Mass-haul Environmental Impact Minimisation

A practical method for greening road procurement

A Sustainable Built Environment National Research Centre (SBEnrc) Industry Report

Sustainable
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National Research Centre

Project Partners

Synopsis

A small but effective change is recommended for procurement processes related to mass-haul/earthworks operations on major road projects. This practical system for motivating GHGE minimisation is presented as a series of interventions in the procurement cycle of major road projects. Recommendations for all procurement phases are based on reducing the effort/work required for mass-haul activities. Hauls planned using a contractor's preferred methods can be used to calculate comparative GHGE reductions by using the planned effort/work involved in the physical movement of loads. This small change to existing methods has the potential to deliver a major reduction in GHGE from earthworks mass haul during construction of major road and other infrastructure projects.

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INTRODUCTION AND CONTENTS

Procurement system innovation

Problem: *Industry needs a method to minimise GHGE arising from mass-haul operations during the construction of major roadworks.*

Solution: *Structured procurement interventions to encourage and reward change, supported by an effective and practical alternative method for calculating, estimating, evaluating and monitoring GHGE using the principle of 'work' calculated from a mass haul plan.*

Purpose of this industry report

This industry report is intended to provide a practical method for reducing one significant component of greenhouse gas emissions (GHGE) produced during the construction of major road projects. Mass haul, a significant producer of GHGE, is defined as the movement of soil, aggregate and rock, around the site, as well as to and from the site.

This method is based on the assumption that reducing fuel consumption will also reduce GHGE. One way of reducing fuel consumption is to motivate and enable contractors to reduce both the amount of material moved and the total distance the materials travel.

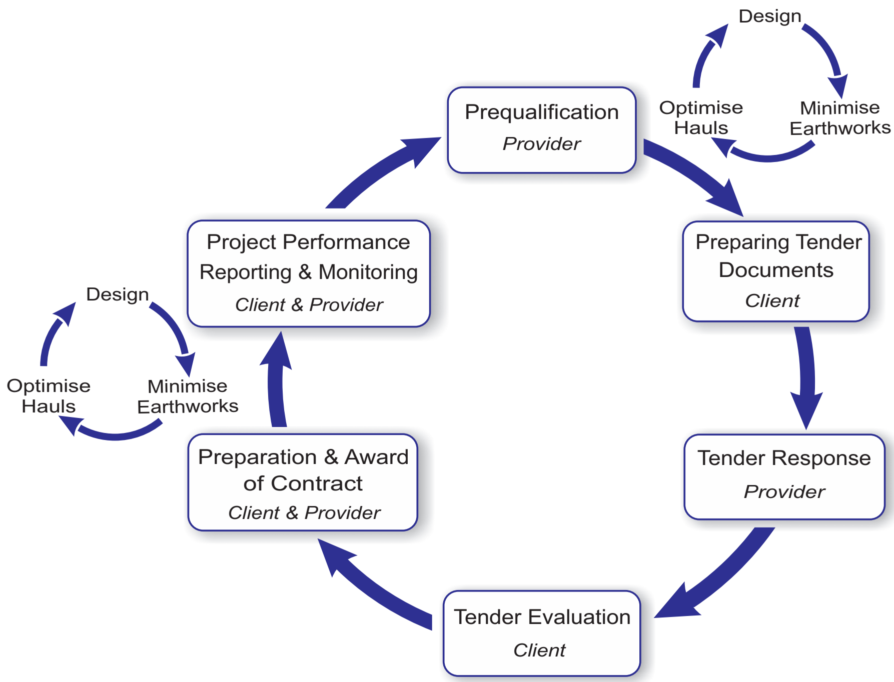

Figure 1: Closed loop procurement cycle for major road works

This method is presented as phases in a procurement cycle. Each phase, as shown in Figure 1, is indicative of the major roadworks procurement phases currently in use within individual state transport authorities.

The cycle includes contractor pre-qualification which is now an important addition to traditional processes for all major works procurement.

There are many ways to reduce GHGE but this guide specifically targets and is limited to a small but significant event in the life-cycle of a road, the GHGE produced by mass-haul during construction. From the view point of sustainably, reducing GHGE is an important objective. The procurement system innovation for each phase aims to encourage GHGE reduction through provision of recommended additional components.

The earlier in the procurement cycle design changes to the road alignment are considered, the more potential value for money can be obtained. To benefit from the possible reductions to GHGE during construction of major roadworks, design should not be separated from the opportunity to optimise earthworks.

In Figure 1, additional design cycles indicate two opportunity points to minimise earthworks in addition to optimising hauls through design. The first opportunity is before the tender documents have been developed. The second opportunity is once the contractor has been selected.

Contents

The Table of Contents provides an easy guide to procurement system innovation for the problem of 'greening' major roadworks.

The assumption underpinning the procurement system innovation is that requesting sustainability activities for each procurement phase will provide a small, but relatively significant overall reduction in GHGE during major roadworks.

There are two parties targeted for procurement system innovations: the client and the provider (contractor).

Client: *For this report, the client is an Australian state road authority with responsibility for major roads. However, the model is applicable to any agency procuring road, rail, or other projects involving major earthworks.*

Provider: *Providers are the general contractors in whatever configuration the procurement model demands (including integrated procurement forms).*

Procurement Process	Essential Procurement Activity	Page
Pre-qualification	• Have the means and method for preparing unconstrained and constrained optimal mass-haul plans and monitoring, controlling & reporting against constrained mass-haul plans.	5
Earthworks minimisation (two opportunities in the procurement process))	• Overall project cost and environmental impact can be reduced by incorporating contractor knowledge of mass-haul during the design stage.	9
Preparing tender documents	Requests: • Earthworks Method Statement • Mass-haul plan (unconstrained) as a table-of-hauls • Mass-haul plan (constrained) as a table-of-hauls	11
Tender response	Provides: • Creation of an earthworks method statement. • An idealised optimal mass-haul plan (unconstrained) represented as a table-of-hauls. • An operational optimal mass-haul plan (constrained) represented as a tables-in-the-hauls.	15
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Preparation and Award of contract	Award contract	23
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	• Calculate work/effort for table of actual hauls and compare with baseline proposal (constrained) • Assess performance and feedback into Contractor Pre-selection Profile	

Table 1: Table of Contents

Industry need

Strategy

To encourage industry to choose sustainable practices for reasons other than lowest price. Industry needs a method to minimise GHGE arising from mass-haul operations during the construction of major roadworks.

For major roadworks, one of the most significant components is the handling and movement of mass materials (soils, aggregates, rock) around the project site, as well as to and from the site. These mass-haul/earthworks operations can cost up to 30% of the project. Table 2 provides a sample of recent major projects in WA and NSW which average 27.3%, typical for projects valued over $50m. The sample of projects without bridges averaged 28%.

However, it is important to realise that the negative environmental impact of the physical effort and movement of men, machines and materials of these operations is often much greater than the corresponding dollar value.

The problem with the current situation is that earthworks operations are necessarily high consumers of diesel fuel. These operations consume millions of litres on large major roadworks projects, and are consequently high contributors to the GHGE.

Optimising mass haul operations has the potential to reduce the cost of construction, as well as adding to the total reduction of GHGE for the life-cycle of the road. While the relative significance of construction phase impacts versus the full life-cycle impact may be small, construction is nevertheless one contributor to the negative environmental impact of a road. It should be considered along with other factors, such as reducing the embodied energy of materials or preventing vegetation reduction.

State	Project	Construc-tion	Earth works	Earthworks
	type	Cost ($m)	Cost ($ m)	Cost (%)
NSW	mixed	793.0	141.6	17.9
WA	mixed	499.0	135.8	27
WA	mixed	387.0	109.2	28
WA	mixed	218.5	61.7	28
WA	mixed	191.0	55.5	29
WA	mixed	150.0	35.1	23
NSW	road	100.0	20.9	20.9
WA	mixed	88.3	23.8	27
WA	road	87.2	30.2	35
WA	road	87.2	25.1	29
NSW	mixed	69.3	20.1	29
WA	road	62.2	16.9	27
NSW	mixed	60.4	20.5	33.9
Ave.		**214.9**	**53.6**	**27.3**

Table 2: Sample of major roadworks & earthworks (WA & NSW)

Current construction industry practice uses fuel consumption as a proxy for GHGE. Measuring the GHGE produced from road construction activity is difficult for two reasons: fuel consumption can only be calculated after the project is completed, and the data is aggregated for all phases of the construction project. This retrospective approach does not assist in the development and management of pro-active fuel reduction strategies.

Solution

An effective and practical alternative method for calculating, estimating, evaluating and monitoring GHGE using the principle of 'work' calculated from a mass haul plan.

As an alternative to measuring GHGE and in order to derive a practical and feasible solution to planning and controlling environmental impact, a new method has been developed. This method is based on the use of work or effort as a relative proxy for GHGE.

The relative measure required to minimise the mass-haul is based on four assumptions:

1. Fuel consumption from the fleet engaged in mass-haul operations is an indicator of GHGE.
2. The effort required to move mass is an indicator of fuel consumption.
3. Effort can be reduced if the amount of material moved, the distance travelled or the height lifted can be reduced.
4. GHGE can be reduced if the amount of mass-haul work/effort can be reduced.

This practical method for greening road procurement adopts the work/effort concept as the primary mechanism for reducing GHGE.

PREQUALIFICATION

Contractor pre-qualification is the outcome of a process that evaluates an organisation's ability to complete contracts satisfactorily before they are invited to tender. This motivates contractors to improve performance.

Procurement system innovation

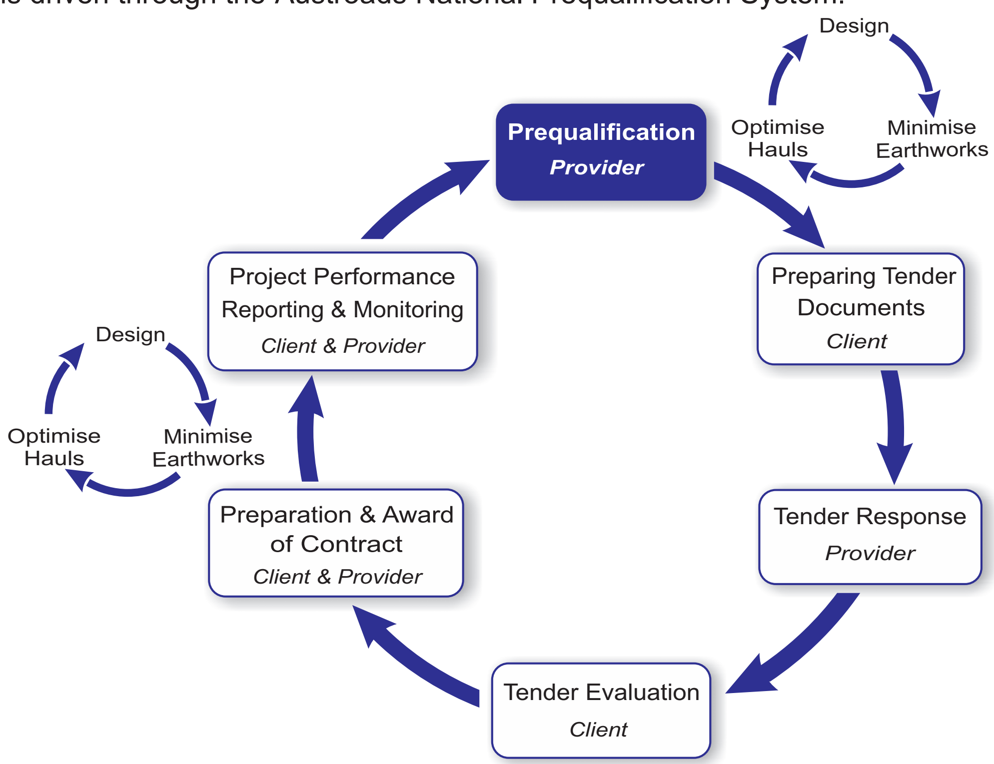
Client:

1. Require contractors to have management systems with the capacity to create, monitor, report and adapt constrained and unconstrained optimal mass-haul plans
2. Require sustainability credentials.

Provider:

1. Have the means and method for preparing unconstrained and constrained optimal mass-haul plans and monitoring, controlling & reporting against constrained mass-haul plans.
2. Have expertise in calculating, monitoring and reporting GHGE.
3. Have sustainability credentials.

This is driven through the Austroads National Prequalification System.



What is the current National Prequalification System?

The National Prequalification System provides the framework and the state authorities have the responsibility of administering the scheme:

- The National Prequalification Scheme for Civil (Road and Bridge) Construction Contracts came into operation on 1 January 2011.
- The national program is operationalised by the state & territory road authorities.
- A process of nationalisation was undertaken by Austroads including the state road authority members.
- The system enables information about contractor performance to be shared.

For road works, the five levels of prequalification (R1–R5) are based on descriptions of the construction of general roadworks including: earthworks, pavement and drainage works that could reasonably be satisfactorily constructed by a general civil engineering contractor with the relevant experience and background.

Major works would probably require R3–R5 capabilities and capacities as noted in these tables that focus on earthworks and management systems. Table 3 shows earthworks management systems relating to categories R3–R5. These relate to the means required to develop mass-haul plans and monitor the project haul, fuel and GHGE results.

The contractor performance report is completed at the end of the project to inform future tender evaluation.

Ongoing satisfactory contractor performance is an essential component of continuation of prequalification status.

Category	Indicative description of earthworks management systems
R5	R4 activities but larger in magnitude and complexity, which may include: • complex grade separated interchanges, multiple carriageways • non-standard and heavy duty pavements (including variations of type and scale within the project) • complex project management • complex consultant team coordination and/or management • complex design management.
R4	R3 activities and activities similar to R3 but more complex. Significant subcontracting is often involved. Additional features may include: • mechanically stabilised earth construction greater than 5 m in height and other substantial retaining structures • grade-separated intersections • consultant team coordination and/or management • design management • complex project management
R3	R2 activities as well as any number of the following: • general earthworks exceeding 5 m in cut or fill • mechanically stabilised earth construction to a nominal 5 m in height • excavation in hard rock where blasting is likely to be required • special foundation and/or subgrade and subsoil drainage treatments • non-complex design management • moderately complex project management including subcontractor management

Table 3: Contractor's level of prequalification (Austroads, 2010)

The criteria listed by Austroads for contractor performance reporting include:

- time management and progress
- contract management
- utilisation of management systems
- relationship management
- quality of work.

Contractors are given a score from 0 to 10 for each sub-criterion under the general criteria.

Earthworks activities are not assigned a discrete score, except under:

- Criterion 5) Quality of work
  Subsection b) Construction
  Part i) Earthworks.

The standard of work is measured against the requirements of the project specifications, including any sustainability requirements.

What are sustainability credentials?

National Greenhouse and Energy Reporting

- National Greenhouse and Energy Reporting (NGER) Act 2007.
- Companies with annual emissions above a certain threshold must report their emissions to the Department of Climate Change and Energy Efficiency.
- Threshold is currently 50 kilotonnes CO_2-e.

Table 4 shows NGER reporting data for several corporations in the civil contracting and mining industries. Leighton Holdings, a large corporation that owns and controls three major construction companies—Leighton Contractors, Thiess and John Holland—reported total direct (Scope 1) greenhouse gas emissions of 775,441 tonnes CO2-e in 2010–11.

Corporation	Scope 1 Emissions (t CO_2-e)
Leighton Holdings (John Holland, Thiess, Leighton)	775,441
John Holland, Thiess, Leighton	Average: 258,480
Downer EDI	217,793
Lend Lease	106,020
Golding Contractors	61,795
Laing O'Rourke	52,290

Table 4: National Greenhouse and Energy Reporting Information 2010–11

- According to industry sources, 70% of Leighton's emissions were from the combustion of diesel.
- But emissions reports do not contain information from separate projects
- Amounts are indicative of both the number of construction projects and the high levels of emissions produced during major roadworks construction.

The NGER technical guidelines[1] make provision for different methods for monitoring GHGE arising from specific activities, and the most common method is to monitor chemical imputs rather than to directly measure GHGE. Inputs, or fuel consumption, can be collected for:

- Different construction activities (e.g. tunnelling, excavation, transport, piling etc.)
- Fuel type (diesel, petrol, LPG)
- Equipment (trucks, excavators, generators, cranes etc.)

1 Technical guidelines for each year may be found at http://www.climatechange.gov.au/government/initiatives/national-greenhouse-energy-reporting/publications/technical-guidelines.aspx

- Zones (different parts of the project or infra-structure e.g. road, shared path, bridge etc.)

Focusing on these different categories of construction could provide important data for benchmarking of emissions from specific projects and activities within projects. The benchmarking across similar types of infrastructure and for sub-components of infrastructure could provide national standards such as kg CO_2-e/km of road built.

Infrastructure Sustainability Rating Scheme

The Australian Green Infrastructure Council (AGIC) launched its Infrastructure Sustainability (IS) Rating Scheme in February 2012. The IS rating tool provides sustainability ratings for the design, construction and operation stages of Australian infrastructure projects. As one purpose of the prequalification system is for contractors to demonstrate they have methods to manage GHGE, the IS rating tool provides an alternative indicator for detailed analysis of a contractor's systems.

Each of the agencies that are partners to this project—Main Roads WA, Queensland Transport and Main Roads and NSW Roads and Maritime Services—have joined AGIC and have either trialed or are intending to trial the IS rating tool and one possible outcome is that the certification be included in national prequalification.

- IS rating tool requires monitoring, modelling and minimising GHGE.
- GHGE reduced by 15–25 % (or more) below the reference footprint, achieve higher score
- IS ratings applied to infrastructure projects at the design stage, the end of construction stage and during operations.

Moves toward AGIC certification be included within the National Prequalification Scheme, for both clients and providers of national infrastructure, is indicative of changing industry attitudes and behaviours.

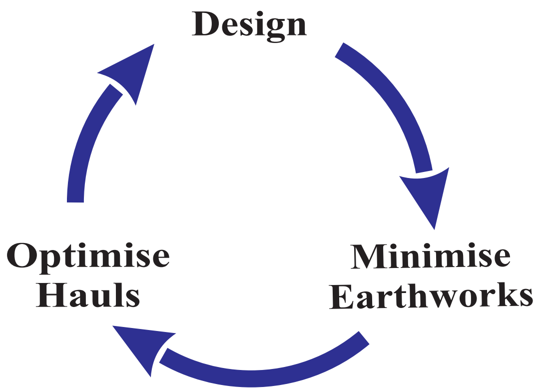


Figure 2: Design intervention cycle

EARTHWORKS MINIMISATION OPPORTUNITIES

In order to maximise 'value for money', clients need to aim for minimisation as well as optimisation of mass haul through contractor involvement with the design. Depending on the procurement structure, there are two opportunities for minimisation of mass-haul through design changes; early and late. Integrated project delivery procurement systems as well as those incorporating early contractor involvement (ECI) provide early opportunities before fixing the alignment, whereas conventional procurement models only allow late opportunities for minimisation after the alignment is fixed.

Procurement System Innovation

Client:

1. Overall project cost and environmental impact can be reduced by incorporating contractor knowledge of mass-haul during the design stage.

Provider:

1. Contractor knowledge, either from a mass haul consultant or direct engagement with a contractor, can be provided in the design stage before the road alignment is fixed.

Early Contractor Involvement:

1. Early use of contractor knowledge during the design can help minimise hauls, not just optimise hauls.
2. Road alignments can be adjusted to avoid long hauls or unbalanced materials (by type).

Late Contractor Involvement:

1. Traditional tender arrangements only allow for minimal design change, such as widening batters and cuts. Hauls can be optimised but it is too late to make design changes to minimise hauls.

Earthworks constructability knowledge during design

Overall project cost and environmental impact can be reduced by incorporating contractor knowledge of mass haul during the design stage and before the road alignment is fixed.

The procurement cycle includes two design–for–minimisation intervention points. The first lies between prequalification and tender documentation, normally referred to as early contractor involvement[1]. The second lies after the design is complete and the contractor has been engaged and is looking for better ways to construct the road.

The use of constructability knowledge and methods to change the design, has the capacity to identify opportunities for minimizing total movement of materials.

More experienced contractors will sort by material suitabilities and consider site constraints such as haul routes, timing of material availability, alternative material use (crushing for engineered fills in lieu of buying crushed rock, etc.). They are able to identify hauls of excessive length and to suggest small changes to the road alignment, cut or batter width, or other minor changes that can nevertheless significantly impact on the total movement of materials. Anecdotal evidence suggests that, with early design intervention, this impact can commonly be as much as 30% of total movement. The key to this process is the provision of sufficient design information, such as geotechnical data, before detailed design.

Contractor knowledge can be derived from both contractors or specialised consultants:

- Contractors can provide their knowledge during construction (late intervention) or through specialised procurement systems that allow design-phase involvement (early).
- Specialised consultants can be engaged during the design phase to provide detailed constructability analysis, including knowledge of mass haul, to assist in design development.

Commissioning a constructability analysis before tendering is a new initiative of the Finnish Transport Agency. It not only allows mass haul minimisation, but it helps identify risks in production planning sufficiently early to react to them during tendering.

Case study

Bruce Highway Cooroy to Currra Section—Queenland Transport & Main Roads

Abigroup Construction Pty Ltd worked on the Bruce Highway—Cooroy to Currra Section (2009-2010). Initial workshops conducted by Queensland Department of Transport and Main Roads resulted in a $100m (approx) ECI contract for contractor participation during design. Changes to the design of earthworks and drainage supported cost reductions and reduced material being hauled. Total savings in the cost of mass haul were estimated to be $19/m3 for 600,000 m3 or over $1m, with a reduction in fuel use of approximately 60%.

1 There are several procurement strategies to achieve this. One approach popular in Australia is a specific form of engagement known as Early Contractor Involvement—ECI.

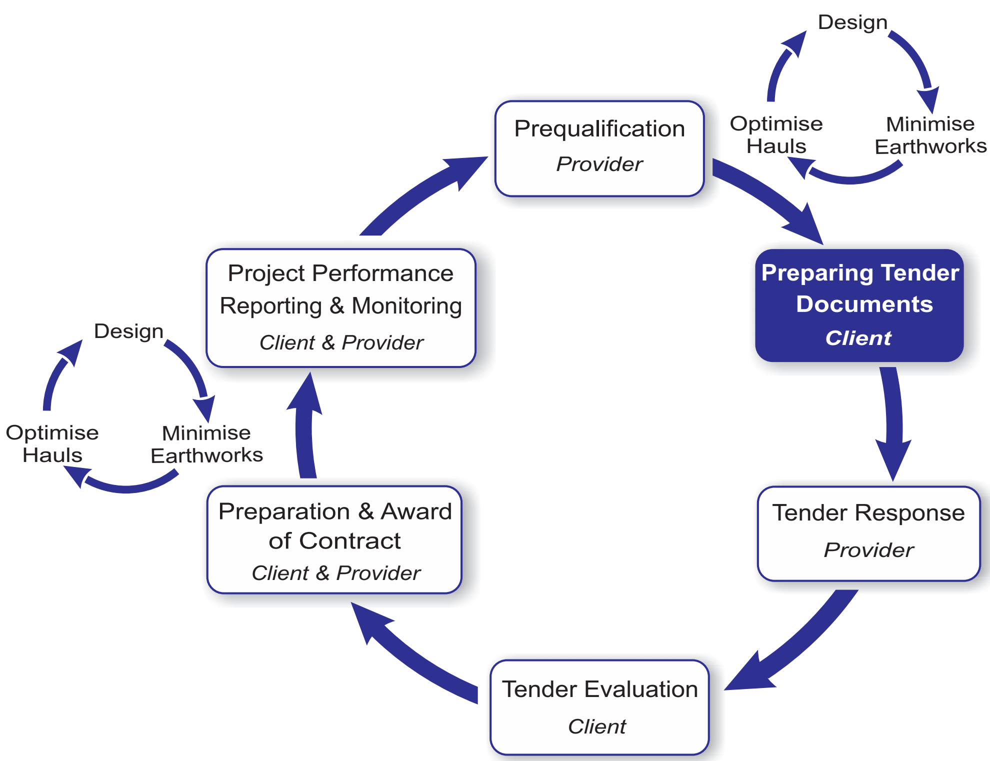
PREPARING TENDER DOCUMENTS

All road authorities are mandated to reduce GHGE. One of the ways to do this is to use the tender documents to encourage contractors to seek practical sustainable solutions. The clients need to request specific indicators from the contractor related to reduction of GHGE through mass-haul minimisation.

Procurement system innovation

Clients should request:

1. Earthworks Method Statement
2. Mass-haul plan (unconstrained) as a table-of-hauls
3. Mass-haul plan (constrained) as a table-of-hauls



Why is it important to discuss earthworks in a method statement?

The project *Method Statement* (sometimes called a *Project Execution Plan*—PEP) provides evidence of competence, capacity and capability, appropriate for the specific needs of the project. Generally all method statements are expected to:

1. Instil certainty and confidence in project planning for all stakeholders.
2. Convey the contractor's understanding of the project.
3. Define and redefine the project scope by removing ambiguity.
4. Provide evidence that all project constraints are identified and solved.
5. Provide evidence of the reasonableness of the solutions.

An earthworks method statement provides specific details of mass-haul related sustainability initiatives as per the Request for Proposals.

Client Method Statement Expectation :

- Evidence of the capability and capacity to improve upon mass-haul plans.
- The most direct, practical and cost-effective means of achieving the project outcomes in relation to mass-haul.
- Mass-plans (constrained and unconstrained) consistent with project targets.
- The practical details of the hauls and materials and fleet.
- The scale of the professional effort that required to meet mass-haul requirements.
- Evidence of methods to plan, monitor, control and measure haulage throughout the project.
- Defined company sustainability objectives linked to calculations for fuel consumption and GHGE reduction.

Does minimising and optimising mass-haul reduce GHGE?

The current approach to mass-haul optimization is predominantly based on cost and does not take into account environmental concerns, especially GHGE.

If the amount of GHGE from mass-haul operations is directly related to the amount of fuel consumed for the operations, then it is important to reduce the fuel consumption. At the same time, the amount of work/effort required for mass-haul activities is an indication of the amount of fuel consumed. So by reducing the amount of work it is expected that the fuel consumption and therefore the amount of GHGE will be correspondingly reduced.

An important advantage of using the work/effort concept is that it also considers the gradient, a factor which is currently ignored in many optimisation methods. Although the contractors usually consider this as a rule of thumb that "when possible haul downhill", it seems that:

1. The gradient of haul routes are not considered when calculating the weighted mean haul distance for different haul plans.
2. The horizontal distances between the cut and fill areas are only considered.

More force is required to go uphill, thus doing more work and using more fuel. The reverse is true for hauling downhill.

Source (Cut)	Source Type	Destination (Fill)	Destination Type	Quantity (BCM or Tonnes)	Density (Kg/bcm)	Distance (m)	Δz (m)	Rolling resistance

Information included in a table of hauls

> *For each 1% increment of grade, an additional 10 Kg of resistance must be overcome for each tonne of total machine weight.*

The total amount of work for any mass-haul plan and schedule can be calculated using physics principles and the result can be used as a factor to compare relative fuel consumption and GHGE generated by differingearthworks solutions.

How does a table-of-hauls support reduction of GHGE?

What is a table of hauls?

A table of hauls provides a structured way for representing mass-haul information. It is the outcome of mass-haul planning and optimisation process. Each row in the table corresponds to the haulage of a single type of material between two specific points. The data required for each specific haul include:

- Source/Cut name or ID
- Source/cut material type (e.g. Rock, OTR, …)
- Destination/fill name or ID
- Destination/fill type (e.g. Core, Base, …)
- The quantity of material hauled from the specified cut to the corresponding fill
- Density of the material hauled
- Haul distance
- Elevation difference between the cut point and the fill point (negative if hauling downhill)
- Rolling resistance factor for the haul-route

Using this structured table provides a template for standardisation of the responses from contractors and helps in comparison of different mass-haul plans. For each material type, the weighted mean haul distance and gradient, as well as the required amount of work/effort for hauling the material can be calculated. These figures can be used as a criteria for comparing different solutions and scenarios, and performing what if analysis.

Types of plans

Baseline Plan (unconstrained): the mass-haul created based on predefined locations for cuts and fills as well as haul costs for different types of material assuming no resource or sequence restrictions. This plan shows the optimal solution for material haulage.

Practical Plan/Schedule (constrained): The realistic mass-haul plan/schedule developed with consideration of all resource availabilities and limitations, as well as other project constraints. This plan is updated regularly during the project to resemble the real situation as much as possible.

Work/Effort as a comparison factor

The completed table-of-hauls from individual tenders can be compared with each other using the calculated work/effort (required to perform the mass-haul plan for the project) as a comparison factor.

Work is done when a force moves a mass over a distance. The amount of work is equal to the amount of energy transferred to the mass by means of the force acting on it. This amount is calculated by multiplying the distance times the component of force acting in the direction of motion.

Comparing the effort is a relational proxy for comparing the amount of fuel consumption and GHGE. The amount of effort (work) undertaken during the mass-haul activities is proportional to the amount of fuel required. So, by reducing the amount of effort (work) it is expected that the amount of fuel consumption and the cost of fuel are correspondingly reduced. Currently, as part of the tendering process for major road projects, it is believed that contractors will undertake mass-haul optimisation and as part of their price calculations, however the evidence suggest this is generally either not the case, or only to a limited extent.

Does minimising and optimising mass-haul reduce GHGE?

In this report, the focus is on reducing fuel consumption emissions. The official definition of greenhouse gas emissions (GHGE) are the gaseous emissions that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation that reduce the loss of heat from the earth's atmosphere; the greenhouse gases regulated by the Kyoto Protocol are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

The GHGE produced by earthmoving vehicles in Australia is mainly CO_2 because these vehicles only produce very small amounts of the other gaseous emissions.

According to NGER (DCCEE, 2012:p26), “at its simplest, emissions may be estimated by reference to reportable data such as fossil fuel consumption, evidenced by invoices, and the use of specified emission factors provided in these Guidelines. For emissions from fuel combustion, for example, data on consumption of a particular fuel would be multiplied by a specific emission factor for that fuel to generate an emissions estimate.”

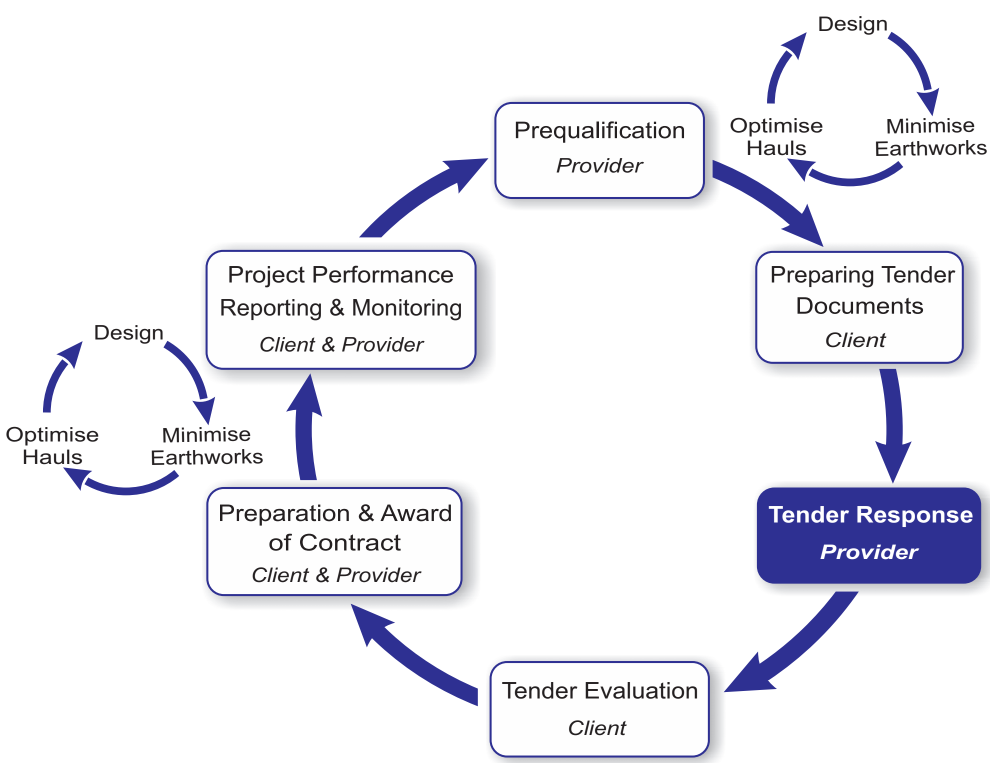
As fuel consumption reporting is a post-hoc analysis, the only method that can be used in advance is to simulate relative fuel consumption through models. The method proposed is to simulate by calculating relative work. Thus an optimised or minimised mass haul plan will indicate relatively less work and thus relatively less fuel consumption and thus proportionably lower GHGE.

TENDER RESPONSE

The tender response (bid documents) is the opportunity for the contractors to show their understanding of project scope as well as the specific nature and aspects of the project. Another important feature of the tender response is that it should provide evidence of commitment to sustainability practices. The contractor shows this through their capability and capacity to address the requested specific GHGE reduction requirements.

Procurement system innovation

1. Creation of an earthworks method statement. The method statement is the opportunity for the contractor to demonstrate understanding of the specific nature of the project as well as the project constraints.
2. An idealised optimal mass-haul plan (unconstrained) represented as a table-of-hauls. This is the tenderers best solution for handling all materials without time and other constraints.
3. An operational optimal mass-haul plan (constrained) represented as a tables-in-the-hauls. This includes consideration of task sequencing and resources.



What are the important elements of the providers' earthworks method statement?

A good method statement : will be tailored to the specific needs of the client and will show how your technical skills and competencies will add value to the project. It will explain:

- The outcomes you will achieve based on your **experience**
- The **distinctive benefits** that your methods and approach offer the client
- The **practicality** of your inputs match the expectations of the client
- Organisational **capacity** to address technical demands of the contract

The key elements of a mass-haul method statement is based on a methodology that indicates mass-haul activities and required resources including (but not limited to):

- Management system capability
- Sequences
- Haul and mass sites
- Plant/Fleet
- Fuel
- Handling
- Other Resources

Method Statements include an estimate of resource allocation, total mass-haul cost and unit cost.

Mass-haul Plan method statement clearly describes the methodology used for calculation of fleet activities, earthworks and haulage. Specific details need to be explained:

- Problems identified
- Risks involved (e.g. rocks assumed suitable for structural requirements, fills may not meet CBR requirements)
- Solutions/methods proposed for the identified risks
- Justifications and examples to show solutions are realistic.

The most important issue to be addressed is what non-price factors have been considered for optimisation.

Why is it important to provide a table-of-hauls?

Un-constrained

A table of hauls provides an *ideal* solution (unconstrained) for hauling the mass materials (soils, aggregates, rock) between points of loading and unloading. The process also includes finding good locations for crushing plants, disposal areas and borrows pits, to minimize material surplus and deficit, and to detect cost and quality issues in the road designs.

The purpose of an unconstrained mass-haul plan is to find the best solution (assuming that there are not sequence, resources and/or project restrictions). This solution becomes the baseline for comparison.

The unconstrained mass-haul plan is created based on predefined locations for cuts and fills including haul costs as well as non-price factors for different types of material.

Opportunities for Road Redesign:

- During the process of optimisation of earthworks, consideration of different scenarios based on road re-alignment or redesign opportunities could lead to better solutions. Better solutions means less haul (distance

Source (Cut)	Source Type	Destina-tion (Fill)	Destination Type	Quantity (BCM or Tonnes)	Density (Kg/ bcm)	Distance (m)	Δz	Rolling resistance
Cut 2 OTR	OTR	Core 2	Core	8247	1700	1518	0.3	On-Road μ_R=0.02
Cut 2 OTR	OTR	Core 3	Core	740	1700	1609	-16.1	On-Road μ_R=0.02
Cut 2 OTR Rip	OTR Rip	Core 4	Core	1860	1800	1723	-20.4	On-Road μ_R=0.02
Cut 3 OTR Rip	OTR Rip	Land Disposal	Disposal Area	15202	1800	1475	3.55	Off-Road μ_R=0.05
Cut 2 Rock	Rock	Crusher	Aggregate	9434	2600	447	0.3	Off-Road μ_R=0.05
Crusher	Capping Aggregate	Capping 2	Capping	9944 t	1300	1726	-24.6	Off-Road μ_R=0.05

Table 5: Sample Table of Hauls (unconstrained)

and amount) and a corresponding reduction in fuel consumption—which is indicative of GHGE reduction.

- This plan shows the optimal solution for material haulage.
- One important non-price factor is the amount of fuel consumed for the earthworks that is indicative of GHGE.

Constrained

A table of hauls provides a workable solution (constrained) for hauling the mass materials (soils, aggregates, rock) between points of loading and unloading. The process also includes finding good locations for crushing plants, disposal areas and borrows pits, to minimize material surplus and deficit, and to detect cost and quality issues in the road designs.

The table-of-hauls based on a constrained, realistic, mass-haul plan is developed with consideration of all resource availabilities and limitations, practical issues, activities, durations and sequences as well as other project constraints.

This plan is updated regularly during the project to resemble the real situation as much as possible.

Opportunities for for Road Redesign:

- During the process of optimisation of earthworks, consideration of different scenarios based on road re-alignment opportunities-within project constraints--could lead to better solutions. Better solutions means less haul (distance and amount) and a reduction in fuel consumption which is indicative of GHGE reduction.
- One important non-price factor is the amount of fuel consumed for the earthworks that is indicative of GHGE.

As an example, table 5 shows an unconstrained table of hauls for a road project. The project includes a bridge in the middle (between Cut 2 and Cut 3) and there is no other haul road across. To come up with the ideal solution, it is assumed that there are no limitations for hauling the material across the bridge, hence material from Cut 2 is planned to be hauled to fill areas

Source (Cut)	Source Type	Destination (Fill)	Destination Type	Quantity (BCM or Tonnes)	Density (Kg/ bcm)	Distance (m)	Δz	Rolling resistance
Cut 2 OTR	OTR	Core 2	Core	8247	1700	1518	0.3	On-Road μ_R=0.02
Cut 2 OTR	OTR	OTR Stockpile	Stockpile	740	1700	100	0.4	On-Road μ_R=0.02
OTR Stockpile	OTR	Core 3	Core	740	1700	1600	-16.1	On-Road μ_R=0.02
Cut 2 OTR Rip	OTR Rip	Land Disposal	Disposal Area	1860	1800	2050	2.8	Off-Road μ_R=0.05
Cut 3 OTR	OTR Rip	Core 4	Core	1860	1800	1738	2.4	On-Road μ_R=0.02
Cut 3 OTR Rip	OTR Rip	Land Disposal	Disposal Area	13342	1800	1475	3.55	Off-Road μ_R=0.05
Cut 2 Rock	Rock	Crusher	Aggregate	9434	2600	447	0.3	Off-Road μ_R=0.05
Crusher	Capping Aggregate	Capping 2	Capping	9944 t	1300	1726	-24.6	Off-Road μ_R=0.05

Table 6: Sample Table of Hauls (Constrained)

(Core 3 and Core 4) on the other side of the bridge.

In practice however, the bridgework may start later in the project. This would prevent the haulage of material from Cut 2 to Core 3 and Core 4 until the bridgework is finished. This limitation should be considered when developing the constrained table of hauls. Table 6 shows this situation. A practical solution to prevent delays in cut activities would be to stockpile the OTR material from Cut 2 in order to finish this cut activity on time, and haul the material to Core 3 after the bridge is finished (as shown in rows 2 and 3 of table 6). Considering OTR Rip material, the solution would be to haul the material from Cut 2 to the disposal area and source the required OTR Rip from Cut 3 on the other side of the bridge (rows 4, 5, and 6 of table 6). Although this solution requires more work, it will prevent delays in cut activities and ensure continued resource usage.

TENDER EVALUATION

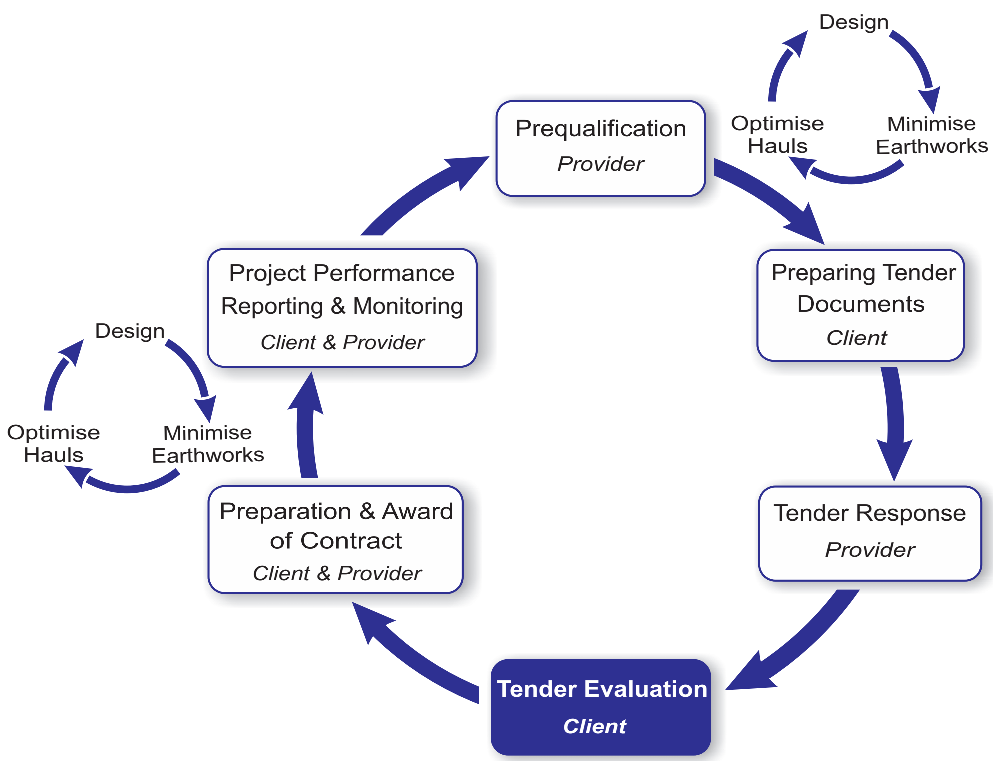
Tender evaluation, including non-price criteria, aims to achieve *best value for money*. Reducing GHGE is one non-price criteria currently required by a number of state road authorities.

It is recommended that clients use work/effort as a relative proxy for GHGE as a non-price criterion to facilitate tender evaluation.

Procurement system innovation

Comparison of non-price criteria for mass-haul GHGE reduction:

1. To compare different haul solutions presented in tables of hauls.
2. To assess the practicality of the earthworks methodology statement.



How is 'Value for Money' related to non-price criteria?

In 2010, Roads Australia reported that several Australian road authorities responded positively to the inclusion of non-price criteria in tender documents, as well as the push by the Roads Australia Sustainability Chapter for the inclusion of sustainability clauses as an expression of 'Value for Money' in major contracts. The links between'Value for Money' and sustainability non-price criteria are quoted below.

Austroads

Value for money should encompass both quality and price, and may also consider relevant social and industry capacity issue.

The tender with best value not only satisfies the assessment criteria, but is also expected to result in the satisfactory completion of the specified work, to the specified quality, **environmental** and safety standards, within the specified time, for the lowest price.

Queensland

Achieving value for money requires consideration of contribution to the advancement of Government Priorities; non-price factors such as:

- Fitness for purpose
- Quality
- Service and support
- Sustainability considerations
- Cost related factors including **whole-of-life** costs and transaction costs associated with acquisition, use holding, maintenance and disposal.

Western Australia

- Any feature of a tender that provides a benefit to the Government of Western Australia and the community.
- It is assessed during tender evaluation by identifying the lowest Comparative Price Tender (this Tender then becomes the benchmark for the value-for-money assessment);
- If the next higher priced Comparative Price Tender has a higher Non-Price Assessment Score than the benchmark,
- Identifying the additional benefits (if any) offered and assessing if the additional benefit is worth the additional price;
- Repeating step (ii) with the remaining Tenders; and determining which of the Tenders, if any, offers the best value for money.

New South Wales

The best value for money tender is the tender that satisfies the assessment criteria in the Information Documents, as well as other tender details that require evaluation and is expected to result in the satisfactory completion of the specified work, at the specified quality, to the **specified environmental and safety standards**, within the specified time, for the lowest price and performed in the spirit of co-operative contracting.

An alternative methodology to compare bids

Client bid comparison is based on the provided tables-of-hauls.

4-step comparison Process

1. Each single haul in a table-of-hauls contains these data:
    - volume of material
    - density of material

- distance hauled
- elevation difference between loading and unloading points.

2. The amount of work for each single haul is calculated using Equation 1.

$$W = \gamma V(\Delta z + \mu_R . d) \qquad (1)$$

W = Work (MJ)
γ = Specific weight of soil (density x g) density is Kg/bcm (bench cubic metre)
V = Volume of material (m^3)
Δz = Gradient difference (net m)
μ_R = Co-efficient of rolling resistance
d = Horizontal distance–haul route (m)

3. Total effort is the sum of the work required for the total number of single hauls.
4. This provides a unique figure for non-price comparison.

In Equation 1, Δz can be regarded as the elevation difference between the centre of mass of a cut and the centre of mass of the corresponding fill where the material goes. Δz is negative when the elevation of the first point is higher than the elevation of the destination point (i.e. when moving downhill).

The rolling resistance factors for each of the haul routes are also available from the table-of-hauls. Using the equation, the amount of work for each single haul is then calculated. These are totalled for the total amount of work for the tables of hauls in the tender documents. This amount is a unique figure for non-price comparison

This unique figure can be used as an indication of the amount of fuel used and GHGE, and can serve as a factor for comparing different mass-haul plans. An alternative is to convert to litres of fuel using the energy value of the fuel (34.7MJ/l).

This approach will give the clients the opportunity to identify and choose the best mass-haul plan.

Using tables of hauls to calculate the amount of work/effort required also provides a competitive opportunity for providers. They are able to indicate their understanding of the project and their ability to address the haul issues to minimise GHGE.

How to accommodate the alternative methodology in the evaluation model?

All tender evaluation models are designed to consider both the capability and the capacity of the contractor to complete the project that has been developed.

The models commonly use a weighting system for both price and non-price criteria.

Multi-factor or multi-criteria tender evaluation is a way of achieving best value for money instead 'lowest-price'. This shift in approach to tender evaluation has been seen in the contractor selection process over the last decade.

Project Bid Evaluation Models

- Multiple Kernel Learning
- Stochastic Decision Model3
- Deductive Logic Structure
- GHGE calculators
- Environmental Cost Assessment tools

The weighting of the non-price criteria can be based on the unique work figure for each bid. The amount of work for each haul can be summed to derive the total amount of work for the table of hauls. This amount is a **unique figure for non-price comparison**.

This unique figure can be used as an indication of the amount of fuel used and GHGE, and can

Source	Source Type	Destination	Destination Type	Vol (BCM)	Density (Kg/bcm)	Haul (m)	Δz (m)	Rolling resistance	Work (MJ)
Cut 2	OTR	Core 2	Core	8247	1700	1518	0.3	0.02	4,211
Cut 2	OTR	Core 3	Core	740	1700	1609	-16.1	0.02	198
Cut 2	OTR Rip	Core 4	Core	1860	1800	1723	-20.4	0.02	461
Cut 3	OTR Rip	Land Disposal	Disposal Area	15202	1800	1475	3.55	0.05	20,724
Cut 2	Rock	Crusher	Aggregate	9434	2600	447	0.3	0.05	5,447
Crusher	Aggregate	Capping 2	Capping	7648t	1300	1726	-24.6	0.05	6,010
Comparative Work/Effort (Mega Joules)									**37,051**
Comparative fuel consumed (Litres)									1,068

Table 7: Calculation of comparative work/effort and fuel (unconstrained)

serve as a factor for comparing different mass-haul plans.

This will give the clients the opportunity to compare contractors and to choose the one with the most suitable mass-haul plan for the project.

Using tables of hauls to calculate the amount of work required also provides a competitive opportunity for providers. They are able to indicate their understanding of the project and their ability to address the haul issues to minimise GHGE.

Source	Source Type	Destination	Destination Type	Vol (BCM)	Density (Kg/bcm)	Haul (m)	Δz (m)	Rolling resistance	Work (MJ)
Cut 2	OTR	Core 2	Core	8247	1700	1518	0.3	0.02	4,211
Cut 2	OTR	OTR Stockpile	Stockpile	740	1700	100	0.4	0.02	30
Stockpile	OTR	Core 3	Core	740	1700	1600	-16.1	0.02	191
Cut 2	OTR Rip	Land Disposal	Disposal Area	1860	1800	2050	2.8	0.05	3,455
Cut 3	OTR Rip	Core 4	Core	1860	1800	1738	2.4	0.02	1,219
Cut 3	OTR Rip	Land Disposal	Disposal Area	13342	1800	1475	3.55	0.05	18,188
Cut 2	Rock	Crusher	Aggregate	9434	2600	447	0.3	0.05	5,447
Crusher	Aggregate	Capping 2	Capping	7648t	1300	1726	-24.6	0.05	6,010
Comparative Work/Effort (Mega Joules)									**38,751**
Comparative fuel consumed (Litres)									1,117

Table 8: Calculation of comparative work/effort and fuel(Constrained)

PREPARE AND AWARD CONTRACT

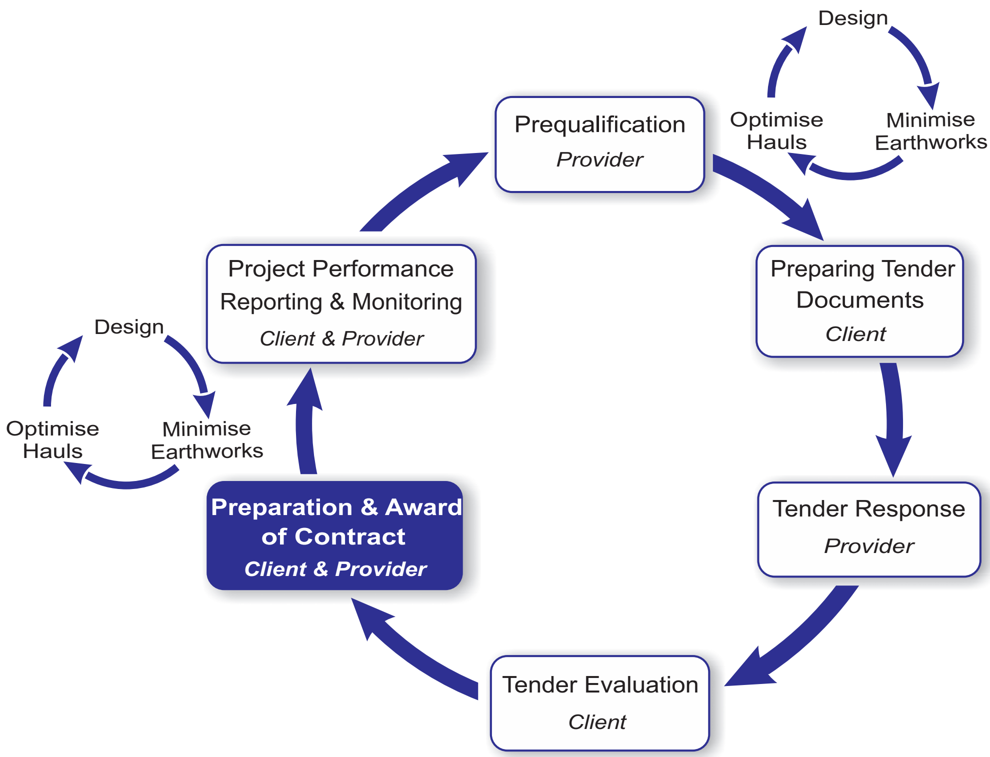
Procurement system innovation

Providing practical procurement system innovations—based on an alternative method for calculating, estimating, evaluating and monitoring GHGE using the principle of calculated 'work' derived from a mass-haul plan—provides opportunities which are better supported by alternative project delivery contract models. The innovations naturally align with forms of early contractor involvement contracts. Especially, contract models that include delivery, reporting and monitoring using Key Performance Indicators as non-price GHGE reduction criteria.

Procurement system innovation

Client

1. Contractor selection using the non-price criteria of work/effort means providing the opportunity for both optimisation of hauls and also design changes to minimise mass-haul to reduce GHGE to facilitate continuing performance improvement resulting in reduced GHGE.
2. Include baseline tables of hauls as performance targets in contract documents.
3. Agreed GHGE incentives are an integral part of the proposed practical procurement system, hence they are included in the contract documents.



Appropriate contract types

All contract types can incorporate the procurement system innovations recommended here. However, some of the more recent forms are better suited to delivering improvements.

For major road projects the complexity of sustainability, resources, and life-cycle outcomes lends itself to relationship contracting principles. These principles include collaborative approaches in project delivery system selection. One strategy for project delivery begins with relationship based contracts such as ECI and Alliances. Relationship contracting principles incorporate the notion of continuous improvement through identified key performance indicators which benefits both the clients and the contractors.

Early Contractor Involvement (ECI)

Early Contractor Involvement (ECI) contracts involve contractors in the early phases of project development.

The ECI procurement model usually involves a two stage process:

- In the first stage contract, a Contractor commits to scoping the project for constructability. The contract is usually based on equal risk.
- In the second stage, a Design & Construct contract (usually) can be put to competitive tender, based on the detailed requirements of the first contract.

Alliance Definition

A Project Alliance is a fixed term partnership for the duration of the project. Partners are selected on the basis of their expertise and ability to meet stringent performance criteria before price is considered. Expected cost savings improved 'value for money' through leverage of skills and expertise of partners from project concept through to delivery (Hauck et al., 2004).

How do you integrate mass-haul reduction into the major roadworks contract?

The contract needs to provide clauses relating to sustainability and/or reducing GHGE. The non-price criteria should have clauses such as:

> *"This schedule to include details of proposed sustainability initiatives for reducing green-house gas emissions."*

A variety of possible non-price factors related to Key Performance Indicators could be:

1. Reduced mass-haul
2. Reduced fuel consumption
3. Reduced materials.

Each of these outcomes could be related to optimised earthworks/minimised hauls at various points in the project.

The inclusion of incentives as well as specifics of performance, based on measurable criteria, in the contract document, is intended to motivate continuing sustainable practices by the contractor during the project.

Inclusion of the optimised table-of-hauls in the contract document as a baseline mass-haul plan is important. This baseline plan provides a reference against which the actuals will be compared during the construction phase. What is more, the baseline plan provides a starting point for re-optimisation as well as forecasting of mass-haul activities to accommodate the real issues and actual hauls as the project continues.

PERFORMANCE MONITORING AND REPORTING

It is not sufficient for a contractor to make a claim of a well optimised or minimised earthworks plan with a low measure of work. It is equally important that the actions on site follow the plan. Thus monitoring and reporting are critically important, and the result of this—the contractor's performance against the plan—should be fed back into the prequalification rating for consideration on the next project.

Procurement system innovation

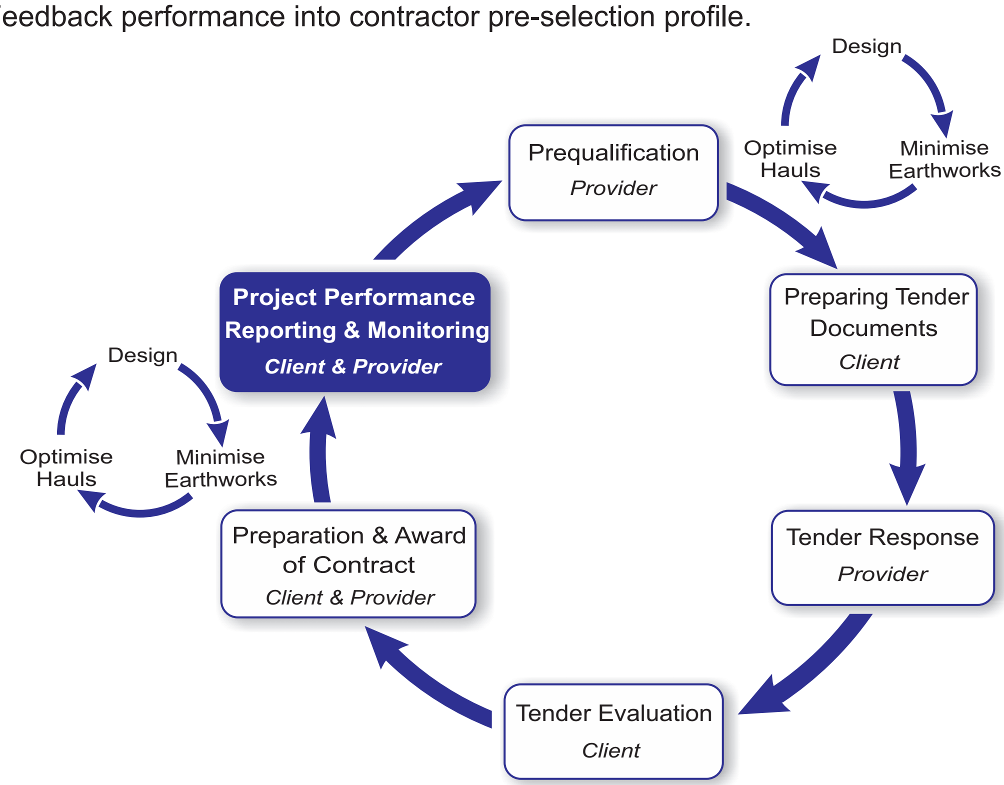
The responsibility is on both parties to reduce GHGE if possible. The client should provide opportunities for the provider, and the provider needs the capability and capacity to optimise for GHGE reduction.

Provider

1. Monitors and provides a table of actual hauls to compare with the constrained baseline
2. Adjusts and re-optimises haul plan based on actual conditions

Client

1. Calculate work/effort for table of actual hauls and compare with baseline work for constrained hauls.
2. Audit mass haul KPIs specified in contract.
3. Feedback performance into contractor pre-selection profile.



How are GHGE produced during road construction monitored?

Current construction industry practise is to use fuel consumption as a proxy for GHGE. However, measuring the GHGE produced from road construction activity is difficult for two reasons: fuel consumed can only be calculated after the project is completed, and the data is aggregated for all phase of the construction project. This retrospective approach does not assist in the development and management of pro-active fuel reduction strategies.

New Solution to the problem

Focus on fuel reduction during project planning is a better method to proactively reduce GHGE. The alternative method suggested in this report is a practicable and feasible solution for planning and controlling the negative environmental impact of GHGE from mass-haul/earthworks operations.

For an individual project it is possible to compare the table of actual hauls with the base-line table-of-hauls to arrive at the difference in the amount of work.

This difference is indicative in the difference between estimated fuel consumption and actual fuel consumption.

Because fuel consumption is currently used as a proxy for GHGE, this figure for fuel consumption provides a proxy for reduced or increased GHGE.

Recording the actual fuel consumption during the project will provide a database for both contractor and client that can facilitate fuel consumption forecasts.

Two opportunities for reduction of fuel consumption are available. The first is deviation identified early in construction. The second is mass-haul can be re-optimised based on actual, rather than estimated, mass-haul plans related to the constraints during construction.

Is there software available to calculate mass-haul or fuel consumption?

The advent of advanced software and IT systems affords visualisation techniques for development of 3D and 4D models. However, the available software does not have the capacity to record fuel consumption in relation to fleet management. *CatVisionLinkTM* can now provide web-based fleet management from data generated by new machines. However, retrofitting old fleet limits the use of this option.

Survey software, such as the Trimble *Connected Machine* solution and Topcon's Automatic *Machine Control* provide machines in the field with 3D design information. This supports more precise grading and earthmoving which could be used to measure GHGE reductions.

Many software packages have been developed to manage construction projects but few have the functionality for both mass-haul planning and optimization. *DynaRoad* provides Project Management for heavy civil engineering projects and is used for planning, optimising and controlling the mass-haul of earthworks based on the location of materials. It helps in creating a construction schedule, and monitoring progress of the project, particularly when linked to Topcon's *Haul Counter* system.

Many contractors use proprietary systems.

Name	Fuel Use	Earthworks Estimation	Mass -Haul Optimisation	Comments
Paydirt®	No	Yes	No	SiteWork Earthwork Estimating Software: calculates both the takeoff quantities and the numbers.
Terramodel® Roadway	No	Yes	No	The Site Design module computes earthwork and material quantities and mass haul diagrams, and applies simple or complex multi-phasing on any project.
Highway 4D	No	Yes	No	Computes station volumes and displays them as an interactive mass haul diagram that aids in identifying balance intervals, optimizing locations for borrow and spoil, calculating haul slopes and differentiating dozer, scraper and truck dirt; outputs used with Trackwork™ plan hauls and monitor production.
RoadEng	No	Yes	No	A road design system ideally suited for rural roads or route location studies; includes facilities for alignment design, mass haul and slope stake calculations.
Cat VisionLink™	Yes	No	No	It is a web-based fleet management application which displays data collected from a Product Link unit installed on a machine. It provides data such as machine location, hours, health information, fuel utilization, etc.
The Trimble Connected Machine solution	No	Yes	No	Fleet management: machines can collect as-built measurement data for office delivery, and receive GNSS corrections using the Internet. A 3D design created in the office can be sent to the machine operator for faster, more precise grading and earthmoving. Additionally, the machine can be used for volume measurements, so expensive measurements by grade checkers occur less frequently.
FPC	Yes	No	No	A software package that assists predicting fleet productivity providing direct comparisons between the various types of fleets, time required doing a given job, and the cost for doing that work under a variety of conditions.
DynaRoad	No	No	Yes	DynaRoad is a Project Management software for heavy civil engineering projects. It is used for planning and optimizing the mass-haul of an earthworks project based on the location of materials. It helps in creating a construction schedule, and monitoring the progress of the project. The project schedule is based on task quantities and locations, resource needs and availabilities, production rates, dependencies, calendars and various constraints. The result is a practical haul plan which is realizable in practice. During the project execution phase, the control module helps to monitor and control the actual progress against the time-location plan. The control module also provides forecasts to avoid future problems.
DynRoad & Topcon	No	No	Yes	Automatic haul counter system with direct input into DynaRoad Mass-Haul software..

Table 9: Road earthworks software packages

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Glossary

Earthworks:

(this definition differentiates earthworks from mass-haul)

1. All operations involved in loosening, removing, depositing, shaping and compacting soil or rock.
2. The structure resulting from the above operations. (AS 1348-2002).

Early contractor involvement (ECI)

A contracting structure that involves the appointment of a construction contractor in the early stages of the pre-feasibility study for the purpose of providing contractor knowledge during the design stage. ECI facilitates more robust risk identification and allocation during early stages of the project resulting in a practical and flexible design as well as development of a realistic project plan.

Estimation

Preparing a calculated prediction of the amount of money required to undertake a specific amount of work, expressed in dollar values of the year in which it was prepared. It is prepared in a systematic manner appropriate to the size and complexity of the project, and to a level of accuracy commensurate with the available information and the intended use of the information developed. It might include some prior expenditure in a mix of year dollar values. (RTA, 2008).

Fuel consumption

The combination of fuel used to power fleet/plant for mass-haul during road construction which includes the amount of fuel used to haul materials to and from sites (Hughes et al., 2011).

Greenhouse gas emissions (GHGE)

In this Practical Guide the focus is on fuel consumption emissions means CO2, because of the small amounts of the other gaseous emissions produced by earthmoving vehicles in Australia (Tan et al., 2012).

The gaseous emissions that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation that reduce the loss of heat from the earth's atmosphere; the greenhouse gases regulated by the Kyoto Protocol are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (Dilger et al., 2011).

Haul

The distance through which material is transported between points of loading and unloading (AS 1348-2002).

Major roadworks

In this report major roadworks are considered to have scope, scale, cost and complexity with significant earthworks accounting for over 20% of the total value of the completed project.

Mass-Haul

The handling and movement of mass materials (soils, aggregates, rock) around the construction project, as well as to and from the construction site.

Mass-Haul Planning

The process of planning a workable solution for hauling the mass materials (soils, aggregates, rock) between points of loading and unloading.

The process also includes "finding good locations for crushing plants, disposal areas and borrows pits, to minimize material surplus and deficit, and to detect cost and quality issues in the road designs." (DynaRoad, 2011)

- **Baseline (unconstrained) Plan**: the mass-haul created based on predefined locations for cuts and fills as well as haul costs for different types of material assuming no resource or sequence restrictions. This plan shows the optimal solution for material haulage.
- **Practical (constrained) Plan/Schedule**: The realistic mass-haul plan/schedule developed with consideration of all resource availabilities and limitations, sequences as well as other project constraints. This plan is updated regularly during the project to resemble the real situation as much as possible.

Mass-Haul Optimization

A process to find the optimal solution based on the determination of the minimum haul distance and direction to haul the material (Son et al., 2005).

Method Statement

A method statement is a set of narratives, related to specific aspects of the project and describes the provider's methods and procedures approach. The method statement provides examples demonstrating provider's experience of comparable projects and the results that have been achieved (Lewis, 2012). In relation to earthworks, a method statement may include considerations of changing alignment as an opportunity to optimise mass-haul.

Plant/Fleet Management for Earthworks

The processes and steps required to ensure:

- Selecting the right type, size, and number of plant for the earthworks to be done
- Organising the job to ensure that all items of plant are kept working to capacity" and continuously (QLD DTMR, Form 11AT23)
- Monitoring the plant activities and movements on the project to identify and resolve any deviations from the earthworks plan.

Procurement

The method of acquiring, securing or obtaining infrastructure assets, facilities or services; it involves the selection of various actors (public and private) and organisation of activities for infrastructure provision and production such as planning, financing, designing, construction, monitoring, regulation, operation and maintenance to facilitate the delivery of infrastructure services (Howes and Robinson, 2005, p. 110).

Tender evaluation

The formal assessment of the tenders received against the evaluation criteria set in advance.

Work/Effort

Work is done when a force moves a mass over a distance. The amount of work is equal to the amount of energy transferred to the mass by means of the force acting on it. This amount is calculated by multiplying the distance times the component of force acting in the direction of motion. Is used as a proxy for fuel consumption.

Sustainable Built Environment National Research Centre

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to Australia's CRC for Construction Innovation. Established on 1 January 2010, the SBEnrc is a key research broker between industry, government and research organisations for the built environment industry.

The SBEnrc is continuing to build an enduring value-adding national research and development centre in sustainable infrastructure and building with significant support from public and private partners around Australia and internationally.

Benefits from SBEnrc activities are realised through national, industry and firm-level competitive advantages; market premiums through engagement in the collaborative research and development process; and early adoption of Centre outputs. The Centre integrates research across the environmental, social and economic sustainability areas in programs respectively titled Greening the Built Environment; Developing Innovation and Safety Cultures; and Driving Productivity through Procurement.

Among the SBEnrc's objectives is to collaborate across organisational, state and national boundaries to develop a strong and enduring network of built environment research stakeholders and to build value-adding collaborative industry research teams.

SBEnrc Core Partners

Government of Western Australia
Queensland Government
NSW Government Transport Roads & Maritime Services
Parsons Brinckerhoff
John Holland
Curtin University
QUT
Swinburne University of Technology

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