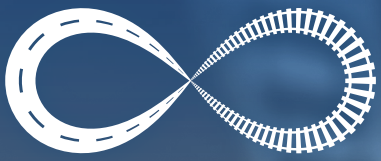

CETRA 2018

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

IRF GLOBAL

FEHRL

Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA 2018
5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

TITLE
Road and Rail Infrastructure V, Proceedings of the Conference CETRA 2018

EDITED BY
Stjepan Lakušić

ISSN
1848-9850

ISBN
978-953-8168-25-3

DOI
10.5592/CO/CETRA.2018

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Marko Uremović · Matej Korlaet

PRINTED IN ZAGREB, CROATIA BY
"Tiskara Zelina", May 2018

COPIES
500

Zagreb, May 2018.

Proceedings of the
5th International Conference on Road and Rail Infrastructures – CETRA 2018
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

CETRA 2018
5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

ORGANISATION

CHAIRMEN

Prof. Stjepan Lakušić, University of Zagreb, Faculty of Civil Engineering
Prof. emer. Željko Korlaet, University of Zagreb, Faculty of Civil Engineering

ORGANIZING COMMITTEE

Prof. Stjepan Lakušić
Prof. emer. Željko Korlaet
Prof. Vesna Dragčević
Prof. Tatjana Rukavina
Assist. Prof. Ivica Stančerić
Assist. Prof. Maja Ahac
Assist. Prof. Saša Ahac
Assist. Prof. Ivo Haladin
Assist. Prof. Josipa Domitrović
Tamara Džambas
Viktorija Grgić
Šime Bezina
Katarina Vranešić
Željko Stepan

Prof. Rudolf Eger
Prof. Kenneth Gavin
Prof. Janusz Madejski
Prof. Nencho Nenov
Prof. Andrei Petriaev
Prof. Otto Plašek
Assist. Prof. Andreas Schoebel
Prof. Adam Szeląg
Brendan Halleman

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Stjepan Lakušić, University of Zagreb, president
Borna Abramović, University of Zagreb
Maja Ahac, University of Zagreb
Saša Ahac, University of Zagreb
Darko Babić, University of Zagreb
Danijela Barić, University of Zagreb
Davor Brčić, University of Zagreb
Domagoj Damjanović, University of Zagreb
Sanja Dimter, J. J. Strossmayer University of Osijek
Aleksandra Deluka Tibljaš, University of Rijeka
Josipa Domitrović, University of Zagreb
Vesna Dragčević, University of Zagreb
Rudolf Eger, RheinMain Univ. of App. Sciences, Wiesbaden
Adelino Ferreira, University of Coimbra
Makoto Fujiu, Kanazawa University
Laszlo Gaspar, Széchenyi István University in Győr
Kenneth Gavin, Delft University of Technology
Nenad Gucunski, Rutgers University
Ivo Haladin, University of Zagreb
Staša Jovanović, University of Novi Sad
Lajos Kisgyörgy, Budapest Univ. of Tech. and Economics

Anastasia Konon, St. Petersburg State Transport Univ.
Željko Korlaet, University of Zagreb
Meho Saša Kovačević, University of Zagreb
Zoran Krakutovski, Ss. Cyril and Methodius Univ. in Skopje
Dirk Lauwers, Ghent University
Janusz Madejski, Silesian University of Technology
Goran Mladenović, University of Belgrade
Tomislav Josip Mlinarić, University of Zagreb
Nencho Nenov, University of Transport in Sofia
Mladen Nikšić, University of Zagreb
Andrei Petriaev, St. Petersburg State Transport University
Otto Plašek, Brno University of Technology
Mauricio Pradena, University of Concepcion
Carmen Racanel, Tech. Univ. of Civil Eng. Bucharest
Tatjana Rukavina, University of Zagreb
Andreas Schoebel, Vienna University of Technology
Ivica Stančerić, University of Zagreb
Adam Szeląg, Warsaw University of Technology
Marjan Tušar, National Institute of Chemistry, Ljubljana
Audrius Vaitkus, Vilnius Gediminas Technical University
Andrei Zaitsev, Russian University of transport, Moscow

CETRA 2018 17–19 May 2018, Zadar, Croatia
5th International Conference on Road and Rail Infrastructure

FEASIBILITY OF INTERCHANGE CONSTRUCTION PROJECTS ALONG MOTORWAYS

Anastasios Mouratidis, Fotini Kehagia
Aristotle University of Thessaloniki, Highway Laboratory of Civil Engineering Department, Greece

Abstract

Existing guidelines and regulations define the conditions to interpose an additional interchange along a motorway. These regulations mainly deal with traffic operations and safety on the transportation system involved and the motorway in question. In the present analysis, cost and land use criteria are also considered as parts of a feasibility investigation meant to grant access to a motorway. However, what is most important is the research on the "inverse" question, that is, the concern of a too long spacing which may be an impediment to sustainability. The basic concept of establishing specific criteria in view of the construction of an additional interchange reflects the need to provide reachable social assets and to permit quick access in case of emergency. The constitutive pattern presented herewith introduces conditions in favor of the potential project. Their expected beneficial effect may turn a controversial construction project to a positive asset for travellers and local society.

Keywords: interchange, highway, motorway, social services, sustainability, transport

1 Introduction

Design of interchange density along a motorway constitutes a basic issue to be addressed, at first place, during the project planning stage. Later on, the engineering design study is meant to provide the overall layout including the position and the type of each interchange along the route.
In this regard, a global policy for the distribution and the design of interchanges, applicable indiscriminately to every new motorway or to every upgrading project, may prove inadequate, due to the variety of the contributing factors: traffic volume, neighboring built environment, type of terrain, land use, environmental features, budget constraints. All these factors, associated with the motorway and its surroundings, may be so different from one case to another, that it is impossible to conceive how a global policy would result in a suitable design all by applying simple rules of geometric considerations. Low-volume motorways must be handled in a quite different way from congested freeways. Expressways traversing underdeveloped regions play a significant role and should be appraised by a broad look beyond the rules concerning an ordinary transportation link.
Accordingly, the scope of planning the number and the position of interchanges along a motorway becomes wider. A sustainable design needs to combine environmental friendliness, engineering capacity, economic efficiency and societal needs, to transform the transportation infrastructure into a substantial means of development and welfare. Traditional and innovative literature on the subject (Baker,1975), (AASHTO,2004), (Institute of Transportation Engineers,2005) primarily deals with the geometric conditions of interchange design, including terms of interposing new interchanges on existing motorways. The main concern throughout

the said literature is to conserve road safety and serviceability at high level. Issues related with traffic operations on ring roads, urban and suburban freeways are thoroughly examined. Traffic deceleration, safety in weaving areas and ramp spacing are common subjects of detailed study and analysis. Operational aspects of the overall transportation system are also investigated and introduced into combined briefs of rules and guidelines.
The contribution of the existing methods of interchange design to preserve high serviceability standards is beneficial in cases of congested freeways or urban ring roads (TRB, 2010). By contrast, in cases of non-congested freeways and common motorways in rural environment, B/C models designed for transportation infrastructure projects can be applied (Caltrans, 2012). They usually consider four categories of benefits resulting from highway construction projects: travel time savings, vehicle operation cost savings, accident cost savings, emission reduction. However, a gap still exists: are the aforesaid rules and guidelines sufficient to ensure economic, environmental and societal sustainability? Should other factors, such as local economy or societal needs, be taken into consideration? The analysis presented hereafter aims at extending the research to a wider area so as to cover all aspects of an effective and sustainable planning of additional interchanges on motorways.

2 Prerequisites for a new interchange

Addressing mainly the case of congested freeways in urban and peri-urban areas, the FHWA proposes the checking process consisting of eight points/criteria in view to granting access to an interstate freeway (Federal Register, 2009). The FHWA analysis focuses on traffic operation and a detailed assessment of the deceleration impact by an interposed interchange (TRB,2011). Safety issues in weaving areas are also dealt with (Table 1).
In an attempt to extend the scope of the subject, it is worth widening the research introducing quantifiable and non-quantifiable factors in the decision producing algorithm. This constitutive algorithm should explore both cases: "Is the distribution of interchanges too dense?" and "Is it too sparse?" A rational planning should avoid both non-sustainable situations.

Table 1 Prerequisites to permit access to a freeway

A/A	FHWA POINTS	Transport Infrastructure affected	Operational criteria
1.	The existing system is incapable of accommodating desired access or traffic demands	TS(*)	Access
2.	All reasonable alternatives to a new interchange have been considered, including transportation system management	TS	Access
3.	The proposal does not have an adverse safety or operational impact on the freeway	Freeway	Safety
4.	A full interchange at a public road is provided	TS	Access
5.	The proposal is consistent with transportation and land use plans	TS	LOS(**)/ Environment
6.	A comprehensive interstate network study is prepared	TS	LOS
7.	There is coordination with transportation system improvements	TS	LOS
8.	The request is considered as an alternative in environmental evaluations	TS	Environment

(*)TS=Transport System, (**)LOS=Level of Service

3 Comparative analysis

A motorway is an expressway with separate carriageways and full access control. Local access along rural motorways is usually provided by frontage roads. Potential interchanges aiming to give access to regional roads, villages or historic settlements (Fig.1) are unlikely to be granted and planned in the frame of an ordinary motorway construction project. Conversely, interchanges must be foreseen to link the motorway to major cities, crossing expressways and principal national roads (Fig.2). These informal, all but, fundamental principles can be effectively applied to motorway construction projects in developed countries, where an extended and highly operational transportation infrastructure exists. However, an eventual application of this policy to every motorway construction project or to every project upgrading an existing facility may prove totally ineffective. Through the existing guidelines, the conditions and the criteria to interpose an interchange on an existing or a planned motorway seem well established. These criteria reflect the concern to raise limitations in the density of interchanges so as to preserve serviceability and safety. Sustainability is considered at risk if the spacing is too short and, as a result, traffic operations and safety criteria are not satisfied. Nevertheless, a relevant question arises: is the opposite concern reasonable and justified? What if the distribution is too sparse? What about sustainability in this case? A meticulous investigation of the subject unveiled several adverse effects of a too sparse distribution of interchanges on motorways. Furthermore, through this research a full overview of the generated impact of a too dense interchange distribution has been recorded. In Table 2, these effects, mainly negative, in both situations, are presented.

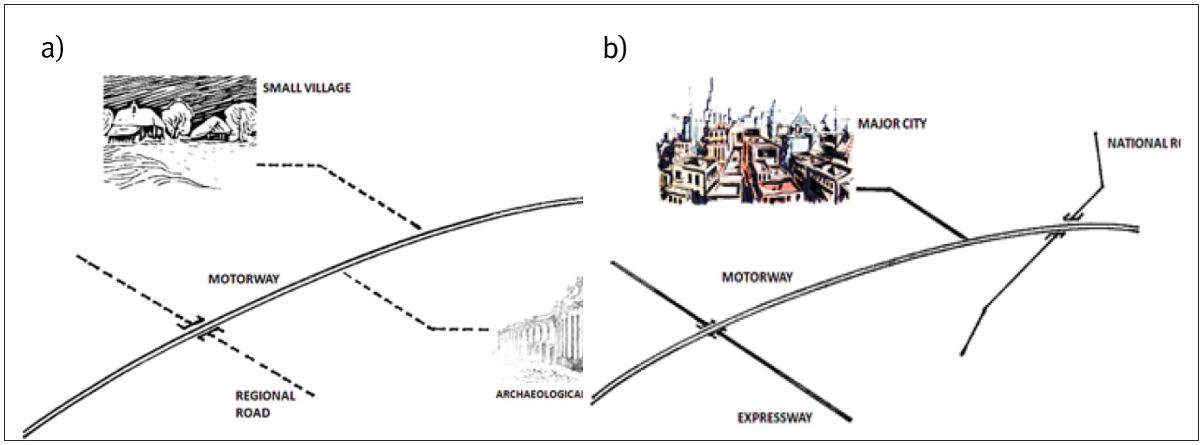

Figure 1 a) Potential access denied b) Potential access granted

Table 2 Negative effects due to inadequate distribution of interchanges

Impact Classification	Distribution of Interchanges	
	Too dense	**Too sparse**
Traffic	· Risk of congestion · Excessive information/traffic signs	· Limited traffic volume · Inability to manage incidents · Congestion on local network
Economic	· Additional construction cost	· Cost-ineffective investment · Impediment to regional development
Societal	Reachable social services	Inaccessible societal assets
Environmental	Negative impact (land use, air pollution)	Limited impact

4 International experience

Generally, interchanges are not placed in an orderly arrangement along a motorway. Minimum interchange spacing is provided by national or state regulations. In the USA, minimum spacing of inter-changes along rural freeways is defined to 3 or 6 miles by different states. In Europe, common practice (Grecu, 2011) reflects a tendency to respect the lower limit of spacing at 8 km (Table 3). The international experience on main expressways records interchanges, placed close enough one to another, the spacing seldom exceeding 15 km. Therefore, the need for establishing an upper limit of spacing seems rather useless.

Table 3 Average distance between exits on European motorway segments

Country	Motorway	Length [km]	Number of exits	Average distance between exits [km]
Austria	A1 West Autobahn	288	39	7.4
Hungary	M1 Budapest towards Vienna	149	20	7.5
Croatia	A1 Zagreb-Split	440	28	15.7
Portugal	A1 Autoestrada do Norte	277	21	13.2
Germany	A7 North-south	599	72	8.3
France	A6 Autoroute du Soleil	404	23	17.5
Greece	A2 (E90) Egnatia Motorway	670	63	10.6
Greece	A6 Attiki Odos (Peri-urban)	65	20	3.3

5 Traffic demand

While facing the feasibility of an additional interchange along a motorway, major traffic concerns are safety and congestion (TRB, 2011). Especially, in urban and peri-urban expressways, it is basically the criterion of congestion that dictates the outcome of the respective analysis. The point raised by the FHWA statement (2009) is relevant: “The existing system is incapable of accommodating desired access or traffic demands”. This criterion applies in case of congested national and local networks. Likewise, when the traffic safety level is low on the local network, diverting a part of traffic volume to the adjacent motorway may prove an effective solution. On congested interurban and rural motorways, exhibiting a low level of service (C or lower), inter-posing a new interchange should not deteriorate the operational traffic condition. Point 3 of FHWA is relevant “the proposal does not have an adverse safety or operational impact on the freeway”. Similar questions about adding a new interchange to an existing motorway, at high serviceability condition (LOS A), may arise. Congestion is the least of concerns, in this case. Feasibility should mainly be addressed in terms of enhancement of accessibility of social assets and cost-effectiveness of the total investment. Nevertheless, screening levels of traffic volume are also useful. A very low volume of expected traffic at the interchange indicates cost/benefit inadequacy or uselessness. By contrast, significant traffic expected may reinforce the feasibility of the planned facility, especially if the traffic on the motorway is low (i.e, ADT ‹ 10.000).

6 Economic appraisal

Deployment of interchanges, in the frame of a new motorway planning or interposing a new inter-change on an existing facility, must go through a comprehensive economic appraisal. On this matter, various methods of assessment, in the frame of a cost-benefit analysis, are available, namely, the “net present value”, the “internal rate of return” and other, each one presenting advantages and drawbacks related to the case in question. The “cost-benefit”

analysis is a comprehensive method and produces, in most cases, reliable and exploitable results (FHWA, 2003). The "investment cost" should include all cost components of the project: design, construction, management, supervision, expropriations, frontage roads, crossroads, maintenance, taxes and insurance. Cost-benefit analysis needs to be carried out incorporating quantifiable and non-quantifiable factors. Reasonably, initial investment, maintenance and operation costs are quantifiable and so are economic development benefits. Travel time savings may also be estimated. On the other hand, safety issues and access to social services may be quantified but not in monetary terms. Any attempt to measure accurately environmental effects due to a new interchange construction project may prove a quite different task. With regard to "benefits", special attention must be paid to the risk of overlapping. Benefits considered elsewhere in the overall evaluation, especially improvement of societal assets, should not re-state to avoid double counting. The economic feasibility of a project aiming at planting a new interchange along a motorway lies on two different and distinct conditions:

- Is the interchange construction project feasible by itself?
- Is the impact of this prospective construction to the motorway in question positive and measurable?

This latter condition is indispensable while considering motorways bearing low traffic volume and widely spaced interchanges. The "cost-benefit" analysis normally results in defining the "benefit-cost ratio" (BCR), a quotient juxtaposing benefits to costs. Commonly, in order to calculate the present value of benefits, a realistic rate of discount is taken in-to account to sum up expected measurable benefits throughout the life-time of the facility. A feasible project is identified by a BCR value greater than 1. Usually, the BCR value is estimated to select a prospective project among different alternatives. While examining a well-defined solution, BCR › 1 is a prerequisite, but depending on the available financing means, a higher threshold value may be adopted to designate the cost effectiveness and affordability of the project. For example, if the additional incoming traffic of a prospective interchange is estimated too low, the alternative choice of upgrading the existing national network must also be considered.

7 Social assets and societal aspects

In developing countries, innovative motorways may be beneficial to the neighboring communities. Remote and low-income regions, deprived from modern transportation infrastructure, may turn to rap-id development following the construction of new high-capacity road links. Economic growth, by in-dustrial and commercial expansion, is expected, in this case, as a result of respective investment to re-vive the lethargic power of productive development. Moreover, direct and quick access to social services is highly appreciated by regional communities. A new motorway crossing a remote region offers the possibility of rapid movement to and from the adjacent major city. Services may include health institutions, public offices, educational establish-ments, finance and credit agencies, commercial centers and other. Thus, services getting closer, the re-mote region becomes less isolated and more inviting. Would this be a decisive criterion to plan or to in-terpose an interchange along a motorway? Probably, it depends, in any case, on other factors as well, such as expected traffic and economic feasibility. However, this is a substantial component of the overall question, not to be neglected. In an attempt to measure the beneficial effect of a prospective interchange on a motorway to support an isolated inhabited area, the gain in travel time must be estimated. The population to acquire indirect profit from this additional infrastructure element is also an important factor to be considered while quantifying the beneficial effect expected.

8 Environmental consideration

In an interchange design study allowing for sustainability, the impact to the environment must be suit-ably estimated. This impact varies with regard to the topography and the location of the project and the complexity of the layout of the link (cloverleaf, diamond, etc.). Constraints related to the surrounding terrain predominate and therefore the design of the inter-change must be closely fitted to it to elude increase in construction cost and land acquisition. The main environmental issues associated with the existing condition of landscape and the proposed interchange are:

- Land use: The extent of right-of-way needed to develop the interchange combined with the com-mercial or residential character of the surrounding area may influence the final design and geome-try. Design features should respect the intrinsic character of the area. Especially, areas in which ra-re agriculture products are cultivated or areas of nature conservation interest should have taken into consideration.
- Water resources: The appropriate measures have to be taken in order no impaired waters locate in the study area.
- Nature conservation issues: Interchanges can be wildlife traps or islands for the species. Well sited and designed constructions must avoid fragmentation. Connectivity between the segments of an interchange with culverts or tunnels may be important for the movement of fauna. Moreover, densely planted land contained in the interchange, minimizes the degree of fragmentation. The correct fencing helps to avoid confusing the fauna and unintentionally leading them onto the road.
- Cultural issues: A flexibility of design standards can be used to by-pass a cultural site without com-promising the operational or safety issues.
- Air quality-Noise: Research of the potential of environmental burden in the area of new access.

9 A pattern for sustainability

In a frame of planning new motorways or upgrading existing ones, the justification of the number and the position of interchanges, along the transportation infrastructure, is required. In this regard, sustain-ability is provided by an effective arrangement among traffic operations, social welfare and environmental protection. The methodology elaborated and presented herewith consists of two distinct and different entities. The first entity replies to the common question: Is the proposed project feasible? Is this project worth financing and carrying it out? Relevant preconditions to identify feasibility are given in Table 4.

Table 4 Conditions to permit a new interchange

Parameter	Condition/Restriction
Traffic	In congested motorways (LOS = C or lower) not to reduce LOS
Cost	"Benefit-Cost" ratio › 1 or greater
Land Use / Environment	Preserve rare agricultural products; Preserve areas of nature conservation interest
Spacing	Respect lower limit: S ≥ 10 km

The second entity goes further: the main concern is a too sparse distribution of interchanges. The criteria to formulate a proposal for a new interchange, not only feasible but substantial prerequisite to develop-ment, growth and welfare of the region are presented in Table 5.

Table 5 Criteria recommending a new interchange

Parameter	Criterion/Benefit
Society	In remote and low-income regions: if quick access is provided to facilities, public services
Traffic	In non-congested motorways (LOS = A) to supply additional traffic and improve sustainability In case of low serviceability and safety level in the adjacent local network
Incident Management	Provide additional entrance to emergency vehicles
Spacing	Respect upper limit: S ≤ 20 km

In a case of planning a new motorway, it would be useful to estimate the consequences of inter-change density options by applying the present methodology. In fact, this analysis consists of two steps: a) determine presumptive traffic flow in the motorway and the local roads and b) evaluate benefits and adverse effects following the proposed pattern. While using the proposed methodology, it must be absolutely clear that this is a pattern mainly based on qualitative effects which cannot be fully converted in monetary terms. The use of the cost-benefit analysis is restrained to the benefits and disbenefits which can, indeed, be adequately ap-praised as capital, income and expenses.

10 Conclusions

The common question about the need for an additional interchange along a motorway reflects the concern of generating traffic congestion and safety problems. The overall subject, however, is quite wider; land use and environmental considerations must also be taken into account to preserve sustain-ability. Moreover, in non-congested motorways, a project providing further access to social services may be not only feasible but much more, beneficial and mandatory. In this respect, the afore-presented methodology is supposed to enhance the societal impact and the traffic serviceability of the transportation infrastructure. Consequently, the cost-effectiveness and the overall sustainability of the entire transportation facility get reinforced and presumed negative effects are eliminated.

References

[1] AASHTO: A policy on geometric design on highways and streets (Green Book), 2004.

[2] Baker R.F.: Handbook of Highway Engineering, Van Wostraud, N.York, 1975.

[3] Caitrans: California Life-Cycle Benefit/Cost Analysis model. California, USA, 2012.

[4] FHWA: Flexibility in Highway Design, Washington, 1997.

[5] FHWA: Transportation Performance Management Economic Analysis Primer, Washington, 2003

[6] Federal Register: Federal Highway Administration, Access to the Interstate system, 74 (2009) 165.

[7] Grecu, M.: An analysis of access point density on rural motorways in some EU countries and a proposal for the Transylvania Motorway. Acta Technica Napocensis: Civil Engineering & Architecture, 54 (2011) 3.

[8] Institute of Transportation Engineers: Freeway and Interchange Design Handbook, Washington, DC, 2005

[9] TRB: Highway Capacity Manual, Washington, 2010

[10] TRB: Guidelines for ramp and interchange spacing, NCHRP Report 687,