INTEGRATION AND CROSS-COUNTRY DIFFUSION OF INTELLIGENT TRANSPORT SYSTEMS IN CEE

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SUMMARY

The paper discusses the concept and prerequisites for cross-country diffusion of Intelligent Transport Systems (ITS) in CEE countries. The basic thesis is that harmonized ITS development and deployment require holistic and country specific design of ITS architecture as a initial framework for defining, planning and integrating intelligent transport systems. Adapted diffusion model is suggested to modelling external and internal influence in cross-country ITS diffusion process.

INTRODUCTION

The deployment of Intelligent Transport Systems (ITS) in European transitional countries (Croatia, Slovenia, Hungary, B & H, etc.) have been compared lately with the developed countries which have first started and implemented ITS program during the last decade of 20^{th} century. Most of the existing transport and communications policies in transitional countries do not consider ITS as an important part of effective and sustainable transport and traffic system development. There are several reasons for this and also some prejudice about ITS which influence ITS development [2], [9].

ITS cannot solve all mobility problems and cannot substitute the necessary road and other network infrastructure facilities. However, ITS can give significant improvements and measurable benefits which are discussed in references [7], [14].

Although CONVERGE-SA and KAREN architectures can be a good starting point and rich source of reference, there are significantly different situations. Preliminary research and stakeholders in CEE countries shows that institutional and financial issues are much more problematic then the pure ITS technology and technical problems. In spite of scarce financial resources, the transport problems have been attacked by building road infrastructure but with small ITS functionalities. Interfaces between transport modes and traffic/travel information support are not designed according to ITS-criteria. The applications of ITS technologies to the road networks has been limited to a few basic functions at lower level of interoperability.

The basic thesis of this paper and background research is that effectiveness and efficiency of ITS development and deployment in each transitional country strongly correlate with performance of national ITS architecture framework and diffusion process influence. For investigating and modelling cross-country ITS diffusion process we adapt diffusion models developed in marketing references [15].

Methodological supports and established ITS architectures which can be relevant for national ITS architecture development were considered in several papers [7], [12]. Examination of European and US system architecture reveals that both offer basically the same system architecture components including user services (requirements), logical (functional), physical and institutional architectures [8], [14]. Systems architecture development guidelines defined in SATIN, CONVERGE and KAREN projects represent European approach for system architecture development. Another relevant model for analysis and design of ITS architecture is the ISO ITS reference architecture defined as Type 2 Technical report by ISO Technical Committee 204. The basic goal of this high-level model is to facilitate harmonised development and interoperable (international) deployment of ITS through a common reference architecture.

SYSTEMS ARCHITECTURE BACKGROUND

Following European System architecture development guidelines and ISO TC 204 reference models, development phases for national ITS architecture are illustrated in Figure 1. The basic development phases are:

- Reference phase,
- Conceptual phase,
- Design phase.

They are linked to the *metalevel system structures* known as:

- functional (logical) architecture,
- physical and communication architecture,
- institutional architecture.

Functional (logical) architecture together with physical and communication architectures belongs to level 1 (*systems architecture*) according to CONVERGE layered model. Institutional architecture belongs to *level 2* and level 3 in that model [7].

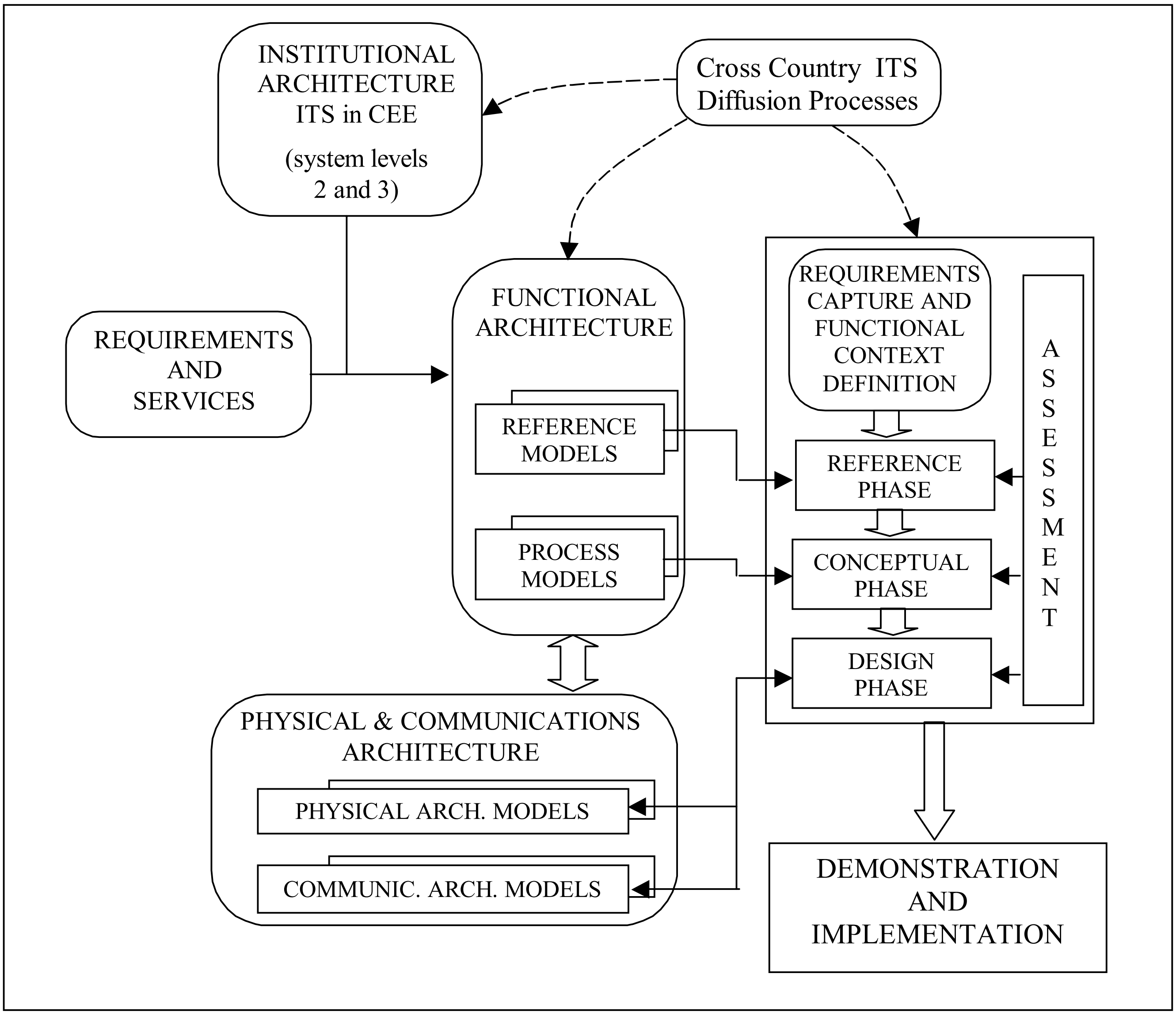

Fig. 1 - *Development of Systems Architecture and cross-country ITS diffusion*

In the reference phase relevant framework architectures and structural high-level models are evaluated. The context, functional and non-functional requirements have to be studied in their entirety and the effective strategy for ITS development has to be proposed. Specifications include services that will be expected and performance of a workable system. Descriptions of services are linked to the control (management) levels and paradigms.

Once the *Reference phase* is finished, the *Conceptual phase* deals with the development of the functional (logical) architecture. Functional architecture depicts the processes and information flows between processes that are needed to meet the functional requirements. It can be described as a metalevel structure that assists in organizing complex entities and relationships in ITS. Functional architecture should be independent of technology and institutional arrangements.

Physical architecture is representation (not a detailed design) of how a system should provide the required functionality. It defines and describes the way in which the constituents of the functional architecture can be grouped to form *physical entities*. Basic characteristics of physical entities are that:

1) they provide one or more user services,
2) they can be created from physical things (such as roadside, equipment etc.) and non-physical things (software, etc.), or a combination of the two.

In the KAREN Architecture [7], Physical Architecture is the result of grouping together the constituents of Functional Architecture into physical entities. Because there is a very large number of possibilities, KAREN approach has been to develop a series of "example systems" with its subsystems and modules (see Fig. 2).

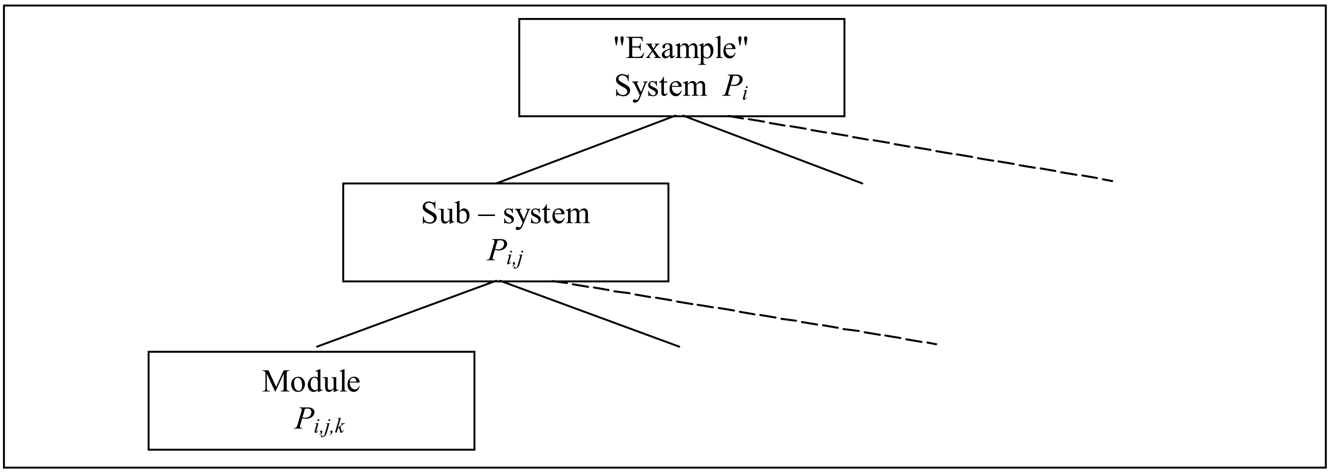

Fig. 2 - *Three main elements of the KAREN Physical Architecture and their numbering convention*

In US National ITS architecture, *physical* architecture takes the process (or P-specs) identified in *logical* architecture and assigns the data flows (from the logical architecture) that originate from one subsystem and end at another and are grouped together into (physical) architecture flows. This means that one architecture flow may contain a number of more detailed data flows. Data flows and their telecommunications requirements determine the interfaces between subsystems and related standards.

Physical Architecture has two basic layers:
- transportation layer,
- communication layer.

Transportation layer shows the relations among the transportation-management related elements. It includes subsystems for travellers, vehicles, transportation management centres, field devices and external system interfaces (→terminators).

The communication layer is concerned with (tele)communications services that connect the transportation layer components (subsystems). It describes all of the telecommunications necessary to transfer information and data among traffic/transportation entities, traveller information and different service providers.

Although CONVERGE-SA and KAREN architectures can be good starting point and rich sources of reference, there are significantly different situations and stakeholders in CEE countries.

DEVELOPING INTEGRATED ITS SOLUTIONS

Although there are several projects and defined specifications of *ITS user needs* (user service requirements) in any single CEE country, there are likely to be significant differences in the scope and priority of ITS services. All users, service providers, transport organizations and other stakeholders should be involved in the process of selection and prioritisation of user services. Appropriate negotiating and consensus building are very important for the efficient and effective development and long-term deployment and operations of ITS.

The existing user services specifications in the European Framework Architecture and earlier architecture building block projects were mainly oriented to Road Transport Telematics (ITS for roads) and include interfaces related to rail, ports, inland shipping and ports [7].

ISO proposed standard list of 32 TICS Fundamental services [ISO TC 204] which are based mainly on the experience and needs of the USA. Relationship between KAREN Groups of services and TICS Fundamental Services were explained in references [7], [9].

Using existed system architecture we want to formalize the system approach in developing integrated national ITS. Selection and prioritisation of ITS requirements can be formalised as a *decision-making problem* (Z, SP) where a set of alternatives (ITS user services) is available and a subset of alternatives has to be selected by the selecting principles SP. The selecting principle may be expressed by a choice function C_{SP} , which operates on any subset:

$$A \subseteq Z \tag{2}$$

to yield an effective subset of A , i.e.:

$$C_{SP}(A) \tag{3}$$

where:
Z is a set of all possible alternatives or variants (possible ITS user services) in all ITS functional areas
C_{SP} is the selecting principle
A is a subset of possible ITS alternatives.

ITS experts or external consultants define subset A of all possible ITS services and variants which satisfy the integration requirements in the defined domain. The functional system design satisfies the stakeholders' requirements and therefore specifies *what* the system should do, not *how* the system can do what it should do. Some functional designs may not be feasible in the available technology, i.e. they are outside the scope of implementable system designs. Another selection in space of possible solutions is given by trade-off between the performance and the cost of integrated ITS solutions.

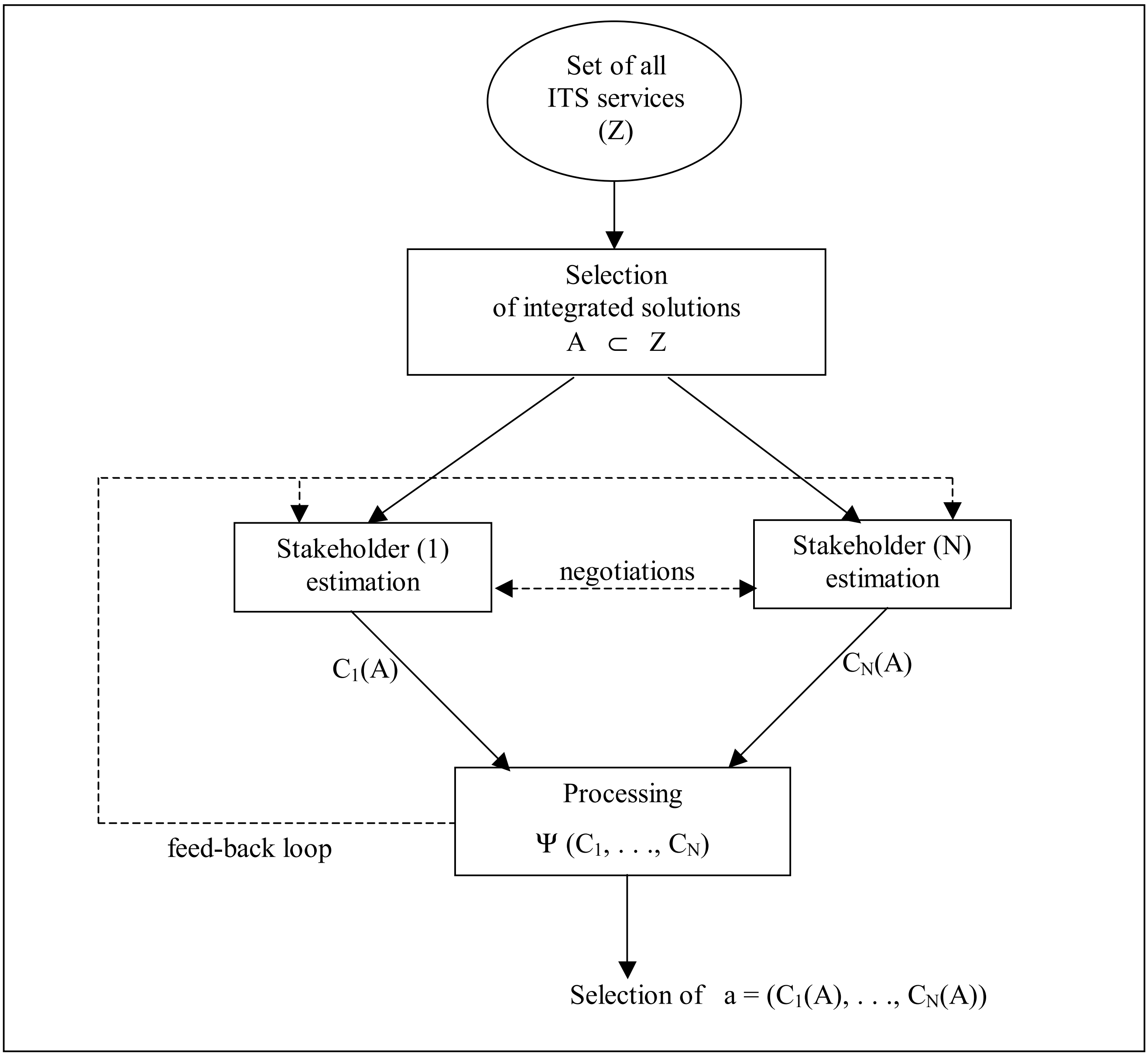

Fig. 3 – *Selecting ITS solutions*

Each stakeholder group selects their own alternative a_i from the functional space (A):

$$a_i = C_i(A) \in Z \qquad i = 1, \ldots, N. \tag{4}$$

System analyst processes the decisions and additional requirements obtained from relevant stakeholders and finds the solution for the initial problem. If the solution does not satisfy overall criteria and cross-country requirements, the analyst may feed back additional information and supporting arguments given by other stakeholders or ITS experts. A solution to the initial problem (Z, SP_Ψ) is a set of ITS alternatives selected by Ψ-composition of selecting functions C_{SP_i} (i = 1,... N).

Relevant strategic decision-makers in transitional countries are often faced with a problematic choice: launching early ITS applications without national architecture (and harmonization), or investing first in ITS architecture and standards development and delaying applications for some later time. Several experiences confirm that lack of systemic integration and technical interoperability can retard ITS development and cost far more than delaying some early applications.

The strategic decision to upstream architecture development can be successful when it is harmonized with the following activities:

- appropriate acceleration in development country-specific ITS architecture based on useful systems methodology and experienced (ITS) consultants,
- effective design and deployment of first ITS applications which promote institutional co-operation and broader apprehension of ITS,
- investing in the co-ordinated collection of reliable and timely traffic information,
- harmonization of ITS facilities with major road building programs.

In the case of ongoing ITS application deployment without the existing national ITS architecture, it would be convenient to develop "retrofitting strategy". It assumes that all existing ITS applications would migrate toward conformance to the national ITS architecture and common cross-country frameworks.

Most transport agencies and professionals are not familiar with ITS concepts and tools and have not included them in the designing facilities and systems operations. With no or little experiences in ITS, transport professionals may feel uncomfortable when they consider ITS services and projects.

There are several strategic guidelines that ITS teams have to follow to achieve the goals of ITS development. These include the following strategic:

- maintain an open architecture,
- assure increasing level of system integration,
- permit a low entry cost,
- enable choice in price/performance traits of user services,
- protect traveller privacy,
- facilitate profitability for private organisations to speed early deployment,
- apply successful model for private/public partnering.

Once the basics of ITS architecture have been established, other evaluations and deployment issues can be explored (Cost-Benefits, Risk Analysis, Deployment study, etc.).

The assessment of impact , cost and benefits of ITS alternatives ("packages") has to include cross-country ITS diffusion influence. Main issues are:

- What is the time scale of the ITS overall deployment process?
- Who are the stakeholders and actors involved?
- What are their different requirements?

The task of "weighting" or rank goals can be carried out.

MODELLING CROSS-COUNTRY DIFFUSION

Existed ITS studies are based to study industrialized countries and little is known to about the nature of the ITS diffusion process in developing countries. Our focus is on the adaptation of Bass diffusion model for ITS product and services in CEE. Conceptual model include three *diffusion-model* (DM) parameters and several explanatory variables.

Relevant DM parameters for ITS diffusion are:

- ▹ penetration potential
- ▹ external influence
- ▹ internal influence.

The discrete time version ITS diffusion model is formulated as follows:

$$(Q_{PS,C}\,(t) - Q_{PS,C}\,(t{-}1) = (k_{PS,C} + (l_{PS,C} / \alpha_{PS,C}) \cdot Q_{PS,C}\,(t{-}1) \\ X\,[\alpha_{PS,C} - Q_{PS,C}\,(t\text{-}1)] \qquad (5)$$

where are:

$Q_{PS,C}$ (t) is the per-capita cumulate sales of ITS product & services $_{PS}$ in the country $_{C}$ at time t,

$k_{PS,C}$ is the coefficient of external influence which captures the influence on the adoption decisions of potential ITS adopters that is independent of the existing ITS penetration,

$l_{PS,C}$ is the coefficient of internal influence which captures the influence of existing number of ITS adapters within the country on potential ITS adapters,

$\alpha_{PS,C}$ is parameter which indicates the ITS market penetration potential.

The total market potential for ITS product and services ($ITS_{PS,C}$) in a country $_{C}$ is given by:

$$ITS_{PS,C}\,(t) = \alpha_{PS,C} \bullet N_C\,(t) \qquad (6)$$

where N_C (t) is the population of the country $_{C}$ at the time t.

Explanatory variables that impact the ITS diffusion process through their influences on the DM parameters can be:

- ▹ ITS disposition
- ▹ urbanization level
- ▹ ability to pay ITS product and services
- ▹ willingness to pay ITS product and services
- ▹ customers´ access to ITS-related information
- ▹ persuasiveness of existing adapters, etc.

Our preliminary data collection from three CEE countries and regression analysis suggest small coefficient of the external influence of ITS introduction lag.

The impact of wide range of explanatory variables are subject of our further study.

CONCLUSION

Existing traffic/transport and communications polices in CEE countries do not consider ITS as a key enabler of efficient, safe and sustainable transport system development. The most of currently available road transport telematics solutions (electronic tool collection, variable signals, etc.) are designed without paper functional and structural integration.

Possible ITS development and deployment in CEE countries have to be associated with ITS cross-countries diffusion process. Identification and real estimation of relevant diffusion parameters (penetration potential, external influence, internal influence) and covariates (that impact DM parameters) can explain ITS diffusion market expansion strategies.

By combining information about past diffusion patterns across countries and ITS solutions, we can improve predictive power of introduced diffusion model.

ABBREVIATIONS

EC – *European Commission*
EU – *European Union*
ISO - *International Standardization Organization*
ITS – *Intelligent Transport Systems*
KAREN - *Keystone Architecture for European Network*
US DOT – *United States Department of Transportation*
TICS – *Transport Information and Control Systems*

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