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Evaluation of Park&Ride Facility inside the PINAVIA Junction from the Perspective of Sustainable Development

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----------ABSTRACT----------

The article deals with the issues of Park & Ride - a tool to decrease the amount of private cars in favor of public transport in order to improve the modal split. A new type of road junction is introduced with a possibility to easily access its center area. A generalized framework of sustainable development by AlQahtany et al. is used to evaluate the new junction with a Park & Ride facility placed inside it. Advantages of this integrated system are described by comparing it to a conventional junction with a Park & Ride nearby it.

KEYWORDS *- Park and Ride (P&R), PINAVIA road junction, sustainable development, urban planning.*

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I. INTRODUCTION

Transport plays a major role in modern economies. Simultaneously it also creates problems. The Intergovernmental Panel on Climate Change states that it is very likely the tropospheric warming during the last 60 years is caused by anthropogenic greenhouse gases (IPCC, 2013). The main contributors to the global CO2 emissions are energy sector (electricity and heat generation) with a 41% share, and transport with a 22% share (IEA, 2012). Close to three quarters (74%) of the transport generated CO2 emissions in 2010 come from road transport (IEA, 2012). Accordingly, International Energy Agency encourages policies favorable to more efficient vehicles, public transportation (or other low-emission modes) and low-carbon fuels. Indeed, if vehicle ownership per 1000 residents in China would increase from 58 in 2010 to the levels found in US, i.e. 800 (Sousanis, 2011), it would double the world population of vehicles. Even if their engines are twice more efficient by that time, road congestion may remain the largest problem of transport in cities offsetting the engine improvements. Currently annual costs of congestion in European Union (EU) are reaching almost 2% of GDP, while total external costs of transport amount to around 4% of GDP (CE Delft, 2011).

The role of public transportation is ever more important in decreasing the number of cars and subsequently - emissions of greenhouse gases. Calculation of average external costs for different transport modes in EU shows that costs of a bus (34 EUR per person per 1000 km) are almost twice lower than that of a car (65 EUR); and rail (15 EUR) is twice more efficient than a bus (CE Delft, 2011). Accidents (mostly road accidents), air pollution, and climate change costs constitute the largest part of the external transport costs. Noise costs, up- and down-stream processes, costs for nature and landscape play a somewhat smaller role, comparable in size for all motorized transport modes. Keeping in mind the data, one could expect a modal split in favor of rail transport, and private cars taking up the smallest part. However, the differences in external costs of the transport modes are not represented in the modal split in most European cities, with 34% of the share taken by private cars, 36% by soft modes, and 31% by public transport (EMTA, 2012). If suburbs are also taken into account, then the share of private cars rises to 49%. The situation is even more dramatic in the faster developing cities around the world, e.g. more than 85% of journeys are being made using private car in Kuwait (UNDP, 2009), evidenced by the congestion map in Fig. 1. Recently authorities of many European cities have recognized the role of railway transport, as it is visible in the growth of transport supply: e.g. during the 2006-2009 the supply of bus transport increased by 8%, metro by 13%, and suburban railway by 17% (EMTA, 2012). This public transport supply growth is larger than increase of population in the corresponding cities during the same time, but it is not enough to solve the congestion problem, because number of cars per capita remains almost constant (Sousanis, 2011), so the total number of cars on city streets is still increasing.

The dominance of private cars in the modal distribution of transport may be due to the "automobile dependency" (Litman & Burwell, 2006), which is encouraged by such governmental policies as dedicated funding for highway facilities, free roads and parking, and other market distortions in favor to motorists. Also, if city planning is focused primarily on private cars - as it was usual in the United States (US), it is very difficult and costly to introduce public transport later on (Mäntynen, 2007).

Global problems created by extensive growth of transport in particular and by all human economic activity in general makes city planners embrace broader views when considering plans for specific projects - decisions are being based on the ideas of sustainable development. Many organizations define sustainable development in their own way, even though the main ideas remain the same: the development should be fair to current and to future generations, regardless of time or space (Litman & Burwell, 2006). The problems arise when specific weights need to be given to different criteria used to evaluate a project, and even the selections of the criteria differ in different frameworks of sustainable planning. AlQahtany et al. discussed three internationally recognized frameworks of sustainable development at urban planning scale - CASBEE of Japan, BREEAM of the United Kingdom, and LEED of the US (AlQahtany, Rezgui, & Li, 2013). The authors addressed the weaknesses of these frameworks and proposed an improved model, which gives more emphasis on the planning issues, in particular - land use and public transport. The framework of AlQahtany et al. is more general and free of regional differences, so we will use the framework to analyze our proposals.

An efficient tool of city authorities for reducing number of private cars inside cities is provision of Park & Ride (P&R) services. In 1990s it was "viewed as one of the principal means of addressing transport problems in urban areas" (Cairns, 1998). Clearly, if a dedicated parking space is allocated in city suburbs close to major rail or bus lines and some motorists switch from their cars to the public transport, then part of the traffic in the city center is eliminated, a possibility to reduce central parking supply arises, and also some first-time users of the public transport may completely switch the mode later on if they like its quality of service (Parkhurst, 1995). It takes however more careful planning in order for the P&R to work as intended. In some cases, it may fail because of lack of interest, as it happened to the first P&R facilities, which were build in Oxford, UK - probably because the concept was too new, or the quality of bus service was unsatisfactory (Cairns, 1998). In other cases, some bus-only users start using P&R, so that the overall kilometers per capita ratio increases with the total negative environmental impact of the P&R (Parkhurst, 1995). This is usually justified by local authorities because the traffic increase happens in less congested suburban areas (Cairns, 1998), or it can be solved in several ways: by carefully introducing pricing policies (Habib, Mahmoud, & Coleman, 2013), or by choosing a correct P&R placement model, such as "Hub-and-Spoke concept" (Meek, Ison, & Enoch, 2011). As a result, P&R remains a powerful tool in the hands of transport planners. In fact, calculations show that if the space of parking nearby a fast public transit route would be used for housing development (many new walk-and-ride travelers are introduced), the ridership on the public transport would decrease (Duncan, 2010).

Despite the attractiveness of P&R, choosing the right location can be problematic. In the UK the "right" location of the P&R "should be on the edge of the built-up area, close to a major radial approach route and to a ring road or bypass, and located before the traffic congestion begins" (Cairns, 1998). In the US, apart from the mentioned criteria, additional elements related to security and satisfaction of the users are listed, such as ambient lighting, security, maintenance and possibly nearby commercial developments - theaters, stadiums, shopping malls, and hotels (MassHighway, 2006). Land costs may be one of major obstacles - a study of P&R nearby light rail stations is the US shows that P&R places are less likely to be found where land costs are high (Duncan & Christensen, 2013). Larger P&R could provide a larger public transport ridership, but then additional problems may arise due to entry and exit roads: they either interfere with the bypassing traffic, or they are laid out in a complicated manner with lots of additional structures - small overpasses and/or tunnels, as it is illustrated in Fig. 2, where the territory of 877 parking places is comparable to the territory taken by all entry and exit roads nearby it.

II. PINAVIA PARK AND RIDE

We propose an alternative placement option for the P&R - inside a road junction. This becomes possible with some modifications of a recently invented junction called PINAVIA (Buteliauskas, 2012).

Up to date PINAVIA is the only known junction with no intersecting traffic flows which is designed on just two levels. In the sense of this functionality it is equivalent to the much more costly fully directional

junction on four levels. Fig. 3 illustrates the basic concept of the PINAVIA junction: it has four tunnels (or overpasses) but they are twice smaller than a usual tunnel or overpass, because they are needed for half the road only. The roadways are arranged so that a safe and unobstructed flow is possible in any direction on any road of the intersection without a need to change either lanes or driving speeds. An arbitrary number of lanes may be chosen for any roadway in order to adjust the junction capacity parameters to the local distribution of traffic, e.g. three lanes for turning left from the first road, while only one lane for turning left from the second road etc.

The size of the PINAVIA junction directly depends on the projected driving speed. E.g. the diameter of the junction is 322 m (1070 ft) for v=50 km/h (31 mph); D=660 m (2200 ft) for v=70 km/h (44 mph); and D=915 m (3000 ft) for v=105 km/h (65 mph). Clearly, it is not suitable for speeds above 70 km/h, because of the excessive left-turn distance, and its overall size. However, for smaller speeds it is comparable in size to the usual "Clover-leaf" junctions.

A simple modification of the original PINAVIA junction - an addition of one more driveway on the left side of the approach road - makes it possible to access the junction center area without any additional elements (tunnels of overpasses). Fig. 4 illustrates the possibility, although the entry/exit roadway is visually shifted away from the bypassing roadway to make it more evident. In practice, it could use the same entry tunnel as the left-turning and through-passing lanes. The exit roadways from the center can also follow the same path as the entry roads, just in the opposite direction, merging from the left the road after the junction. Left turns from the left lane, and merging the road from the left would not be suitable for highways, but the layout can be feasible for smaller category roads nearby a city.

Useful area inside the junction can be quite considerable in size - around 18 ha for the 70 km/h junction. A possibility to enter this area from all four roads without any intersections makes it very attractive for housing developers and businesses - shopping or logistics centers, theaters or stadiums, especially when one considers the unobstructed evacuation into all four roads at once. Considering the location of the junction, it cannot be located deep inside an urbanized zone because of its size, and neither it is efficient away from the city where driving speed is high. Consequently, it should be located on the crossings of major radial roads and city bypass roads - the so-called "ideal" location of a P&R. Easy access to its center makes it perfect for bus- or metro-served P&R.

III. COMPARISON OF TWO ALTERNATIVES

In order to compare the two alternatives - an ordinary P&R nearby a conventional junction and a P&R inside the PINAVIA junction of 70 km/h design speed - we use the relevant categories and criteria of the sustainable urban planning development framework by AlQahtany et al. (AlQahtany et al., 2013). The comparison is presented in the Table 1. In order for the objects to be comparable, we assume the conventional junction has a nearby P&R facility of the same size as the one inside the PINAVIA. It is not so easy to decide what kind of conventional junction to take for the comparison. E.g., fully directional interchange could be comparable to PINAVIA in the sense of capacity, but fully directional interchange has an advantage of a possibility of infinite speeds when going straight, while PINAVIA has only circular roadways whose radii limit the driving speed. Other more popular and cheaper junctions - "Clover-leafs" - are limited in capacity because of weaving and they have safety issues. We therefore choose not to specify exact parameters of the "conventional" junction, assuming its overall size together with extra entry and exit roads of the P&R similar in size to the chosen PINAVIA.

The comparison shows a clear advantage of the PINAVIA P&R over the conventional junction and P&R. Most of it builds upon the specific geometry of the PINAVIA junction, which enables a perfect access to a large area inside it.

There are several serious obstacles for the PINAVIA concept to be applied in practice. First of all, it is a new idea, and it meets a natural resistance similar to all inventions. Secondly, the window of its applicability is rather narrow: the traffic volume of the intersecting road should be sufficiently high, while the allowed driving speeds sufficiently low. Even though it allows reclaiming part of the land it occupies, it takes up a substantial territory during the construction phase. Finally, it works best as an integrated solution - not just as a standalone junction, but as a junction with an additional infrastructure inside, such as P&R, a stadium, etc. This last fact is especially problematic, because as a rule there are different authorities for each of these elements, and a wider view and cooperation between them might be difficult to achieve (cf. Litman & Burwell, 2006).

I. FIGURES AND TABLES

Figure 1: Congestion in Kuwait City at noon, 18 November 2013 (Google Maps)

Figure 2: Parking nearby Luxembourg City (Google Maps) close to a congested bypass road

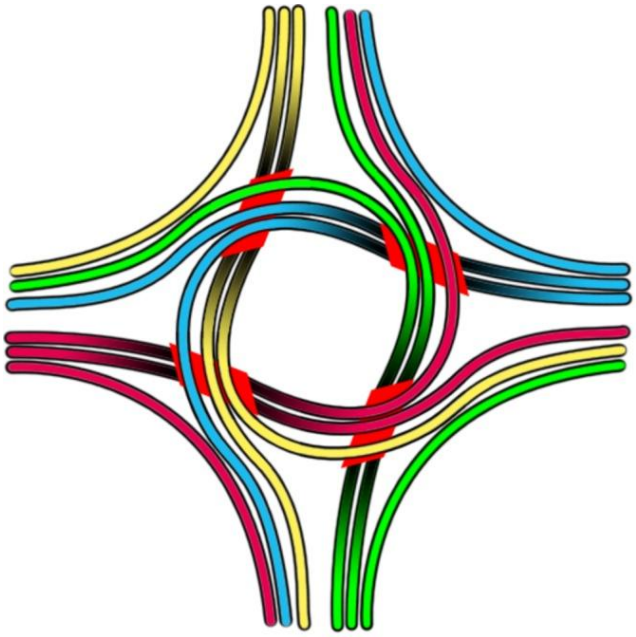

Figure 3: Layout of the PINAVIA junction

Figure 4: PINAVIA junction with an internal infrastructure

Table 1: Comparison of Two P&R Facilities

Criterion	PINAVIA 70km/h and P&R	Conventional P&R and junction
PLANNING DIMENSION		
Land Use	PINAVIA has an advantage of a freed-up internal area up to 18 ha in size. The area is easily accessible from all four roads without crossing any lanes.	To create a corresponding P&R an extra 18 ha of land are needed nearby the junction. The P&R is accessible from just one road; otherwise, it takes an extra overpass/tunnel to get to other roads.
Infrastructure	The easily accessible area inside the junction is attractive for creating additional infrastructure, e.g. a stadium, office buildings, or any kind of business. A considerable quantity of new working places can be created (decentralization of the city).	If some infrastructure is built due to the P&R, it is not so easily connected, and tends to be limited in size.
Transport	A natural hub for any kind of public or private transport. If working places are present, then P&R users are travelling towards the city, while some city-center residents are travelling in the opposite direction making private transport more efficient.	No specific advantages.
Management	Easy to manage traffic flows - in case of need all or part of traffic approaching the PINAVIA from any road can be redirected to other roads or to the parking inside it.	No specific advantages.
ENVIRONMENTAL DIMENSION		
Pollution / Resource / Energy / Ecology / Climate	The compared objects are very similar in this respect. However, PINAVIA may have an advantage considering architectural pollution - its symmetrical shape and very low vertical dimension have smaller visual noise than an ordinary junction. Additionally, each resident of the city taking public transport (let us say - a bus) to a working place inside the PINAVIA would effectively create an environmental impact equal to zero travelled kilometers, because the bus would have been driving anyway to return to the P&R users.	As discussed previously, recent research indicates the usual P&R shifts the traffic from the city center towards the suburbs with an overall environmental impact close to zero.
SOCIAL DIMENSION		
Health	Due to perfect connectivity, PINAVIA center may attract a health institution, especially if some other working places (e.g. offices) are established.	No specific advantages.
Education	Even though the location of schools or child-care centers seems improbable inside a circle of a continuously moving traffic, they may be removed from it by up to 300 m of various other barriers, which might be better than a location inside the city center.	No specific advantages.
Security	Parts of the circular road can be on the same level as the surrounding ground. Also the four designed exits with small overpasses pose no large threat in case of an earth quake. In case of other natural disasters there is a possibility to evacuate into four main roads simultaneously.	No specific advantages.
ECONOMIC DIMENSION		
Sustainable	PINAVIA has a possibility to become a hub of local economy.	No specific advantages.
Growth	New investments and businesses are very likely inside the PINAVIA.	Any P&R attracts businesses to some extent.
Employment	Many new working places are probable and easily accessible.	Some new working places are possible.
Productivity	Due to the location of PINAVIA (in the suburbs) most of the services will be cheaper than in the city center.	No specific advantages.

IV. CONCLUSION

Park and Ride services are being implemented in order to decrease transport congestion in cities by eliminating part of the private cars in its traffic. A unique location of P&R is suggested by introducing a newly invented road junction PINAVIA. The symmetrical circular layout of the PINAVIA and its location on a crossing of large roads creates these advantages: it uses the land efficiently and releases part of it inside the junction; it is easily accessible by all transport modes; it is convenient to change transport modes there because of small walking distances inside the junction; it creates a possibility to establish new working places and a small center of local suburban economy. From the perspective of sustainable development PINAVIA junction together with an inside P&R facility is advantageous over a stand-alone conventional junction and a separate P&R.

REFERENCES

[1] AlQahtany, A., Rezgui, Y., & Li, H. (2013). A proposed model for sustainable urban planning development for environmentally friendly communities. *Architectural Engineering and Design Management*, *9*(3), 176–194. doi:10.1080/17452007.2012.738042

[2] Buteliauskas, S. (2012). Road Junction EP 1 778 918 B1. EU: European Patent Office.

[3] Cairns, M. R. (1998). The development of Park and Ride in Scotland. *Journal of Transport Geography*, *6*(4), 295–307. doi:10.1016/S0966-6923(98)00016-7

[4] CE Delft. (2011). *External Costs of Transport in Europe Update Study for 2008*.

[5] Duncan, M. (2010). To Park or To Develop: Trade-Off in Rail Transit Passenger Demand. *Journal of Planning Education and Research* , *30* (2), 162–181. doi:10.1177/0739456X10385935

[6] Duncan, M., & Christensen, R. K. (2013). An analysis of park-and-ride provision at light rail stations across the US. *Transport Policy*, *25*, 148–157. doi:10.1016/j.tranpol.2012.11.014

[7] EMTA. (2012). *EMTA Barometer of Public Transport in European Metropolitan Areas (2009)*.

[8] Habib, K., Mahmoud, M., & Coleman, J. (2013). Effect of Parking Charges at Transit Stations on Park-and-Ride Mode Choice. *Transportation Research Record: Journal of the Transportation Research Board*, *2351*(1), 163–170. doi:10.3141/2351-18

[9] IEA. (2012). *CO2 Emissions from Fuel Combustion 2012 - Highlights*.

[10] IPCC. (2013). Summary for Policymakers. In *: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge UK, and New York USA: Cambridge University Press.

[11] Litman, T., & Burwell, D. (2006). Issues in sustainable transportation. *International Journal of Global Environmental Issues*, *6*(4), 331. doi:10.1504/IJGENVI.2006.010889

[12] Mäntynen, J. (2007). Public transport in Finland: today and tomorrow. In *The Future of Public Transport JOTU*. Oulu: Liikenne- ja viestintäministeriö JOTU-hanke.

[13] MassHighway. (2006). *Project Development and Design Guide*. Boston, MA. Retrieved from http://www.massdot.state.ma.us/highway/DoingBusinessWithUs/ManualsPublicationsForms/ProjectDevelopmentDesignGuide.aspx

[14] Meek, S., Ison, S., & Enoch, M. (2011). Evaluating alternative concepts of bus-based park and ride. *Transport Policy*, *18*(2), 456–467. doi:10.1016/j.tranpol.2010.09.006

[15] Parkhurst, G. (1995). Park and ride: Could it lead to an increase in car traffic? *Transport Policy*, *2*(1), 15–23. doi:10.1016/0967-070X(95)93242-Q

[16] Sousanis, J. (2011). World Vehicle Population Tops 1 Billion Units. Retrieved February 25, 2014, from http://wardsauto.com/ar/world_vehicle_population_110815

[17] UNDP. (2009). *National Traffic & Transport Sector Strategy for Kuwait 2009-2019*. Retrieved from http://www.undp.org/content/dam/kuwait/documents/projectdocuments/Human Development/General Directorate of Traffic Project 2009-2013 SIGNED.pdf