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Road cost benchmarking

2 FEBRUARY 2018

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Search Terms:: Benchmark, Construction benchmarking, Construction cost, Cost estimating, Highway project, Highways, Road cost, Road project, Road, Transport economics,

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1. **Advanced Methodology to Determine Highway Construction Cost Index (HCCI)**
   Jeong, H David; Gransberg, Douglas D; Shrestha, K Joseph
   FHWA/MT-17-006/8232-001, 2017
   A highway construction cost index (HCCI) is an indicator of the purchasing power of a highway agency. Thus, it must reflect the actual construction market conditions. However, the current method used by MDT is not robust enough to meet this primary goal due to (1) a significantly insufficient sample size of bid items used in HCCI calculation and (2) inability to address the need to track cost trend of construction submarket segments such as, but not limited to, various project types, sizes, and locations. This study develops an advanced methodology to overcome these apparent limitations using two new concepts: (1) dynamic item basket; and (2) multidimensional HCCIs. The dynamic item basket process identifies and utilizes an optimum amount of bid-item data to calculate HCCIs in order to minimize the potential error due to a small sample size, which leads to a better reflection of the current market conditions. Multidimensional HCCIs dissect the state highway construction market into distinctively smaller sectors of interest and thus allow MDT to understand the market conditions with much higher granularity. A methodology is developed to integrate these two concepts and a standalone 'MDT HCCI Calculation and Bid Analysis System' is developed to automate the HCCI calculation process. The results show an eightfold increase in terms of the number of bid items used in calculating HCCIs and at least a 20% increase in terms of the total cost of bid items used. In addition, the multidimensional HCCIs reveal different cost-change patterns across different highway sectors. For example, the bridge construction market historically shows a very different trend compared with the overall highway construction market. The new methodology is expected to aid MDT in making more-reliable decisions in preparing business plans and budgets with more accurate and detailed information about the construction market conditions. Further, the system is expected to provide insights on the cost trends of a specific item; aid in identifying project types, locations, and sizes with higher construction cost growth; and aid in identifying hidden relationships such as cost-quality relationship. (TRID)

2. **Benchmarking highways England: report to the Office of Rail and Road**
   KPMG, 2016, 121 p.
   The Office of Rail and Road (ORR) acting as the Highways Monitor is required to assess the performance of Highways England across a range of objectives and performance indicators. It is also required to assess the overall efficiency of the organisation and to highlight areas for potential improvement to inform its future business plans. A key part of this process will involve benchmarking Highways England's costs and performance against comparable organisations in the UK and overseas to identify efficiency levels to which Highways England should aspire. The

objective of this study is to review and assess the benchmarking evidence and analysis across all aspects of Highways England's objectives and activities and to provide recommendations over how this evidence could be used and developed by the Highways Monitor and Highways England. (Google scholar)
http://orr.gov.uk/__data/assets/pdf_file/0015/20805/kpmg-benchmarking-highways-england-february-2016.pdf

3. **Benefit cost models to support pavement management decisions**
Chou, E; Wang, S
FHWA/OH report 2012/10, 126 p.
A critical role of pavement management is to provide decision makers with estimates of the required budget level to achieve specific steady-state network conditions, and to recommend the best allocation of available budget among competing needs for maintenance, rehabilitation, and repair (MR&R) projects or among different networks such as among Districts. This research study developed a model/procedure that uses the current state of the network and a specified future target state, condition deterioration trends (based on the MR&R treatments received) expressed as Markov condition transition matrices, and the unit cost of treatments, to determine the minimum total cost required and the corresponding treatment policy to achieve the desired target state of the network. The model can also determine the best network condition state achievable (and the corresponding treatment policy) with a given budget. The corresponding optimization problems with the objective of either minimizing total cost or maximizing overall network condition are formulated as linear programming problems, so that they can be solved very efficiently. The network level optimization model provides a valuable tool to ODOT decision makers to determine the required network budget and optimal budget allocations. (First)
http://home.rta.nsw.gov.au/org/tnsw/bsg/lfms/library/ebooks/2012/138398.pdf

4. **BITRE road construction and maintenance price index and sub-indexes : 2013 update**
Australia. Bureau of Infrastructure, Transport and Regional Economics
This information sheet presents the 2013 re-calibrated BITRE Road Construction and Maintenance Price Index and Sub-Indexes. The revised index is an indicator of the change in input costs faced by the road construction and maintenance industry in Australia. The sub-indexes show the change in road costs by road types and road works activities. (First)
http://home.rta.nsw.gov.au/org/tnsw/bsg/lfms/library/ebooks/2014/151447.pdf

5. **Comparing state DOTs" construction project cost & schedule performance – 28 best practices from 9 states – final report**
Crossett, Joe; Hines, Lauren
AASHTO, 2007, 28 p.
This study provides a succinct overview of twenty eight good practices applied among nine state DOTs that outperform their peers in constructing projects within expected cost amounts and schedules.1 It is based on a detailed analysis of the performance by 20 states in completing more than 26,500 projects over a five year period between 2001 and 2005. The study was initiated in September 2006 at the request of AASHTO's Standing Committee on Quality, as part of a broader effort to encourage DOTs to compare performance among peers. The study focuses on the construction phase of project delivery, during which adherence to cost and schedule is particularly important. In schedule terms, construction is when the public, as one participating DOT attests, expects their state transportation agency to "get in, get out, and stay out," while in budget terms, a project construction cost overrun directly affects the agency's ability to deliver a promised slate of projects on time. The foundations for the study are simple cost and schedule measures – variations of "was the project built for the expected cost," and "was the project built on the expected schedule?" They are already used by most DOTs, but performance results are rarely shared. In the study, these measures are applied to carefully reviewed data supplied by state DOTs themselves that is as close to "apples to apples" as possible.2 To maintain states' anonymity on this sensitive topic, the results comparing states identify only the top performer(s) for each measure by name.
http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/20-24(37)A_FR.pdf

6. **Comparison of Public-Private Partnerships and Traditional Procurement Methods in North American Highway Construction**
Chasey, Allan; Maddex, William; Bansal, Ankit
Transportation Research Record, 2012, No.2268, pp. 26–32
The number of public-private partnership (P3) projects in North America has increased significantly since the early 1990s, as policy makers and transportation officials seek alternative methods to supplement traditional funding

sources to finance and deliver projects. Scholars have compared the cost and schedule overruns of P3 projects against publicly funded projects in mature P3 markets in Europe, but not in the North American market. This paper begins filling that gap by comparing the cost- and schedule-overrun results of 12 completed large-scale (greater than ~US$90 million) P3 highway projects in North America with previous research studies reporting on large-scale design-bid-build (DBB) or design-build (DB) highway projects. P3 project performance data were collected through interviews with project executives, and then findings were used from previous studies of traditional projects for comparative benchmarking data. Research results indicate that the P3 sample cost overruns averaged 0.81% and schedule overruns averaged -0.30%, compared with 1.49% cost overruns and 11.04% schedule overruns for DB projects and 12.71% cost overruns and 4.34% schedule overruns for publicly financed large-scale DBB highway projects. With a relatively small universe of completed construction phase efforts to examine, it is premature to draw explicit conclusions, yet results reported in this study point to tighter control of highway construction costs and delivery schedules when projects are delivered by the P3 method. Findings from this study provide empirical evidence for various theoretical advantages and limitations of P3 projects, as well as serve as a reference tool to compare the appropriateness of different project delivery methods. (TRR)
http://trrjournalonline.trb.org/doi/pdf/10.3141/2268-04

7. **Cost and Schedule Performance Benchmarks of U.S. Transportation Public–Private Partnership Projects - Preliminary Results**
   Ramsey, David W; Asmar, Mounir El
   Transportation Research Record, 2015, No. 2504, pp. 58–65
   The use of public–private partnerships (PPPs) has steadily increased in the United States since the early 1990s. Infrastructure design and construction projects have seen significant variations in costs and schedules. Therefore this paper aims to quantify the cost and schedule performance of recently completed PPP projects in the U.S. transportation sector and compare them to their non-PPP counterparts. The authors collected and verified data from professional data sets, publicly available websites, and structured interviews with key project constituents. The paper presents results from 25 completed PPP transportation projects. All projects in the data set were completed between 1995 and 2013; project costs ranged from $18 million to $2.1 billion and totaled about $14 billion. The results of the analysis showed an average cost growth of 3.22% and an average schedule growth of 1.2%; when compared with traditional design–bid–build delivery, these findings illustrate superior performance. This paper fills a gap in the knowledge of PPP project performance in the U.S. transportation sector and compares the results with previous research efforts in the international PPP market. (TRR)
   http://trrjournalonline.trb.org/doi/pdf/10.3141/2504-07

8. Cost Escalation **in Road and Rail Construction Projects-NSW Experience**
   Raniga, Pravin
   Australasian Transport Research Forum, 2015, Proceedings 30 September - 2 October 2015, Sydney, Australia
   Cost escalation is a topic of much interest for transport planners, project managers and economists who are keen to understand the drivers underlying cost increases in transport projects. Research undertaken in Australia and overseas indicates that there are several underlying drivers including inflationary trends, market factors, scope changes and changing regulatory requirements. This paper focuses on the inflationary aspects of cost increases over the last 15 years in NSW and shows that cost of road and rail projects have increased faster than the CPI (Consumer Price Index). However, transport agencies in NSW use cost escalation factors that reflect general price trends such as the CPI for budget planning. The use of the CPI or other medium term forecasts for escalation is likely to lead to under-budgeting of project costs in terms of outturn dollars leading to potential shortfalls in cash flow budgets of transport projects. This paper develops specific price indices for road and rail construction based on sample data from road and rail agencies in NSW and proposes escalation factors based on 15 year compound average growth rates (CAGR). A “principal component method” was used to analyse cost trends in key road and rail transport construction projects and forecast escalation factors were developed. The research for NSW indicates that road construction project costs have increased at a compound average growth rate (CAGR) of 3.8% compared to the overall general inflationary trend of 2.8% as measured by the CPI. The corresponding figure for rail construction projects is 4.0%.
   http://atrf.info/papers/2015/files/ATRF2015_Resubmission_36.pdf

9. **Cost overruns in transport infrastructure**
   Terrill, Marion; Danks, Lucille
   Grattan Institute, 2016, 84 p.

Over the past 15 years, Australian governments have spent $28 billion more on transport infrastructure than they told taxpayers they would. The cost overruns amounted to nearly a quarter of total project budgets. Western Australia's Forrest Highway between Perth and Bunbury cost nearly five times, and New South Wales' Hunter Expressway cost over four times, the amounts initially promised. Yet despite their sometimes staggering size, cost overruns attract little public attention. There is little interest in understanding and fixing the underlying causes.
Producing more reliable cost estimates is vital. Current cost estimation guidance is inconsistent, omits valuable tools, and can't draw on previous projects because we don't collect the data. Governments set aside large contingency funds for every project, and on many projects this is ultimately spent on add-ons that are poor value for money. (First)
http://home.rta.nsw.gov.au/org/tnsw/bsg/lfms/library/ebooks/2016/163711.pdf

10. **Developing and validating a highway construction project cost estimation tool – final report**
Kyte, Cheryl; Perfater, Michael, Haynes, Stephen; Lee, Harry
VTRC 05-R1, 2004, 39 p.
In May 2002, Virginia's Commonwealth Transportation Commissioner tasked his Chief of Technology, Research & Innovation with leading an effort to develop a definitive, consistent, and well-documented approach for estimating the cost of delivering construction projects. A task force that included Virginia Department of Transportation (VDOT) central and district office staff, Virginia Transportation Research Council staff, Commonwealth Transportation Board members, and a metropolitan planning organization member was formed to either locate a well-founded, tested method for estimating project costs that could be adapted for use by VDOT or develop one. The task group found that a VDOT district had been using an estimation worksheet for several years that produced consistent and reliable results for certain types of roadway and bridge construction. The task group determined that no other method examined had the specificity and potential of this tool. The project team expanded the tool by collecting extensive project data and obtaining evaluations of VDOT project management personnel statewide to develop it further. The existing Excel worksheet with roadway and bridge estimates was expanded to include construction engineering, to be applicable for interstates, and to generate estimates for right-of-way and utilities costs. Data on completed projects were collected from all VDOT districts to help calibrate the model further to account for cost variations across the state. The task group also recognized early on that a very strong focus on project scoping was essential to accurate project estimation. A previous VDOT scoping committee had determined that VDOT did not have a consistent, uniform method that was being used statewide to scope projects. As a result, project cost estimates made at the scoping stage often did not hold up over time because key project features were invariably overlooked. The result was inaccurate estimates. Testing of the cost estimation tool was completed in the summer of 2003. Analysis of a sample of completed VDOT construction projects throughout the state showed that the tool yielded results that, on average, differed from actual final project costs by 22 percent. After further modifications, the Project Cost Estimation System (PCES), as it was named, became a fully operational system for VDOT in October 2003. The PCES is composed of three elements: a cost estimation tool, an improved scoping process, and a project development website. The responsibility for maintaining and updating the PCES now rests with VDOT's Scheduling & Contract Development Division (TRID)
https://rosap.ntl.bts.gov/view/dot/19663

11. **Effects of varying functional classification on cost of roadways**
Glessen, Steven Vander; Kladianos, James R; Young, Rhonda Kae
Journal of transportation engineering: 2009, Vol. 135,No. 1, pp. 37-42
Weakened purchasing power and dwindling funds are causing transportation agencies to rethink their engineering practices in order to achieve more cost effective designs. Increasing public awareness of the impact of highway construction on the surrounding environment has also resulted in pressure on transportation agencies to minimise impacts by incorporating context sensitive solutions in their designs. Major design criteria, such as design speed and design traffic volume, ultimately determine how expensive a project will be and the level of environmental impacts that it will have. Selection of design criteria, however, begins with the determination of the functional classification of the roadway. The purpose of this technical note is to determine the costs and impacts of several typical roadways with different functional classifications, using typical design criteria for each functional classification. This work is not presented as fundamental research, but is intended to provide decision makers with an estimated range of costs and impacts associated with different functional classifications in different types of terrain, for use in making early policy level decisions. (First)

12. **Essays on cost estimations and their uncertainties in transportation projects**
Welde, M

Norwegian University of Science and Technology, 2011, 124 p.
This thesis deals with risk and uncertainity in the planning of transport projects. The overall objective is to reveal potential risks and uncertainties in road projects and propose methods by which forecasts can be made with increased accuracy. The main focus is on the period after the project is implemented. The first part of the thesis consists of an introduction containing a discussion of the role of cost-benefit analysis in the impact assessment of road projects and in the decision making process. The concepts of risk and uncertainity are introduced and their sources and consequences are discussed from both an international and a Norwegian perspective. The second part of the thesis consists of six individual papers. The main findings in the papers dealing with forecast inaccuracies in Norwegian transport planning are as follows: Traffic forecasts is on average 2.5 per cent higher than forecasts but variations are large. Inaccuracies are common among all project types and sizes and estimates do not become more accurate over time. The main conclusion in this thesis is that there are risks inherent in Norwegian transport appraisal which have not been brought to the attention of decsion makers. (First)
http://home.rta.nsw.gov.au/org/tnsw/bsg/lfms/library/ebooks/2012/132839.pdf

13. **Estimating and benchmarking transport infratsucture costs**
Tsamboulas, Dimitrios
2nd session Benchmarking of Transport Infrastructure Construction Costs, 2014, September 8th Geneva
This presentation workshops good practices and new tools for financing transport infrastructure.
https://www.unece.org/fileadmin/DAM/trans/doc/2014/wp5/7_Mr_Tsamboulas_WP5_workshop_8Sept2014.pdf

14. **Estimating highway preconstruction services costs : volume 1 : guidebook**
National Cooperative Highway Research Program
NCHRP research report, 2016, Vol. 826
This report presents guidance for state departments of transportation (DOTs) and other agencies for estimating preconstruction services (PCS) costs for transportation project development. PCS refers to a varied assortment of project-specific engineering and other professional services required before construction begins on a bridge, highway, or other transportation project, whether provided by agency staff or consultants. Volume 1 addresses principal sources and components of PCS costs, PCS estimating methodologies, trends (such as changes in design and construction technology, design standards, program requirements, and professional workforce) likely to affect PCS costs, and advice on agency policies and practices that can help control program risk through improved PCS cost estimation. The accompanying volume 2 documents the development, testing, validation, and packaging of an accurate, consistent, and reliable method for estimating PCS costs. (First)
http://home.rta.nsw.gov.au/org/tnsw/bsg/lfms/library/ebooks/2016/163237.pdf

15. **Estimating highway preconstruction services costs : volume 2 : research report**
National Cooperative Highway Research Program
NCHRP research report, 2016, Vol. 826, 98 p.
This report presents guidance for state departments of transportation (DOTs) and other agencies for estimating preconstruction services (PCS) costs for transportation project development. PCS refers to a varied assortment of project-specific engineering and other professional services required before construction begins on a bridge, highway, or other transportation project, whether provided by agency staff or consultants. This volume documents the development, testing, validation, and packaging of an accurate, consistent, and reliable method for estimating PCS costs. Volume 1addresses principal sources and components of PCS costs, PCS estimating methodologies, trends (such as changes in design and construction technology, design standards, program requirements, and professional workforce) likely to affect PCS costs, and advice on agency policies and practices that can help control program risk through improved PCS cost estimation. (First)
http://home.rta.nsw.gov.au/org/tnsw/bsg/lfms/library/ebooks/2016/163238.pdf

16. **Estimating manual – road and rail projects**
Jaensch, Ashley
Dept of Planning, Transport and Infrastructure, South Australia, 2015, 81 p.
Accurate and reliable project cost estimates are fundamental to achieving successful project outcomes. This new release of the Estimating Manual – 'Estimating Manual for Road and Rail Projects' builds on the best practices of earlier versions and introduces new practices to support estimate development, review and approval. It addresses issues relating to contingencies, risks and escalation – all of which have a major impact on project cost. The manual provides the business context and instructions for estimating, covering the various stages from strategic estimates

through to final cost. It links to and provides practical tools and information, including electronic spreadsheets. The manual captures improvements from recent reviews, best practice studies and suggestions from practitioners. It demonstrates the department's commitment to the adoption of the Federal Department of Infrastructure and Transport's 'Best Practice Cost Estimation for Publicly Funded Road and Rail Construction (the Standard)'. (Website) https://www.dpti.sa.gov.au/__data/assets/pdf_file/0003/173532/Estimating_Manual.pdf

17. **Forecasting Completed Cost of Highway Construction Projects Using LASSO Regularized Regression**
Yuanxin, Zhang; Edward, Minchin R; Duzgun, Agdas
Journal of Construction Engineering and Management, 2017, Vol. 143, No. 10
Finishing highway projects within budget is critical for state highway agencies (SHAs) because budget overruns can result in severe damage to their reputation and credibility. Cost overruns in highway projects have plagued public agencies globally. Hence, this research aims to develop a parametric cost estimation model for SHAs to forecast the completed project cost prior to project execution to take necessary measures to prevent cost escalation. Ordinary least-square (OLS) regression has been a commonly used parametric estimation method in the literature. However, OLS regression has certain limitations. It, for instance, requires strict statistical assumptions. This paper proposes an alternative approach—least absolute shrinkage and selection operator (LASSO)—that has proved in other fields of research to be significantly better than the OLS method in many respects, including automatic feature selection, the ability to handle highly correlated data, ease of interpretability, and numerical stability of the model predictions. Another contribution to the body of knowledge is that this study simultaneously explores project-related variables with some economic factors that have not been used in previous research, but economic conditions are widely considered to be influential on highway construction costs. The data were separated into two groups: one for training the model and the other for validation purposes. Using the same data set, both LASSO and OLS were used to build models, and then their performance was evaluated based on the mean absolute error, mean absolute percentage error, and root-mean-square error. The results showed that the LASSO regression model outperformed the OLS regression model based on the criteria. (TRID)

18. **Highway construction cost comparison survey : final report**
Washington State Department of Transportatoin 2002, 17 p.
Over the past few years the Washington State Department of Transportation (WSDOT) has been asked numerous questions related to the cost of highway construction in Washington State as compared to other states. In order to address these questions, WSDOT has completed a survey of other states. This report is a summary of that survey. Twenty five states responded to the survey. Over fifty WSDOT interchange projects were considered as potential candidates for the survey. A team was assembled to review the projects. The team looked for a representative project that would be universal in all the states. The SE 192 nd Avenue Interchange Project on SR 14 met these criteria. The survey form was sent to members of the AASHTO Subcommittee on Design. Participants were asked to provide the unit costs in their states for the bid items included in the survey, and the percentage of project cost devoted to mobilization, preliminary engineering, and construction engineering. The information gathered provides detail for calculation of the construction cost of the interchange and the construction cost of a lane mile of highway. (WSDOT is frequently asked how much it costs to construct a lane mile of highway.) Survey participants were asked to identify the range of project cost in their state for right of way, environmental documentation (SEPA, NEPA, permitting), and environmental compliance and mitigation associated with construction. Participants were also asked if their state has a state prevailing wage law in addition to the federal prevailing wage law. The survey form is included in Appendix B. (TRID)
https://rosap.ntl.bts.gov/view/dot/14953

19. **Infrastructure benchmarking report**
BITRE, 2015
Australian, State and Territory Governments are committed to improving the infrastructure that is critical to efficient, productive and equitable operations of our economy. Achieving this objective requires efficient procurement processes and careful examination of costs to ensure value for money in infrastructure investments. Governments have cooperated to conclude the first national pilot benchmarking of infrastructure procurement processes and construction costs (as recommended by the 2014 Productivity Commission Inquiry into Public Infrastructure and agreed by the Council on 28 August 2014). This report covers the findings of the initial benchmarking and outlines plans for continued and improved future monitoring of infrastructure procurement performance and construction costs. The analysis was undertaken by the Bureau of Infrastructure, Transport and Regional Economics (BITRE) for the Infrastructure Working Group of the Transport and Infrastructure Council. (Google scholar)

http://transportinfrastructurecouncil.gov.au/publications/files/Infrastructure_Benchmarking_Report.pdf

20. **International comparison of road infrastructure investment**
    Hay, Neil
    ATRF 31st Australasian transport research forum 2008, 14 p.
    It has been argued that transport infrastructure in New Zealand is consistently under-funded and is restricting economic growth arising from gains in productivity. This paper compares recent investment levels and funding mechanisms for road infrastructure in New Zealand with those in Ireland and Norway. The findings are that New Zealand road transport investment is comparable in relation to other countries, while the available information suggests the road transport network is performing well. In the light of this and other evidence, it is suggested that there are questions over whether the level of investment in transport infrastructure is restricting economic growth in New Zealand. The discussion identifies a number of issues, which are likely to impact upon the outcomes of road infrastructure investment. The following section briefly reviews the significance of transport infrastructure investment and policy. Section 3 compares international data on transport investment and makes other relevant comparisons. Section 3 also includes an investigation of similarities and differences between New Zealand, Ireland and Norway. Section 4 sets out some conclusions based on the evidence**.**
    http://atrf.info/papers/2008/2008_Hay.pdf

21. **International construction costs 2017: cost certainty in an uncertain world**
    Christie, Edel
    Arcadis, 2017
    This latest edition of our annual International Construction Costs report details the relative cost of construction in 44 of the world's major cities. Last year's theme was 'forewarned is forearmed', where we highlighted that cost was one of the key factors that determine which developments go ahead and deliver positive outcomes. We made the case that access to reliable data and insight, combined with effective control, was a key part of the toolkit for successful delivery. In 2017, our theme is Cost Certainty in an Uncertain World. Risk can result in increased costs, and given construction's poor record in improving productivity, there is a possibility that growing uncertainty might become a barrier to the successful delivery of project investment. Given the significant shift in the political landscape seen in 2016, the challenge for businesses and government has increased in many markets. Meeting investment decision criteria and achieving predictable project outcomes may be increasingly challenging in many markets, but will remain essential if vital infrastructure investment is to be delivered. Agility is a valuable capability in uncertain markets. The ability of investors and developers to flex their approaches to project procurement, finance and delivery will continue to be extremely valuable as politics and markets continue to be buffeted by both unexpected events and shifts in the business cycle. However, in seeking to be agile, developers and investors may have to relinquish some level of control over the detail of project delivery. Ultimately the challenge for clients remains how to make smart investments in an increasingly uncertain world. Having access to high quality data and current, relevant market insight is one tool that will help clients to successfully navigate these challenges. (Website)
    https://www.arcadis.com/media/3/6/8/%7B368131AD-E31B-4552-821B-1F66DC62F805%7DICC%202017_FINAL_singles.pdf

22. **McKinsey road and bridge benchmarking tool**
    McKinsey & Co, 2018
    It is notoriously hard for national and local governments or even private operators to accurately estimate the cost of building roads and bridges. This results in wide variations in the prices negotiated for similar projects. Moreover, completed projects often come in above the agreed price and schedule—as their scope drifts, change orders are made when it is found that essential items have been overlooked in the original contract, and poor engineering or poor planning cause rework and further delays. McKinsey's road-and-bridge-benchmarking tool gives asset owners a far more realistic view of what their projects should cost. It details more than 17,000 completed road-and-bridge-construction projects with price tags of between $100,000 and $300 million, and it breaks down the overall cost of each to show the preliminary engineering cost, the construction-engineering cost, and the construction cost. Analysis then reveals the average cost of similar types of project of similar size and scope. There are 12 project types in all, including the widening of freeways, bridge reconstruction, and building of new roads. (Website)
    https://www.mckinsey.com/industries/capital-projects-and-infrastructure/how-we-help-clients/road-and-bridge-benchmarking

23. **NRA Pavement cost model: manual**
Buckland, T
Transport Research Laboratory project report, 2012, No. 594, 34 p.
Road authorities require pavement information and decision support tools to assist them in the management of their asset, particularly in determining the budgets and maintenance that are needed on their network. This report covers the modelling methodology and processes that have been developed and implemented in a pavement cost model for the National Roads Authority, Ireland. The model has been developed so that the reference data and imported network data link into a workspace, which is then used as the calculation space during an analysis. A user can choose to create a range of different analyses in order to provide answers and associated sensitivity analysis to issues such as how much budget is needed to maintain the network in a steady state. (First)
http://home.rta.nsw.gov.au/org/tnsw/bsg/lfms/library/ebooks/2012/136516.pdf

24. **NRA Pavement cost model: model development and data issues**
Transport Research Laboratory project report, 2012, No. 597, 16 p.
This report documents a number of issues that were encountered during the development of a pavement cost model for the National Roads Authority, Ireland. These issues were primarily brought about because the data was being used for new purposes in predicting maintenance on the Irish network. The issues are highlighted in this report so that any future development of a pavement cost model on this, or any network can take them on board at the design stage. (First)
http://home.rta.nsw.gov.au/org/tnsw/bsg/lfms/library/ebooks/2012/136517.pdf

25. **Reduction of construction time and cost of road pavements**
PIARC. Technical Committee Rad Pavements (D2), 2012, R09EN
For many different reasons road authorities who want to build, rehabilitate or repair a pavement wish to do this in the shortest possible construction time and for the lowest possible initial cost. These reasons can be related to their limited available resources, to benefit the road users by a minimal disruption of the traffic flow or to a policy of environmental friendliness or road safety. However construction time and construction cost are often conflicting parameters. This publication describes a list of methods to optimise time and cost for a given quality. It analyses them and gives a number of case histories illustrating the different techniques that are available and their use. (First)
http://home.rta.nsw.gov.au/org/tnsw/bsg/lfms/library/ebooks/2013/143097.pdf

26. **State highway cost allocation studies**
Balducci, Patrick
NCHRP synthesis, 2008, Vol. 378, 65 p.
This synthesis examines the history and evolution of Highway Cost Allocation Study (HCAS) practice, and reports on the current state of the practice. This report is designed to aid states by laying the foundation required to build on current thought and improve current HCAS methods. This report addresses numerous issues, including what states have completed cost allocation studies, the conceptual basis of HCAS methods, methods used to allocate the costs associated with many highway program elements, methods for revenue attribution, and emerging HCAS issues. Information for the study was obtained through review of literature and a survey of state transportation agencies that have performed HCASs. Eleven key states are highlighted: Arizona, California, Idaho, Indiana, Kentucky, Maine, Minnesota, Nevada, Oregon, Texas, and Vermont. The study also reports on survey responses on procedures for completing both traditional HCASs and for conducting HCAS analysis in new and emerging areas. (First)
http://home.rta.nsw.gov.au/org/tnsw/bsg/lfms/library/ebooks/2009/113623.pdf

27. **Timing of Cost Certainty in Highway Construction Project Delivery: Perceptions Versus Empirical**
Antoine, Arthur L C; Molenaar, Keith R
Transportation Research Board 97th Annual Meeting, 2018
The early timing of cost certainty during highway project delivery is a primary reason for using alternative contracting methods. However, the actual timing has not been documented by researchers. This study addresses the gap in knowledge by quantitatively showing how the traditional design-bid-build (D-B-B) delivery method and the alternative contracting methods of construction manager/general contractor (CM/GC) and design-build (D-B) compare in the timing of cost certainty on US highway construction projects. The study performs a novel comparison of the performance of CM/GC versus D-B projects procured by best value. The results reveal a difference between the perceptions of agency decision makers and empirical project performance. Though a comparison of empirical project data from 30 completed projects, findings from experts in a Delphi study, and a review of the limited relevant

literature, this paper highlights contradictory findings and inconsistencies in the relative performance among the different sources of information. For the alternative contracting methods, the empirical project results show earlier timing for cost certainty than perceived by agency experts. In particular, results reveal that agency personnel underestimate the potential time savings of CM/GC because they believe that D-B is the faster to the point of cost certainty. However, empirical data show CM/GC is substantially faster. The authors emphasize the need for further research to clarify the contradictions and inconsistencies in order to produce reliable, validated results that can present useful recommendations for application in highway construction project delivery. (TRID)