OECD

International Transport Forum

TRANSPORT RESEARCH CENTRE

IMPROVING RELIABILITY ON SURFACE TRANSPORT NETWORKS

Summary Document

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SUMMARY DOCUMENT

This is a summary of the report *Improving Reliability on Surface Transport Networks*. The report was developed by a group of international experts representing 13 countries under the aegis of the Joint Transport Research Centre of the Organisation for Economic Co-operation and Development (OECD) and the International Transport Forum.

The report examines the extent to which appropriate levels of transport reliability are delivered, examining experience in each of the major ITF regions. It focuses on national and international movements of passengers and goods on roads and railways. Although reliability has long been identified as central to the quality of transport services, research on valuing reliability and how best to reflect it in assessments of transport projects and policies began only recently. The results of this recent research are reviewed and used as a basis to explore a range of reliability performance measures useful to policy makers in identifying strategies to ensure appropriate levels of reliability. Recommendations are made for possible improvements in transport planning and operations that explicitly incorporate values of reliability. Case studies of commercial operations and a range of policy initiatives across OECD and ITF countries provide examples of analytical tools that can be used to deliver more reliable networks in a cost-effective manner.

This summary document comprises the key messages, executive summary and table of contents of the full report together with details of the experts that contributed to the work.

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KEY MESSAGES

Reliability can be better integrated into transport policy making

The objective of this report is to provide policy makers with a framework for understanding reliability issues and for designing reliability management policies. The report has made significant progress in identifying methodology for incorporating improvements in reliability into project and policy evaluation, while exploring the pitfalls that need to be avoided.

At present, network and service reliability is not systematically incorporated in the transport planning process and thus is not reflected adequately in decision making. Reliability is rarely factored into cost-benefit analysis, the core planning tool for surface transport networks.

Increasingly complex scheduling places more importance on reliability

Technological advances and investments in infrastructure have lowered transport costs and increased average transport speeds. This has facilitated and complemented product specialisation. Supply chains are, more than ever—on a global scale—underpinned by global and, often, just-in-time production and distribution systems. This complexity is echoed in passenger movements, both for business and social purposes. These changing patterns have increased the importance of schedules – and of keeping to those schedules. This increases the focus on transport reliability.

Responses to unreliability

Individuals, companies and infrastructure managers affected by changing reliability can respond in a number of ways; individuals build extra (buffer) time into their journeys to allow for the possibility of delay, companies adapt their pattern and timing of operations, while infrastructure managers often provide traffic flow information to reduce the impact of unreliability.

Reliability improvements can be delivered by both users and network providers. It should not be presumed that the infrastructure (or service) provider/government always has to be the source of reliability enhancements. The low-hanging fruit of cost-effective reliability improvements may come from network users.

Four main instruments are available to optimise reliability on transport networks

A wide range of instruments is available to manage reliability. The policy framework proposed in this study distils these into four principal options:

- Increasing the physical capacity of infrastructure, either through supplying extra capacity or improving the quality of existing capacity. Capacity enhancements are generally costly, time consuming and often politically difficult. Setting appropriate network standards and improving the robustness of infrastructure (for instance, durability of material) also influences reliability.

- Better management of existing capacity can facilitate reliability, just as poor management can increase unreliability. Infrastructure managers can improve reliability through better incident management and appropriate scheduling and publicising of maintenance. The core management skills can be supplemented by pro-active network oversight.

- Where feasible, charging directly for reliability could be used to achieve more efficient levels of reliability. However, it is often difficult to provide different levels of reliability according to the value different users place on reliability, and equally difficult to extract different charges for differential performance.

- Information can be provided to users enabling them to mitigate the adverse effects of poor reliability. This may be a cost-effective way to reduce both unreliability and the impacts of traffic incidents on subsequent business and personal schedules.

Incorporating reliability into cost-benefit assessments encourages proper consideration of options for delivering appropriate levels of reliability

In the absence of a direct market for reliability, cost-benefit assessments can be used to determine appropriate levels of reliability. If a separate market existed for reliability, then prices would encourage an efficient level of reliability and would allocate responsibility for reliability to the party that could bear it at least cost. A cost-benefit analysis attempts to proxy such a market. This study has found that reliability is very rarely embodied in such analyses.

Projects designed to deliver travel time benefits (such as those arising when congestion is reduced) are sometimes credited with generating reliability benefits. However, standard appraisals fail to unbundle improved reliability (reductions in travel time variability) from the benefits due to the reductions in average travel time. This omission removes the factual basis for arguing that a project really does improve reliability.

There are ways to measure and value reliability that can be integrated into cost-benefit analysis. These have been used on a pilot basis in a small number of countries. These approaches provide a foundation for explicitly incorporating reliability benefits into investment appraisals and, consequently, policy frameworks.

Diversity in network user demands for reliability means that no simple mark-up can be applied to incorporate reliability into project assessments

It is difficult to generalise about the value of reliability as it will be project, location, user, and time-specific. For one project studied, the value of improvements in reliability were found to be negligible, whereas for another project they were found to add 25% to the welfare benefits of time savings achieved. It is important to recognise the granularity of reliability—that is that different values are placed on reliability by different network users at different times and for different trip purposes.

Since the demand for reliability varies markedly across users, products, locations and firms, a single monetary value for reliability will be of little, if any, use in project appraisal—a range of values is required that represents the major user groups in each case. Practitioners cannot assume that values used in one study are readily transferable to a project in another situation.

It is also important to avoid potential double-counting when factoring reliability into project assessment. This can arise if the standard values of time used to assess average time savings already have an implicit, crude value for reliability incorporated in them.

Reliability targets need to be applied with caution, distinguishing between the network operator and the user perspective

Reliability targets and performance indicators for services and infrastructure performance can facilitate discussions between users, operators and decision makers regarding the right levels of reliability. But employing fixed targets may be distorting as they can dominate other service characteristics that may be of equal, or greater, importance. Such targets also invariably present an average level of reliability not reflecting diversity in the demand for reliability.

There are also trade-offs to be made. For instance, a rail infrastructure manager may enhance reliability by reducing the number of trains that it operates. The improvements in reliability may then come at the cost of a more limited train schedule and higher overcrowding on the trains. Reliability targets need to be carefully coordinated with other key performance indicators. In those cases where only passenger trains face performance targets, network managers may be inclined to give higher priority to passenger trains over freight trains than is economically justified. Targets should therefore aim at reflecting both the network and the user perspective. For a network provider, the focus is on system vulnerability or operating performance. For a network user, the focus is on the variability of travel times experienced by the user. The incentives that the targets create in relation to other policy goals and the overall efficiency of transport systems need regular review.

EXECUTIVE SUMMARY

Most of us face unreliable travel services in our daily lives, with unexpected delays leading us to miss a train or arrive late for school or work. Whether it be for social or business events or deliveries of goods, reliability is a key quality of movement. A review of policies in OECD/ITF countries shows, however, that few countries explicitly incorporate reliability into transport policy making. This report aims at providing policy makers with a framework for understanding reliability issues, for incorporating reliability into project assessment, and for designing reliability management policies.

The economics of reliability

Reliability is unanimously regarded as a desirable transport network attribute. There is less unanimity in defining reliability. Yet the definition adopted has major implications for policy. Technically, a reliable system is one that performs its required functions under stated conditions for a specified period of time. Under this definition, a road system that becomes choked with traffic during peak hour, reducing speeds to a slow 20 kilometers per hour, could be regarded as unreliable, or 50% reliable, depending on the conditions specified.

An alternative definition of reliability draws on the attribute of predictability. In this context, a congested road system where the speeds at different times of day and different days of the week are consistent, and hence predictable, would be ranked as highly reliable. While both interpretations are valid, the focus of this study will be on the second definition.

Like all desirable features of a transport network, reliability comes at a cost. It is subject to the standard rules of supply and demand: the higher the price, the higher the quantity that will be supplied but the lower the quantity that will be demanded. Conversely, the lower the price, the more consumers will demand it. The challenge for policy makers arises in two areas. The first is in formulating the institutional arrangements that affect the market for reliability. For instance, legal frameworks that prevent discrimination between transport system users can create impediments to differentiating between services on the basis of reliability. The second is in the treatment of reliability when assessing publicly-funded transport infrastructure projects.

In other words, the role of the government is two-fold: encouraging a market for reliability and incorporating reliability into the assessment of transport infrastructure projects. In terms of the first role, it is important to note that, as a service attribute, reliability is often bundled with other attributes such as speed, convenience and cost, making it very difficult to differentiate a separate market for reliability.[1]

An important point that follows from this is that only when, say, two parallel services are provided with reliability being the key differentiating feature is there an explicit market for reliability. Without

1. This is a common feature of all markets as rarely, if ever, is the array of goods and services so vast that all consumers can select the exact amount of each attribute that they are willing to pay for.

this, there is a major challenge in developing sound estimates of the value placed on reliability by network users.[2]

Ideally, market incentives would encourage not only an efficient level of reliability but would also allocate responsibility for reliability to the party that could bear it at least cost.[3] This point is also explored in the report.

Factoring reliability into cost-benefit analysis is clearly desirable but also problematic. The values placed on reliability vary from project to project. Using an incorrect value could result in a worse outcome than a failure to incorporate a value for reliability at all. Cost-benefit analysis, as a set of rationalised economic principles, has evolved over more than a century and useful refinements are unlikely to be developed overnight. However, this report has made significant progress in identifying possible methodology for incorporating a value for reliability into project evaluation, as well as exploring the possible pitfalls that need to be avoided.

Demand for reliability is increasing

Changes in commerce and personal travel patterns have increased the importance of a reliable transport system. Reliable transport networks and services are required because of more complex and inter-related supply chains and increasingly complex scheduled activities. The physical way that the economy operates has changed, facilitated by—and demanding—transport system enhancements.

Transport productivity has increased markedly, yielding benefits for business through the specialisation of production on a global scale and the spread of just-in-time production and distribution systems. One aspect of that productivity is the reduction in transit time, which expands the market for the goods and services, and broadens the way in which firms can interact. The increased interaction between businesses puts a premium on reliability. In modern dispersed production systems, time has become the critical factor where timely delivery of components has replaced traditional stock-holding. These developments have facilitated and accompanied the growing operational sphere of influence for businesses. Multinational businesses have consolidated into larger, but fewer, physical locations, growing with the globalised economy. Broadening national and international trade links, with increasing goods movements, have brought greater volumes of goods, moving further and in increasingly complex and—crucially—interdependent ways. That interdependence depends on reliable transport.

There are also changes in personal lifestyles. Passenger movements, both for business and social purposes, have become more complex with changing patterns of employment, increased disposable income, recreational choices and leisure time. These diverse and geographically-spread activities have led to more intensive use of transport systems, bringing greater dependence on transport to be reliable so that delays do not cascade through the busy calendar of events. The scheduling approach increasingly adopted in private lives echoes the just-in-time deliveries in commerce.

The importance of scheduling in personal and freight activities has grown, so that transport unreliability has an increasingly-marked effect on downstream activities. The expectation from these demand trends is increasingly that transport should provide high levels of reliability.

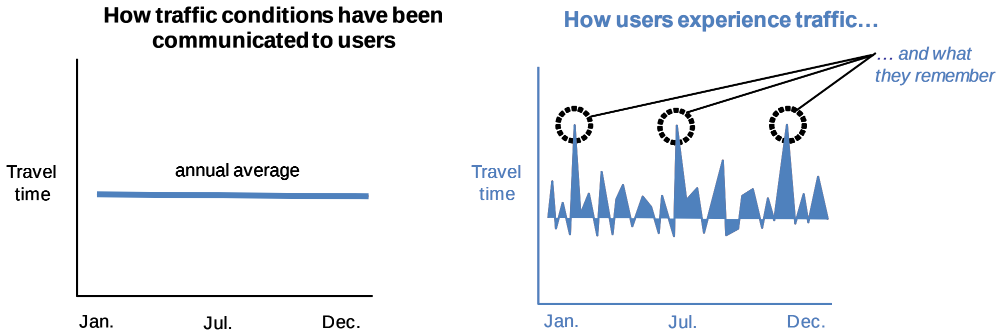
2. For instance, if they cannot be charged directly, they are likely to say they place a much higher value on reliability than otherwise.

3. In this way, reliability is analogous to risk.

Unreliability makes trips frustrating

Unreliability makes journeys frustrating and causes stress. The feeling of travelling without control over one's travel time is a disempowering experience, and bad experiences are remembered by travellers. Traffic conditions in the past have often been communicated to travellers only in terms of simple averages (left chart in figure ES1). However, most travellers experience and remember something much different than a simple average of commuting travel time (right chart in figure ES1). Users have deeply negative perceptions of unexpected delays, which colour their attitude to the experience.

Figure ES1. **Travellers' perception of traffic conditions**



Source: FHWA (2006), *Travel time reliability: Making it there on time, all the time*, United States Federal Highway Administration, Washington, D.C.

Unreliability constitutes a cost

Where performance is inconsistent, network users may simply have to accept the consequences of the delay, albeit that it may have ripple-effects or, worse, snowballing (compounding, or growing) effects, affecting other activities or stages in the personal or logistics chain, constituting a cost to those involved.

The ripple-effect of delays is an important reminder of the inter-connectedness of many individual schedules. A delay at one stage in a person's schedule of activities can mean delays in later related, or unrelated, tasks. Similarly, while logistics chains are built in such a way as to reduce their vulnerability to individual events, any delays in individual consignments can still reverberate through the chain. Indeed, because the transport task is part of a chain, a break in any part of it is a break in the entire chain. An assembled television set with only 99 of its 100 components is an incomplete product that can be neither shipped nor sold.

Costs of unreliability may rival those of congestion. Bearing in mind that the results are not transferable across locations, it is nonetheless significant that there is evidence that the cost of unreliability may cause around half of total underlying delay costs.

Journey-time predictability is the defining feature of reliability

In this report, reliability is defined as:

> *the ability of the transport system to provide the expected level of service quality, upon which users have organised their activities.*

The key word is "expected". According to the definition, reliability can be improved either by supplying a higher level of reliability, or by changing expectations of the level of reliability. In other words, unpredictability (or inconsistency) of network performance is the defining characteristic of unreliability. The more random (less predictable) the performance, the harder it is for the network user to ensure against delays.

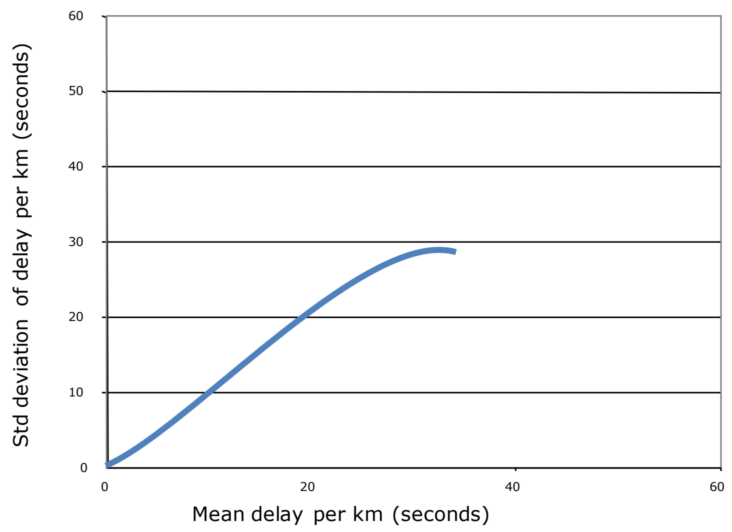
Average travel time between two destinations includes both expected and unexpected delays. It is assumed that network users accommodate expected delays into their travel time through, say, the inclusion of buffer time. However, it is more difficult and costly to incorporate the unpredictable—the unexpected—delays that lead to variation from planned or anticipated travel time.

Disturbances that cause delays can also be classified as recurrent (such as weekday peak-hour congestion) or non-recurrent (such as delays caused by crashes, inclement weather and other events of nature). The essence of the degree of recurrence is that it provides information about the predictability of the event.

The terms unreliability and congestion are often used synonymously. However, as follows from the foregoing discussion, a congested network does not have to be unreliable. Unreliability refers to unanticipated delays, and therefore a congested network is not necessarily unreliable because journey time along a congested road can be fairly predictable.

That said, congestion increases the likelihood of unreliability: as traffic levels increase, the time delays due to slight perturbations tend to increase more than proportionately. This is illustrated by one example, a motorway in the United Kingdom (see Figure ES2 below), where there is a clear correlation between the level of congestion and reliability until high levels of congestion are reached. That said, it is not possible to say whether the variability of travel time was predictable or not.

Figure ES2. **Relationship between reliability (vertical axis) and congestion (horizontal axis) on the M42 motorway in the UK**



Source: Mott MacDonald (2009), *Development of INCA to incorporate single carriageways and managed motorways,* UK Department for Transport, *http://www.dft.gov.uk/pgr/economics/rdg/ttv/incaresearch/inca.pdf*.

The distinction between reliability and congestion is important because of the different policy implications. However, it is also recognised that remedial actions directed at congestion can improve reliability and, similarly, actions that improve reliability can reduce congestion. For instance, many of the bottlenecks in international supply chains are located in congested urban areas. Reducing congestion at port and hinterland connections may also improve the reliability of the entire logistic chain. There can be overlaps.

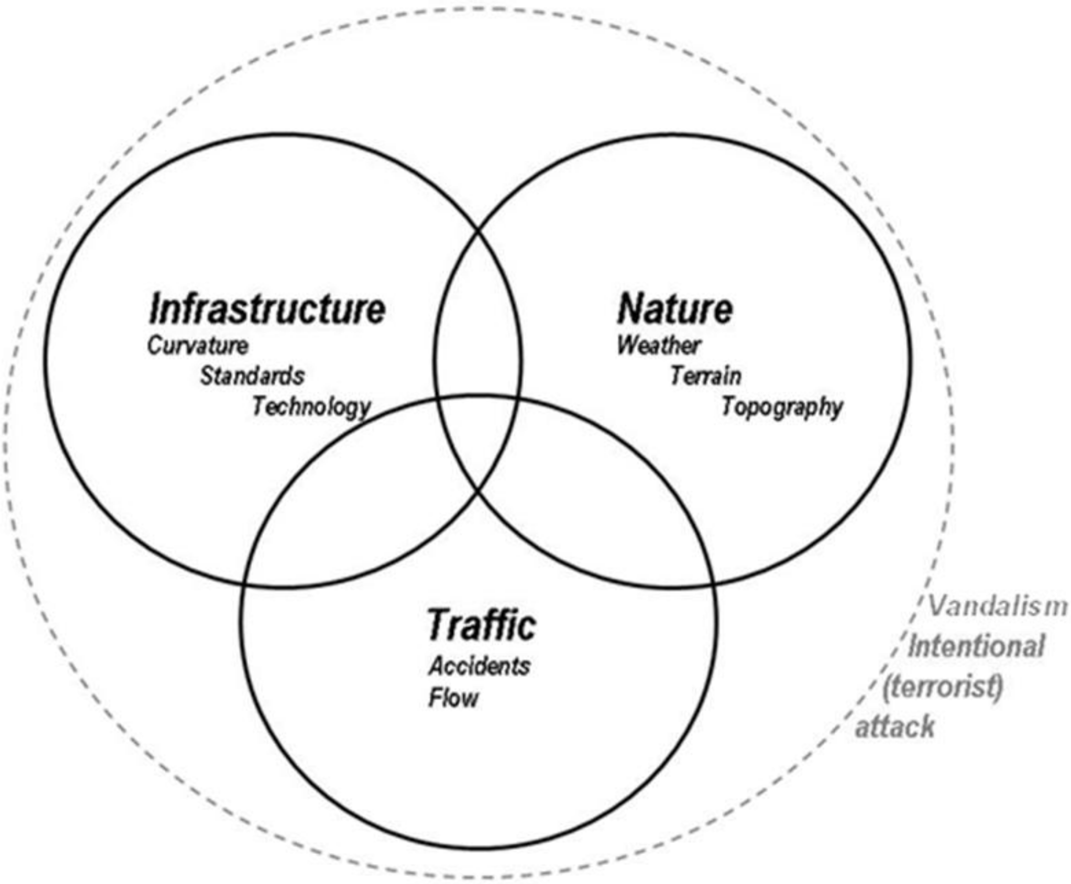
Unreliability arises from multiple sources, each requiring different ways to manage the problem

Unreliability can arise from various activities that are within the control of the network user or network provider. Unreliability of the transport infrastructure network arises from two primary sources:

- Unpredictable demand-related traffic interactions between users (congestion).
- Unanticipated supply-related events:
  - traffic incidents (crashes and vehicle break-downs);
  - natural events (*e.g.* floods and earthquakes);
  - network maintenance (causing temporary reduction in supply); and
  - mismanagement in infrastructure supply, which can also include inappropriate maintenance programs.

Mismanagement of road and railway networks can reinforce other sources of unreliability. It is possible that an uncongested road can be unreliable if the network is poorly-managed; similarly, a congested road with poor management is likely to magnify unreliability. This observation is represented by the intersection of the circles in Figure ES3, showing the primary sources of unreliability.

Figure ES3. **Primary sources of unreliability and inter-relationships**



Source: Derived from Husdal, J. (2004), Reliability and vulnerability versus costs and benefits, Paper presented at the European Transport Conference 2004, Strasbourg, 4-6 October, *http://husdal.typepad.com/blog/docs/etc2004_epr08ii_husdal_revised.pdf*.

The figure above illustrates the interfaces between the various sources of unreliability. For example, low standard infrastructure is likely to be more prone to unreliability arising from events of nature than if the infrastructure is designed to a high standard. This is not to argue for infrastructure to be built to a high standard by default. Given prevailing conditions, such as the likelihood of disruption and levels of traffic, it may be highly appropriate for the infrastructure to be built to a relatively low standard.

Finally, reliability issues are very location- and time-specific—and this affects potential actions to manage the problem, as well as the degree to which costs and benefits from one situation can be inferred to another situation.

Network users develop strategies to deal with unreliability

Individuals and companies affected by deterioration in reliability respond in a number of ways. To reduce the risk of being late at the destination, network users may allow more time for the travel (the so-called safety margin, or buffer). This means, in practice, leaving earlier to ensure arriving on-time. Companies and logistic managers adapt their operations either through changing the way they operate, or by building in buffer stocks of goods. Deliveries can avoid daytime and peak delays, and there has been a growth in evening or night-time deliveries; in some instances companies make greater use of regional depots. Companies also adapt their logistic operations through active traffic management schemes. Increased use of vehicle telematics, routing software and fleet management packages have assisted the adjustment to more congested infrastructure. Minimising the impact of delays on the cost and quality of logistics has become a core skill for freight and logistics managers.

However, each of these options has an associated cost. Leaving earlier to ensure arriving on-time consumes the time available for other, potentially more productive, activities. Holding additional stocks of goods “just in case” involves a capital cost both in terms of the storage facilities and financing the stocks.

Governments have started monitoring and targeting reliability

The first step to recognising the importance of reliability is to monitor it. A number of countries have been exploring ways to monitor reliability. Two distinctive activities are involved here: monitoring service reliability, and setting targets against which the service provider’s actual performance is compared.

A review of existing reliability indicators suggests that the purpose of such monitoring is for ascertaining performance and the quality of transport service delivery.

Performance targets are set for three primary reasons:

- Reliability is an important service characteristic in the transport sector.
- The services to which targets are applied often involve monopoly provision underwritten by the taxpayer. Hence governments have an interest in seeking attractive services and efficient provision.
- Reliability targets are important for initiating discussions between politicians, operators, providers and users on the appropriate delivery of service standards.

Most of the existing reliability targets can be found in the rail sector, a transport mode that seeks to run to strict working timetables. Target-setting practice is prevalent in passenger railways. The scheduling of arrival times readily enables these types of targets to be set (setting actual train arrivals against scheduled arrivals) and rail service providers are generally considered a monopoly. To the extent that the provider is perceived to be a monopoly, governments usually oversee supply standards by monitoring and setting performance standards; the target provides a degree of accountability in service quality. Data on service reliability are essential for this oversight. A similar approach is adopted in aviation, where airline service punctuality statistics provide bellwethers for regulatory and policy monitoring.

The actual service performance and the performance against targets are often published as a way for regulators and governments to make service providers accountable, and as implicit encouragement to improve services. The publication of service performance is also relevant for network users to understand the quality of service delivery, enabling users to allow adequate buffer time against delays.

There are several shortcomings in some of the reliability indicators currently available:

- ***Aggregation across users***. Most existing reliability indicators monitor the performance characteristics of the whole system rather than satisfaction of users’ needs. That is, whether different users actually receive reliable services.

- ***Aggregation across time***. The indicators normally show overall annual averages only, and therefore mask shorter-term variations in service standards.

- ***Reporting partial data.*** More generally, most of the existing indicators were originally designed to provide feedback to network managers, rather than to measure reliability as perceived by end-users. Thus, the indicators may report operational details such as freight train arrival times, rather than those of primary interest to customers, such as the predictability of collection or delivery times.

As noted earlier, this study has found that, despite its obvious importance, there is generally no explicit view on what travel time reliability *is* precisely; similarly, there is no consensus on how reliability should be monitored. Various definitions for travel time reliability exist, and consequently many different relevant indicators are available. Crucially, there is little recognition of the risks in setting targets (or the difficulty in establishing cost-effective targets); too high might distort desirable management decisions, while low targets might make service provision quality too lax.

There are also trade-offs to be made when influencing reliability through explicit targets. For instance, a railway operator may enhance reliability by reducing the number of passenger trains that it operates. The higher reliability then comes at the cost of less-frequent, higher-loaded trains. Similarly, if performance targets were applied only to passenger trains, the network managers may be inclined to give higher priority to those trains over freight trains than economically justified.

A small number of countries have incorporated reliability into project cost-benefit assessment, but so far fail to reflect diversity in reliability valuations

Case studies reviewed in this study illustrate that some projects are carried out specifically in order to improve reliability. However, there are very few cases where reliability is formally incorporated into the cost-benefit assessment (and hence in the decision making process). Even where decision-making guidelines *do* incorporate reliability, most of the actual project appraisals do not include monetised parameters for reliability.

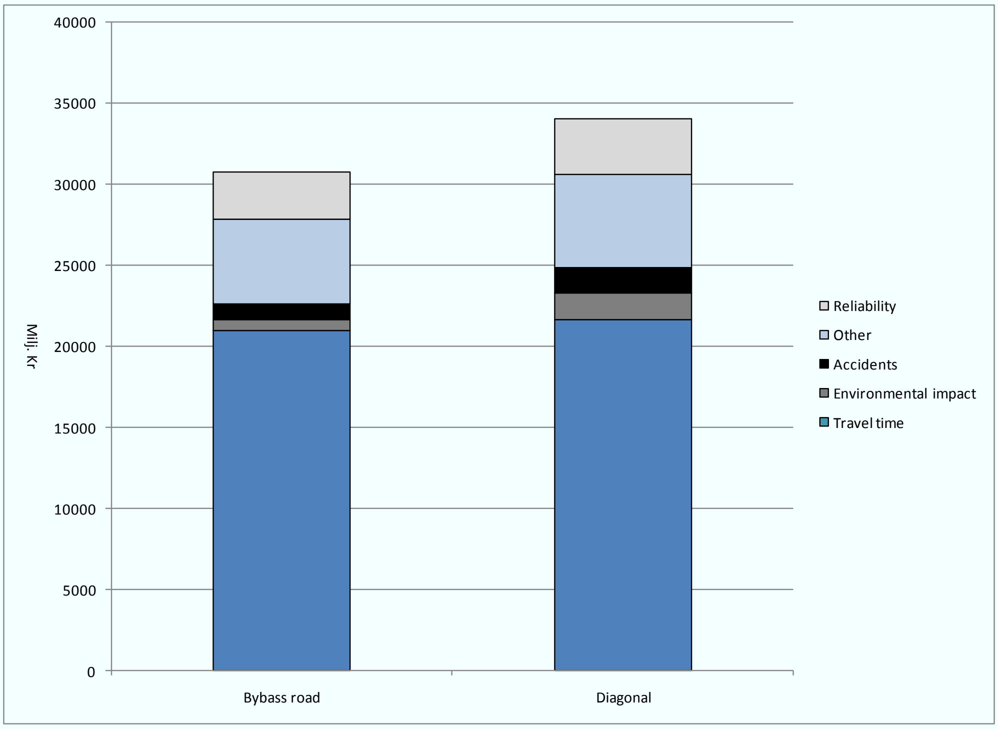
When appraising transport investments, projects are often dominated by improvements in safety and travel time. The time benefits are traditionally measured as the improvement in journey time. In incorporating reliability, those time benefits need to be split into travel time savings and savings in reliability (buffer time). A monetary value is then given to time. Both travel time and buffer time values will vary across users, trip purpose, and location. Differences can be large.

In a small number of countries (the United Kingdom, Netherlands, Denmark, New Zealand, Norway and Sweden), some project appraisals do incorporate reliability. However, the values used are typically the same for all users. This approach is not fully adequate: the value of reliability is, inevitably, very granular—diverse across users—with a wide spectrum of values. It is important to identify values that differentiate between the transport modes and journey purpose/task. Using a coarse or, worse, a single value for reliability improvement will distort the outcome; even more so if the value is not location-specific.

Box ES1. **North-South road connection in Stockholm, Sweden**

Cost-benefit analysis for proposed North-South road connections in Stockholm, Sweden, includes an estimate of reliability benefits. The following figure summarises results of the cost benefit assessment for a Stockholm bypass road and for an alternative project, the Ulvsunda Diagonal. The inclusion of reliability into the calculation added around 12-13 percent to the user benefits.

Figure. **Benefits of the Stockholm bypass and Ulvsunda Diagonal options**



Source: Transek (2006), *Samhällsekonomiska kalkyler för Nord-sydlika förbindelser i Stockholm*, 18:2006.

Delivering optimal levels of reliability

At present, reliability is generally not taken into account when evaluating a project. If an infrastructure investment, for example, improves travel time reliability rather than average travel time, such project merits will be overlooked.

To appraise reliability effects in cost-benefit analysis it is important to measure both average travel time and travel time variability. If the assessment fails to separate these two measurements, but argues that the project does indeed improving reliability, the assessment lacks a factual basis.

Incorporating reliability requires three sets of data:

1. Existing travel time reliability, defined in minutes.
2. Anticipated reliability level (in minutes) after intervention.
3. Monetary values of reliability, disaggregated at the appropriate level of granularity.

What this report proposes for incorporating reliability into project appraisal is that the temporal journey time improvement should be split into pure journey time improvement and buffer time (or other temporal reliability measure) improvement *for each granulation*. The change in time savings benefit then equals the change in pure journey time multiplied by monetary value of time, plus the change in buffer time multiplied by monetary value of reliability.

Average time savings should be split into travel time reductions and a reduction of travel time variation. Both of these components should be identified. An appreciation of the traveller types using the link would then enable appropriate values for the components to be applied. This unbundling enables planners to gain insight into the relative levels of reliability benefits.

Further, *ex ante*, cost benefit analysis will require some quantification of the expected reliability effects of policies. This is a poorly documented field and probably requires some improvement of current traffic forecasting tools and models. Ideally, these tools should be able to provide estimates of future changes in the standard deviations of travel times on links, and model the influence of such variables on travel demand and network use.

Above all, because reliability issues are location, user, and time-specific, assessments should avoid applying or repeating the use of a single value for reliability, or applying a value that has been used in one study to a project in another situation. For each project, there are differences in the mix of user groups and time/reliability splits.

Options for achieving reliability should be selected on the basis of cost-effectiveness

A key policy challenge is to create incentive structures that encourage selection of the most cost-effective reliability option—that is, adopting the option that delivers a given level of reliability improvement for the lowest cost. The objective is to ensure that option is chosen ahead of the less-effective options, regardless of whether the responsibility for adopting the option lies with the network provider or the network user. For instance, one project scenario might conclude that the cost-effective way for shippers to achieve greater reliability would be to hold more stocks than for the network provider to incur incremental infrastructure costs.

In order to be able to take into account reliability in policy impact evaluation, only a cost-benefit assessment framework provides consistency in assessing the societal pros and cons of policy interventions in terms of their positive, or negative, effects on reliability.

Network operator perspective and user perspective should be distinguished

For policy making, it is important to measure and report on both network operator and user perspectives of reliability. The way reliability is measured and communicated provides a policy signal in itself. Also, the better informed regulators are about the appropriate reliability targets, the better the policy.

There is a clear dichotomy in performance indicators: indicators of network quality (what is provided and planned); and indicators of what the user experiences (or how they respond to network experiences). It is recommended that a distinction be made between the system- and user-perspective of reliability.

1. For a network *provider or operator*, the focus is on:

   – System robustness/vulnerability. Here, a further distinction is made between link and network performance indicators, under changing conditions,

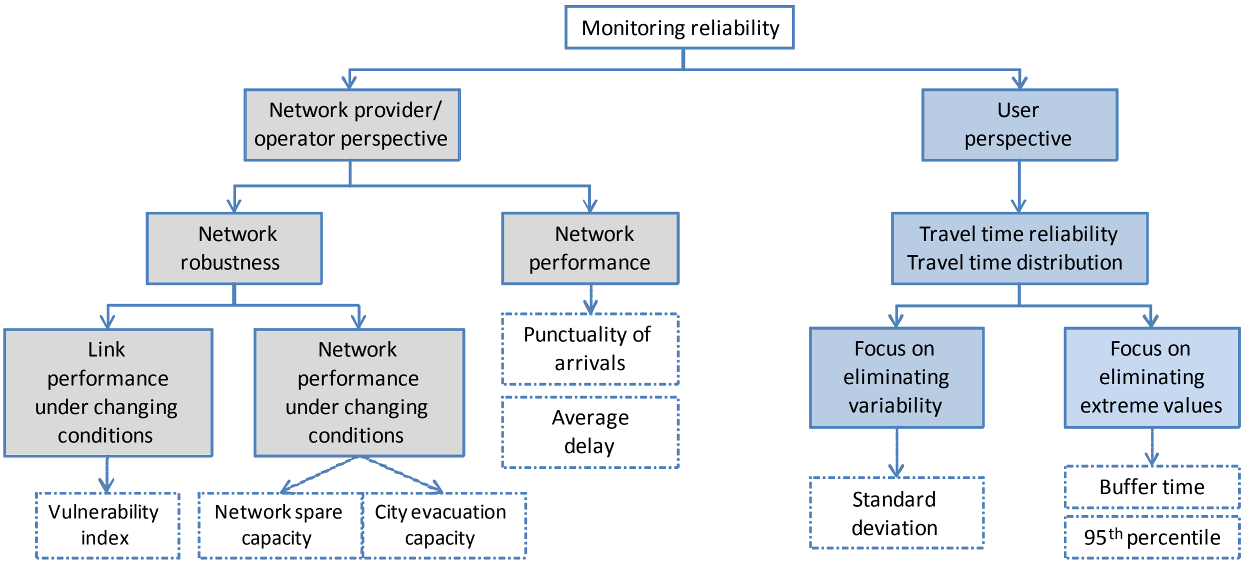
   – System operating performance. Here, the focus is on indicators to describe the performance of a system in terms of deviations from expected, or agreed, levels of service.

2. For a network *user*, the focus is on:

   – The variability of travel times experienced by the user. This can provide useful travel-planning information. A further distinction is made between indicators to describe issues regarding general variability of travel times, and issues regarding the elimination of extreme, unexpected, travel times.

Based on the review of existing indicators, the following schematic overview of the different purposes for indicator combinations was derived (Figure ES4). The main conclusion is that it is extremely important to look at both network and user perspectives, as each has different policy implications.

Figure ES4. **Network and user perspective of reliability**



New policy framework

There are many techniques and instruments available that can be used to improve the reliability of the transport network—both individually and in combination with each other. Four principal policy options available to manage reliability can be identified:

- Physical expansion of capacity.

- Better management of capacity.

- Pricing mechanisms to deliver a market for reliability.
- Information systems intended to mitigate the adverse consequences of unreliability (*i.e.* reduce its costs), rather than to reduce the incidence of the unreliability.

These are not necessarily alternative options but, nonetheless, each should be subject to cost-benefit appraisals.

Physical expansion of capacity

On the supply side, infrastructure design and construction can incorporate reliability options. Improving supply-side reliability entails reducing the probability of an unexpected disruption in service. There is a wide array of options to enhance capacity by expanding infrastructure: upgrading and adding line capacity, increasing transport service in corridors and transfer points, construction of new highway lanes and improving alignment, construction of new rail lines and terminals.

Infrastructure can also be built at standards that reduce the need for maintenance or improve the robustness of the capacity. It is notable that these supply side, capital-based, build options are implemented before any incident takes place. Hence, adaptability of the infrastructure is a key issue.

Box ES2. **East Coast Main Line in the UK**

The East Coast Main Line extends 393 miles from London to Edinburgh with a 30 mile branch from Doncaster to Leeds. Investment in the line was undertaken to a low standard compared with other British routes. In particular, economies were applied to the frequency of, and wire tension on, stanchions (electricity poles). The consequence of this standard is that the route is relatively vulnerable to the electrical wires being displaced by winds.

The quality and reliability of the overhead line electrical supply is a cause for concern. This has an impact on performance in two ways. First, as a precautionary measure, electric trains are slowed down in times of strong winds, introducing delays for all journeys on the route. Second, if the wires become detached there can be wholesale delay or cancellation of services until engineers can repair the wiring.

One way to reduce the line’s vulnerability to damage from the winds might be to splice in additional catenary support poles (or to respace the poles) at locations where the wiring is most vulnerable to wind damage. However, as there are extended lengths of the northern end of the line that are exposed to the north coast (and the strong north-eastern winds), this remedy could be extremely costly.

Source: *East Coast Main Line, www.absoluteastronomy.com/topics/East_Coast_Main_Line#encyclopedia*.

Supplying new capacity is costly, time consuming, and often politically difficult, while setting higher network standards and improving the robustness of capacity may deliver higher reliability more cost-effectively. It is too often the case that additional supply is considered as the only option, whereas it should be considered as one option among others.

Better management of capacity

There is a wide range of techniques and instruments available to better manage network capacity to improve reliability. These include pro-active oversight and management of vulnerable parts of the network, and enhanced incident management. For instance, the impact of congestion on reliability can be reduced by the use of variable road speed limits and the temporary addition of road capacity, using emergency hard-shoulder break-down lanes. Similarly, improved management oversight can also be applied on the railway network. Optimised timetabling, a dynamic rescheduling of rail networks in case of an incident, and advanced train management systems can be used.

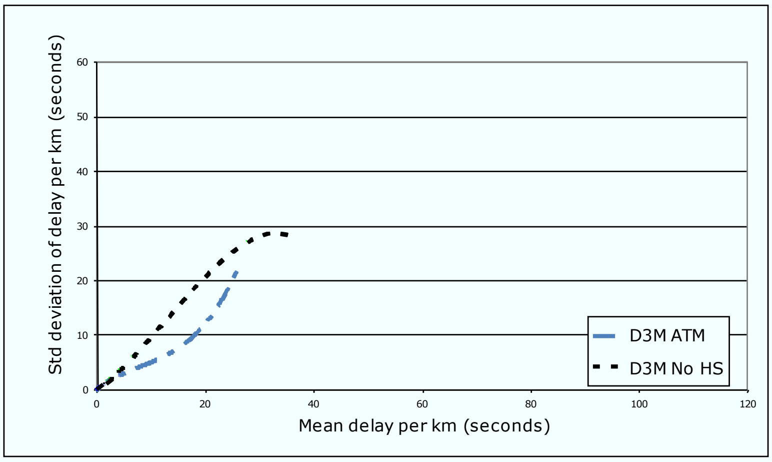
Enhanced management techniques can assist in reducing the impact of maintenance on network users and reduce the cost of the maintenance activity itself. For example, some contracts in Public-Private Partnership projects have included charges for maintenance works to discourage private network owners from adding too many work zones at the same time.

Box ES3. **Use of motorway hard shoulders in the United Kingdom**

Since late 2005, the UK Highways Agency has allowed use of the hard shoulder of a 16 kilometre section of the M42 motorway at the most congested times. At such times, the speed limit on the section is reduced from 70 miles per hour to 50 miles per hour, with the option for a further reduction to 40mph depending on the operating conditions. The Agency is also investigating the merits of a (higher) 60mph speed limit when the hard shoulder is being used. To provide a safety offset for the loss of the hard shoulder, emergency refuges have been added, providing emergency telephones and lighting, and CCTV monitoring. A variety of monitoring equipment and information systems have been put into place on gantries spaced at 500m intervals. As well as switching between regimes with and without hard shoulder running, the technology is also used to vary the speed limits on the three lanes.

The figure indicates results from active traffic management. The black dashed line (D3M No HS) indicates the variability/average delay plot of the M42. The blue dash (D3M ATM) indicates what happens to this relationship as active traffic management uses the hard-shoulder running regime. The delay penalty due to the speed restriction applied when hard shoulder running is permitted is compensated by reduced variability (improved reliability).

Figure 1. Figure. **Delay and day-to-day variability for different motorway regimes (M42, UK)**



Source: Mott MacDonald (2009), *Development of INCA to incorporate single carriageways and managed motorways*, UK Department for Transport, *http://www.dft.gov.uk/pgr/economics/rdg/ttv/incaresearch/inca.pdf*.

In summary, an important policy focus for delivering reliability is to better manage capacity through dynamic network management. A focus on interfaces, such as border crossings and ports and hinterland connections where unreliability is likely to occur, might also be appropriate.

Developing mechanisms for charging directly for reliability

Charging for the use of transport networks, or portions thereof, is becoming a more common method of managing traffic demand, and consequently traffic flow and network reliability. It is also possible to charge for information systems, such as GPS guidance systems, which network users can subscribe to in order to mitigate the worst effects of delays. Charges can be applied selectively to segments of the transport network, or more broadly over large sections of the network.

Developments in technology have facilitated an expansion of charging systems and techniques that can be used to manage demand on transport networks. Although most of these techniques are directed at cost recovery and congestion management, they can also be effective in improving reliability.

There are a few situations where access to road networks has been restricted and where charges have been introduced to improve reliability. Dynamic pricing on the Interstate-15 in the USA is one of the few instances. In this case, charges are adjusted up and down to ensure a predictable travel time for the 8 miles of road involved.

Box ES4. **Interstate-15 toll lanes, USA**

Pricing attuned to delivering reliable travel times has been applied to segregated lanes on the I-15 freeway in California, linking San Diego to its northern suburbs. Prices are varied so as to maintain the level of reliability on the tolled lanes. In this case, the speed of traffic is used as a proxy for reliability.

The charges are varied in accordance with the flow of traffic on the road, with charges rising so as to discourage some use of the tolled lanes. Tolls are varied at 6-minute intervals and the level is set so as to attract the level of demand that is consistent with a constant speed. These toll charges also convey information to drivers before entering the free/tolled section of roadway: if the tolls are relatively high traffic is likely to be very heavy on the free lane ways.

Source: Brownstone, K. and Small, K. (2005), Valuing time and reliability: assessing the evidence from road pricing demonstrations, *Transportation Research Part A*, 39, pp. 279-293.

Railways are better placed to use charging as a tool to deliver a consistent level of reliability because full control of access to the network allows network-link charges. There are limited examples (in North America and Australia, for example) where high-reliability freight train services are offered for a premium. In general, however, freight railways' profit-maximising strategy is to move large amounts of freight that does not require very high reliability standards. By contrast, high-speed passenger trains/tracks (ICE, TGV, Pendolino, etc.) have been built to provide near-exclusive rights for services with low transit time and high reliability. Infrastructure charges for these trains are correspondingly high.

In summary, charging directly for reliability by setting differential charges for infrastructure use and service supply, according to the level of reliability, might deliver an appropriate level of reliability. However, it should be noted that it is often difficult (or impossible) to differentiate charges sufficiently to match the level of reliability demanded by different types of user of transport infrastructure. The cost of a charging system that discriminates on the basis of reliability could outweigh its benefits, and must be included in cost-benefit assessments of charging systems.

Mitigating the cost burden associated with unreliability using information

Information systems can reduce the consequences of network incidents. Network demand can be deflected away from the site of congestion or traffic incidents. Information can also reduce stress associated with unreliability, and enable the problems associated with delays to schedules to be managed.

As noted previously, travel time reliability depends, to some extent, on the user’s expectation of predictable travel times; this expectation can vary according to the information available. Network providers can facilitate network usage and reduce the impact of incidents by informing users of prevailing conditions. Even if information does not prevent incidents from happening, it can reduce the costs that arise from the incident. For example, the widespread adoption of the mobile phone in recent years has provided the network user with the means to alert interested parties (the warehouse, the family) that arrival will be delayed; the latter parties might then be able to reduce the impact of that delay. Hence, information can mitigate unreliability and reduce the ripple effect that otherwise would be the result of unreliability.

In a specific commercial application, the port of Southampton schedules pick-up times for containers. If a truck is delayed, and will miss its slot, it must phone and reschedule. This can be done up to five minutes before the slot, otherwise a fine is imposed.

Information options may be divided between pre-trip and on-trip measures. Information may be used in different ways to improve reliability depending on whether a traveller has left the origin, whether a traveller can divert to another route, or if the traveller cannot divert but can reduce the ripple effect (consequences). Different tools exist for delivering this information, including variable message signs, car navigators, the internet, and text messages on mobile phones.

Information can be provided to users to mitigate the effects of poor reliability. This is often a cost-effective way to reduce unreliability costs and the cascading impacts of traffic incidents.

Conclusion

A wide range of policy instruments is available to manage reliability. Because there generally is no direct market for reliability, cost-benefit assessment needs to be used to determine appropriate levels of reliability and to select cost-effective policies to manage reliability. Cost-benefit assessment has so far been applied to projects designed to improve reliability in only a small number of countries, with techniques that have been in some important respects unsatisfactory. This report makes significant progress in identifying appropriate methodology for incorporating values for reliability into project and policy evaluations, and it explores the pitfalls that need to be avoided.

Robust and consistent reliability assessments can be developed. Their deployment is important for informing decisions on achieving more optimal levels of reliability on surface transport networks, and for the selection of cost-effective policies and projects.

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The following consulting reports were developed as inputs to this project, both of which are available in their entirety on the Joint Transport Research Centre's website, at

http://www.internationaltransportforum.org/jtrc/infrastructure/networks/documents.html

McKinnon, A., Palmer, A., Edwards, J., Piecyk, M. (2008), *Reliability of Road Transport from the Perspective of Logistics Managers and Freight Operators*, Logistics Research Centre, Heriot-Watt University.

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