

## INTELLIGENT TRANSPORT SYSTEMS—TECHNOLOGICAL, ECONOMIC, SYSTEM PERFORMANCE AND MARKET VIEWS

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### ABSTRACT

This paper introduces a holistic view to intelligent transport systems (ITS) by providing four different perspectives: the technological, economic, system performance and market views. These perspectives are essential for a thorough understanding of ITS systems, which extend beyond traditional transportation engineering. ITS require management tools related to systems engineering (i.e. architectures); unique features are related to transport economics, and they differ from traditional transport engineering solutions. ITS technologies can improve transport system performance in numerous ways; furthermore, ITS is an important business segment for many technology companies and an industry by its own right. Different types of expertise and management are required for this meta-system, which is comparable to the entire transport system in terms of organisational objectives.

*Keywords:* Benefits; Impacts; Management; System architecture; ITS; Transport

### 1. INTRODUCTION

Intelligent transport systems (ITS) are already a part of our daily lives. By definition, ITS refers to the transport sector's adoption and application of modern information and communications technologies (ICT). As a holistic and complex system of systems, ITS can be analysed from a number of different perspectives. First, it is a technological system that represents the leap of a mature industrial system (transport system) into the age of ICT. As a technological system, ITS requires the tools of system theories and system engineering to be managed, designed, procured, operated and developed. Multiple examples of ITS system architectures may be found in private sector corporations (Leviäkangas, 2007), local and national sector authorities (Leviäkangas, 2007; Hautala et al., 2003), and at multi-national levels, such as the European Union (EU) ([www.frame-online.net](http://www.frame-online.net)). In this study, examples of selected architectures and their use are discussed.

From the economic point of view, ITS presents financial and budget alternatives for resolving traffic and transport challenges. As an economic system, ITS has not been studied thoroughly, yet it can provide short-term solutions for delaying traditional physical transport system improvements. For example, delaying an investment in a motorway capacity enhancement (e.g. adding new lanes) for 10 years or so could be an extremely profitable option for investors (private or public). Clearly, the evaluation of ITS projects is still in its infancy. For instance, the standard cost-benefit analysis currently used for transport projects in many countries insufficiently recognises the special characteristics of ITS investments.

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A transport system does not exist for itself; rather, it serves a purpose or a set of purposes. System performance is described typically by indicators such as travel times, accident rates, connectivity and accessibility, emissions, and efficiency. ITS can improve the performance of a transport system significantly. Therefore, it is an excellent tool for modern transport system management. Most recently, an objective to reduce the carbon footprint of mobility has been identified. Hence, ITS has become not only a transport system management tool but also a tool for climate change mitigation and adaptation.

Finally, ITS has grown into an industry of its own. The market projections for ITS are usually generous and optimistic. The market can already be approximated, and a few countries have performed the estimations. Obviously, the market perspective is not detached from the industrial policy context—a subject associated with many countries’ ITS deployment. Countries with strong automotive industries have been the key promoters of ITS; therefore, mainstream research and deployment attention have focused on the road sector and in-vehicle applications. However, ITS is a multi-modal art form, and impressive examples of related innovations can be found in the rail and maritime sectors. Finland is cited in this paper as a country that identifies the strengths and weaknesses of ITS, an industry that is expected to provide transport solutions and generate income and jobs.

**2. TECHNOLOGICAL MANAGEMENT OF TRANSPORT SYSTEMS WITH INCREASING BUILT-IN INTELLIGENCE**

Transport systems are complex and require innovative management strategies. First, the transport system is by definition multi-modal; it includes road, rail, water and airborne transport. Furthermore, the system can be divided into passenger and freight systems, which for the most part utilise the same infrastructures but are otherwise quite different.

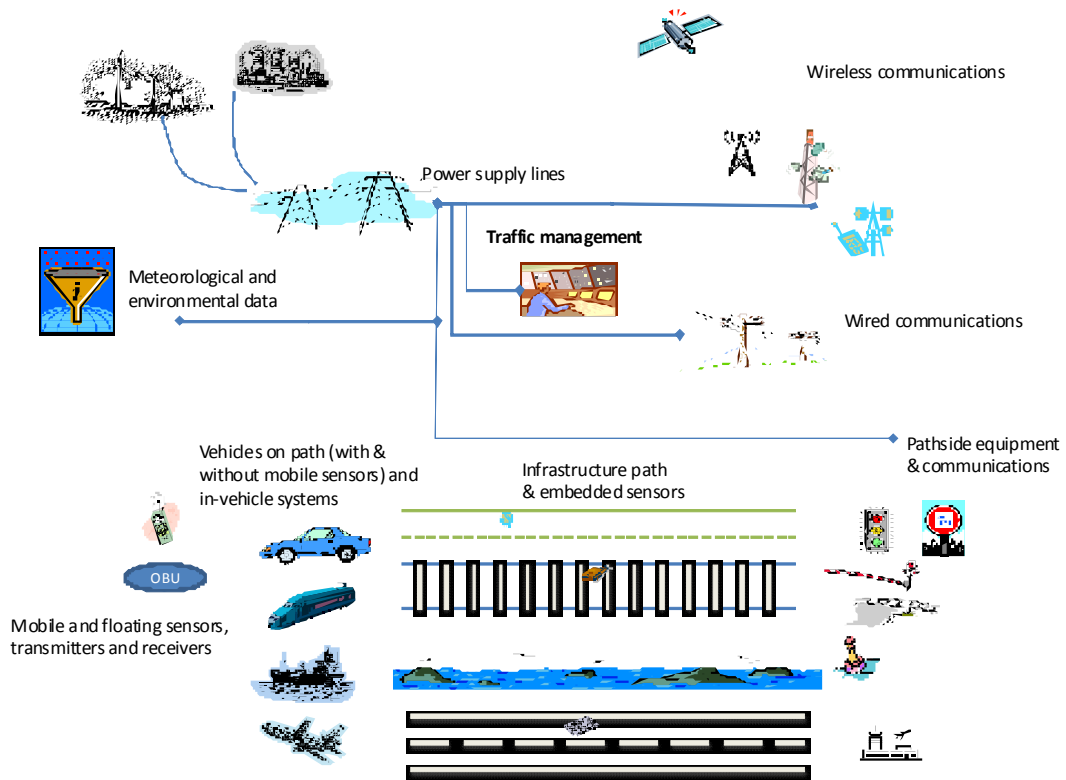


Figure 1 The physical ITS meta-system (modified from Leviäkangas, 2011)

The system involves numerous stakeholders as regulators, owners, users or suppliers. Therefore, a holistic approach is challenging, and management of the system requires the consideration of all players. A system cannot be managed technologically unless all stakeholders are recognised.

Adding one crucial subsystem to the picture—the information and communications technology system—complicates the scene even more. In the past, for example, the road system involved road users, infrastructure managers, hauliers and maintenance/construction contractors, but the current communications infrastructure includes owners and operators, information service providers, clearing houses, operators of road user charges, and so forth. Therefore, the management of vast, complex systems is not only about technology, but also about people and organisations with responsibilities, mandates and objectives that sometimes can be conflicting.

Systems engineering is the tool for managing and controlling complex systems. Systems architecture describes the complex ‘system of systems’. Crawley et al. (2004) have defined systems architecture as ‘an abstract description of the entities [sub-systems] of a system and relationships between those entities’. In a manner of speaking, systems engineering represents the top-down design philosophy, in which the sub-systems that interact and compose the meta-system are described before the technical details or operating solutions of these sub-systems are specified. The US Federal Highway Administration has developed a similar philosophy: ‘[An] ITS architecture is a specific, tailored framework for ensuring institutional agreement and technical integration for the implementation of ITS projects or groups of projects in a particular region. It functionally defines what pieces of the system are linked to others and what information is exchanged between them’ (U.S. Department of Transportation and Caltrans, 2009).

For ITS, system architectures first appeared in the USA as part of a national strategy to boost deployment of new technology in the automotive industry and in the overall transport system. Later, it was discovered that architecture for the latter was simply too vast, and regionalisation was instituted for manageability. For example, ITS applications in Alaska would, logically, be somewhat different than those in Florida. Clearly, architectures are contextual and contingent.

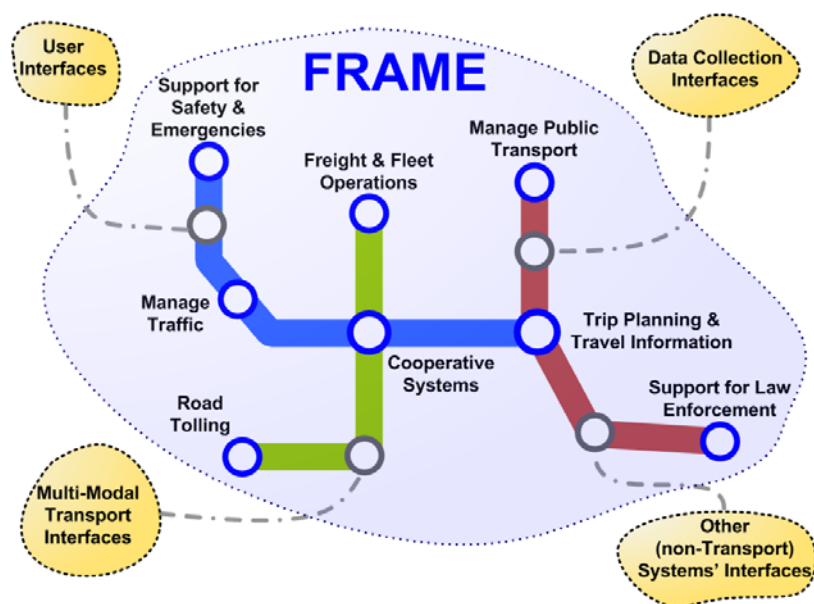


Figure 2 FRAME architecture and map of its elements (www.frame-online.net)

The same phenomenon can be observed in Europe. Following the US example, the EU designed a European ITS architecture Framework Architecture Made for Europe (FRAME), which was meant to be an EU tool for implementing ITS systems across the Union while enabling individual member states, regions, cities or modes to create their own architectures. It was 'designed so that it can be used as the starting point for National or Regional ITS Framework Architectures, or [for] Defined and Specific Architectures.... This approach will also give the users of the National and Regional ITS Framework Architectures great flexibility in how they can create their specific ITS architectures' ([www.frame-online.net](http://www.frame-online.net)). FRAME architecture initially consisted of various layers (i.e. organisational, physical, logical and conceptual), but it was simplified later into a web-based reference tool. Keeping a large number of architectural documents up-to-date proved to be an overwhelming task.

National level architectures have been further designed in Japan, Norway (Natvig et al., 2009), France, Netherlands, and Australia, among numerous others (Williams, 2008). It is the author's subjective opinion that architectures serve their purposes for limited timeframes, and then technology renders them obsolete. They provide understanding regarding the complex ITS meta-system, and they aid in the design of state-of-the-art ITS sub-systems, but as time passes their usability as managerial tools deteriorates rapidly. In short, architectures are linked to a deterministic approach to technological evolution and top-down management styles, while the real world tends to introduce unexpected environmental, organisational and technological changes.

The principle behind architectures is simple and lucrative. Most begin with the identification of user needs and the services that satisfy those needs. Then, preliminary functional specifications (what does the system have to do?) are developed to deliver the services. Problematically, these steps change over time, across user groups, and between geographical and cultural locations. The technological evolution, sometimes unpredictable because it introduces new 'game changers', adds to the list of challenges.

Nevertheless, it seems that architectures are needed from time to time, possibly because each generation of management needs to 'see the big picture'. However, sticking with architectures for too long could slow the progress of technological innovation, as well as social advancement (new services and new user needs). In Finland, the first national ITS architectures were created in the early 2000s, but they were not utilised effectively during the late 2000s and early 2010s. Now, their usefulness has been recognised again, and they are to be redesigned according to the new national ITS strategy drafted by the Ministry of Transport and Communications (The Ministry of Transport and Communications Finland, 2013). The main reason for this rediscovery was the restructuring of the transport administration, which led to new actors with new roles and mandates. Hence, a new master plan for ITS is needed.

All countries probably need ITS architectures, and those that have physical transport and communications infrastructures still require improvements because modern ICT will change the transport system eventually, regardless of its condition in the conventional sense (Yokota, 2004).

### **3. ECONOMICS OF ITS**

ITS is a meta-system (i.e. System of systems) that delivers benefits for users and owners of the transport system. The system's capability of delivering benefits is measured by cost-benefit analysis, as is typical for evaluating transport system investments. There are challenges, however. First, a comparison between ITS investments and traditional transport infrastructure investments is not at all straightforward due to the different characteristics of ITS and conventional transport engineering solutions (Leviäkangas, 2002). Second, the returns required

on ITS investments differ from the returns required on other types of infrastructure improvements due to variations in life spans of the investments (Leviäkangas, 2011). Third, the build-up of sustainable ITS services is more difficult than it appears because stability of the revenue logic and business ecosystems is risky since there is not too much relevant experience within the transport sector (Leviäkangas, 2011).

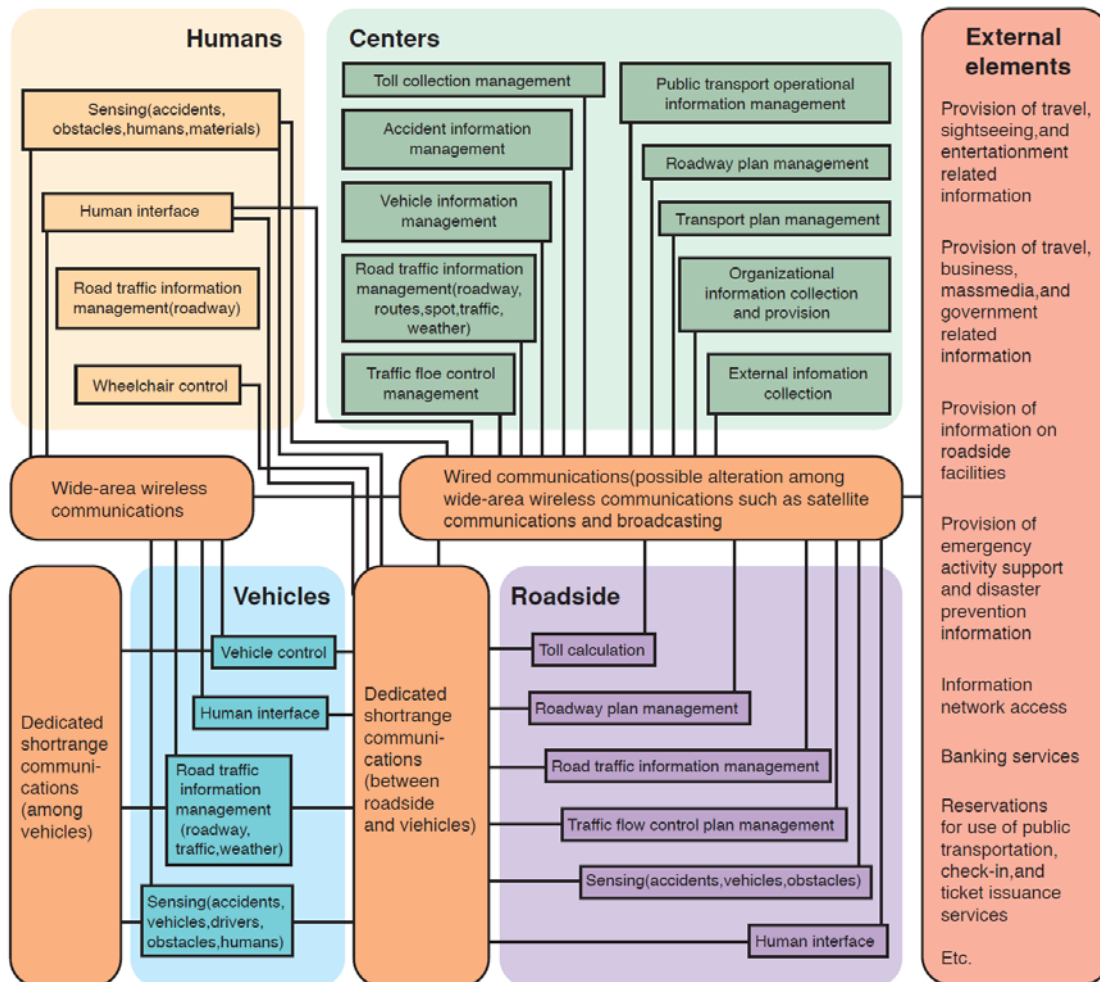


Figure 3 Japanese ITS architecture overview (source: ITS Japan)

Investments in ITS differ in many ways from traditional infrastructure engineering investments, yet the objectives are the same: time savings, safety, decrease in maintenance costs, greater reliability in transport operations, etc. The main difference originates usually from the sheer volume of the investment. Placing traffic signs along a road corridor versus building an extra lane in both directions differs in terms of costs by a minimum ratio of 1:10. Investing in variable information signs and speed limits may cost 10 million eur, but expansion of the road would cost at least 100 million eur (€). With both investments, a capacity enhancement could be the primary target. One point of comparison could be cost efficiency; in other words, which of the alternatives gives a more durable and effective solution in terms of capacity improvement per 1 million €? However, the other alternative (new lanes) would be an irreversible investment decision because the widened road corridor would be in place about 50 years or so. With the its alternative, the prospective life span would be 10 years; new lanes could be built later when this option is regarded as insufficient. Thus, ITS may be a realistic choice for postponing larger

capital projects with high expenditures.

The required return on any investment should be reflected in the discount rate applied to investments. The risk-return trade-off is an empirical observation and principle representing a cornerstone of modern investment theory (see e.g. Van Horne, 2011). Table 1 shows that the required return on investment (i.e. the discount rate used in the investment appraisal) should be lower for ITS investments than for traditional infrastructure investments because the former carry fewer risks. However, this is seldom the case although proposed in some countries already some time ago (Leviäkangas et al., 1999).

Table 1 ITS and traditional infrastructure investments—some risks and benefits

Type of risk or benefit	ITS investment	Infrastructure investment
Technological risks	High; may delay ITS projects	Medium, as infrastructure engineering is based mostly on mature technologies
Demand risk (is there enough traffic?)	Low, since the service life span of any ITS investment is probably not greater than 10 years	High, as the infrastructure will be in place for about half a century; during this time period, any demand risk may materialise
Financial risk	Low, as investments are typically not as capital-intensive as traditional infrastructure projects	High; projects are usually very capital-intensive
Flexibility with regard to the whole system	High, as the technologies could be replaced and the whole system disassembled or replaced if needed	Low, as the infrastructure will be in place for many decades and the investment is irreversible

The creation of any its service often demands that several actors work together for its delivery. An information service supply chain is necessary for combining and refining raw data, and ultimately packaging it into a service so that it can be distributed to users via selected channels (Leviäkangas, 2011). Composing these ‘business ecosystems’ is not simple. The addition of actors for the ecosystem and service supply chain creates more risks. In this framework, services may become overpriced because of multiplication in risk accounting in the service supply chain (i.e. all actors try to shield their cash flows).

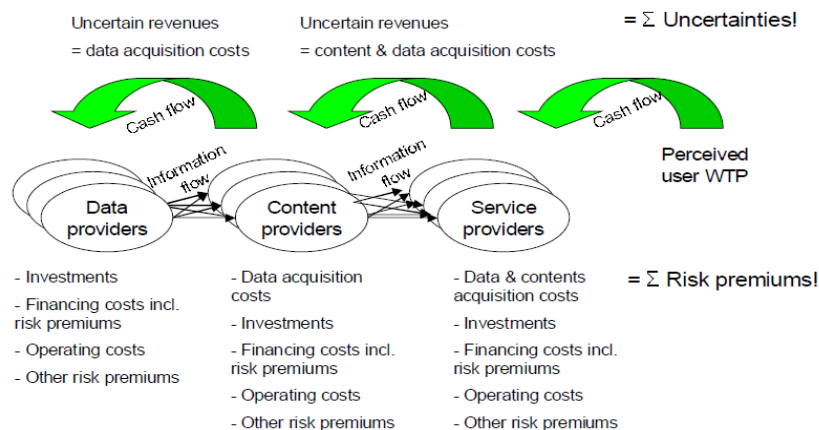


Figure 4 ITS service supply chain and multiple accounting systems for risks and uncertainties (Leviäkangas, 2011)

Finally, we need to acknowledge that ITS as a technical meta-system does not generate actual benefits. Only services that have an impact on human behaviour or choices will generate them.



Services are based on demand; furthermore, they require certain physical and organisational structures as platforms on which to offer them. Capital-intensive investments in ITS are needed when the physical architectures are built. From there, organisational aspects, business ecosystems, efficiency of distribution systems and user acceptance, demand, and market penetration will dictate how beneficial the system is. There is a natural evolution in service provision. First, services are offered to the mass market through the media; later, personalisation and tailoring is performed according to market segment needs and the willingness to pay for services.

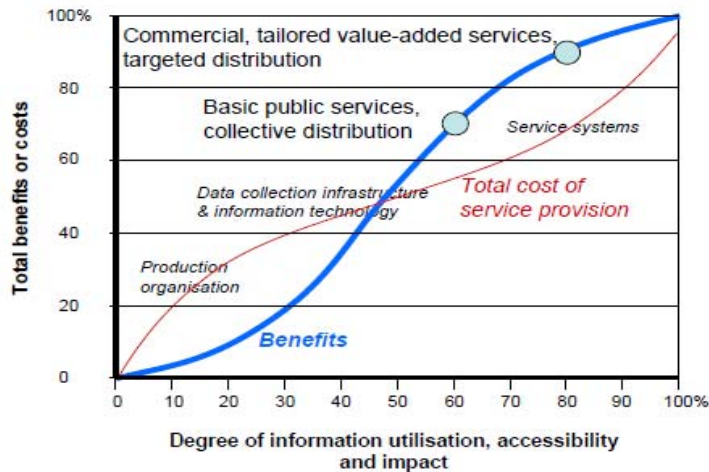


Figure 5 Benefits and costs of information-intensive services (Leviäkangas, 2009)

#### 4. SYSTEM PERFORMANCE IMPROVEMENT WITH ITS

Some ITS applications and sub-systems are better than others with regard to their ability to generate benefits. Some are more cost-efficient and lower-priced than others that require considerable investments. Some systems are interoperable, while others are closed. Therefore, successful uses and applications of ITS are highly contextual and dependent on countless viewpoints and motives, including the user market's preferences and maturity. A good system or service in a wrong environment could prove to be counter-beneficial or unable to deliver benefits as it was designed to do. Not surprisingly, however, reports on incidents with unwanted outcomes are few due to tendencies associated with human behaviour.

Key objectives of the EU Common Transport Policy (CTP) are economic, social, and environmental (Gleave, 2009). The economic objectives aim to increase efficiency and competitiveness of EU member states by providing fairly priced transport options for citizens and industries while at the same making the transport market more competitive. Social aspects include traffic safety and level of service. The first results in huge costs for each member state; thus, it becomes a serious economic problem as well. Under the most recent environmental objectives, issues of climate change mitigation and adaptation dominate.

The EASYWAY project (7th Framework Programme, <http://www.easyway-its.eu/>) estimated that in 2020 ITS services and applications will reduce accidents and congestion by 25% and environmental damages (mainly reduction of CO<sub>2</sub>) by 15% (ITS Denmark, 2012). The Danish ITS lobby organisation proposed 13 measures to be implemented in Denmark. Environmental measures include intelligent ramp metering, signal optimisation, GPS-based road pricing, and intelligent mobility management; safety actions include, among others, intelligent speed adaptation (ISA), automatic speed control and driver support systems.

Solid empirical data on the impact and benefits of ITS are lacking. However, the work has begun, and results are accumulating quickly. For example, the US Federal Highway Administration has compiled a reference guide to assess the benefits of various ITS solutions, particularly for traffic management projects (Sallman et al., 2012).

Any manager within transport administration must consider whether ITS could solve part of his/her business-related problems. ITS can be a quick-to-realise and low-cost alternative to traditional engineering measures, especially in urban environments where flows are considerable and even marginal changes in the performance of a system may lead to substantial aggregate impacts. The Finnish transport agency estimated impacts of ITS and compiled a list shown in Table 2 below.

Table 2 Estimated impacts of ITS

Sub-system/application	Fatalities	Injuries	Congestion	Emissions
In-vehicle, real-time weather and road condition warnings	decrease	-3%	n.k./0%	n.k./0%
Roadside variable warning signs	-2%...-5%	-1%...-3%	-1%...-3%	-0.5%...-3%
Real-time traffic status information	n.k./0%	n.k./0%	-1%...-3%	-0.5%...-2%
Alternative routing/mode guidance	decrease	decrease	decrease	-1%...-2%
Variable speed limit signs	decrease	-6%...-10%	decrease	decrease
Intelligent signalling (rural roads)	decrease	-15%...-25%	n.k./0%	n.k./0%
Regional intelligent signalling	n.k./0%	n.k./0%	-3%	decrease
Public transport priority	n.k./0%	n.k./0%	-1%...-2%	-1%...-3%
Road/street pricing (urban)	decrease	decrease	-10%...-20%	-10%...-20%
Incident detection and management	n.k./0%	n.k./0%	-5%...-20%	-5%...-15%
Automatic speed control	-35%	-34%	n.k./0%	n.k./0%
Automatic control for signalled intersections	decrease	-12%	n.k./0%	n.k./0%
Fleet management	n.k./0%	n.k./%	n.k./0%	-3%...-6%
Electronic stability control	-17%	-7%	n.k./0%	n.k./0%
Lane keeping support	-15%	-9%	n.k./0%	n.k./0%
In-vehicle speed guard	-9%	-6%	decrease	decrease
eCall (emergency call system)	-4%...-8%	n.k./0%	decrease	decrease

The list combined results from several national and international studies (Kulmala et al., 2009). Standard cost estimates according to impact may benefit engineers and managers in selection of the most cost-efficient improvement measures.

Some relatively low-cost measures have resulted in positive impacts, such as automatic speed control and in-vehicle systems provided by automotive manufacturers (e.g. electronic stability control, lane-keeping assistance and speed guards). Therefore, good results can be achieved via measures that do not require meta-scale design or overwhelmingly advanced technological systems. In particular, the automotive industry is moving forward to improve performance of the road transport system.

## 5. ITS AS AN INDUSTRY AND MARKET

ITS has a place in the toolbox of decision makers and transport system engineers; there is no doubt that the best of ITS can deliver significant benefits. The economic importance of ITS has been recognised as well, and many analyst reports show significant growth projections for the ITS market as a whole. Most importantly, a strong and competitive supply side within the ITS



industry creates the potential for greater benefits. Zulkarnain and Leviäkangas (Zulkarnain et al., 2012) gathered market data from various sources and reported the following:

- Strong growth is projected for the ITS device market; the worldwide market was valued at US\$24 billion in 2010, and it is expected to increase at a 22.2% compound annual growth rate during the forecast period to reach a value of \$65 billion in 2015 (BCC Research, 2010).
- Between 2000 and 2010, the EU market for ITS equipment and services increased from 1 to 21 billion €per year (Kristensen, 2011).

However, size and structure of the market vary from region to region and from country to country based on significant differences in the technological advancement and purchasing powers of the various countries/regions. For example, the Finnish ITS market measurements for the supply side (aggregate turnover of ITS industry) were approximately €300 million in 2010 with about 1700 employees in Finland. The Finnish ITS market had a significant growth in 2007, but since then, it has been turning upwards slowly after negative growth was reported in 2008 and 2009. The fast growing firms had been showing good growth, but the weakest performers experienced a continuous decline (Zulkarnain et al., 2012).

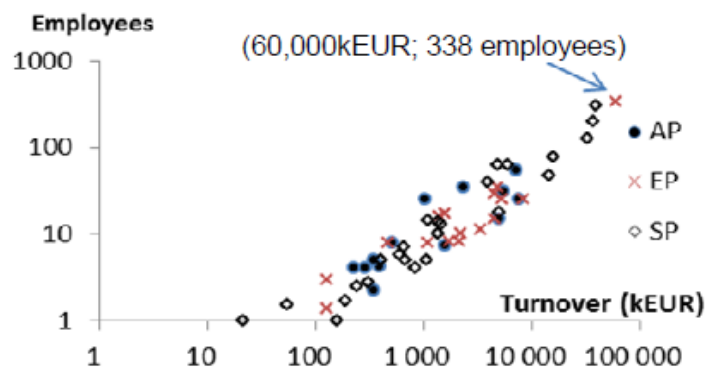


Figure 5 ITS industry in Finland in 2010 and employee population (AP: application and system provider, EP: equipment manufacturer, SP: service provider) (Zulkarnain et al., 2012)

The Finnish ITS industry accounted for 0.17% of the country's gross domestic product in 2010. This, of course, is a figure of national importance. However, a great deal of the industry comprises business by service providers, which in turn is dominated by consultancies. There is a risk that such business is associated with consultancy to the public sector. From an industrial policy point of view, this would not be a good signal based on the industrial basis of the country. This signal is strengthened by the fact that there are only few real services in the Finnish market that deliver the benefits expected from ITS.

Zulkarnain and Leviäkangas (Zulkarnain et al., 2012) also argued that stronger manufacturing and system providers within the ITS industry would signal greater industrial potential for Finland. Even with the current trend of industry servitization, the roles of traditional equipment and hardware providers are crucial because the integration of the value chain occurs mostly from upstream to downstream. In other words, the hardware and equipment manufacturers move downstream to provide services, not vice versa. Unless there is a strong equipment and hardware manufacturing base in the country, there will be fewer opportunities to create a domestic service sector to come alongside manufacturing.

These findings lead to the conclusion that if a country intends to build a successful new industry, for example ITS (but not restricted to that), it would need to find a solid and tangible base (i.e. companies that deliver hardware, equipment and systems). It is no surprise that the greatest enthusiasm and commitment to ITS can be found from countries with a strong vehicle and automotive industry, such as Japan, US, and Germany.

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