BUNDLING OF MODES

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ABSTRACT

In recent years, many cities around the world are faced with a rapid growth of private vehicle ownership and usage. This shift in modal split is a threat to economic development and has negative impact on accessibility, liveability and safety. It also leads to a reduction of active modes, which causes the problems to grow even larger. This vicious circle must be interrupted and a new sustainable development is needed.

This paper is based on experiences from the Dutch research and awareness program 'Ruimte en Mobiliteit' (Urban space and Mobility). Good and bad experiences are used to illustrate how bundling of modes can be realised to get out of the vicious circle. Key ingredients for bundling of qualities are by (pulling) urban planning and design; stimulation of the use of public transport and active modes of transport; bundling of modes and by (pushing) policy on reduction of car usage.

Urban/metropolitan policy should take the concept of bundling of qualities as fundamental base in consistent urban planning. Planning cycles typically last longer than political cycles, but in order to obtain good results, a focus on consistent long term planning is required.

The city of Rio de Janeiro can benefit from bundling of modes on at least three axes: providing good connections between private modes and public transport through park and ride facilities for cars and bicycles, bundling of cycling and the ferries across the bay and by development of comprehensive transport hubs where as many transport modes as possible come together.

Keywords: cycling, comprehensive planning, bundling, multimodal, planning, transport hubs

1. INTRODUCTION

Nowadays, more than 50 per cent of the global population live in cities. This number is still growing. Also growing is the usage of the private car as a means of transport. Both trends are a threat to the quality of life and the environmental impact is huge, both locally (noise, air quality) and global (greenhouse gas emission). Moreover as shown in figure 1, a larger share of active and public transport in high density cities lead to lower cost of transportation, compared to low density cities. Active and public transport make transportation in high density compact cities less expensive than transportation costs in low density expanded cities. In other words, the transportation costs rise when the private car becomes more dominant within urban areas. The vicious circle of negative urban development must be broken, especially the effects in terms of declining urban quality of life. A new sustainable development is needed. We must turn the steering wheel around and find another way.

In the Netherlands, a four year national program called 'Urban Planning and Mobility' ('Ruimte en Mobiliteit') has tried to find solutions and raise awareness to these problems. In this program, that ended in March 2008, specialist from the fields of urban planning, traffic and transport, housing and environment were involved. The major conclusion from the research is that the expertises from these different fields should be brought together in one joint planning effort.

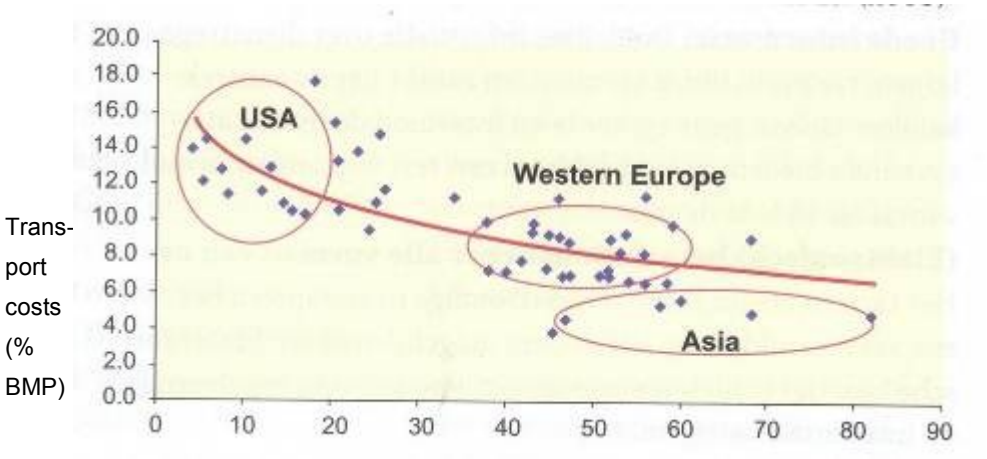

Figure 1. Relation between transportation costs and share of non-motorised transport modes.

As a result of this 'bundling of expertise', 'bundles of qualities' should emerge on all levels of planning: the (inter)national level, the regional and local level. 'Bundles of qualities' are the physical results of integrated planning that comprised a mix of interventions. There is not one solution to a problem. The key ingredients are:

1. Urban planning;
2. Limitation of the use of the private car; and
3. Stimulation of use of public transport, cycling and walking

In this paper the various elements of these key ingredients will be described and the way they can contribute to the bundling of qualities. Dutch and international (including Brazilian) examples will be described to show that this bundling approach is feasible and effective. Since the end of the 'Urban Planning and Mobility' program in 2008, bundling of modes has become one of the key ingredients in Dutch mobility policies on national, regional and local level. Therefore, in the aforementioned examples, emphasise will lay on the this bundling of modes. Optimisation of the connection between various modes used in a single trip provides the traveller with a door-to-door alternative to the use of the private car for the whole trip. The quality of the alternative is thereby highly related to the chain of the various modes of transportation. Public transport often plays a major role in this mode chain. The private car, however, is not ruled out completely. It can be part of the chain as a feeder mode to the public transport network, e.g. by by providing the connection from the origin to the train station or bus stop.

This paper concludes that bundling is both an inevitable working method and the physical result and that policies to optimize the connection between modes – 'chaining them' – is very important to limit the use of the private car as well as to stimulate the use of public transport.

2. BUNDLING OF QUALITIES: INGREDIENTS

Bundling of qualities is the way to go. Worldwide there are good examples of successful implementation of this course. Figure 2 shows that urban quality highly depends on the way urban mobility is organised.

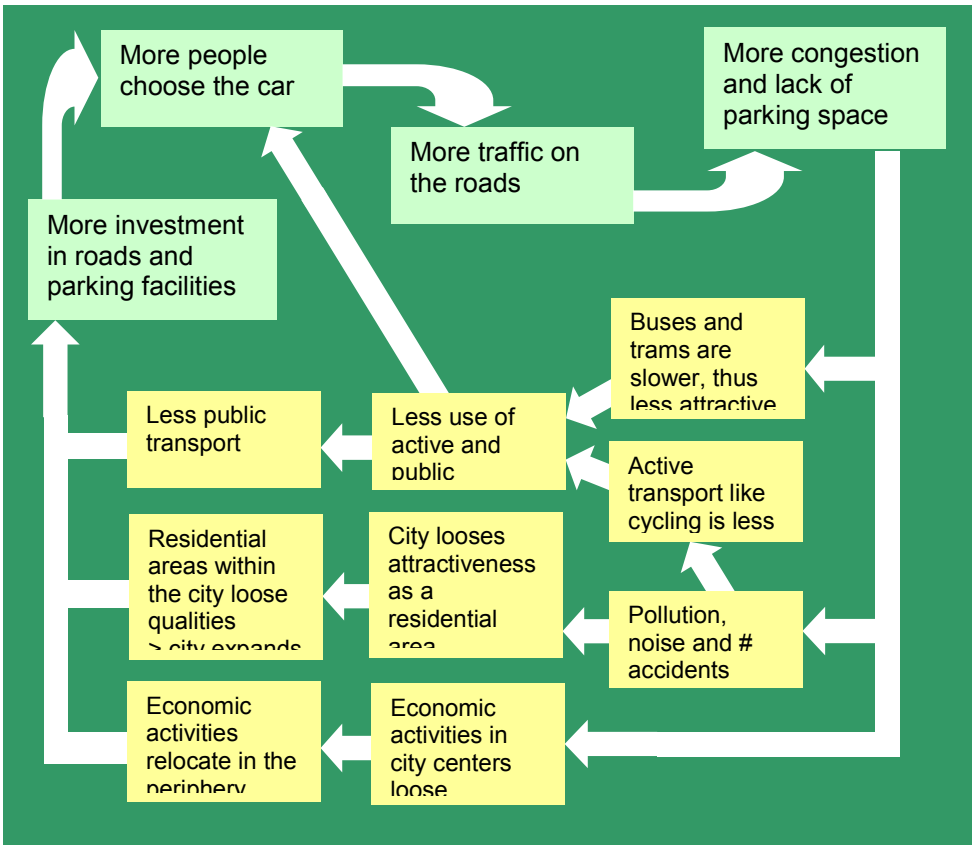

Figure 2. The negative vicious circle in cities caused by overflowing car mobility

Bundling of qualities is part of this organisation and comprises:

- Pull: urban planning and design
- Pull: stimulation of the use of public (collective) transport as well as active ways of transport (e.g. walking, cycling)
- Pull: bundling of modes, making multi modal trips fast, easy and comfortable
- Push: reduction of car use

Successful ways out of the vicious circle always include these three elements. It only works if the policy is a mix of push and pull. Otherwise, the policy is not likely to succeed. In The Netherlands, current policy is aiming at an increase of urban density, preventing the scarce open landscape from being occupied by urban functions and providing opportunities for the usage of active and public transport. It is recognised that a comprehensive approach on national, regional and local level is required to achieve this (Ministerie van Infrastructuur en Milieu, 2012). The so called 'Regional Approach' is an example from this comprehensive approach. Several governments and organisations in a region sit down together and define a set of shared goals, which form the basis for more detailed policies and actions. Although this approach is strong in setting shared ambitions, it is not a guarantee for success, for the simple reason that often specific (local) interest influence or interfere with the goals. During the Urban Planning and Mobility program it has become clear that a strong vision is needed. This vision should be unambiguous, comprehensive and pointing into one direction and must be constantly communicated to all parties involved.

2.1 Pull: urban planning and design

High densities. There is a strong relation between urban density and modal split. Urban sprawl leads to a large share of the private car in the modal split, while high urban density leads to a larger share of active and public transport. Public transport requires nearness: a concentration of the high density areas in the vicinity of the stations. The Dutch Railway company (NS) developed a rule of thumb for catchment areas. This rule is based on the notion that the typical catchment area of a train or metro station has a 600-1000 meters radius and the catchment radius of a tramway or bus rapid transit station is about 300-400 meters. The likelihood of people within the catchment area to choose for the public transport option is significantly higher than for those outside of the catchment zone. It should be considered that in The Netherlands many people use the bicycle as a feeder mode. The circle rule is used to make an estimation of the future use of public transport when areas are transformed or developed or when new stations are opened in existing urban areas.

Direct access to stops and stations. The shorter the distance between the origin and the public transport station, the more people will use public transport. This is not only a function of distance, but also of directness. By providing straight routes between the origin and the station, the walking and cycling time will drop and hence the usage of the public transport will rise. Apart from distance, active transport is much more influenced by the directness to travel than by other efforts to make.

Mix of functions. A mix of land use functions typically increases the probability for shorter travel distances. Hence, active modes of transportation are stimulated and the usage of cars decreases. Important functions to mix are housing, work, shops, schools, health facilities and other regular destinations.

Concentration of facilities at public transport nodes. Facilities that show high numbers of visitors, for instance hospitals, large educational institutions, shopping areas and large leisure facilities should be located at public transport nodes. As public transport is specialised in the transportation of large numbers of people this is an effective way to reduce the use of cars. In addition, when car use is less, the space and investments needed to provide parking capacity at those facilities can be reduced too.

Reservation of space for public transport. Providing an adequate public transport system requires that public transport is given the space it needs. Not only for tracks, bus lanes and stations, but also for park and ride facilities, bicycle sheds etc. An ample amount of space should be reserved for extension in the future, when ridership of public transport grows and the capacity needs to be enlarged. This reservation should be included in the site plans but in such a way, that the reserved space is attractive and serves a function until it is needed.

Use the value of real estate to finance public transport. Good accessibility by public transport rises the value of real estate property. This increase of value can be used for the investment in the public transport infrastructure by the real estate companies. In the Netherlands value capturing is not common practice yet, while in Europe more and more successful examples show the benefits. Examples are the automatic metro line that connects the new town of Oresund with Copenhagen and the tramway in the Docklands in London. In Japan it is common practice that the private companies develop the real estate and the public transport infrastructure together.

2.2 Pull: improvement of active and public transport

Transportation is an important part of our social and economic life. Effective and lasting reduction of car use in urban areas is only possible if alternative modes are available in terms of quality and quantity. Several components, including capacity, trip times, comfort and safety, all influence the Level of Service. In order to make the public transport system compete against the private car, high standards need to be met.

Active transport. Walking and cycling are important transport modes. In mid-sized cities in the Netherlands, like Groningen, Delft, Enschede and Almelo, the share in the modal split in internal trips (including feeder trips to public transport nodes) is about 15-20% for walking and 40-50% for cycling. As a result, these active transport modes take far more than half of the trips within these cities. This is not only good for the environment and the usage of scarce urban space, but also cheap and healthy for the travellers. These kind of huge shares of active transport can only be achieved by comprehensive planning. Facilities like foot- and cycle paths, cycle lanes and bicycle shelters should not be added to plans at a later stage, but be incorporated from the beginning. Only then these facilities can implemented in space

and time such that they serve the travellers needs in the best way. Dutch cities have implemented large variety of additional facilities to make walking and cycling attractive and – very important – safe. These include facilities like priority at traffic lights, separated cycle paths at roundabouts, crossings where cars have to give way to cyclists and bicycle racks or shelters at all destinations. Direct routes (where cars have to make detours) are very important to increase the attractiveness – and as a result use – of active transport modes. The Dutch new town of Houten is a very good example of this. Although it is possible to go everywhere by car, cars have to make long detours and cycling and (often) walking are faster and more comfortable. Of course, it is much more complicated to achieve this effect in existing cities. In the Netherlands however, there are many situations were short-cuts for active transport, e.g. dedicated tunnels and bridges that cross main roads, railways and canals, or bike paths through green areas have the same positive effect on the trip time of active transport compared to the private car.

Speed and frequency of public transport services. Increase of speed, frequency and punctuality make public transport more attractive, resulting in an increase of ridership and hence of revenues from fares. Moreover, they are key factors to the improvement of the image of public transport In The Netherlands. This image is, in general, not very good, especially among those that rarely or never use it (car drivers). Improvement of the image is important to convince these people to use public transport. Examples in France (e.g. Strasbourg, Montpellier, Lille), England (e.g. Manchester), Germany (e.g. Karlsruhe, Saarbrücken, Kassel) show how that high quality services of public transport contribute to image, ridership and change in modal split. In South America, Bogóta and Curitiba are good examples. In Curitiba for instance, the public transport system was integrated in the urban planning since the sixties, resulting in high quality and frequent metro-like bus services (Expresso). In addition, circular and feeder lines, as well as special direct services complete the system. Moreover, the fare system is integrated, allowing the passengers to ride the whole system on one fare. As most inhabitants find a bus stop at walking distance and travel speeds are high due to an extensive system of free bus lanes, the share of public transport in the modal split is high.

Intramodal complementarity. Public transport should be approached as one system, irrespective of the transport technique (train, metro, tram, bus, boat) or the way of public authorities and transportation companies are organised. These organisational aspects are of no importance to the public. Passengers simply want one system to serve them, with quick interchanges, simple and integrated fares and comprehensive traveller information. The example of Curitiba shows what can be achieved when a systems is presented as one to the public. Until now, public transport in The Netherlands presents itself very fragmented, making the usage of the services available too complicated for travellers. The Dutch public transport sector has introduced an integrated payment system for all available services, including the national railway system, in 2009, named OV-chipcard. Unfortunately, due to the various interests of the operators and authorities involved, the passenger faces a complicated system with transactions still necessary during an intermodal public transport trip. Integration of the various fare systems of all operators and authorities in one comprehensive system is

now in discussion. It would make intermodal public transport trips more easy and contribute to the image of public transport as one integrated system.

Image and comfort. Public and active transport often suffer from a bad image. This is not only due to traditional 'qualities' like bad schedules and low frequent or slow services, but also to aspects like dirtiness, lack of safety and uncomfortable vehicles. When car drivers should be tempted to use public and/or active transport, raising comfort to – as far as possible – car standards is important. However, a bad image is not easily abandoned. Often the image stays bad even when the quality has been dramatically improved. Therefore it is important to tell you're good when you are and raise the image by comprehensive campaigns, well organised aiming at specific, important target groups.

2.3 Pull: bundling of modes

Intermodal complementarity . Quality of public transport depends for a large part on feeder transport. Therefore it is important that the feeder transport modalities have at least the same quality as the public transport they are feeding. Good and safe Park and Ride facilities at carefully chosen stations are very important, as well as bike shelters at all stations and stops. At transport nodes, guarded bicycle shelters and bicycle rental facilities stimulate cycling as a feeder mode. Public transport itself can play an important role as a feeder mode to main airports, reducing the dependency of the private car and thus increasing accessibility of those transport hubs. For instance London Heathrow and Amsterdam-Schiphol offer excellent train services taking up to 45 % of the airline passengers (Schiphol Group, 2009).

Attractive transport nodes. Changing over from one (public transport) mode to another takes time and hassle and is therefore always a setback in a journey, in travel time and in comfort. Loss of time can be minimised by excellent scheduling of services and punctuality of these services. The discomfort of changing modes can be reduced by attractive facilities at the interchange nodes. Stations should offer shops and places to get drinks and food. Accessibility should be excellent in every way. Not only in the sense that it should be easy to leave or enter the trains or vehicles. Routes within the transport nodes must be without obstacles and offer escalators and/or elevators for vertical transportation. Additional, the information provided within the transport node should always equally cover all modes available. Signposting in the whole building or area is important to allow people to easily find the platforms and facilities. The more things are made easy, the less discomfort a change causes and the better the public transport system performs. Accessibility of stations and stops for people coming with other transport modes should be safe and easy. Facilities to park bicycles and cars should be abundant and secure. Actual pre-trip information about the availability of services and facilities in transport nodes and their actual accessibility is very important to provide a reliable interchange to the traveller. See also paragraph 4.4.

Park and Ride for Cars and Bicycles. Even when the urban planning policy to increase density and nearness is successful, the majority of the population will not live or work near public transport stations. Within cities and suburbs, the bicycle can play an important role to link the origins and destinations to the stations. This is true until a distance of 7 to 10

kilometres. Beyond this range, the car is the dominant feeder mode. For cyclists, parking facilities at stations and stops are very important. In general, parking facilities should be free of charge. Bicycle parkings that offer special services, like a guard or a repair shop, may charge a small amount of money. Specially assigned park and ride stations, with large, comfortable and safe parking facilities facilitate the feeder function of the car. This way it is possible to avoid that at every station a parking problem emerges. Moreover, by offering good facilities, people can be attracted to use the combination of their car and the public transport, instead of using their car all the way. Park and ride stations should offer frequent public transport services with high quality information, waiting facilities etc. Additional services like shops may increase the attraction, because they reduce the subjective waiting time and give the opportunity to do the shopping that has to be done anyway, thus saving time on the way home.

Bike Rental facilities. To increase the potential for cycling as a feeder mode, bike rental facilities can play an important role. In the Netherlands, two major types of bike rental facilities exists. The first type is a traditional bike rental shop that can be located anywhere in the city, including at major transport hubs. The second type, so-called OV-Fiets, is specifically aiming at travellers that use the public transport system. The rental facilities are located at stations and bikes are offered at very low rates for those that can show a valid ticket for the public transport system. This makes the system very useful as feeder mode at the destination side of trips (Fietsersbond, 2010).

Take-your-bike facilities. If active travellers have the option to take their bike with them, this allows them to use cycling as a feeder mode for both access and egress. Worldwide many examples exist of possibilities to take bicycles on the train, metro and ferry.

2.4 Push: reduction of car use

Only when alternative modes of transport are available with high quantities and qualities, restrictive policies on car use can be successful. It is no use to limit car usage if there are no feasible alternatives. Therefore, in addition to improvements in public and active transport systems, ‘push’ policies can be developed and implemented. In the follow paragraph the most promising policies in The Netherlands are described.

Restrictive parking policy. Parking opportunity is an important element of car accessibility in an area. If a traveller cannot park its car, it is useless to go by car. This applies to origin areas (e.g. residential areas) as well as to destination areas (e.g. working and leisure areas). Restriction of parking urges people to consider other modes of transport. Restriction policies can include a wide variety of measures. Well known examples are decreasing the number of parking spaces, increasing the costs of parking and regulation by issuing permits. Less known, but also effective is enlarging the distance between the parking facility and the final destination. This way, the car user also has to walk – or cycle – to his final destination, like the passengers of public transport. He may even need to use public transport as an additional mode of transport. This way the difference in quality between the car and public transport diminishes and more people will consider to use public transport all the way. In The

Netherlands, the government started a restrictive parking policy in the early 1990s. This policy, that could have been very successful, was abolished by the end of the decennium because it did not have enough support from regional and local governments and other parties involved. This lack of support was due to several circumstances. One important factor was that local governments did not get the instruments to enforce the rules the policy implied. A second factor was that the sense of urgency was not spread equally between the parties involved. Especially real estate developers did everything they could to avoid a restricted parking policy in the areas where they invested. A restrictive parking policy should include a comprehensive and continuous communication effort to convince parties involved, especially real estate developers and investors that reduction of parking facilities and thus of car use reduces investment costs and improves attractiveness of the area involved.

Car free city center. Many shop owners think that a parking space near their shop is essential for their sales. This is not true. In cities in The Netherlands sales raised 10-40 percent when streets were changed into more attractive pedestrian zones. Recreational shopping plays an important role in the sales in city centres and people nowadays do not want to be hindered by moving and parking vehicles. Built car parks, either multi-storey or underground, should accommodate the cars to improve the quality of the urban space. This policy also favours the use of active and public transport modes to visit the city centre, because car users will have to walk to their final destination, making the use of the car relatively less attractive.

Congestion charge and toll. Pricing the use of the road rather than the use of the public parking space is an interesting method to urge people to use other modes of transport. In the Netherlands cities are, until now, not allowed to apply road pricing. The national government is preparing a nationwide system that should be implemented within the next five years. Foreign examples (e.g. Singapore, London, Stockholm) show that local implementation can be very successful in reducing the number of cars within the cities. In London, within six months congestion reduced by 30%, resulting in 14% reduction in trip times (by car!) and more than 50% increase of public transport usage. In London the revenues of the congestion charge are used to improve the transportation networks, especially public transport. The examples also show that besides improvement of the quality of life in the cities, the accessibility for cars (some car use is inevitable) improves and therefore the local economy benefits from pricing the roads.

3. POLICY

Policies should, to be successful, comprehensive and consequent. It's not enough to adopt some of the ingredients mentioned above or to use them only in specific areas. Moreover, policy should, in this matter, shift from the traditional short term approach to the long term approach. Many of the interventions have only effect in the long term and some, e.g. road pricing are very unpopular in the short term. For most politicians this change of scope of their action is difficult to make, because they face elections every few years. Therefore it is important that the professionals make a large and enduring effort to put bundling of qualities

on the short lists of politicians. Only that way successful implementation can be achieved. Comprehensive policy should include at least the following elements.

Consistent urban planning. The longer a specific urban planning is carried out consistently the better the results are. Examples like Copenhagen, Curitiba, and, in The Netherlands, Almere and Houten show how successful this can be.

New developments along public transport lines. Locating new developments along public transport lines, means giving public transport the best opportunities to become a popular mode of transport to disclose those new areas. Successful examples include train (Madrid, Den Haag), metro (Hong Kong, Rotterdam), tram (Den Haag, Utrecht) and bus (London, Cambridge).

Increasing densities around stations. This development is also called Transit Oriented Development (TOD). It serves the purpose in two ways. At first there are more potential customers and therefore ridership is likely to rise, resulting in more and better public transport services. Secondly, the increase of density will make property values higher, which encourage new investment in even higher densities. This positive self propelling development leads to high frequent and high quality public transport services. Moreover, the rise of property values enables value capturing resulting in investments not only in real estate, but also in (preferably public and active) transportation infrastructure and facilities. International examples of this can be found in Bern, Frankfurt and many cities in Japan. In The Netherlands, which have no tradition in this matter, development of higher densities started in the 1990s in the metropolitan areas of Amsterdam, Den Haag and Rotterdam.

Urban renewal. Worldwide there are many good examples where urban renewal has been used to improve public and active transport services and facilities. For instance Bogotá, Baltimore, Manchester, Montpellier, Strasbourg and Gothenburg. In The Netherlands, improvement of cycling facilities in conjunction to urban renewal is very common nowadays, but large improvements of public transport are scarce.

Policies on choice of location and mobility management. In The Netherlands a strong policy on choice of location (“every company at its optimal location”) was formulated in the early 1990s. However, the implementation lacked consensus between national, regional and local governments. Moreover, the instruments provided to enforce this policy were by far not as strong as the formulation of the policy itself. As a result, by the beginning of the new millennium, the policy has been withdrawn due to a lack of success. This does not mean that this kind of policy does not have a large potential, but it should be supported by strong instruments. Rather new in The Netherlands is mobility management. This policy urges companies to formulate and implement a policy of how workers and visitors get access to their plants, offices and stores. As the companies are aware of the urgency of the mobility problems (in terms of their own accessibility for customers and workers and costs reduction), first results are encouraging (KpVV, 2012)

Active transport included in all urban planning. Active transport does not require large investments or space. Although often cyclist are allowed to use existing infrastructure, they will not do this as motorised traffic makes the roads unsafe, unpleasant or even because cyclists hinder the flow of motorised traffic. Dedicated infrastructure such as cycling lanes and cycle paths overcome these problems. When planning of active transport is included in every urban planning scheme, the position of active transport will improve and as a result, the attractiveness as a everyday mode of transport. Urban planning in many cities in Denmark, The Netherlands and recently some cities in Germany (e.g. Münster) prove this (KpVV, 2012)

4. BUNDLING OF MODES – OPPORTUNITIES IN RIO DE JANEIRO

4.1 Mobility in Rio de Janeiro, introduction

The city of Rio de Janeiro is the second largest city in Brazil. The metropolitan area (Região Metropolitana do Rio de Janeiro, RMRJ) has a total population of about 11.8 million people, of which 6.3 million live in the Rio de Janeiro municipality. Economic growth in Brazil in general and in Rio de Janeiro in particular causes a large increase in travel demand. Especially the growth of income of the middle class contributes to the large growth in private car ownership and usage. As a result, congestion on Rio's roads is increasing rapidly (Rio Prefeitura/SMTR, 2006).

Rio de Janeiro is a typical example of a city that faces the vicious circle depicted in figure 2 (page 3). In the Plano Diretor (mobility master plan) the city recognizes that the growth of car traffic will deteriorate mobility in the city and the metropolitan area. This will lead to a slowdown of economic development and threaten liveability and the environment. Goal of the master plan is to get out of the vicious circle of mobility and to develop a more sustainable transportation system (Rio Prefeitura/SMTR, 2006).

The city of Rio de Janeiro is characterised by many hills that are natural barriers between the different parts of the city. Tunnels provide access to these parts, though be it with limited capacity. At the metropolitan level, only a few city highways link the various parts of the city and the metropolitan area. The majority of bus routes follow regular car infrastructure. Only a few dedicated bus lanes are available where flow of busses is not affected by regular traffic. As the bus system in Rio de Janeiro accounts for about 50% of all daily trips, one can state that a lock of the road system practically locks the transport system in the metropolitan area.

Recent years have shown a rapid increase in mobility. Especially since 2006 the growth of car traffic has been such that it has affected the performance of the road network (figure 3). The limited infrastructure is under continuous stress, not only during peak hours, which leads to undesired conditions in terms of safety and emissions (noise and air pollution threatening people's wealth and wellbeing). The traffic sprawls over the network, leading to a conditions that no longer fit the functional classes of the roads. Moreover, these conditions hinder

pedestrians and cyclists on their way in and between neighbourhoods. Gridlocks on the road network can even grow to the point where also state traffic is affected, including many intercity bus lines that connect with other major cities and regions of Brazil, as they all operate on the road network.

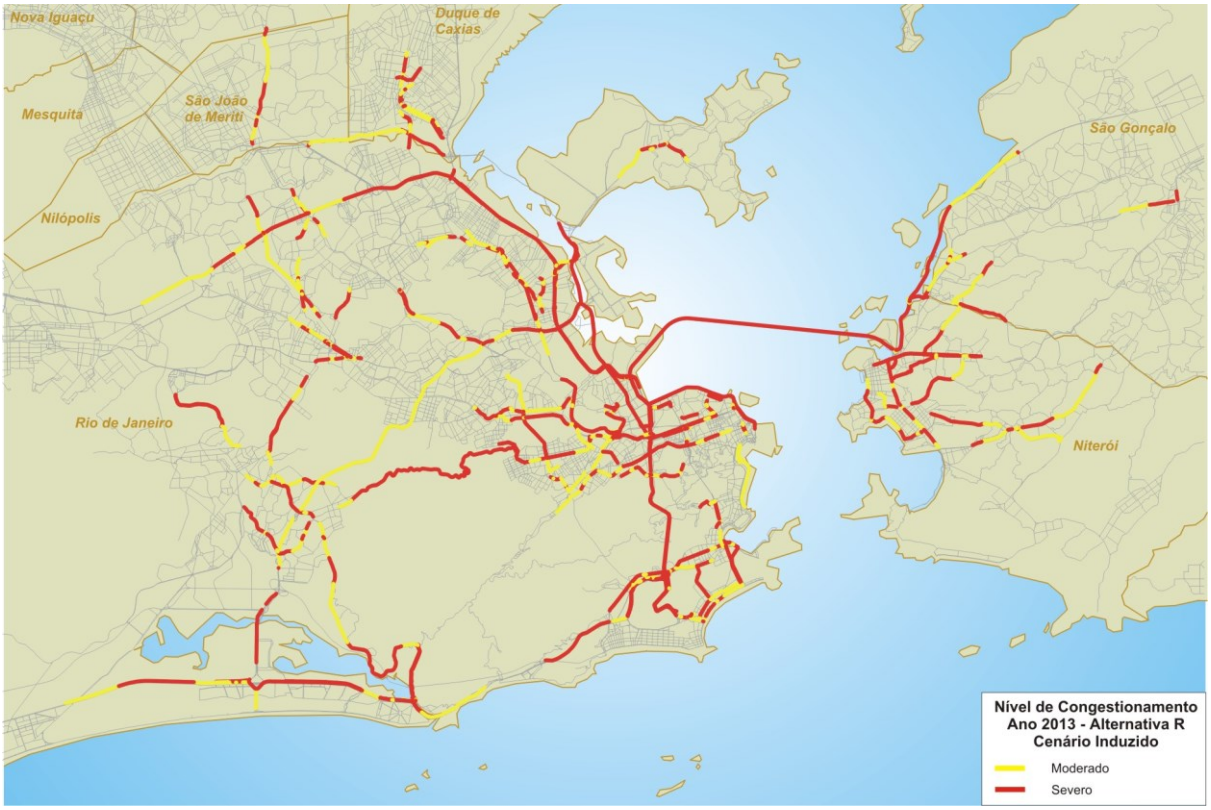

Figure 3. Level of congestion 2013 in the Metropolitan area of Rio de Janeiro (Plano Diretor)

Taxis play an important role in the congestion problem of Rio de Janeiro,. As taxi drivers are confronted with a low level of service due to the congestion, they tend to find passengers by driving around typical places of interest. When transporting a passenger, the taxi drivers will use their knowledge of the network to find the fastest route using all kinds of detours. These two components however, heavily contribute to the total mileage travelled in the network and hence to the congestion problem itself.

Finding a way out of the vicious circle is not the only challenge in the field of mobility that Rio faces. In 2007 Brazil won the right to host the soccer World Cup tournament of 2014 and it was clear that Rio would be one of the cities where matches would be played (FIFA, 2013). Moreover, the city applied to be the host city of the Olympic Games of 2016. Especially the Olympic Games will put a large pressure on the city's transportation network. This implies that the network for all modes must be extended and that the dependency of public transport on the performance of the road network must decline. Hence, the city needs an excellent functioning transportation network where all modes act together as one coherent system. In chapter 15 of the Bidbook for the Olympic Games (Rio 2016, 2009) the city has drawn an outline of this enhanced transportation network. This plan has been developed and detailed ever since.

Figure 4. Backbone network of public transport in Rio de Janeiro (2016)
Metro Rio, SuperVia (suburban train), BRT (bus) and Barcas (ferries)

The public transport system within the city and the metropolitan area consists of four major modes, bus lines, underground, suburban train and ferry. Bus lines are still the most important element in the public transport system. Therefore on major routes the city builds exclusive bus lanes for BRT (Bus Rapid Transit) and BRS (Bus Rapid Systems) buses. In 2011, exclusive BRS bus lanes with streamlined bus stops opened in the neighbourhoods of Copacabanca, Leblon and Ipanema, as well as the city centre. In the meanwhile, four
Bus Rapid Transit (BRT) corridors are under construction. In June 2012, the first, called Transoeste, was opened in the western part of the city. This 32-kilometre BRT corridor links the neighbourhoods of Santa Cruz and Barra da Tijuca. It has cut travel times between these two area's by 50%. Three more BRT corridors will be opened by 2016:

- Transcarioca, which will connect the neighbourhood of Barra da Tijuca, the heart of the Olympic Games with the North Zone of the city and the International Airport;
- Transolímpica, which will link Barra da Tijuca and Deodoro, two important Rio 2016 Olympic and Paralympic Games zones;
- Transbrasil, which will provide access from Avenida Brasil, one of the main routes in and out of the city, to the competition zones.

The MetroRio (underground) system consists of two lines: Line 1 connects the area of Tijuca, via the city centre and areas like Botafogo and Copacabana, with Ipanema. It connects to integrated metro-bus services going to areas like Barra da Tijuca and Gávea. Line 2 runs from the area of Pavuna to Cidade Nova in Rio's city centre, where it connects to line 1. It has integrated metro-bus services to Barra da Tijuca, Jacarepaguá and Fundão (University Campus). Metro line 1 is being extended to the west, adding 14 kilometres linking Ipanema, São Conrado and Barra da Tijuca. The extension (earlier called line 4) is scheduled to open in December 2015, in time for the Olympic Games. This extension of line 1 will terminate the dependency of the public transport system on the highly congested road link between

Ipanema and Barra da Tijuca, where buses often travel two or three times slower than they should according to schedule.

In the extensive suburban north and west zone of Rio de Janeiro the four train lines of SuperVia are the backbone of public transport. These lines are structured like the fingers of a hand, spreading from the Central do Brasil station in the city centre to areas more than 50 kilometres away. Central do Brasil is a large terminus station linking the SuperVia trains to the metro system and the numerous bus lines in the city. It is by far the most important hub in Rio.


Figure 5. Metro Rio station Cinelândia (left) and SuperVia train in Santa Cruz (right)

Another important mode of transport within the metropolitan region of Rio de Janeiro is the ferry across the bay. The 'Barcas' ferry connects the Rio de Janeiro city centre (at Praça XV) with the satellite city Niteroí at the east side of the bay. Today, two main connections operate, to the Niteroí city centre and the the area of Charitas respectively. These Barcas connections provide a very important link in the bay area and its importance will even grow because congestion on the bridge linking the two sides of the bay is growing year by year. In peak hours the ferries are already overloaded, which means more capacity is required to keep up with the growth in travel demand.


Figure 6. Ferries (Barcas) from Rio-Center/Praça XV to Niteroí-Center (left) and Niteroí-Charitas (right)

Special attention should be given to the bicycle. Although its share in the modal split is still small, the bicycle is a promising mode of transport for the future. Due to its hilly character, not all parts of the city have an equal potential for bicycle. But still many areas in the city could be transformed in cycle friendly neighbourhoods using traffic calming measures for reasons of safety and comfort and smoothe pavement to enhance comfort of cycling compared to walking. The introduction of electric bikes and well-placed public bike systems also contribute to the attractiveness of cycling.

Both the city and state governments have committed themselves to foster bicycle use as a mode of transport rather than, as it was before, a means of leisure. The city for instance, has extended its dedicated bicycle network from 150 kilometres in 2008 to 300 kilometres in 2012 (Altamirando, 2011). New bicycle paths and lanes and traffic calming zones provide more safety for cyclists, making the bicycle more attractive to use. The state government, which is in charge of the metro and train system, extends the number of bicycle parkings at stations, enabling the usage of the bicycle as a feeder mode (see paragraph 4.2). In recent years, the introduction of a public bike systems in cities like Paris, Barcelona, Stockholm but also Rio de Janeiro itself has contributed to the attractiveness of the bicycle as a mode of transport. Where at first the public bikes were primarily considered by the population as a transport mode for leisure trips, it is getting to be used more and more for non-leisure trips.

Figure 7 shows that the modal split in Rio is still dominated by public transport. Of public transport modes, the local bus is dominant with over 40% of all trips. Train and metro have a small share with only a few percent of all trips, but are indispensable within the city's transport system, because they channel large flows of people within and into the city. The high share of non-motorised transport is mainly due to walking. Like metro and suburban train, the bicycle only has a share of a few percent in number of trips. From both the mobility and the sustainability point of view, the challenge is to decrease the growth of the share of the private car by providing attractive alternatives for daily travel. Bundling of modes, by chaining private modes like the bicycle and the private car to public transport is a crucial instrument to achieve this. The next paragraphs show three ways to bundle modes in Rio de Janeiro. In the context of this paper, they can only be described briefly. Of course, there are many more opportunities in Rio and the metropolitan area to bundle modes and they should be elaborated, planned and realised step by step in the years to come.

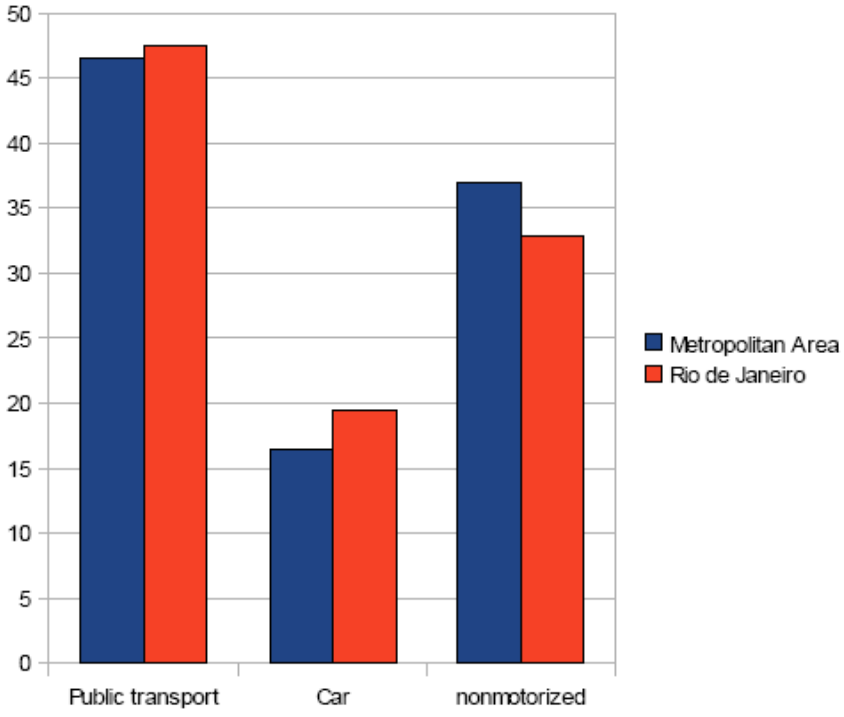

Figure 7. Modal split the Metropolitan Area and the City of Rio de Janeiro (2003)

4.2 Bundling private car and bicycle with public transport

The extensive backbone network of public transport in the Metropolitan Area of Rio de Janeiro (figure 4) extends over distances of more than 50 kilometres from the central part of the city (Centro and Zona Sul (south zone)). Combined with the fact that the trunk roads leading into the central part of the city are already congested, a sophisticated network of park and ride facilities at stations and stops for both cars and bicycles will enlarge the catchment area of the public transport network and hence be an attractive alternative to the use of the private car for the whole trip. This way, the park and ride network can contribute to:

- improvement of accessibility of the city;
- improvement of traffic safety (less vehicle kilometres);
- improvement of the environment (noise and air pollution, including CO_2); and
- improvement of attractiveness of the urban space otherwise consumed by cars.

Stations and stops for park and ride facilities should be carefully chosen. Primary criterion is the potential ridership. It is important to make a distinction between facilities for cars and for bicycles. As cars can be used at larger distances (up to 20-25 kilometres) the number of park and ride stations and stops can be smaller. More important than distance is the existence of a good road network connecting the areas of origin with the stations. The network may not be congested and must be safe. The potential catchment area for bicycles is smaller than for cars (maximum 5-7 kilometres) and therefore it is obvious that the park and ride network for bicycles will be more dense than for cars. Moreover, cyclist demand even more safety and directness on feeder routes. For those parts of the city where feeder routes are non-existing or of poor quality, bicycle lanes or paths are needed. The Dutch concept of bicycle highways (wide, separated two directional bicycle paths with as few interference with other traffic as possible) are a good example of safe and direct bicycle routes. In the Netherlands the bicycle highways, combined with the use of electric bicycles, even extend the traditional range of the bicycle up to 15 kilometres.

In the selection process of stations and stops, the availability of space for parking plays an important role. Especially car parks need either a lot of space or a large investment to build a parking garage. For bicycles less space is required, making bicycle parkings easier to implement. However, this does not mean that bicycle parkings do not need detailed planning. The quality and location of bicycle stands is very important and guarded bicycle parkings should be considered. For instance in the suburb of Santa Cruz, 50 kilometres from the central station, cycling is already a popular feeder mode, amongst others because of the availability of privately owned guarded bicycle parkings.

On the public transport side, only stations and stops with frequent services and enough capacity to handle the extra passengers can be part of the park and ride network.

To conclude, the high potential of the park and ride concept in Rio de Janeiro should be used by developing and implementing a comprehensive plan for the whole metropolitan area. Of course this does not mean that local initiatives should be put on hold before the plan is ready. Provided that a station meets minimum criteria on accessibility, parking facilities and public transport services there is no reason to postpone implementation.

4.3 Bundling bicycle and ferry

The ferries across the bay between Rio and Niteroí play a very important part in the transport system of the metropolitan area, the six lane bridge being the only alternative (for private cars and buses). These ferries only carry pedestrians. In rush hours, the ferries are very crowded, so increase of ferry capacity is needed. This can be done by either using more, faster and/or larger ships on the existing lines or by adding more lines to other destinations across the bay. The latter is preferable, because every new line will not only add capacity, but also increase the catchment area of the ferry system, thus enlarging ridership. This is important, because the growth of congestion on the bridge and the feeding roads is a big threat to the accessibility of large parts of the metropolitan area.

Sophisticated bundling of bicycle and ferry can also extend the catchment area of the ferry services and thus enlarge ridership. There are two methods to bundle:

1. Provide park and sail facilities at the ferry terminals and improve accessibility by providing safe and direct bicycle routes from the places of origin. This is actually the same concept as for other modes of public transport (see paragraph 4.2);
2. Bring into service dedicated ferries for bicycles or provide facilities to take the bicycle on the normal ferries.

To enlarge the number of people using the bicycle-ferry combination, the second method is much more effective than the first because it enlarges the catchment area of both stations, at both the origin and the destination side. In The Netherlands there are some successful examples of ferries where people can take their bicycle with them, the most famous being the ‘pont over het IJ’ in Amsterdam. This ferry, for pedestrians and cyclists, connects the Amsterdam-Noord area with the city centre and is used by thousands of cyclists every day.

Figure 8. Amsterdam ferry for cyclists and pedestrians (pont over het IJ)

The existing ferry terminals in Rio de Janeiro (Praça XV) and Niteroí (Av. Visconde do Rio Branco) do not have the capacity, nor the layout to handle passengers with their bicycle. This means that these terminals must be enlarged (but that needs to be done anyway) and adapted to this new function. To enable swift embarking and disembarking a roll-on-roll-off concept for cyclists is needed, as well as a sophisticated ticketing and access system. Moreover, of course, cyclists need safe and direct cycle routes to the terminals. In addition, special services could be considered, like a bicycle repair shop on the ferry. Unlike the Amsterdam ‘pont over het IJ’, which takes only

about five minutes for the trip, the trip by the ferry across the bay takes about twenty minutes. So special bicycle services on the ferry may be interesting for the users. Last but not least, the bicycle networks on both sides of the bay should be extended to include direct and safe access to the ferry terminals.

One of the key aspects of good services is availability. Outside rush hours, for instance in the evenings and on Sundays, ridership of cyclists may be too small to justify running dedicated cyclists ferries. For those periods of time the existing ferries should fill-in and enable cyclists to travel with their bicycle. Therefore the ships and the terminals should be modified to make this possible. As ridership of cyclists in these hours probably will not be very large (otherwise running the dedicated bicycle ferry should be feasible), the modifications needed will be not too far reaching.

4.4 Bundling of modes in comprehensive hubs

As mentioned before, Rio de Janeiro has an extensive transportation network, including city highways, metro and suburban train lines, bus rapid transit lines and the ferries across the bay. In addition, Rio is connected to other cities in Brazil through the intercity bus station (Rodoviária Novo Rio) and two airports. One of those airports, Galeão on Ilha do Governador (Governador Island) connects Rio to international destinations all over the world.

A peculiarity of the transportation network in Rio de Janeiro is the absence of one or more comprehensive hubs where all (or at least most) transport modes meet and provide interchange amongst each other. The intercity bus station for instance is accessible by local bus, taxi and private car (collect and drop off) only. Park and ride, metro, suburban train or BRT are not available at this station.

To bundle modes in Rio de Janeiro it is important to create a few comprehensive transport hubs that link as many modes as possible in one place. The search for locations for these hubs should be based on modes like metro, suburban train, intercity bus, BRT and local bus, taxi and private car (kiss & ride and park & ride). Because of their particular locations, it will not be easy to include the ferries and airports in one of these hubs, although they should not be excluded from the search. This central hub has the potential to speed up the integration of transport modes, leading to a more effective and efficient transport system.

Figure 9 shows a conceptual model of such a comprehensive hub. This model was developed in the Netherlands about ten years ago (CROW #197, 2004 and CROW #219e 2005-2007). In essence every mode has one or more arrival and departure locations. These locations can be seen as small ‘terminals’. All ‘terminals’ are joined together in one compound or building, forming the comprehensive multi-mode transport hub.

The hub should not only be an efficient and effective site of transportation. Houses, offices, schools, shops, theatres and so do not only add to the transport value of the hub but also add to the amenity and the activeness of the hub and its surrounding area. The latter is very important, because a comprehensive hub must operate during all public transport service hours and therefore be attractive and secure to use during these hours. Far too often even

large public transport nodes are quasi abandoned late at night and on Sundays, leaving the people using them feeling alone and insecure.

One of the key design requirements of an efficient and effective hub is transparency. Preferably, the hub explains itself to the people using it. Logical grouping of functions is one aspect of this, ample views from one part of the hub to other parts of the hub is another. For instance all 'terminals' within the hub should be visible (directly or indirectly) from the central hall. Of course this will not be possible for all parts and functions within the hub, so an sufficient system of signposting is necessary (CROW #197, 2004). This also applies to real time travel information. Knowing the real time of departure of the connection service makes people feel at ease and they can use the time left effectively. This also adds to the turnover of shops, bars and restaurants and therefore the economic basis of the hub. This means travellers need to have access to real time travel information not only in the 'terminal' of departure, but also in the 'terminal' of arrival, waiting areas, shops, bars and restaurants. Although new technology such as smartphones can play a role in this, traditional ways of providing information to travellers, such as large travel information panels, should not be forgotten, especially to serve lower income classes and elderly people.

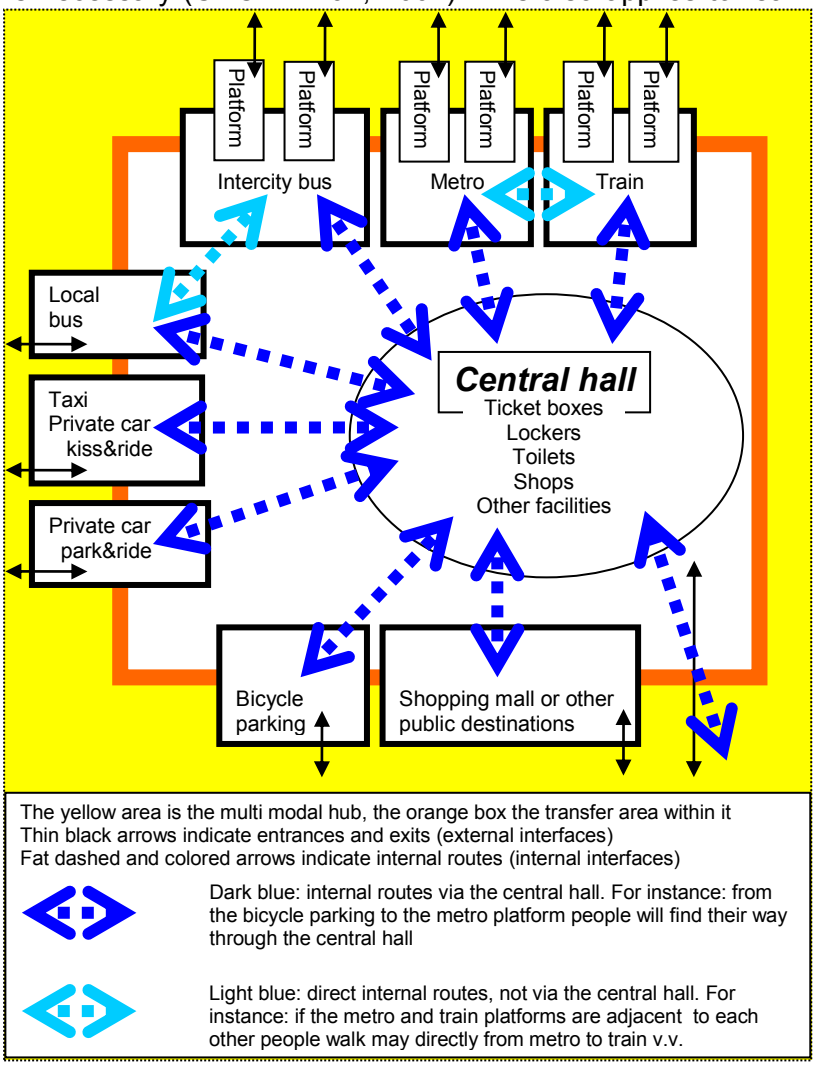

Figure 9. Conceptual model of a comprehensive multimodal hub

To find the best locations for comprehensive hubs in the Metropolitan Area of Rio de Janeiro will require more research. Basis for this research is the backbone network map (figure 4). Important criteria in the search are intercity bus lines, bundles of local bus lines, city highways and the availability of space to developed the hub. In figure 10 some potential locations are depicted. Of course detailed research is needed to find out which locations are really feasible in terms of value in the network, accessibility by various modes of transport, availability of space and property conditions.

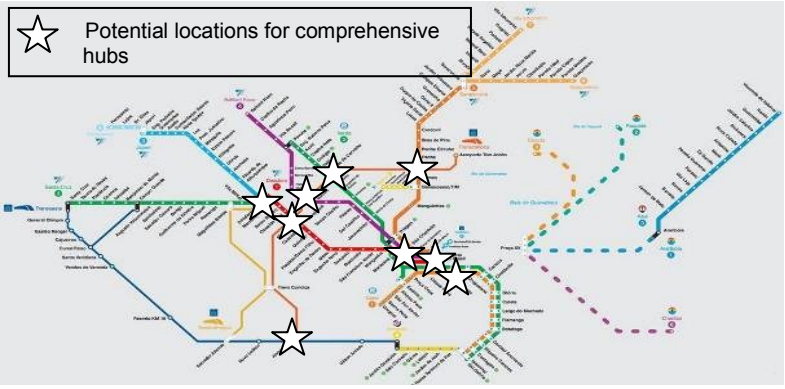

Figure 10. Potential locations for comprehensive hubs in Rio de Janeiro

5. CONCLUSION

Bundling of qualities (functions and values) is crucial to get out of the vicious circle of negative urban development in terms of congestion and environmental impact. It makes alternative modes of transport more usable and attractive and rises accessibility of urban areas. On the other hand, bundling is also the physical result of successful policy making and planning making cities more liveable than the autonomous trend of urban sprawl.

Bundling of modes is a very powerful instrument to reduce the use of the private car and at the same time provides fast and comfortable door-to-door transportation services. In order to bundle modes successfully, transport nodes are needed where excellent public transport services are joined with good and safe accessibility by private modes like walking, cycling and the private car. Bicycle and car parks, pre-trip and on trip travel information services and facilities that reduce the discomfort of waiting should be available at all major transport nodes in a region. Also bicycle hiring facilities or public bikes should be available. Integrated payment or fares are also important. A specific way to 'chain' modes is to enable cyclists to take their bicycle with them on public transport. This is often considered impossible, because of the space a bicycle takes and the time needed to load and unload it. But for instance on trains and ferries it should be considered seriously, because it really enhances the value of the chain.

In Rio de Janeiro integration of transport modes is still very deficient. This is an opportunity rather than a problem. Three examples of bundling are described in this paper:

- Bundling private car and bicycle with public transport;
- Bundling bicycle and ferry;
- Bundling most transport modes in comprehensive hubs.

These promising examples show that bundling of modes is still a powerful method to improve the transportation system in the city of Rio de Janeiro and to slow down the growth of car traffic and thus the growth of congestion. It is recommended that these and other opportunities are studied, planned and implemented in the coming years. Once more it should be noted that integral planning focuses not only on short term but also on long term activities and require consistent planning that often spans over several political cycles. If possible a start can be made with this in time for the Olympic Games of 2016 when the Rio de Janeiro transport system will have to prove its capabilities and robustness.

REFERENCES

Altamirando, Fernandes Maraes (2011) Rio de Janeiro, La oportunidad de instalar un sitema de bici carril de forma integrada, contribution to Velo-City Sevilla, Rio de Janeiro

Buunk, Willem; Linssen, Raymond (2007) Expedities in mobiliteitsgerichte gebiedsontwikkeling, lessen uit vernieuwende projecten van ruimtelijke ontwikkeling op en rond infrastructuur. Nirov, Den Haag

CROW (2004) Reis- en route-informatie op en nabij vervoersknooppunten, publicatie 197, Ede

CROW (2005) Verblijfsduurheffing, publicatie 214, Ede

CROW (2005-2007) Toegankelijkheid collectief personenvervoer, publicatie 219 a t/m f, Ede

CROW (2006) Handboek halteplaatsen, publicatie 233, Ede

CROW (2007) Design manual for bicycle traffic, record 25, Ede

Fietsersbond (2010) Hoe bevalt de OV-fiets? Klantonderzoek 2009, Utrecht

FIFA (2013) website http://www.fifa.com/worldcup/index.html

IBGE website (2013) http://www.ibge.gov.br

iRoute (2012) OV Bureau Randstad Procesversneller reisinformatie P+R-terreinen – rapportage, Dordrecht

KpVV (2012) Slim Reizen: Hoe Europese landen, steden en regio's gedrag veranderen, Utrecht

Lopes, Julio; Lobo, José e Santor, Cláudio (2011) Bicicleta, a cara do Rio, Rio de Janeiro

Ministerie van Infrastructuur en Milieu (2012) Structuurvisie Infrastructuur en Ruimte (SVIR), Den Haag

Ministerie van Infrastructuur en Milieu (2013) Lange Termijn Spooragenda, Den Haag

Raad voor Verkeer en Waterstaat (2004) Ieder zijn deel: locatiebeleid anders aanpakken, Den Haag

Raad voor Verkeer en Waterstaat (2008) Einde aan vrijblijvendheid, advies over locatiebereikbaarheid, Den Haag

Rio 2016 (2009) Bidbook Rio 2016 candidate city

Rio 2016 (2013) website http://www.rio2016.org.br

Rio Prefeitura/SMAC (2013) website http://www.rio.rj.gov.br/web/smac

Rio Prefeitura/SMTR (2006) Plano Diretor de Transportes da Cidade do Rio de Janeiro

Hulleman, Rob; Zandee, Rianne (2008) Bundling of qualities, contribution to Pleuris Conference, Santos

Schiphol Group (2009) Visie Duurzame Mobiliteit, Schiphol

Teixeira, Maria Amelia (2011) Rio de Janeiro: Mobility for the 2016 Olympic Games, contribution to Stadium meeting Ancona, Rio de Janeiro

Transporte Ativo (2013) website http://www.ta.org.br

Zandee, Rianne c.s. (2007) Bundeling een Gouden Greep, de betekenis van bundeling van verstedelijking en infrastructuur in verleden, heden en toekomst. KpVV, Rotterdam.

Zandee, Rianne c.s. (2007) Bundelen van kwaliteiten, voor een duurzame leefbare stad, ROM-magazine, Rotterdam