Project Report

Program 3

Productivity through Innovation

Project 3.48

Sustainable Asset Management

Subtopic: Carbon emissions modelling of road pavement treatment strategies

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Executive summary

The emissions of eight pavement treatment strategies are investigated in this project.

The eight pavement treatment strategies include:

- ASDG: Dense Graded Asphalt Overlay/Replacement
- ASIM: Intersection Mix Asphalt Overlay/Replacement
- ASOG: Open Graded Asphalt Replacement
- ASRS: Structural Asphalt Work
- GrOL: Heavy Rehabilitation - Gravel Overlay/Stabilisation
- RipSeal: Light rehabilitation treatment for strong pavement
- Slurry: Rutting smoothing treatment with slurry
- CS: Sprayed Seal

Through a detailed life cycle assessment of the material and equipment usage of each treatment type, the emission factors of each treatment strategy and their related environmental costs are calculated. Asphalt replacement, including ASDG, ASIM and ASOG, has relatively low emission value, from 3.15 to 4.20 kg CO_2-e / m^2. The environmental cost of these three asphalt replacement strategies are from A$0.074 to A$0.099 per m^2. Slurry has a similar emission value and cost value. Sprayed Seal has the lowest emission value of 2.15 kg CO_2-e / m^2. It also has the lowest environmental cost of A$0.051 per m^2. On the other hand, GrOL, RipSeal and ASRA have the highest emission values of 25.72, 22.94 and 9.92 kg CO_2-e / m^2 respectively. The environment cost of GrOL, RipSeal and ASRA are 0.606, 0.541 and 0.234 A$ per m^2.

Keywords: Pavement treatment; Emission value; Carbon emissions; Environmental cost.

Introduction

Global climate change has been recognized one of the biggest threats to human development. In order to address the challenge, environmental consideration, especially greenhouse gas emissions, should be integrated into the decision making process of business, individuals and policy makers.

In recent years, road maintenance has been a preferred option compared to new road construction. Road maintenance and rehabilitation activities can be very resource-intensive. As such, calculating the emission produced in maintenance and rehabilitation activities is important. This project aims to calculate the emissions of various pavement treatment strategies used in Main Roads Western Australia.

Pavement treatment strategies

Eight pavement treatment strategies are considered in this study, including:

1. ASDG: Dense Graded Asphalt Overlay/Replacement
2. ASIM: Intersection Mix Asphalt Overlay/Replacement
3. ASOG: Open Graded Asphalt Replacement
4. ASRS: Structural Asphalt work
5. GrOL: Heavy Rehabilitation - Gravel Overlay/Stabilisation
6. RipSeal: Light rehabilitation treatment for strong pavement, mainly for roughness reduction
7. Slurry: Rutting smoothing treatment with slurry
8. CS: Sprayed Seal

Research method

Life-cycle assessment (LCA) has been widely adopted to evaluate the environmental impacts in both the manufacturing industrial and construction sectors (Harris 1999; Petersen and Solberg 2002). LCA assigns elementary flows and potential environmental impacts to a specific product system An LCA study can be carried out in four steps, as illustrated in Figure 1.

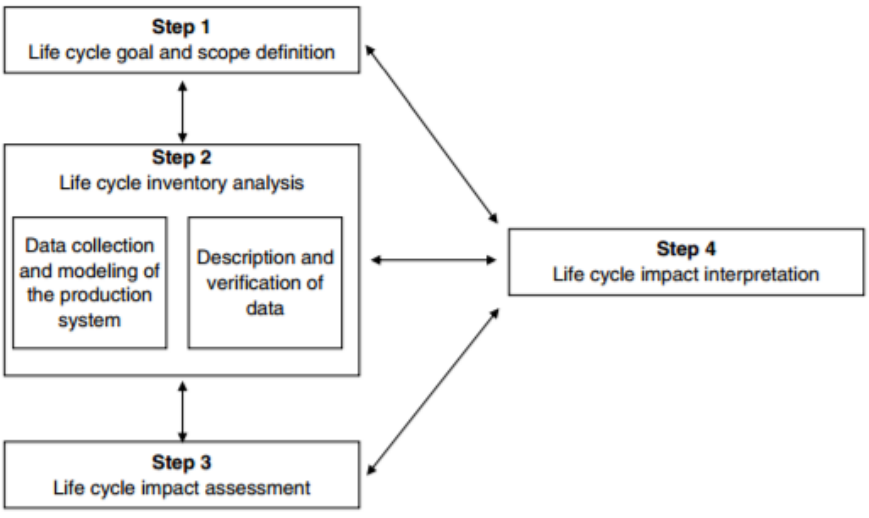

Figure 1. The four stages of a complete life cycle assessment

The detailed calculation activities following the LCA method are presented in Figure 2.

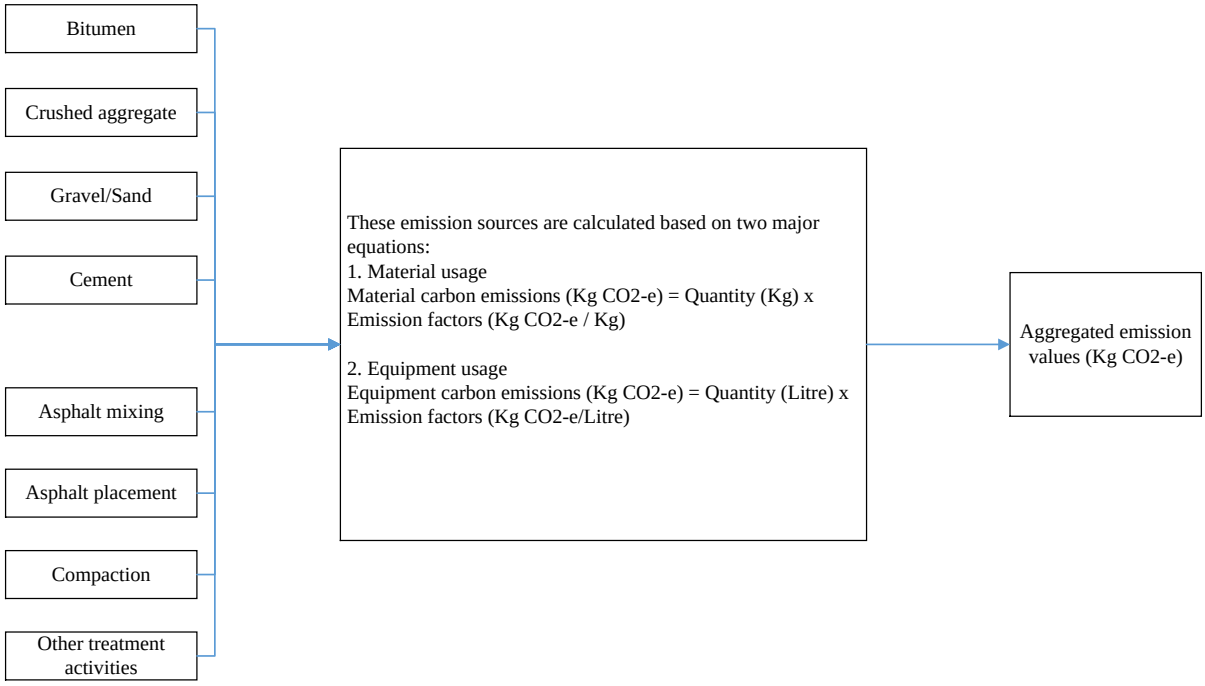

Figure 2. Detailed calculation activities in this project

Assumptions

The Greenhouse Gas Assessment Workbook for Road Projects, published by the Transport Authorities Greenhouse Group in 2013, was referred to as the main source for emission factors.

Emission factors for materials

The four commonly used materials in these treatments include:

1. Bitumen;
2. Crushed aggregate;
3. Gravel; and
4. Cement.

The emission factors for these four types of materials are available in *The Greenhouse Gas Assessment Workbook for Road Projects* and are shown in the following Table 1.

Table 1. The emission factors of materials used in pavement maintenance

Materials	Boundary	Unit	Emission factor
Bitumen	Mine to end-of-production	t CO_2-e/t	0.630
Crushed aggregate	Mine to end-of-production	t CO_2-e/t	0.005
Gravel (sand)	Mine to end-of-production	t CO_2-e/t	0.003
Cement	Mine to end-of-production	t CO_2-e/t	0.82

Emission factors for equipment usage

This project refers to a series of studies to investigate the emission factors of equipment usage in various maintenance treatments. These studies are presented in Table 2. It should be noted that the estimation is based on the technical details of the pavement treatment strategy in a general condition. As detailed activities in each site may vary, the emission factors may not accurately measure the carbon emissions in specific road sites. However, at the macro-scale, this estimation is useful to estimation the emissions of thousands of road sections, as the detailed work programs from the thousands of road sections may not be available.

The following Table 2 provides the emission factors used in this project. These emission factors from *The Greenhouse Gas Assessment Workbook for Road Projects* are preferred because these factors are calculated based on an Australian context. The world average emission factors from the World Bank (2010) and the U.S emission factors from the Pavement Research Centre at the University of California, Davis are referred to when Australian specific emission factors are not available.

Some general assumptions of the treatment strategies have also been made:

1. ASDG, ASIM and ASOG are related to asphalt replacement. The activities in these three types of pavement treatment strategies include asphalt mixing, paving and compacting. The equipment used in these three types of treatment strategies including asphalt mixing plant, asphalt paver and asphalt compactor. The depth of ASDG and ASOG is assumed to be 30mm while to depth of ASIM is assumed to be 40mm.

2. ASRS aims to increase the structural capacity of the pavement as well as providing a surfacing with adequate properties. Based on the information obtained, the full depth asphalt (One major rehabilitation with top 150mm replaced - once every 50 years and 5% of road replaced to full depth every 50 years for patching/repair) in the workbook is chosen to best simulate the ASRS.

3. GrOL. Granular + spray and seal (Assumes two respray and one major rehabilitation within 50 years. 150mm of aggregate replaced). In addition, pavement stabilisation and seal are also included in GrOL.

4. RipSeal. RipSeal includes a 150mm cement stabilisation, a placement of 50mm gravel and a seal of 10mm.

5. Slurry. Slurry refers to slurry/micro surfacing. It is cold mix surface treatment which consists of applying a 3 - 20mm layer of in - situ mixed: aggregate; (polymer modified) bitumen emulsion; adhesion agents; water; and cement or lime.

6. CS. It refers to surface dressing, i.e. the spraying of bitumen on a road surface followed by the spreading of a layer or layers of aggregates

Table 2. Emission factors for different treatment strategies.

Pavement treatments	Descriptions	Emission factors	References
ASDG	Asphalt replacement (Asphalt mixing plant, paver and compactor) (30mm)	6.313 L/m^3	World Bank (2010)
ASIM	Asphalt replacement (Asphalt mixing plant, paver and compactor) (40mm)	6.313 L/m^3	World Bank (2010)
ASOG	Asphalt replacement (Asphalt mixing plant, paver and compactor) (30mm)	6.313 L/m^3	World Bank (2010)
ASRS	Full depth asphalt (One major rehabilitation with top 150mm replaced - once every 50 years and 5% of road replaced to full depth every 50 years for patching/repair)	4.3×10^{-4} KL/m^2 (Diesel)	Transport Authorities Greenhouse Group (2013)
GrOL	Granular + spray and seal (Assumes two respray and one major rehabilitation within 50 years. 150mm of aggregate replaced.) + pavement stabilisation and seal	0.19 L/m^3	World Bank (2010)
RipSeal	150mm cement stabilisation + 50mm gravel + seal (10mm)	0.31 L/m^3	World Bank (2010)
Slurry	Slurry/Micro Surfacing: cold mix surface treatments which consist of applying a 3 - 20mm layer of in - situ mixed: aggregate; (polymer modified) bitumen emulsion; adhesion agents; water; and cement or lime.	2.87kg CO_2-e/m^2	Spray et al. (2014)
CS	Surface Dressing: the spraying of bitumen on a road surface followed by the spreading of a layer or layers of aggregates	1.00kg CO_2-e/m^2	Spray et al. (2014)

Results

Background information of the road sections

Based on the information provided by MRWA, there are 5,007 road sections which have gone through maintenance in 2016. The following Table 3 lists the treatment areas and number of road sections for each treatment type. As can be seen from Table 3, the most commonly adopted treatment strategy is Sprayed Seal (CS) with 2,980 road sections. The following commonly used strategies include Dense Graded Asphalt Overlay/Replacement (ASDG) with 1,077 road sections, Ripseal with 261 road sections and Intersection Mix Asphalt Overlay/Replacement (ASIM) with 254 road sections

Table 3. Background information of the 5,007 road sections

Treatment types	**Treatment areas (m^2)**	**No. of road sections**
ASDG	120-107,008	1077
ASIM	78-38,717	254
ASOG	198-98,719	136
ASRS	82-14,672	42
GrOL	84-88,386	169
RipSeal	108-160,066	261
Slurry	270-160,621	88
CS	22-284,520	2980

Emissions by treatment types

The emissions of the eight treatment strategies are shown in Table 4. As can be seen from Table 4, GrOL has the highest emissions with an average emission factor of 22.94 kg CO_2-e/m^2 while Sprayed Seal has the lowest emissions with an average emission factor of 2.15 kg CO_2-e/m^2. The high emissions from GrOL and RipSeal are caused by pavement stabilisation.

Table 4. Emissions of different pavement treatment strategies.

Treatment types	**Emissions from raw material production (kg CO_2e/m^2)**	**Equipment usage (l/m^3)**	**Emissions from equipment (kg CO_2e/m^2)**	**Total emissions (kg CO_2e/m^2)**
ASDG (30mm)	2.60	6.313	0.55	3.15
ASIM (40mm)	3.47	6.313	0.73	4.20
ASOG (30mm)	2.60	6.313	0.55	3.15
ASRS	8.68		1.24	9.92
GrOL (150mm)	6.22	0.190	0.08	6.30
RipSeal (50mm)	5.55	0.310	0.04	5.59
Slurry	1.49		2.87	4.36
CS	1.15		1.00	2.15

Environmental costs by treatment types

The carbon tax was introduced by the Labor Government in 2011. Although the carbon tax was revoked from July 2014, it provided a useful guidance on the value of environmental impacts,

especially global climate change. According to the Labor Government, the carbon price from 2012-2013 and 2013-2014 were A$23.00 and A$24.15 respectively. An average value of A$23.58 is adopted. The environmental cost for each strategy can be seen in Table 5.

Table 5. Environmental cost of the eight pavement treatment strategies.

Treatment types	**Total emissions (kg CO_2e/m^2)**	**Carbon price (A$23.58 / tonne CO_2-e)**	**Environmental cost (A$/$m^2$)**
ASDG	3.15	23.58	0.074
ASIM	4.20	23.58	0.099
ASOG	3.15	23.58	0.074
ASRS	9.92	23.58	0.234
GrOL	6.30	23.58	0.148
RipSeal	5.59	23.58	0.131
Slurry	4.36	23.58	0.103
CS	2.15	23.58	0.051

Conclusions

The carbon emission value and its associated cost of eight pavement treatment strategies have been investigated in this project. The carbon emission value is estimated based on the life cycle assessment method and its associated cost is evaluated based on the carbon pricing.

These values will be integrated into the decision making model.

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