ROADEX Network
For better rural roads

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EVALUATION OF ROADEX BENEFITS AND SAVINGS

CONTENTS

PURPOSE AND BACKGROUND

The purpose of this evaluation memorandum is to provide an external independent assessment of benefits and savings of alternative road asset management strategies suggested by the ROADEX project that executed during 1998 – 2012. While the project delivered multiple notable reports analysing road behaviour in different circumstances, mainly focusing on northern peripheral Europe, the main source of this evaluation memorandum is the report by Saarenketo, Munro & Matintupa: *ROADEX benefits and savings – achieving more with less*. In the aforementioned report the ROADEX project's results were summarised and alternative road asset management strategies were presented in detail, calculating potential savings and benefits.

The primary aim of this independent memorandum is to critically evaluate the summary report on ROADEX results, methodologies and approaches. The evaluation looks into the substance, analytical issues, data and its processing, and pure presentational aspects of ROADEX summary report. The idea is that based on the evaluation and observations ROADEX consortium will be able to take its findings one step further and enhance the visibility and awareness of the interesting and important results that are of clear significance. Hence the purpose is not to find the 'flaws' – since all research projects have them, and any clever academic can easily list such flaws after a careful review – but to point out shortfalls or weaknesses the improving of which can bring added value when taking the project's outcomes into practice and into deeper research. The normative power of ROADEX project is substantial, for it challenges some of the principle *modus operandi* of road authorities. It also lifts up relevant technological issues in road engineering and road maintenance.

However, the main focus will be in economic and financial matters of ROADEX strategies in managing the road assets that are of paramount importance to all countries and regions across the globe. These assets are one of the cornerstones of our well-being and form a significant share of national assets.

This evaluation is drafted by a single academic. Therefore, it is far from exhaustive. The evaluator carries his own history of experience, qualifications and skills, all that will inevitably have their effect on which issues are prioritised and what is considered less relevant. It is neither said that all weaknesses are discovered nor that all strengths are recognised. With these limitations in mind, however, the evaluation will serve a starting point for follow-up projects and be a learning experience both for the future project planners, executers as well as for the evaluator.

STRUCTURE OF EVALUATION

First, the overall impressions and perceptions on the report are in the main focus of the evaluation. The key strengths and weaknesses that are apparent are addressed and discussed. Secondly, the evaluation is drilling down to each chapter of the report which are all covering different issues. Each main chapter is discussed separately. Finally, some propositions are made how ROADEX results can be disseminated more effectively and how more value can be extracted, e.g. by enhancing the economic and financial analysis, or selecting more diverse dissemination strategies.

OVERALL EVALUATION

The overall impression is clear. The results and findings of ROADEX project are significant and intuitively appealing. The main messages are clear and punchy as they should. The abstract pretty well summarises the key findings, albeit being somewhat varying collection of different themes

covered by ROADEX. But since the report is a summarising document, this mixture of themes is understandable, but may also cause some confusion for a hasty reader.

The report structure is clear and conclusions and recommendations are drawn in the end.

A particularly strong impression is given to the reader that the issues covered in ROADEX were highly practically investigated and therefore the results carry an extra loading: ROADEX was clearly an empirical project. Illustrations, photos and graphs fortify this impression. Now, here comes then the other side of this coin. The theoretical background is unfortunately missing totally in the summary report and this obvious shortfall limits the true value of the report. Any academic reader will spot this weakness and, depending on the academic's preferences, may result in an impression that results are not scientifically valid. True or not, this impression may inflate the value of the report so strongly that the findings are bypassed as scientifically invalid and therefore lacking the necessary credibility that is needed for policy recommendations. Any study that wishes to make an impact on policy level must go through the 'science test' and have the necessary theoretical background covered. Alternatively, recommendations suggested in the report should be promoted via different media in order to raise public awareness followed usually by the policymakers' attention.

The above observation is discussed later in greater depth when addressing future steps that can be taken to enhance ROADEX project's impact on road policies.

The introduction section would have been a correct place to present the 'undeniable' arguments why ROADEX project matters and why the results should be taken seriously. This important piece of the analysis is now missing in the summary report. Also a few words and explanations on the methodological issues would have been necessary. The Principles chapter attempts to do this but falls short in order to convince a critical reader. The point is not that such lengthy introductions and methodological justifications would necessarily add to the real value of actual results – the point is simply that these must be convincingly present if research analysis is reported.

Again, it should be noted that the report is summarising the results and economic and financial implications, not reporting all the details of the study. However, the report is stuck 'in between' of thorough research report and executive summary. It is too general to be considered as the first mentioned, and too extensive and detailed to be considered as the latter.

Really good discussion papers are available for example from the International Transport Forum (ITF) of the OECD, which can be regarded as a must-read for any transport authority. These papers often cover the literature (note: 'the science test') and build practical guidelines and recommendations that national authorities can follow ('executive summary').

Whether a project report is supposed to fulfil all the above mentioned criteria is another matter and depends on the contextual space where the project is taking place. However, ITF reports make a significant impact. There is no reason to assume that skilful project researchers could not achieve the same quality level. Hence the overall conclusion is that ROADEX could have benefited by partnering with some research organisations that could have assumed the task of providing the 'science test'.

But as stated earlier, the key messages of the ROADEX report are obvious, well summarised and serve well their function. The critique is targeted at how the results 'appear' in the eyes of those that make critical assessment how seriously the findings should be considered. In today's information overflow the dissemination of research findings is ever more challenging.

STRENGTHENING DESIGN

This is the chapter 3 of the report under evaluation. Again, the introductory parts of most sub-chapters are clear and convey unambiguous messages. In one section (3.1) the empirical sources of data are unclear, whereas in the other sections it is mentioned explicitly (which road, what type of road, etc.). But even so, the first section (3.1) is very illustrative and intellectually appealing. But the extent in which the design practices truly are following the traditional path, showed with practical examples of the design standards, is missing. This makes the intellectually appealing approach no more than a good idea - a strong idea, but still just an idea. The logic, however, is convincing and should be taken seriously. But the normative guidelines would have needed examples from the real world.

The following section (3.2) is particularly enlightening with a clear case (Timmerleden) and clear methodology (ROADEX method vs. consultants' proposals). More illustrations with this example would have been justified. Also the discussion on including externalities (emissions / carbon footprint) is a good point. The externalities analysis could have been more present in ROADEX project because obviously that perspective would have strengthened the arguments favouring ROADEX methods and approaches. The whole set up for 3.2 is good: one road stretch, alternative scenarios, empirical numbers. All these provide a very convincing case, where the 'white noise' has been mostly filtered out. In short, it makes an excellent analysis case.

The third case has similar quantities: one project context within which different, alternative analyses are carried out. The cost analysis is on one hand clear but on the other hand includes some theoretical problems. Since it is a 'single-project' context, the comparisons are fairly straightforward. However, when discounted costs are annualised as an average, some theoretical errors take place. Present values are present values and should not be averaged over the time line. The correct method would have been to calculate the annuity costs that are a slightly different concept. The error may not seem significant, but it is an error nevertheless. Furthermore, the error is to the undesired direction, i.e. the suggested ranking of costs may not be correct or the differences as large as assumed. In Table 33_2, for example, option 8 might well compete with option 4 that is the recommended option. How significant the error in fact is depends on the input values and how they spread over time.

Only net present value costs as a sum or annuities would have been the correct metrics. The following table illustrates the differences between the concepts.

Table 1: Difference between averaged present values and annuities

Year	0	1	2	3	4	5	6	7	8	9	10	Sum
Nominal cost	100,0	5,0	5,0	5,0	5,0	25,0	5,0	5,0	5,0	5,0	50,0	**215,0**
Present value of cost (4%)	100,0	4,8	4,6	4,4	4,3	20,5	4,0	3,8	3,7	3,5	33,8	**187,4**
Present value averaged over years	17,0	17,0	17,0	17,0	17,0	17,0	17,0	17,0	17,0	17,0	17,0	**187,4**
Annuity factor for 11 years, 4%	9,1109											
Annuity payments	20,6	20,6	20,6	20,6	20,6	20,6	20,6	20,6	20,6	20,6	20,6	**226,2**
Present value of annual payments	20,6	19,8	19,0	18,3	17,6	16,9	16,3	15,6	15,0	14,5	13,9	**187,4**

The annuity payments come when present value sum 187,4 is divided by annuity factor 9,1109. The present value of annual payments is then totalling exactly the total present value again. Thus the true annual cost spread evenly over the investment cycle here is 20,6 and not 17,0. The time value of money plays a trick here.

The same natured problem is with Figure 33_2 in the report under evaluation. While the presentation as such is probably correct, it may mislead a reader with no analytical finance or economics orientation. It shows the distribution of timing of investments but the resulting conclusion is extremely hard to draw. In fact, if the usual economic decision models, such as net

present value, would be used, option 4 would be overwhelmingly the best alternative – much better than the figure suggests to a hasty reader.

Section 3.4 is mainly a technical description and would require technical expertise to be evaluated decently. The descriptive analysis seems impeccable, though.

DRAINAGE MANAGEMENT

This chapter (chapter 4) is very intriguing despite it being about such an everyday topic such as drainage. Looking at some relevant research project findings, such as the European Framework project EWENT (ewent.vtt.fi), ROADEX is right on the track. Simple maintenance measures are more important than usually realised. In fact, this topic would deserve so much more attention than what is given to it, the reason probably being that it is not very 'sexy'. Yet the entire philosophy of resilience and life-cycle management relies heavily on day-to-day maintenance, whatever asset is being considered.

However, the summary report under evaluation is attempting to include too much information. Either the report should have been condensed to carry only some of the crucial messages or it should have been formatted more as a true research report. The report stays now in an uncomfortable middle ground. Perhaps the more technical reports should have included most of the conclusions / findings and this summary report only focusing on the very few most important ones?

Figure 4_1 in the report is vital in showing the effect of drainage on pavement lifetime. But it is very hard to read and interpret, because it contains so much complex information somewhat blurring the message. The figure is apparently based on PMS-object software outputs, but the models behind the software remain a black box. Partly this is understandable because of the nature and scope of the summary report.

While having done some limited investigation elsewhere, the evaluator believes that the models of road deterioration are in fact immature. There are global models dealing with pavement lifecycle management but few (if any) models deal credibly with the dynamics of the different structural elements of a road – drainage being one the essential sub-structures of the superstructure. This is both surprising and alarming. Our world is full of road assets, the behaviour of which we understand in fact very little. Pavements are just one part of the superstructure (or structural system), and while its condition is critical thinking of the entire lifecycle management of a road, its dynamic relationship with other structural elements of the road system is based mainly on expert experience, estimates and quite simplistic models that have limited features of system dynamics. The Finnish case brought forth is interesting and serve well the purpose. The report clearly benefits from such cases and the monitoring technologies reveal their usefulness (e.g. Figure 4_3).

The profitability discussion on drainage is again on the right track, but if one wants to seek for the weak points, the discussion stays at a level of manifest rather than research evidence. The practical case from Lapland on the other hand offers valuable material. The potential savings (Table 43_2) is an illustrative example. This piece of analysis alone would have been quality material for any scientific journal.

SPRING THAW AND ROAD-FRIENDLY VEHICLES

Chapters 5 and 6 are somewhat related and therefore discussed under same title of this evaluation. The drainage discussion could have been integrated into the previous chapter (4) and the tyre pressure management to following chapter (6).

The tyre pressure issue is remarkably innovative in its simplicity. The problem remains how to control the pressures, but future technologies might bring solutions sooner than we think. Already today it is possible to remote monitor in real time the tyre pressures and locations of heavy vehicles as well as other parameters. What is needed is the information technology architecture at operational level to realise this (who and how). The legislative and regulatory aspects might well be the true bottleneck.

QUALITY CONTROL AND ASSURANCE

The issue raised concerning outsourcing of many operational activities of road administrations is valid and ROADEX is precisely hitting one nail here. The contractors' incentive to save money when building/rebuilding roads is argued clearly with some examples of potential contractor savings. However, these incentives should have been compared side by side with potential lifecycle costs of the road. That is the only missing part, but an essential one, in the analysis. This comparison would have been very relevant addition to ROADEX summary report. Hopefully that will be carried out in the future.

LAST CHAPTERS: CONCLUSIONS AND RECOMMENDATIONS

Some more time and effort could have been spent on this section. It should have been made clear as a whistle to the decision-makers what they should be deciding on in the future to increase life spans of road infrastructures, make them more resilient and deliver more value for money for the taxpayers.

The focus on drainage and lifting it to the front is probably correct. Many examples from the EWENT project as well as from the US highlight the importance of letting the water flow freely without washing away or weakening the road structures - a very simple thing in principle but surprisingly hard to implement in practice.

Precision maintenance operations and advanced diagnostics are also apparent conclusions and should be delivered to road asset managers. The message is not limited to northern peripheral areas but concerns global road authority community.

EVALUATOR'S FINAL REMARKS AND SUGGESTIONS

ROADEX summary report on the benefits of ROADEX technologies and asset management strategies is a refreshing exception to the body of knowledge in road asset management research. It is highly empirical and has a number of practical examples that offer observations, insight and understanding. Furthermore, everything in the report is intellectually appealing and logical. Anyone who has worked with road asset and lifecycle management issues understands the value of ROADEX project.

However, the summary report is not covering the theoretical background and scientific evidence adequately. How much these are available in other technical ROADEX report is beyond the scope of this evaluation task, but one alternative could be to summarise empirical results one more time and on other *fora,* in scientific journal articles, for example, and professional media. There are only few years to do this, if the ROADEX group decides to proceed. After that, the empirical material

starts to be outdated and many others are harvesting the same fruits. In today's fast-track information exchange and digital networks, good ideas are replicated promptly. The results and calculations should be published in credible journals - not because of academic interests but because the issues raised are so important, that they deserve to go through the 'science test', i.e. peer reviewed journals.

Another issue relates to lifecycle accounting. As showed previously, this accounting practice is far from simple and sometimes presents conceptual complexities that are not so easy to digest. The risk of technical errors is quite high. Furthermore, the deterioration models are still in inadequate. For example OECD, FHWA and Austroads have studies these models for a long time, published stacks of technical reports, but still a feasible, simple to use models are not at hands. It is also because of this that the ROADEX models and findings can be debatable. And to be frank, the debate may not always be related to academic or technical feasibility of the models, technologies or approaches, but there are many vested interests that affect this discussion. ROADEX consortium should be aware of this fact and prepare itself accordingly. But, the consortium also possesses something that others do not have: experience and an existing collaboration network. This competitive advantage should not be underestimated. For the private companies this means business potential, and for the public bodies this means acknowledgement of forerunning and possibility to demonstrate value for money to the taxpayers.

In the appendix of this evaluation there is an example how the life-cycle asset management problem could be addressed. It is just a tentative idea, and needs to be evaluated properly in turn. However, similar ideas are in an increasing pace appearing in academic press. One recent example is also OECD's International Transport Forum report Asset Management for Sustainable Road Funding. The report issued in 2013 is freely downloadable from the OECD's website.

ROADEX project conveys a message to the global community: everyday maintenance and small-scale upgrading is something that much of our infrastructures are calling for. There are probably two major problems or challenges. First, the routine maintenance work is not politically appealing to many decision makers. 'Ribbon-cutting' is still one of the favourite activities of the high-level political and administrative staff. It brings media visibility and public attention. Secondly, the current national asset accounting systems poorly take into account the quality of the assets. Usually only capital investments and major upgrades are considered as 'capital building', whereas in reality this is not at all the case. Good quality infrastructure can be old and yet valuable in capital asset terms. Brand new, put poor quality infrastructure can in fact be a negative value asset. It may turn out to be a money-pit, instead of a productive asset. Both these aspects are neglected in the national accounting systems, which in turn affects for example the budget allocations of the ministries and thereafter the budgets of road administrations.

It is also fair to conclude that ROADEX message is identified by many economists around the world. The problem is called 'generation equity gap'. Are we postponing debt to be paid by the next generation because we consider that it is not economically rational enough to act right now? Just because our decision making models are in fact from a period before the climate change and before the realisation of the sustainability challenges, does not justify that type of decision making anymore.

Finally it is in place to raise the issue of clarifying and simplifying the messages. If the evaluator with an academic background is having some issues with the summary report, then what can we expect from a decision-maker and high-level official? This is the key challenge for ROADEX results: how to make them at the same time scientifically valid and easy to understand? The answer lies in the segmentation of dissemination. One report for the politicians and authorities, another published in a journal. Unfortunately, there is not an easy way out from the double-effort that needs to be carried out. For future collaborative efforts planned by ROADEX partners, the dissemination strategy needs to be rethought and reserve enough both time and resources for dissemination activities. Research should be taken an integral part of the work.

ROADEX e-learning material (www.roadex.org/e-learning/) is a good start to raise the visibility of findings and changing the mindset of road asset managers and decision makers, as well as educate the younger generation, who inevitably need to tackle with many of the problems raised by ROADEX. This type of promotional material, along with brief technical reports, supplemented by credible research publications covers the spectrum needed. In the end, it is first and foremost about visibility – whether we like it or not. The material is abundant enough to even write a book published by a global publisher such as Emerald, Springer, etc.

ROADEX has been concentrating on Northern peripheral roads. However, the philosophy of ROADEX is not restricted to this geography alone. ROADEX partners could make an effort to influence PIARC, OECD/ITF and institutional infrastructure investors (EIB, WB, ABD, etc.) to revise some of their guidelines, standards or best practices. This could be done either directly or through national bodies, depending on each partner's network. The voice of ROADEX would definitely deserve to be heard.

APPENDIX: EXAMPLE OF LIFE-CYCLE ASSET MANAGEMENT APPROACH

A road is a dynamic system comprising different structural elements that are in dynamic interaction with each other. Also the external forces that affect the road and which the road is designed to absorb or carry are highly dynamic. The existing deterioration models seem to focus in most cases on pavements, i.e. how the pavement is behaving over time when exposed to different traffic volumes, traffic compositions, weather conditions and other external factors.

As far as the evaluator could judge, one of the main messages of the ROADEX report is the understanding of some of these dynamics, and not only that, but proposing mitigation strategies how to neutralise or dampen the effect of external loadings on the entire road system. One of the key external loadings was in fact precipitation that should be taken care of the drainage system and should be sheltered by non-cracked pavements.

The question arises, and also explicitly raised by ROADEX, that how much can we extend the life-time and hence the value of the asset if we eliminate the impacts of e.g. precipitation on road structures. And doing this, focusing on particularly low-cost items such as pavement crack filling and cleaning of culverts, should have a potentially very cost-effective impact on asset life-cycle value.

A hypothetical approach is presented below. It relies on very simple principles of economics by assuming deterioration (or depreciation) model frequently used in economic analysis. Let us assume that different parts of a road have different natural life-cycles and they deteriorate in different pace. Pavements, exposed to immediate traffic load are short-lived assets that must be repaired and renewed more frequently, whereas substructures are very long-living asset elements. Many (particularly pavement) asset deterioration (or depreciation) models assume a decelerating ageing and value profile. However, the exact profile is seldom known and a great deal of academic work is published on the topic but few (in fact, if any) have come up with a model that reflects the reality even in a satisfactory manner. These models are developed to meet the needs of long-term asset management budgeting of road agencies, manifesting the real demand that exists.

Decelerating models have intuitive weaknesses. While their popularity is probably partly based on mathematical feasibility (decelerating curves are easy to present, understand and program), the value of the asset is in fact on an accelerating deterioration curve once the system elements start to interact dynamically with each other. In plain words, when culverts are not cleaned, extra water absorbing to sub-structures is weakening the entire road although the problem with naked eye is still on the upper parts of the road. The same phenomenon regarding cracked pavements takes place.

Therefore a more realistic deterioration model is accelerating and furthermore should include system dynamics. An illustration below is provided. There is a single structure with elements of different life-cycles. The elements have dynamic relationships, i.e. weakening of one part affects negatively to the value and life-time of others. A simple geometric series model is applied. This model is in fact a negative compounding interest rate series. (See Figure 1).

Then, when the most short-living asset is repaired and its life-time extended in year 5, it continues the life of other parts of the structural system, and the value of the entire system is enhanced (see Figure 2). This is precisely according to ROADEX philosophy.

The economics works as follows. If we assume that these six elements with lives of 10, 20, 30, 40, 50, and 60 years comprise 5%, 10%, 10%, 15%, 30% and 30%, respectively, of the total asset

value. If we further assume that these relative shares also represent the shares of major maintenance and repair costs (i.e. renewing 5% -asset costs 5% of the original asset build-up cost) we can relatively easily optimise the life-cycle costs of the system. The uncertainties relate to almost all issues, however: what are the relative shares, what are the true life-times of asset's elements and what are the dynamic relationships between the elements? Current body of knowledge does not seem to give a clear answer, although it can be possible that the answers are found when integrating scattered research. It would not be the first time when integrative research manages to fusion different results into a more holistic understanding of the behaviour and dynamics of the system.

Figure 1: Geometric series deterioration of six different structural components

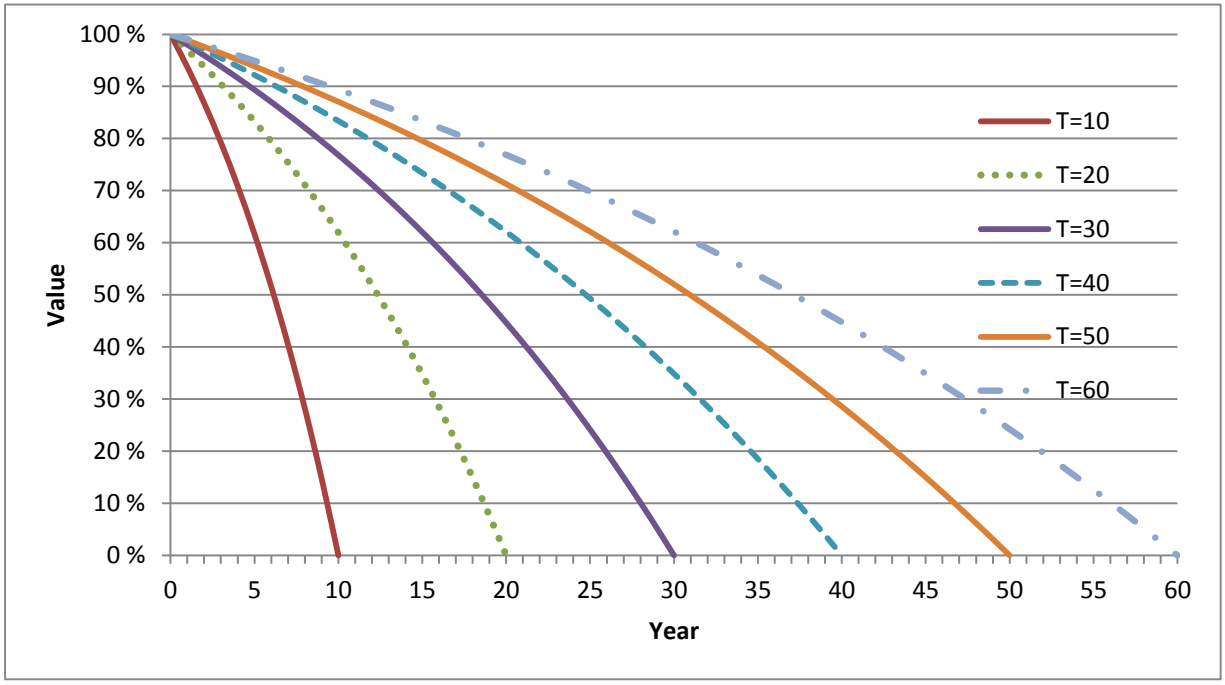
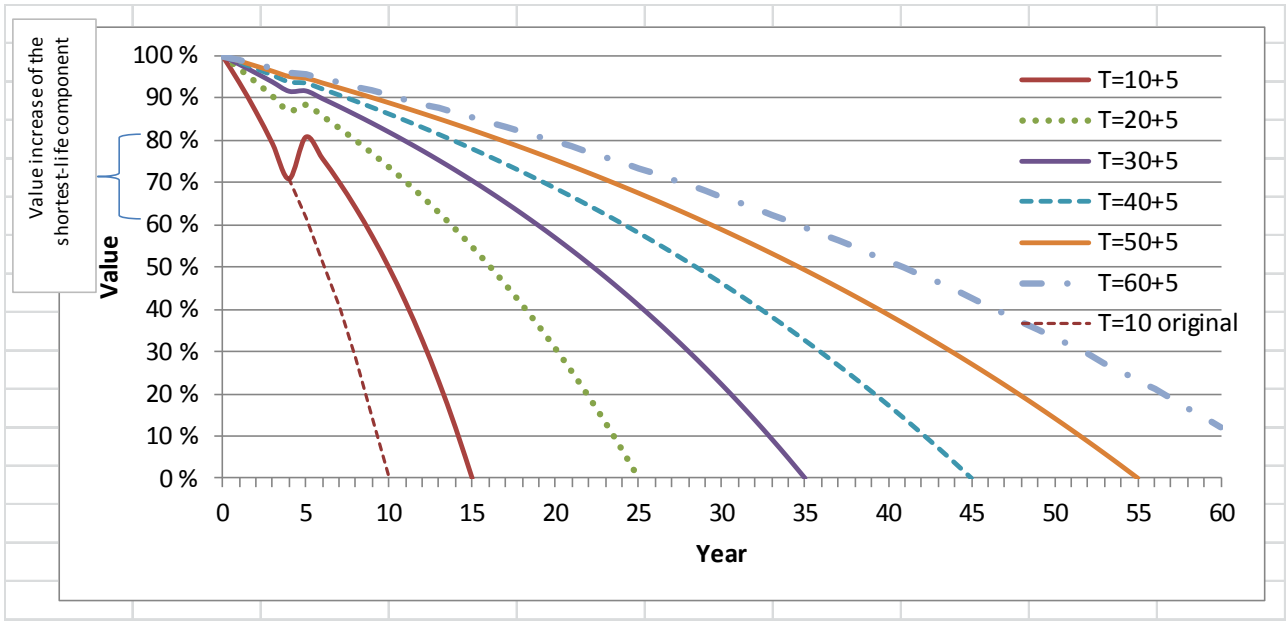


Figure 2: Extending the structure life-time by five years



Our simplified example, where dynamic relationship between the six elements is linear, has the following results, as shown in Table 2, in a scenario where a repair / upgrade is made in year T=5 that continues the system life-time for another five years as whole as far as individual components are concerned.

Table 2: Comparison of two scenarios: do-nothing (Figure 1 deterioration curves) and asset repair in T=5 (Figure 2 curves)

		Sub-systems' value relative to total asset value						
	Time point	0,05	0,1	0,1	0,15	0,3	0,3	Total asset value (weighed by relative values)
Asset values in do-nothing scenario	T=5	62 %	83 %	89 %	92 %	94 %	95 %	91 %
	T=20	0 %	0 %	45 %	62 %	71 %	77 %	58 %
Asset values in repair in T=5 scenario	T=5	81 %	88 %	92 %	94 %	95 %	96 %	93 %
	T=20	0 %	31 %	57 %	69 %	75 %	80 %	66 %

Table 2 shows the logic in of Figures 1 and 2 in numbers. The total value of the asset is increased only by 2 %-units (91% => 93%) in actual year of repair in T=5. However, the value increase of the most shortest-life component was 19% (62% => 81%) and since this component represented the least valuable part of the total asset, even 2% increase in total asset value is significant. As deterioration is slowed down, the total value in T=20 is increased by 8 %-units (58% => 66%). This would be a significant figure. Investing slightly more 'sooner' will save money and increase value 'later'.

The above example highlights ROADEX project's message exactly. Needless to say, all the calculus here is simplified, but yet with a relatively moderate effort a more sophisticated model of the system behaviour can be achieved, the economics of asset management can be made more explicit, and optimised as well as rational strategic decisions can be made. Still the value analysis of road assets is far from straightforward. Value metrics can be so many different things, and the concept of value is getting more complex. For example, the value of resilience of road infrastructures is gaining more attention as debate on climate change and extreme weather phenomena is heating up.

But in the end the greatest potential lies in the smart application of models, aiding better and sounder decisions to be made, rather than in the sophistication of the actual models.

SHORT BIO OF THE EVALUATOR

Pekka Leviäkangas (born in 1962, PhD in technology) has worked in management and expert positions as a civil servant, business manager, expert and researcher. He is currently Associate Professor at Curtin University, in the School of Built Environment and Research Professor at University of Oulu in industrial engineering and management. At Curtin he acts also as Program Director of the Australasian Joint Research Centre of Building Information Modelling, where his main task is to ensure industry engagement with Centre's research portfolio and support and advice the Centre's research strategies. He has acted as Chief Research Scientist, Team Leader and Customer Manager in VTT Ltd. (Technological Research Centre of Finland), Vice-President of Jaakko Pöyry Group subsidiary, Corporate Analyst of Finnish Railways (VR-Group Ltd), R&D Manager of Finnish National Road Administration's South-eastern region, and private consultant. He is an adjunct professor of Tampere University of Technology in the department of Logistics and Business Information. His own research covers innovation management, value analysis, service sciences, project finance, investment, financial and socio-economic analysis, restructuring issues and new technology deployment, particularly in transport sector, but also in other fields such as education, construction and infrastructure management. His research extends all the way to bioeconomy, climate change, meteorology and information intensive services. He has published widely (articles, reports, book chapters, professional media, press) and has more than 20 years' experience on international r&d projects and 30 years working experience in public and private sectors. He has been awarded by National Academy of Sciences (Transportation Research Board), VTT Technical Research Centre, Finnish Road Administration, ITS Japan/ERTICO/ITS America, University of Indonesia, Emerald Publishing Group and scholar funds. He has represented Finland in the OECD's International Transport Forum working groups and in European science & technology researcher networks (COST). He has also been a member of Transportation Research Board committees and sub-committees, Special Interests Groups of the World Congress on Transport Research Society, as well as expert groups of UNECE (United Nations Economic Commission for Europe). He has also contributed to the work of International Union Railways (UIC) and World Meteorological Organisation (WMO/UN). Dr Leviäkangas has advised Finnish companies, agencies and ministries, and during his research career he has been awarded several millions (€) of research funding.

ROADEX Pilot Project reports (1998–2001):
Road Condition Management in the Northern Periphery
Road Condition Management of Low Traffic Volume Roads in the Northern Periphery
Winter Maintenance Practice in the Northern Periphery,
ROADEX Sub Project B Phase I Extended Summary and Conclusions
Winter Maintenance Practice in the Northern Periphery,
ROADEX Sub Project B Phase I State-of-the-Art Study Report
Generation of 'Snow Smoke' behind Heavy Vehicles

ROADEX II reports (2002–2005):
User Perspective to ROADEX II Test Areas' Road Network Service Level
Permanent deformation
Material Treatment
Managing spring thaw weakening on low volume roads
Socio-economic impacts of road conditions on low volume roads
Dealing with bearing capacity problems on low volume roads constructed on peat
Drainage on low traffic volume roads
Environmental guidelines
Environmental guidelines, pocket book
Road management policies for low volume roads – some proposals
Structural Innovations
Monitoring, communication and information systems & tools for focusing actions

ROADEX III Executive summaries (2006–2007):
Managing Rutting in Low Volume Roads
Treatment of Moisture Susceptible Materials
Design and Repair of Roads Suffering Spring Thaw Weakening
Managing Peat Related Problems on Low Volume Roads
Managing Drainage on Low Volume Roads
Socio-economic Impacts of Road Conditions on Low Volume Roads
Environmental Guidelines & Checklist
Monitoring Low Volume Roads

ROADEX III reports (2006–2007):
Drainage guidelines
Deformation mitigation measures
Health considerations
Road condition management policies
ROADEX III Case Study in Greenland

ROADEX IV reports (2009-2012):
Drainage analysis in Ireland
Drainage analysis in Western Isles, Scotland
Drainage analysis in Highland, Scotland
Drainage analysis in Nuuk, Greenland
Drainage analysis in Sisimiut, Greenland
Drainage analysis in Iceland
Drainage analysis in Umeå, Sweden
Use of laser scanning and thermal cameras, Sweden

Drainage Analysis in Region Nord, Norway
Rovaniemi drainage update
Kittila drainage update
Drainage maintenance follow up
Ground pressure demonstration, Scotland
Traction demonstration, Ivalo & Niinisalo, Finland
Timmerleden forest road, Sweden
Gleann Mor forest road, Scotland
Glenfiddich forest road, Scotland
Road 16583 Ehikki-Juokslahti I, reducing permanent deformations by improving drainage
Road 16583 Ehikki-Juokslahti II, reducing permanent deformations by improving drainage
Road 16583 Ehikki-Juokslahti III, geo-reinforcement on peat
Road 16589 Saalahti, reducing Mode 2 rutting by using geo-reinforcement on a silty subgrade
Road 16681 Humalamäentie, homogenization and coarsening of the road structure
Road AC 1093 Morkan – Dikanäs, Västerbotten, Sweden
Road 229 Senja, Norway
Road 582 Selet-Boden demonstrations, Sweden
N56 risk analysis, Drumnaraw-Cashelmore, Co Donegal, Ireland
N59 risk analysis, Newport-Mulranny, Co Mayo, Ireland
Pajala Mine Road Impact Analysis, Sweden
Pajala Mine Road Transport Options, Sweden
ROADEX in Ireland
ROADEX benefits and savings
ROADEX history and index of reports
Climate change
Road widening literature review and questionnaire
Road widening field survey report
Road widening guidelines
Vehicle and human vibrations