Introducing the ITS Index: A Method of Evaluating Transport System Competencies

Transport Policy Working Group

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Introduction

This paper proposes a method of scoring the Intelligent Transport Systems (ITS) of various cities with intent to contribute to developing a worldwide engineering standard. It is very reasonable to suggest that ITS generally constitutes a number of elements of varying importance corresponding to the context of the location (town, city or province) undergoing analysis. ITS requirements are subject to change as pedestrian accessibilities may, for example, induce greater concern in a city improving on its bus, metro and road accessibilities. Before introducing the "ITS Index", it is important to pursue an analytical review which confirms the ways in which ITS deployment can help nurture socio-economic development. The argument specifically highlights that, under very specific conditions, infrastructural growth can assist a more even distribution of income and a subsequent reduction in gap between upper and lower classes. An "ITS Index" can therefore prove absolutely vital in incentivising beneficial ITS deployment.

Socio-Economic Effects of ITS

It is important to determine the existing theories which correlate ITS deployment with socio-economic development as this establishes a purpose or *raison d'être* for establishing an ITS Index – *what exactly would evaluating and encouraging infrastructural progress achieve? How beneficial is a positive competitive spirit between smart cities?*

By looking at the bigger picture the use of information technology intuitively increases a country's productivity. Within urban development, ITS deployment offers a range of benefits for congestion, reduction in travel time and delays, and even more efficient fuel consumption.[1] In the UK, the Highways Agency's ramp metering deployment that was initiated in 2005 has resulted in higher

[1] R.L. Bertini *et al.*, "Benefits of Intelligent Transportation Systems Technologies in Urban Areas: A Literature Review", http://www.its.pdx.edu/upload_docs/1248894206QpPC5zVqkd.pdf, 2005 [accessed 26th April, 2014]

travel speeds and improved traffic flow.[2] Due to the sheer number, variety, and complexities of ITS applications used, each one can provide a unique benefit to a particular region, country or city. It is in this light that the Research and Innovative Technology Administration, part of the U.S. Department of Transportation, maintains a database documenting findings from evaluations of ITS deployments.[3]

Whilst inevitably there will be direct and indirect benefits that cannot be quantified, the majority of ITS applications are evaluated through a cost-benefit analysis by policymakers and other stakeholders. However, in the words of J. Zhicai *et al.*, appraisal of ITS projects "should include technical assessments, user acceptance assessments, traffic impact assessments, environmental impact assessments, and socio-economic assessments".[4] Government policymakers, in particular, make the most use of socio-economic assessments.[5]

Transportation projects aimed at improving efficiency supply continual public and private sector employment opportunities for engineers, electronics technicians, software developers and system integrators.[6] The positive externalities experienced in the form of reduced travel time and improved traffic flow, coupled with higher employment, enhances individual and organisational productivity. Another aspect of efficiency is concerned by fuel usage - improvements in fuel consumption reduce individual energy consumption whilst reducing environmental impact through decreasing emissions. Potential positive spillover effect is general reduction in environmental damage, i.e. ecosystem preservation and noise reduction, due to more effective use of infrastructure.

Projects focused on safety improvements that decrease the number of accidents, reduce human casualties, preventing emotional and financial trauma that also affect families and relatives. Fewer casualties also reduce the burden on the health care system, police, fire department, and justice system. Insurance companies receiving fewer claims should subsequently lower average insurance premiums resulting in a cost decrease for individuals. Furthermore, reducing the negative spillover effect of traffic delay due to accidents lowers the external costs associated with aforementioned delays. In general, however, the substantial positive impact on individuals' disposable income and employment opportunities, as well as improved infrastructure, productivity, traffic flow, decreased delays, environmental quality, political stability, and safety, results in a higher standard of living.

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[2] S. Lehn, "Delivering ramp metering in the UK – the Highways Agency", http://www.paconsulting.com/our-experience/delivering-ramp-metering-in-the-uk-the-highways-agency/, n.d. [accessed 26th April, 2014]
[3] *See* RITA, "Benefits Database Overview", http://www.itsbenefits.its.dot.gov, n.d. [accessed 26th April, 2014]
[4] J. Zhicai *et al.*, "Socio-Economic Impact Assessment of Intelligent Transport Systems", *Tsinghua Science and Technology*, 11(3), June 2006, p.339
[5] Ibid
[6] RITA, "Investment Opportunities for Managing Transportation Performance through Technology", http://www.its.dot.gov/press/2009/transportation_tech.htm, 2009 [accessed 28th April, 2014]

A substantial amount of work is undertaken to develop suitable evaluation guidelines for assessing socio-economic impacts of ITS projects by Europe and the U.S., but the inherent difficulty in measuring some benefits could prevent such from becoming an exact science altogether.[7] For example, as of yet, it is impossible and morally questionable to objectively place a price on a human life. A similarly difficult yet not so ethically burdened concept to quantify is an individual's value of time. Nonetheless, decision-making must and does proceed – this paper is not concerned with whether a quantitative analysis may or may not be appropriate in accurately and reliably assessing socioeconomic impacts but rather aims to increase the general awareness of ITS deployment not only on the general economy, but on the level of integration between the upper and lower classes and hence stability as a whole.

At the international level, increased economic integration through trade liberalisation and greater political coordination poses some risks – the large number of ITS applications from various 'independent players' in the form of confederation, cities, and licensed transport companies, can "hamstring the sustainable development of an integrated overall system".[8] Differential preferences of relevant regional authorities can result in suboptimal, inefficient solutions and a lack of transparency and coordination.

Whilst efforts for standardisation have been undertaken, there is a need for increased linkages and interoperability. A recent example of this is the intelligence and technological cooperation between various nations in the rescue mission for missing Malaysia Airlines flight MH370. The mission has been extensive but does not continue without critics underlying a perceived lack of informational transparency. Political issues further hamper the creation of a global airworthiness alert system and a global commercial airline monitoring system. However, from such intensive surveillance and transport data collection, privacy could be compromised and may reach the wrong hands. One thing is certain – ITS technologies play an integral part of national security.

Under appropriate conditions, it seems that infrastructure can have a disproportionate impact on the welfare of the poor. Amongst the explanations given by Calderón & Servén are increased access to jobs, reduced transaction costs for newly connected areas, an increase in the value of assets in rural areas and increased access to adequate health care.[9] Whilst there exists no such ITS Index governed by the principles defined below, this means that income is disproportionately skewed in favour of the lower classes, and the greater equalities between the classes are not merely realised

[7] *See* Zhicai *et al.*, *loc. cit.*
[8] its-ch, "Intelligent Transport Systems for Switzerland – Focus on the future", brochure, http://www.its-ch.ch/fileadmin/redacteur/pdf/Publication_Broschüre_Focus_on_Future_RZ_Web_Engl.pdf [accessed 12th May, 2014]
[9] *See generally* C. Calderón & L. Servén, "The Effects of Infrastructure Development on Growth and Income Distribution", http://elibrary.worldbank.org/doi/pdf/10.1596/1813-9450-3400, 2004 [accessed 12th May, 2014]

in percentage terms; there is a fundamental, quantitative difference in the monetary increases between the two classes.

ITS Index

Here, the mathematical model determining the *DEFS* analysis is explained. Its intention is not to impose some ultimate claim to knowledge but to simply provide a clearer sense of direction in a field of continuing research. This paper initially focuses on certain qualitative preferences, which initiate the model. The purposes of the index must be considered by the interpreter, whose intention may not be limited to comparing cities against one-another. Furthermore, should the analysis, for example, reflect the economic growth of the locations concerned? Scoring a nation is ambitious and can result in a depreciation of accuracy, and one may henceforth prefer employing the model with the intention of analysing individual towns, cities or provinces; this ultimately manifests at a question of pragmatism. Nevertheless, these deliberations must be made, as they will likely determine the nature of the subsequent scoring procedure employed by the model expressed throughout this part.

With the above in mind, certain conditions that should be met are:

1. The model should be governed by a well-defined set of principles in order to avoid substantial bias and other statistical problems.
2. The model should be multidimensional in order to induce further accuracy.
3. The model should be flexible in order to facilitate progress and development.
4. The model should produce a proportional result, which reflects a percentage score.

To satisfy these conditions, a matrix is devised, which coordinates underlying engineering components on its column t with certain qualitative attributes defined on row k. These qualitative attributes are *Development (D)*, *Efficiency (E)*, *Effectiveness (F)* and *Safety (S).* The variables on column t must therefore represent various components, which consensually underlie intelligent transport systems according to engineering solutions. These broad categories respectively reflect *Transportation information and notification (N)*, *Traffic detection and identification (I)*, *Cable and wireless communication (C)*, *Traffic management and control (M)* and *Transport and traffic engineering* (E_2). Scores can then be applied to their corresponding vectors on a five-point scale, with 5 representing total advancement and 0 signifying total lack of advancement.

By using this matrix, *Traffic management and control* may not (for example) be accessible or deployed to all parts of a given location but such an instance could be reflected in its corresponding *Effectiveness* scoring. Equally, economic value can be reflected in the *Efficiency* assessment corresponding to the underlying component concerned. When a particular component is not contextually applicable to either one of the *DEFS* assessments it will be omitted from holding any particular value in the mathematical formula and graded “n/a” or “not applicable” in its vector. In this instance, the index would fail to be constructed, as simply equating “n/a” results to 0 would result in a lower score when the location undergoing analysis may not have necessarily experienced an overall depreciation of quality. In this respect, we cannot similarly displace such events by a score of 5. Whilst the scoring procedure will be elaborated with greater detail below, an example is compiled for *location* χ in *Figure 1* such that the above approaches can be explained with greater clarity. All vectors are completed such that a final score can be realised at a later stage:

Figure 1

	Development (D)	***Efficiency (E)***	***Effectiveness (F)***	***Safety (S)***
Transport information and notification (N)	2	2	4	2
Traffic detection and identification (I)	3	2	3	1
Cable and wireless communication (C)	4	1	4	2
Traffic management and control (M)	3	2	2	4
Transport and traffic engineering (E_2)	4	3	2	3

Now that the multidimensional condition has been fundamentally satisfied by use of a kxt matrix, the variables on row k and column t can be altered or extended, though their individual weightings or values would have to have been considered beforehand. If weightings are not deduced in advance the whole analysis might become subject to bias interpretation due to the subjectivity involved in assigning and allocating specific weights. *On every occasion*, these variables must be weighed according to factors, which prevail across and beyond other factors, which may or may not appear on the table. Thus, as a substantial principle by which the model should be approached, it would have to merely occur that two variables – such as *D*x*I* – happen to coincide at the bottom of the prioritisation in terms of their combined value, and hence its function remains *k*x*t* and not some newly-defined value which detaches the *DEFS* analysis from its wider political and macroeconomic contexts. Please refer to the proportional representation of the example expressed in *Figure 2* below:

Figure 2

Weights	***0.1***	***0.2***	***0.3***	***0.4***
0.2	0.4	0.4	0.8	0.4
0.1	0.6	0.4	0.6	0.2
0.2	0.8	0.2	0.8	0.4
0.4	0.6	0.4	0.4	0.8
0.1	0.8	0.6	0.4	0.6

The factors determining *k* and *t* are valued and expressed in *Figure 2* such that they aggregate each time at 1.0 (or 100%). These individual values would represent their unique contexts, considerations and, ultimately, responsibilities in the overall analysis. Individual assignments of weighting would, in the ways recommended by this paper, truly reflect the mathematical interpretation proposed by the *DEFS* analysis, and assessments concerning the values of underlying variables on both row *k* and column *t* should hence be made in *lieu* of external factors which may or may not be included in the table. This is reiterated as a “statistically sound” method of assessment, which can more effectively generate a wider socio-economic context just as it minimises the prospect of confirmation bias and unwarranted data-manipulation. In other words, the variables represented by row *k* and column *t* are not necessarily (and should not necessarily) be mutually-constitutive or hold any profound sense of interdependency if we are to satisfy the preconditions governing sound statistical representation and accuracy affirmed above.

Problems in this respect are:

- Which factors should be included in the determination of individual weights or values for the underlying variables?
- Which models can be applied given the information that economists, political-scientists and engineers provide?
- Should estimation problems require the further interpretation of statisticians or would this response result in further interdisciplinary contention?
- Considering the above, whose interpretation should hold priority over the other, and according to whom?

For example, a policymaker may hypothetically wish to assign *Traffic detection and identification (I)* with a uniquely assigned *score* of 5 if a specific camera system appears once every 10km of highway. A score of 0 would subsequently be assigned if such a camera appears for merely >100km of highway. Whilst this is just one of various prospective methods by which scores can be assigned and contextualised, it must be stressed once more that a crucial extension to the model is the use of macro and industry-specific research to assign any such appropriate weightings and scores according and corresponding to each of the variables featured throughout the *DEFS* analysis. Corresponding vectors would hence represent an average score of two uniquely determined scores, satisfying the five-point scale desired by our model.

All-in-all, according to the scores marked in the *kxt* matrix featured in *Figure 1* and their corresponding weightings expressed throughout row *k* and column *t* for *Figure 2*, the aggregate index or final scoring for *location χ* can be computed as follows:

$$I^{(\chi)} = \frac{1}{\text{max\_}score} \sum_{i=1}^{k} \sum_{j=1}^{t} \omega_{ij} \alpha_{ij}^{(\chi)}$$

Each score *within* the location matrix, represented by $\alpha_{ij}^{(\chi)}$, is multiplied by its corresponding weights on both *k* and *t*, given by ω_{ij}. The resulting numbers are hence summed and divided by the maximum score – in our case 5 – as to satisfy the condition of a proportional result, which can be interpreted as a raw percentage score. Thus, for *location* χ, $\omega_{i.}$ each time corresponds to 0.1, 0.2, 0.3 and 0.4. Similarly, $\omega_{.j}$=(0.2, 0.1, 0.2, 0.4, 0.1). The algebraic function is thus an expression of the following calculation whereby the bold integers are scores now expressed in their proportional senses:

$$I^{(x)}=(0.1\text{x}0.2\text{x}\mathbf{0.4})+(0.1\text{x}0.1\text{x}\mathbf{0.6})+(0.1\text{x}0.2\text{x}\mathbf{0.8})+(0.1\text{x}0.4\text{x}\mathbf{0.6})+(0.1\text{x}0.1\text{x}\mathbf{0.8})+(0.2\text{x}0.2\text{x}\mathbf{0.4})+(0.2\text{x}0.1\text{x}\mathbf{0.4})+(0.2\text{x}0.2\text{x}\mathbf{0.2})+(0.2\text{x}0.4\text{x}\mathbf{0.4})+(0.2\text{x}0.1\text{x}\mathbf{0.6})+(0.3\text{x}0.2\text{x}\mathbf{0.8})+(0.3\text{x}0.1\text{x}\mathbf{0.6})+(0.3\text{x}0.2\text{x}\mathbf{0.8})+(0.3\text{x}0.4\text{x}\mathbf{0.4})+(0.3\text{x}0.1\text{x}\mathbf{0.4})+(0.4\text{x}0.2\text{x}\mathbf{0.4})+(0.4\text{x}0.1\text{x}\mathbf{0.2})+(0.4\text{x}0.2\text{x}\mathbf{0.4})+(0.4\text{x}0.4\text{x}\mathbf{0.8})+(0.4\text{x}0.1\text{x}\mathbf{0.6}).$$

Thus, for our example:

$$I^{(x)}=0.536.$$

Whilst a score of 1.0 (or 100%) would be representative of “engineering perfection” in the context of our analysis, the formula satisfies the condition of a ranking procedure whose outcome will fall between 0 and 1. Despite this, the proportional representation (which can be interpreted as 53.6% for *location* χ) does not necessarily affirm that an above-average score has been achieved in our example. A location score would rather need to be assessed against similar scores in order to establish each result within certain percentiles ranges. Raw data must be assessed in relative terms and not in respect of itself.

It is henceforth stressed that weighting assignments should stem from careful socio-economic analysis as mathematics, in the context of our “*DEFS* analysis” model, is fundamentally meaningless without interpretation. Why should *Effectiveness* be more or less important than *Development*, say? Deliberation concerning the determination of corresponding values requires the consultation of both social scientists and engineering experts alike. Subsequently, whilst the *DEFS* analysis proposes a method of scoring which can substantially reflect the relative engineering and socio-economic contexts of the location concerned, the model cannot determine which external variables should, specifically, be taken into account – and to what extent they should be taken into account. The model cannot similarly determine its practical scope or *ipso facto* prioritise certain interpretations or discipline-specific approaches as more or less reliable. The responsibility of these decisions ultimately falls in the hands of the policymaker should the model be employed. Assuming that adequate interpretation can be realised, the *DEFS* analysis can nevertheless substantially reflect the particular contexts of the location concerned and graphically represent its assessment through a raw, proportional score.

Conclusion

A foundational method of assessing the intelligent transport systems of various cities against one-another is proposed. The *DEFS* analysis is expressed as a matrix whose underlying weights and corresponding scores are determined by several variables, which underpin ITS functionalities and their various competency assessments. This model has been necessitated and logically deduced in order to address certain defined preferences and aspirations for the indexing procedure.

Variables for row *k* are hence at this stage expressed as *Development, Efficiency, Effectiveness* and *Safety*. The variables featured on column *t* similarly represent *Transport information and notification*, *Traffic detection and identification*, *Cable and wireless communication*, *Traffic management and control* and *Transport and traffic engineering*. The model is flexible to potential alteration given its underlying formula, which generally outputs an index score as:

$$I^{(\chi)} = \frac{1}{\max\_score} \sum_{i=1}^{k} \sum_{j=1}^{t} \omega_{ij} \alpha_{ij}^{(\chi)}$$

The intention or purpose of indexing certain locations must nonetheless be defined beforehand, followed with a pensive assignment of proportional weightings and scores for both row *k* and column *t* according to their wider socio-economic and engineering circumstances. Scores (as opposed to weightings) will be averaged, and this minimises a “narrow-minded” interpretation and the potential tendency to manipulate the data involved in computing a final result.

Finally, the ultimate score must be assessed in relation to other index scores as observing results in isolation would reveal very little about their relative positions on a broader mathematical scale. From this perspective, other cities will determine the standard across the board and this might be politically contentious, but it is more accurate and less contentious than employing the model to score states.