Especially in developing countries, the healthy completion of national infrastructure development can be achieved under the umbrella of sustainability, metropolitanization, urbanization, and high-capacity high-speed transportation integration. Sustainability trends have become even stronger today. Western countries and developed countries have a role to play in this. In this context, sustainability, digitization and urbanization indicate the need for increased investments in high-speed rail lines, metro lines, high-capacity high speed bus lines. These three systems could be the first driving force for autonomous transportation systems in developing countries.

Urbanization is one of the strongest phenomena of our time. In the context of mobility, its impact and importance are increasing day by day. Since the Industrial Revolution, urban development has been continuously triggered. However, a significant leap occurred in the 20th century. By the end of the 20th century, it had entered a new threshold. At the beginning of the 21st century, this bar was raised even higher. In the present day, as we reach the end of the first quarter of this century, significant and revolutionary developments are expected and planned in the next 20-40 years in urbanization, metropolitanization, large urban areas, innovative transportation, smart technologies, autonomous vehicles, electric vehicles, and unmanned technologies. The phenomenon of urbanization will be at the center of all these developments and will continue to be the driving force of mobility. Mobility will start to take up more space in our daily lives, reshaped with a highly

innovative version and in the context of smart technologies, with a different scale and content. It is expected that all these trends will continue to strengthen.

Urbanization trends are becoming increasingly stronger. There are dozens of cities worldwide with populations of 10 million and above; these are megacities. In countries such as India, China, Japan, Indonesia, Brazil, Turkey, Egypt, Iran, Pakistan, the Philippines, Colombia, Congo, Nigeria, Ethiopia, and similar nations, there are numerous metropolises and megacities. It is also possible to include developed Western countries such as the USA, England, Germany, and France.

The number of metropolises and megacities on a global scale will continue to increase. By the year 2050, the urbanization landscape will have reached a significantly different state on global, continental, and national levels. At this point, transportation holds a very important position. For this reason, high-speed transportation, smart transportation, Maglev, and autonomous systems are coming to the forefront and will increasingly gain a strategic position.

Transportation engineering is an important part of infrastructural development for nations. Especially for developed and developing countries, this importance has a strategical point of view. For managing of hazards, economical risks, wars and other crisis, changing concepts. cultural interactions, transportation is a very strong, robust and reliable tool and argument. Regional, national, international, continental and intercontinental transportation necessitates high technology more and more day by day. New age metropolization is the basic issue at this point. Because of all of these, understanding, resolving and re establishing of metropolization are quite vital issues for civilization and advancement.

Brazil is a member of BRICS. It is one of the most important countries in this union and also its western component. As a country on the American continent, Brazil is one of the largest countries in the world in terms of population, area, and population density. It has a large, young, and educated population. It is a candidate to become a global power in the future. It is also a neighbor to MIKTA thru Mexico. MIKTA is a global alliance of developing countries. Brazil, Mexico, Colombia, Venezuela, and Argentina together create a significant regional sphere of influence. The multilayered and rich history and culture of the Americas are represented in Central and South America. Brazil, along with Mexico and Colombia, constitutes the most central area of this. Brazil's global outreach and cooperation policy with many developing countries, from the farthest east to the farthest west, from the farthest north to the farthest south, will be quite significant.

In this context, Brazil's infrastructure-building process as a developing country is ongoing and has to allocate a significant share of the budget to investment. However, under the current circumstances, the proper use of global resources has become vital for nations. As a developing country in this context, the spread of

high speed-high capacity-high comfort transport in Brazil is a significant saving (Givoni, 2006).

Metropolitanization can occur in the form of sub-regionalization, regionalization, polycentric development, monocentric development, and urban core formation thru the convergence of two centers. In all of these, the establishment of a transportation network is either a cause or an effect. However, especially rapid transportation, triggers and develops these centralization processes. At this point, the question arises of which rapid transit network reinforces what kind of metropolitanization. This is also an issue that has been the subject of ongoing research. Emphasizing metropolitanization is an advanced step toward nationalization for both developed and developing countries. Beyond national unity, it also supports regional integration.

The number of metropolises and megacities on a global scale will continue to increase. By the year 2050, the urbanization landscape will have reached a significantly different state on global, continental, and national levels. At this point, transportation holds a very important position. For this reason, high-speed transportation, smart transportation, Maglev, and autonomous systems are coming to the forefront and will increasingly gain a strategic position.

Kenger and friends studied a copmerative approach for clusterings of cities in terms of various methods for smart city and sustainable aims on 2023. Kyoungok Kim identified smart card data and did clusterings based on it for identification of structures of cities in 2020. Rodrigues and friends studied socio economic and functional zoning for city within clustering approaches in 2025. Cao and friends analysed composition of cities by the usage of spatial clustering.

3. Methodology

Clustering Analysis

Clustering statistical analysis have been conducted via K means method, PAM and Clara method. On the other hand, this case will highlight high speed transportation and mobility plans in terms intercity distances for competition and superior services. Than clustering analysis between these metropolitans via R Studio program in terms of K means, PAM and CLARA has given the robust and reliable results for prior metropolitan cities' specification. Then prior classes are selected for national prior urbans for national integration via strong metropolization and metropolitan connections between this centers.

To identify potential high-speed rail corridors and regional connectivity patterns across India, a multivariate cluster analysis was performed using several established statistical clustering techniques. Specifically, the K-Means, Partitioning Around Medoids (PAM), and Clustering Large Applications (CLARA) methods were applied to a dataset comprising demographic and economic indicators such as population and liveability.

1. K Means Method

Here are results for number of clusters and cluster visulation in terms of K means method in Figure 4 and Figure 5.

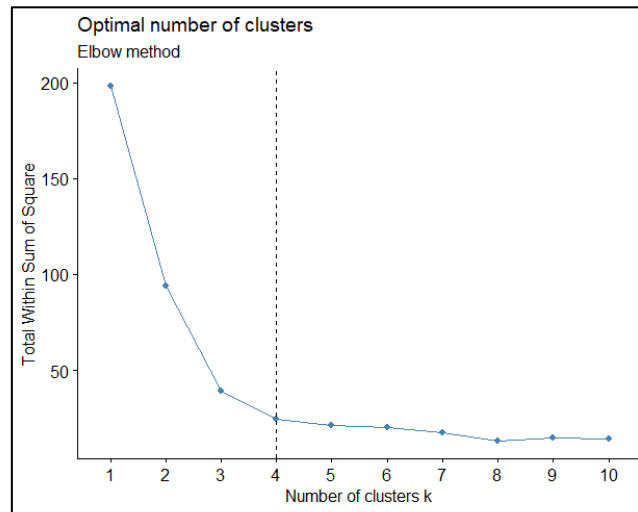


Fig. 4. Number of Clusters in Terms of K Means Method

Cluster Visulation

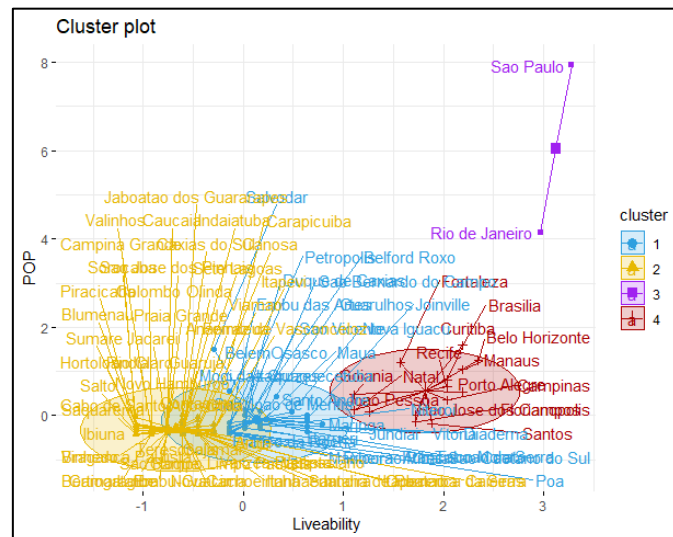


Fig. 5. Cluster Visulation In Terms Of K Means Method

2. PAM

Here are results for number of clusters and cluster visulation in

terms of PAM in Figure 6 and Figure 7.

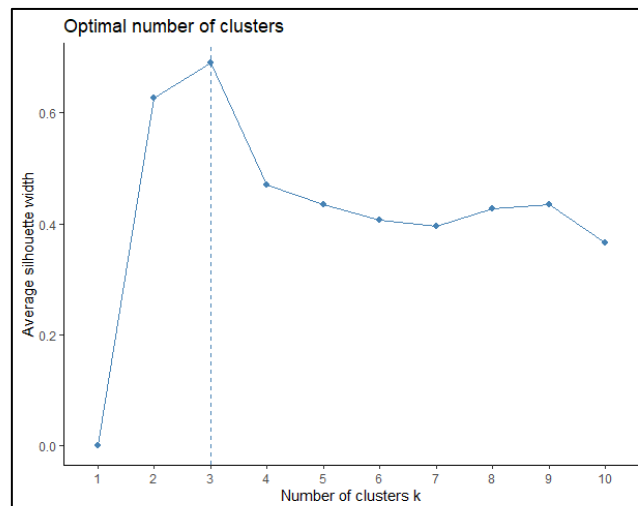


Fig. 6. Number of Clusters in Terms of PAM

Cluster Visulation

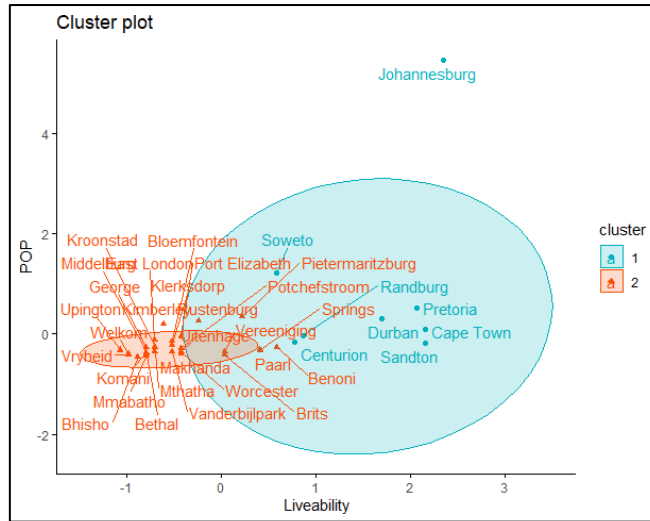


Fig. 7. Cluster Visulation In Terms Of PAM

terms of Clara method in Figure 8 and Figure 9.

3. Clara Method

Here are results for number of clusters and cluster visulation in

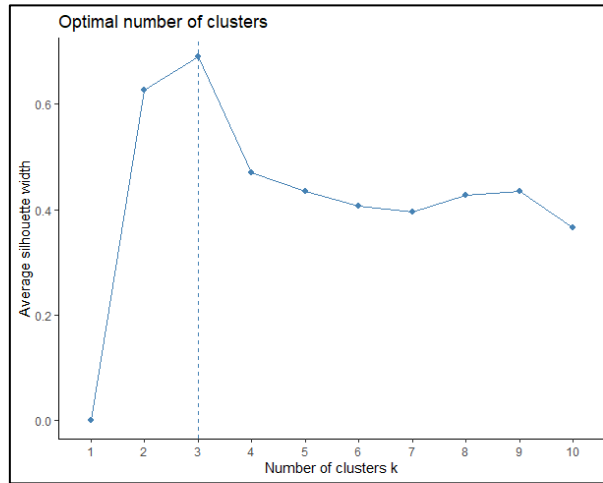


Fig. 8. Number of Clusters in Terms of Clara Method

Cluster Visulation

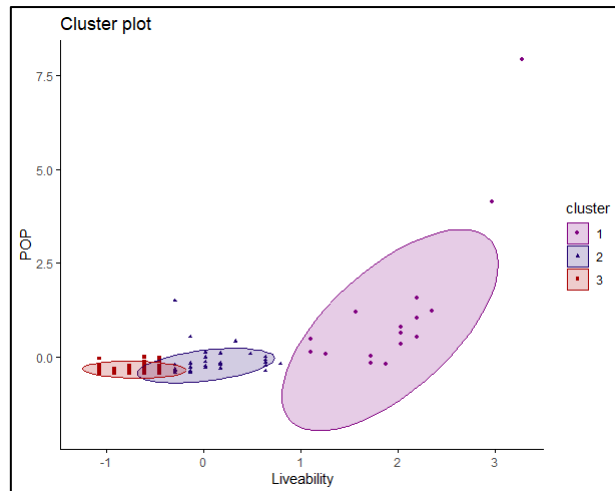


Fig. 9. Cluster Visulation In Terms Of Clara Method

As a result of all methods and agglomerations, the biggest cities has been emerged into two clusters, 4 main clusters has emerged for these dataset. On Table 2, clustering list of the cities has been given.

Table 2: Cluster List Of Brazil Cities

City	Cluster	Population
Sao Paulo	3	12300000
Rio de Janeiro	3	6750000
Belo Horizonte	4	2510000
Brasilia	4	3020000
Manaus	4	2220000
Porto Alegre	4	1480000
Campinas	4	1210000
Recife	4	1650000
Curitiba	4	1880000
Santos	4	434000
Sao Jose dos Campos	4	730000
Florianopolis	4	478000
Fortaleza	4	2450000
Joao Pessoa	4	818000
Goiania	4	1390000
Natal	4	878000
Maringa	1	436000
Niteroi	1	497000
Sao Caetano do Sul	1	162000
Vitoria	1	356000
Santo Andre	1	721000
Joinville	1	598000
Nova Iguacu	1	823000
Guarulhos	1	1320000
Barueri	1	262000
Sao Joao de Meritis	1	473000
Maua	1	453000
Diadema	1	427000
Sao Bernardo do Campo	1	844000
Jundiai	1	402000
Itaquaquecetuba	1	353000
Osasco	1	695000
Duque de Caxias	1	887000
Taboao da Serra	1	294000
Sao Vicente	1	356000
Belford Roxo	1	513000
Mogi das Cruzes	1	451000
Embu das Artes	1	277000
Belem	1	1500000
Francisco Morato	1	168000

Poa	1	114000
Atibaia	1	137000
Mairipora	1	100000
Franco da Rocha	1	146000
Ribeirao Pires	1	120000
Petropolis	1	298000
Carapicuiaba	2	403000
Caieiras	2	95800
Ferraz de Vasconceloz	2	185000
Aruja	2	83900
Salvador	2	2890000
Cotia	2	230000
Itapevi	2	223000
Itapecerica da Serra	2	167000
Canosa	2	348000
Vespasiano	2	130000
Jandira	2	126000
Varzea Paulista	2	117000
Santana de Parnaiba	2	127000
Cajamar	2	71800
Campo Limpo Paulista	2	80800
Cubatao	2	132000
Contagem	2	649000
Ananindeua	2	540000
Viamao	2	256000
Itanhaem	2	96200
Guaruja	2	311000
Nova Lima	2	96200
Jaboatao dos Guararapes	2	707000
Caxias do Sul	2	517000
Olinda	2	393000
Indaiatuba	2	256000
Cachoeirinha	2	118000
Sete Lagoas	2	242000
Teresopolis	2	184000
Embu-Guacu	2	67300
Novo Hamburgo	2	247000
Praia Grande	2	299000
Itatiba	2	123000
Jacarei	2	235000
Caucaia	2	369000
Sao Roque	2	86500
Camargibe	2	155000

Braganca Paulista	2	161000
Sao Jose dos Pinhais	2	335000
Vinhedo	2	72600
Bertioga	2	64700
Valinhos	2	120000
Colombo	2	247000
Rio Claro	2	200000
Cabo de Santo Agostinho	2	209000
Ibiuna	2	76400
Campina Grande	2	405000
Salto	2	114000
Sorocaba	2	645000
Saquarema	2	90600
Piracicaba	2	391000
Blumenau	2	362000
Sumare	2	266000
Hortoloandia	2	216000

4. Results

After statistical analysis, prior urbans were gathered on 3-4 clusters

Table 3: Selected Cities Via Clustering Analyse

City	Cluster	Population
Sao Paulo	3	12300000
Rio de Janeiro	3	6750000
Belo Horizonte	4	2510000
Brasilia	4	3020000
Manaus	4	2220000
Porto Alegre	4	1480000
Campinas	4	1210000
Recife	4	1650000
Curitiba	4	1880000
Santos	4	434000
Sao Jose dos Campos	4	730000
Florianopolis	4	478000
Fortaleza	4	2450000
Joao Pessoa	4	818000
Goiania	4	1390000
Natal	4	878000
Guarulhos	1	1320000
Belem	1	1500000

High-speed trains are currently the most competitive mode of passenger transport for distances between 400 and 600 kilometers. (HST). Air passenger transport is predominant on distances over 600 kilometers. Experiences and experiments in many Western and

and >1.000.000 populated 1 no cluster cities. On Table 3 selected cities are listed below.

developed countries show that high-speed trains outperform road and air passenger transport at speeds of 200 km/h and above for distances of 400-600 km. (Kiziltas, 2020).

5. Discussion And Conclusions

Figure 10 shows metropolization and high capacity transport

proposal map of Brazil.



Fig. 10. Metropolization and High Capacity National Network Proposal Regions Map of Brazil

As shown in the map, the cities proposed for metropolization and high transport on this paper also include most of Brazil's central natural, developing sustainable and densely populated areas. When these areas are equipped with high-speed trains, a robust planning, high capacity transport and inter-city transportation, a metropolization core and agglomeration will be created in the country's geographically significant and strategic areas. On the other hand, with the completion of all these planning's and projects, national robust integration and north-south high degree connection will be provided.

Metropolization can occur in the form of sub-regionalization, regionalization, polycentric development, monocentric development, and urban core formation thru the convergence of two centers. In all of these, the establishment of a transportation network is either a cause or an effect. However, especially rapid transportation, triggers and develops these centralization processes. At this point, the question arises of which rapid transit network reinforces what kind of metropolization. This is also an issue that has been the subject of ongoing research. Emphasizing metropolization is an advanced step toward nationalization for both developed and developing countries. Beyond national unity, it also supports regional integration.

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