Comparative Eco-Efficiency Analysis between Hot In-place Recycling and Milling-and-Filling

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Outline

1. Objective
2. Eco-efficiency Analysis
3. Case Study
4. Service Life Sensitivity Analysis
5. Conclusions

Objective

To **quantify** and **visualize** advantages and disadvantages of two asphalt pavement rehabilitation techniques in terms of economy and environment by employing **Eco-efficiency analysis (EEA)**:

- Hot In-place Recycling (**HIPR**)
- Milling- and-Filling (**M&F**)

Eco-Efficiency Analysis (1/4)

Initially developed by a **German chemicals company BASF**

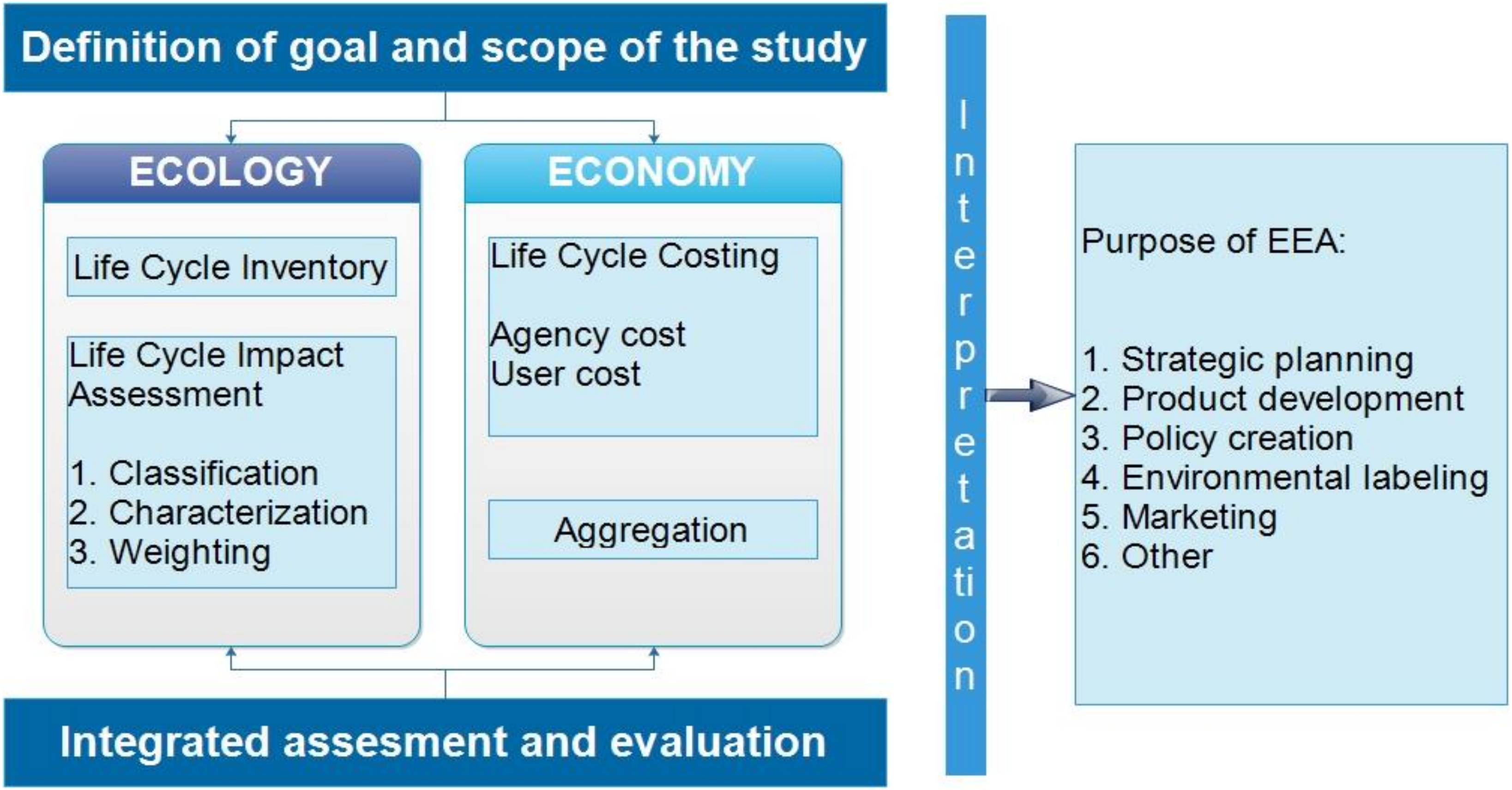
Environmental Impact

Economic Performance

Identify

The best alternative (Competing products, Processes, or **Services)**

Eco-Efficiency Analysis (2/4)

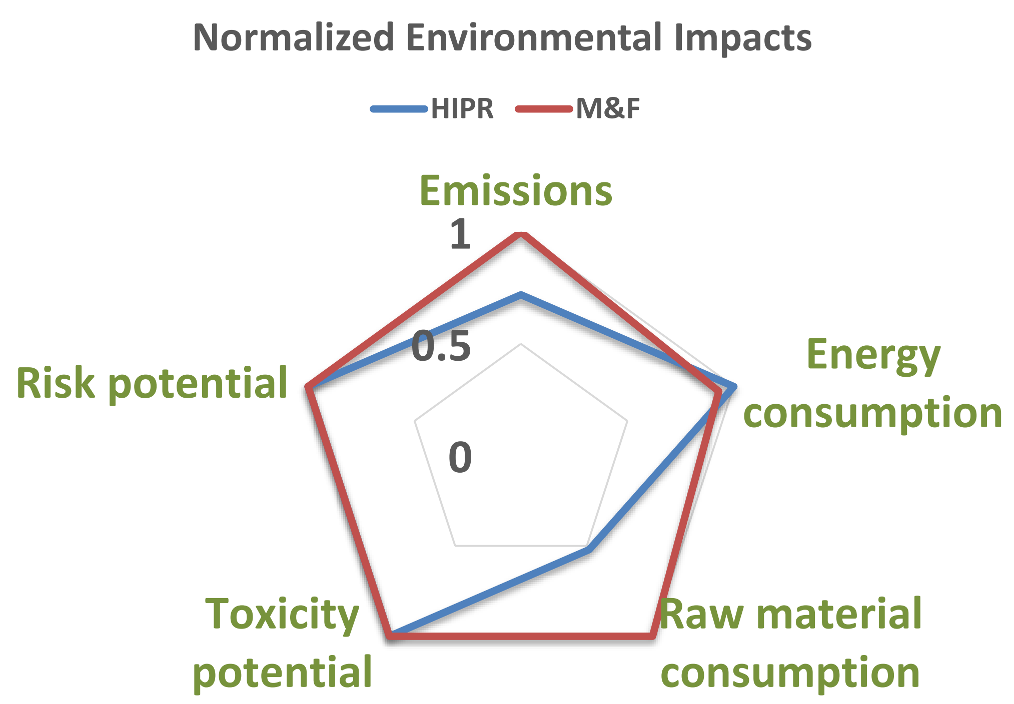


The general framework of Eco-efficiency Analysis

Eco-Efficiency Analysis (3/4)-Integration

Step 1: Normalization

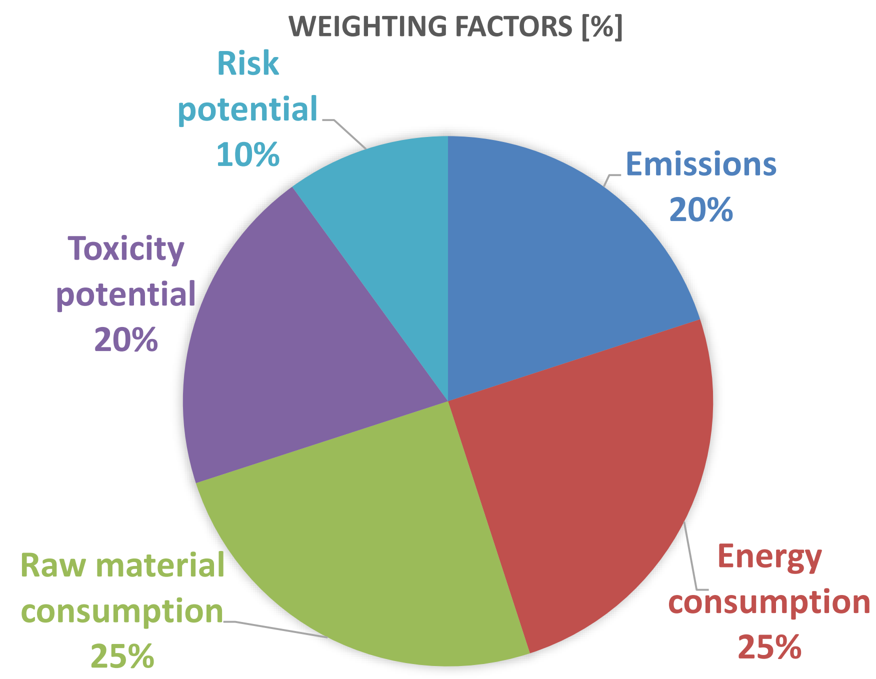
The impact of each of environmental categories is normalized with respect to one another.



Eco-Efficiency Analysis (3/4)-Integration

Step 2: Weighting

Combine the normalized values via a weighting scheme to form a total index for the environmental impact categories.



Eco-Efficiency Analysis (3/4)-Integration

Step 3: Eco-efficiency portfolio position	
The EI and the NF_C are used to calculate the portfolio position. (Kicherer et al., 2007)	$$PP_{E,\alpha} = \frac{EI_\alpha}{(\Sigma EI)/j}$$ $$PP_{C,\alpha} = \frac{NF_{C,\alpha}}{(\Sigma NF_C)/j}$$ Where, $PP_{E'}$ = Environmental impact portfolio position for product α $PP_{C'}$= Cost impact portfolio position for product α EI_α= Environmental impact of product α $NF_{C,\alpha}$= Normalization factor for the costs of product system α j = Number of products under consideration

Eco-Efficiency Analysis (3/4)-Integration

Step 3: Eco-efficiency portfolio position

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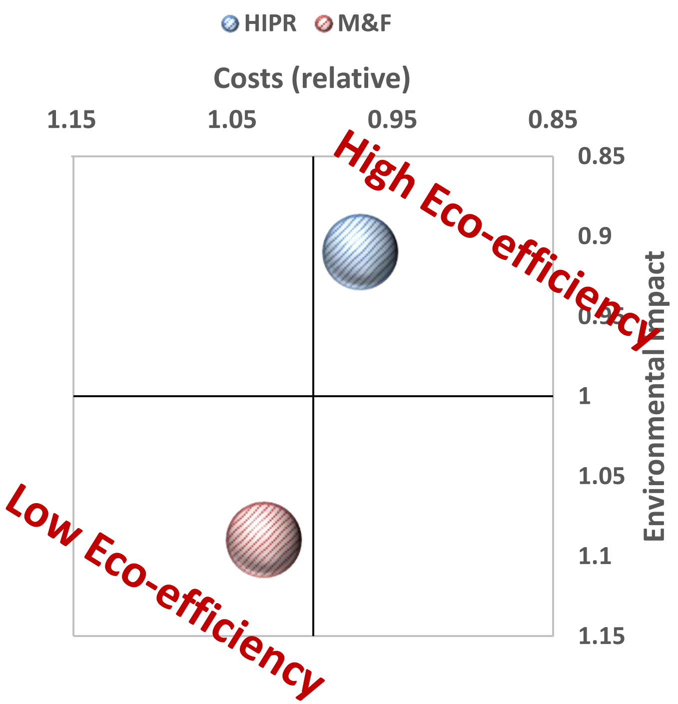


Case Study (1/4) - Basic Information

Yingbin Avenue

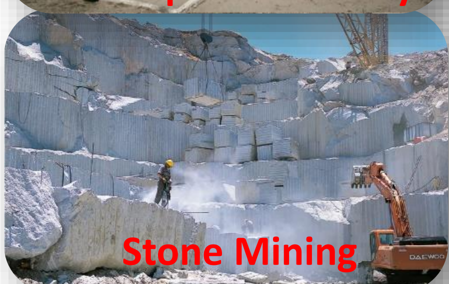
Location
Xianyang, Shaanxi, China
Rehabilitation Method: HIPR
Time: 2015
Length: 3.8km

Case Study (1/4)-Basic Information

	HIPR (Real case)	M & F (Mock case)
Construction Scheme	**Wearing course: AC-10 30mm** **Base course: AC-25 50mm** **Before**	**Wearing course: AC-13 40mm** **Base course: AC-25 50mm** **After**
	Half Range Closure	Half Range Closure
Reference	Construction Report from the Freetech Technology Ltd.	The Chinese Industry Recommendatory Standards: JTG-D50-2006 JTG-F40-2004 JTG/T B06-02-2007
Service Life	15 years (Assumption)	15 years (Assumption)

Case Study (2/4)-System Boundary

Materials Extraction and Production Phase → Transportation Phase → Construction Phase → End-of-Life Phase



Quarry/Asphalt Production Plant
↓ 40km
Hot Asphalt Mixing Plant (Type 3000)
↓ 0.5km
Construction Site
↓ 15km
Scrap Yard

HIPR

Heating & Softening current pavement
↓
Lifting & Remixing with new HMA and rejuvenator

M&F

Milling & Removing current pavement
↓
Laying down the new HMA

↓

Paving
↓
Compacting

Case Study (3/4)-Data Acquisition

- **Environmental Impact Data**

Life Cycle Phase	Software	Function	Developer
Material production phase	Simapro 7.0	Model the GHGs, energy and raw material used in the material extraction phase	PRe Consultants
Transportation phase	MOVES 2014a	Evaluate the GHGs and energy during the transportation of material	US EPA
Construction phase	NONROAD	Provides emission factors for various ranges of horsepower of different construction equipment.	US EPA
End-of-life phase		"Cut-off" allocation method	

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Case Study (3/4)-Data Acquisition

- **Cost Data**

Assumptions

AADT: 15000

Speed limit: 90km/h ⟶ 60km/h (work zone speed)

	Cost	Reference	Developer
Agency Cost	Construction cost	Contract & JTG/T b06-02-2007	Ministry of Communications of PRC
	Energy consumption cost		
User cost	Traffic delay cost	Real Cost	FHWA

Case Study (4/4)-Results

- **Normalized numerical results**

Same service life:
15 years

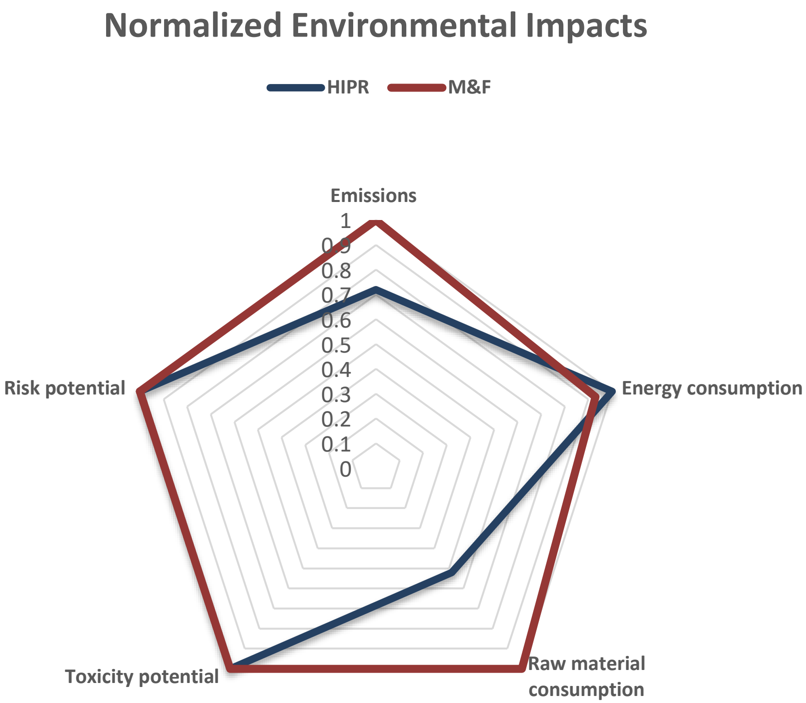
Normalized results		HIPR	M&F
Environmental Impacts	Emissions (20%)	0.72	1
	Energy consumption (25%)	1	0.93
	Raw material consumption (25%)	0.52	1
	Toxicity potential (20%)	1	1
	Risk potential (10%)	1	1
Overall environmental impact		0.84	1
Cost Performance	Agency cost (50%)	0.71	1
	User cost (50%)	1	0.99
	Total Cost performance	0.95	1
PP_E		0.91	1.09
PP_C		0.97	1.03

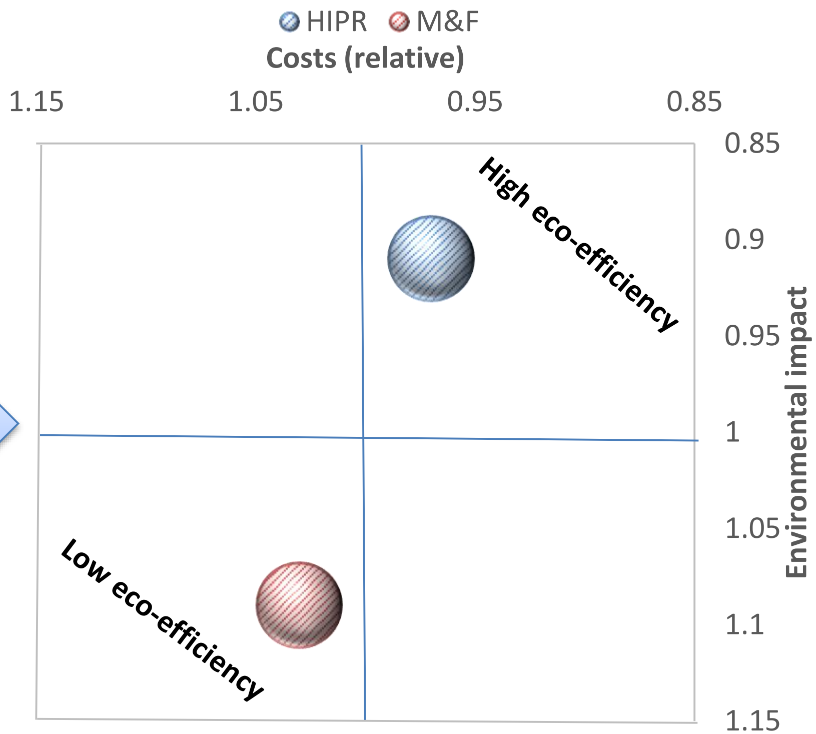
- Reduce 28%
- 7% more
- Save 48%

- Reduce 16%
- Save 29%
- Almost same
- Reduce 5%

Case Study (4/4)-Results

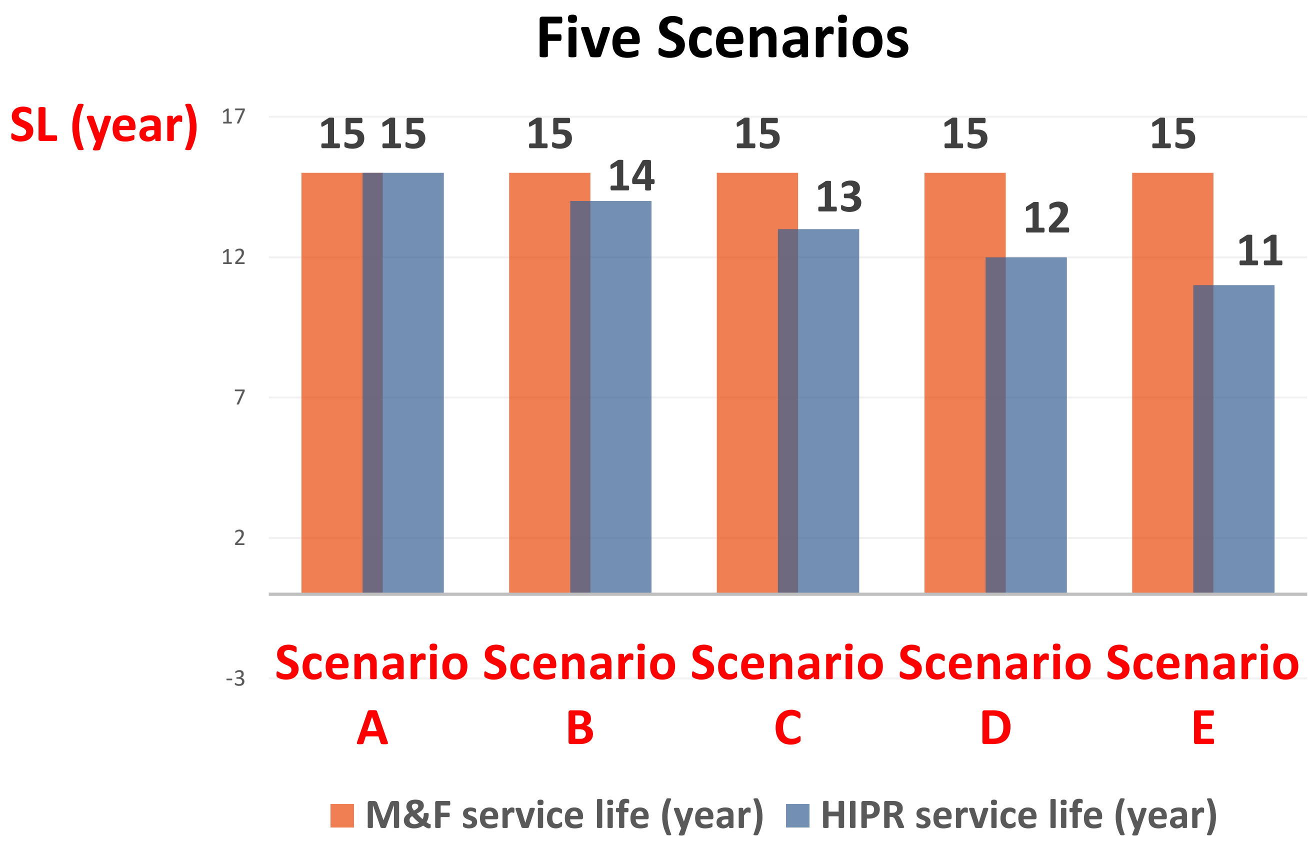
- **Graphical Results**



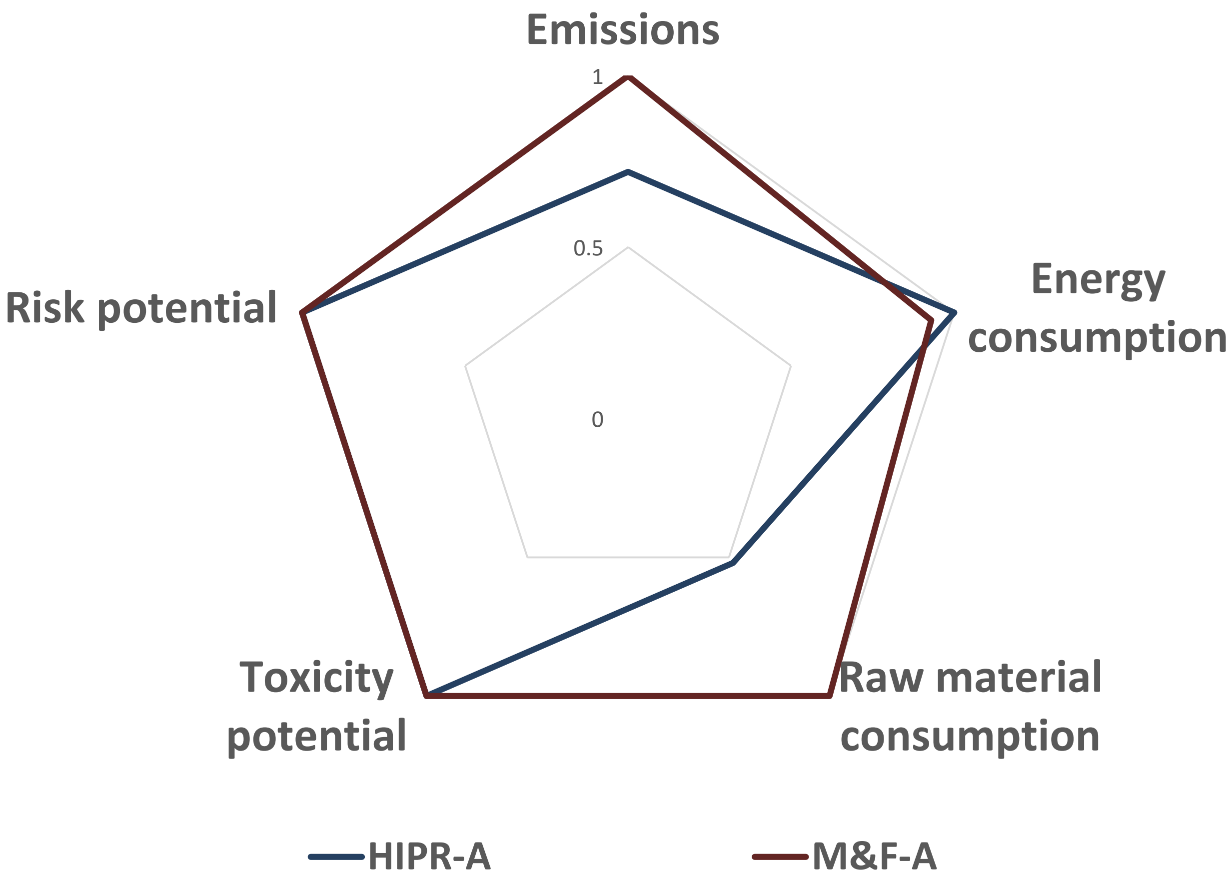


It is clear to identify that the HIPR has the higher eco-efficiency than M&F for this case.

Service Life Sensitivity Analysis (1/3)

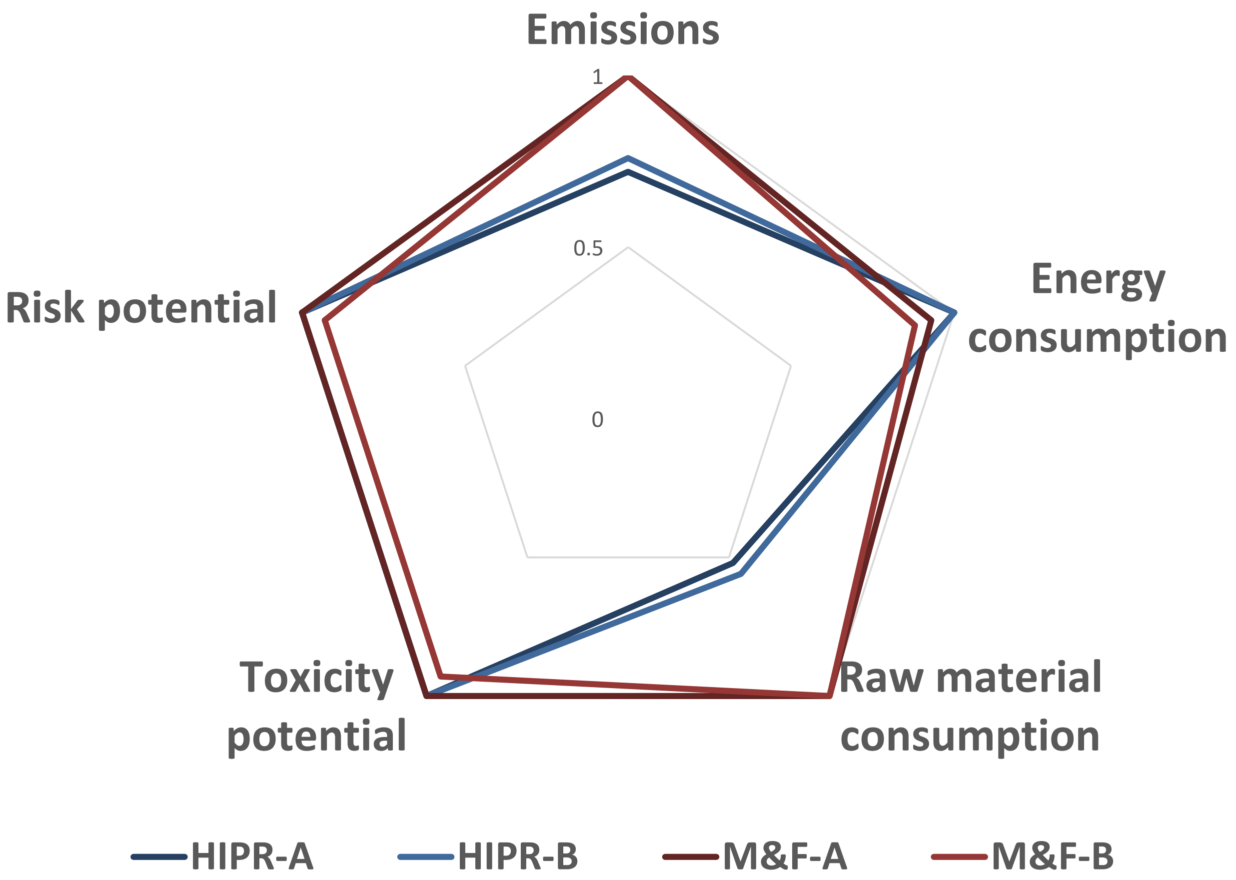


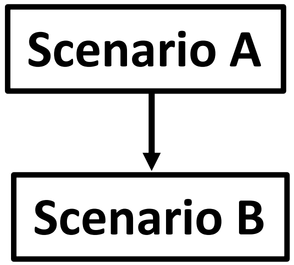
Service Life Sensitivity Analysis (2/3)



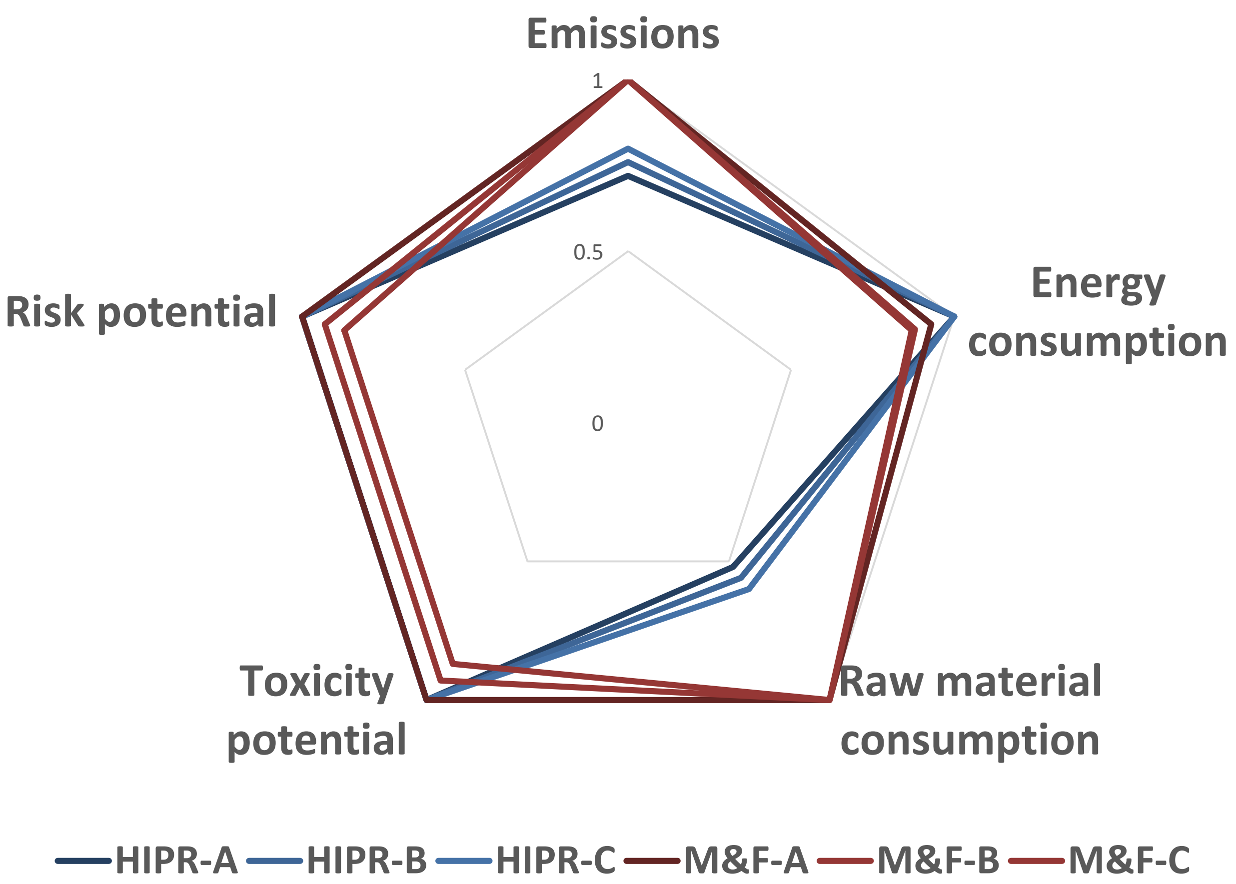
Scenario A

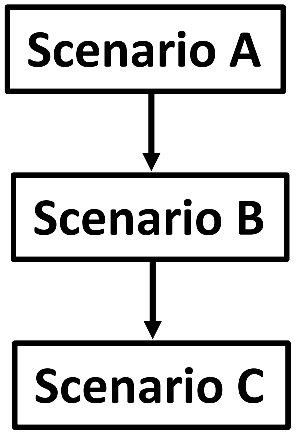
Service Life Sensitivity Analysis (2/3)



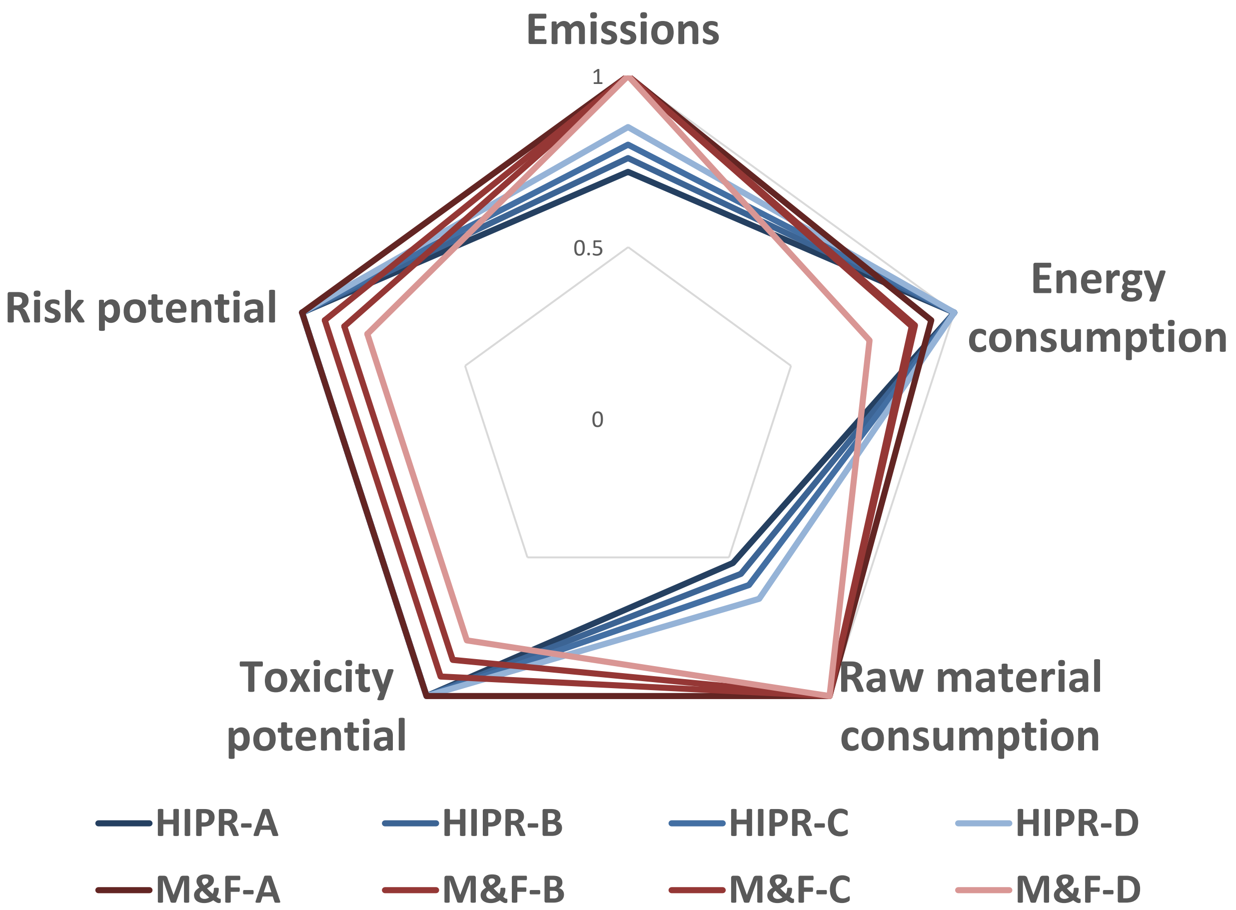


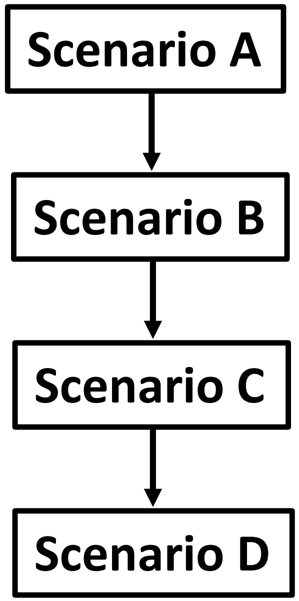
Service Life Sensitivity Analysis (2/3)



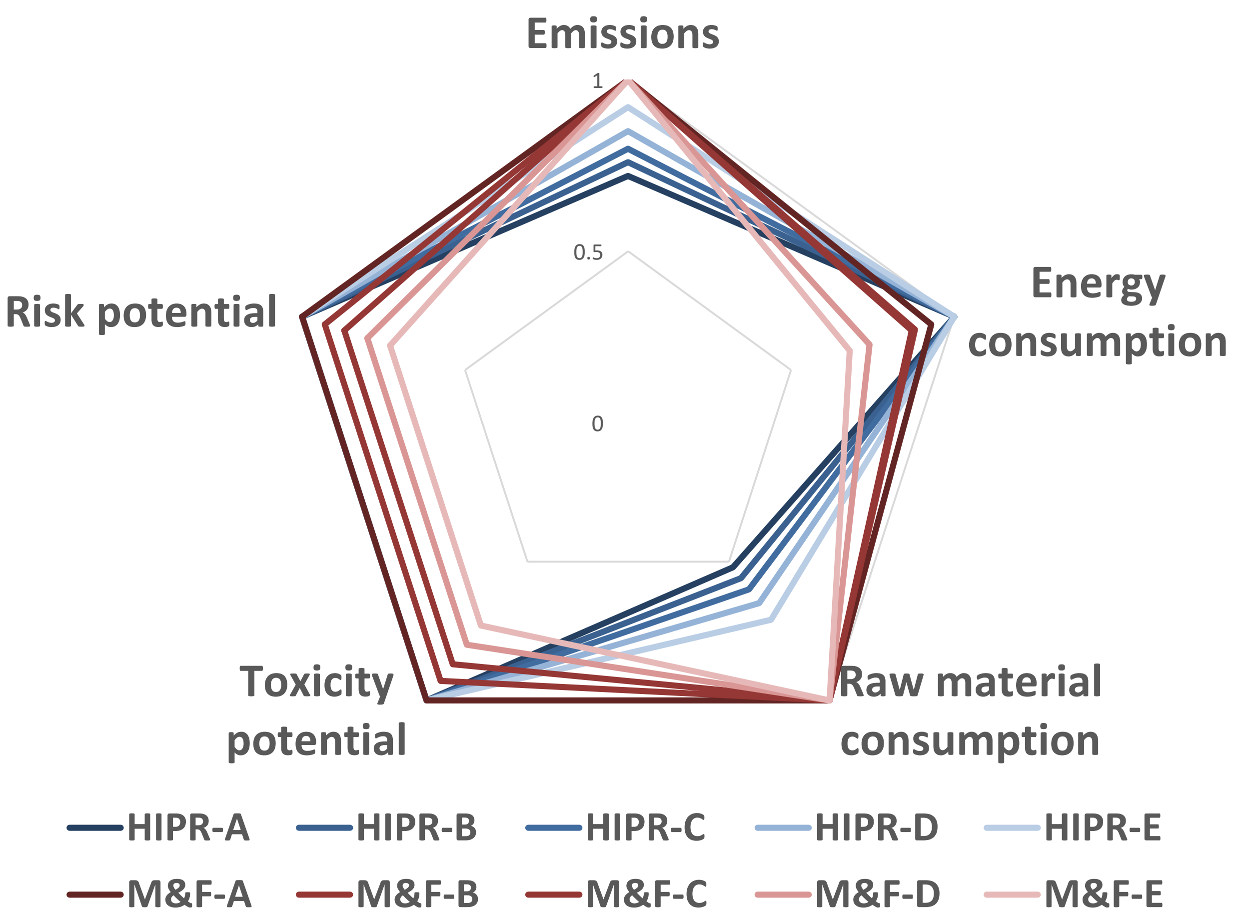


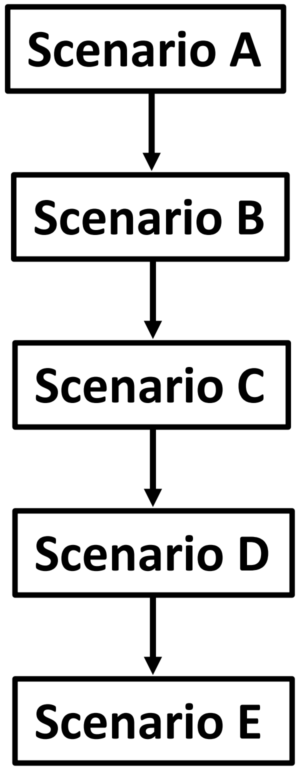
Service Life Sensitivity Analysis (2/3)



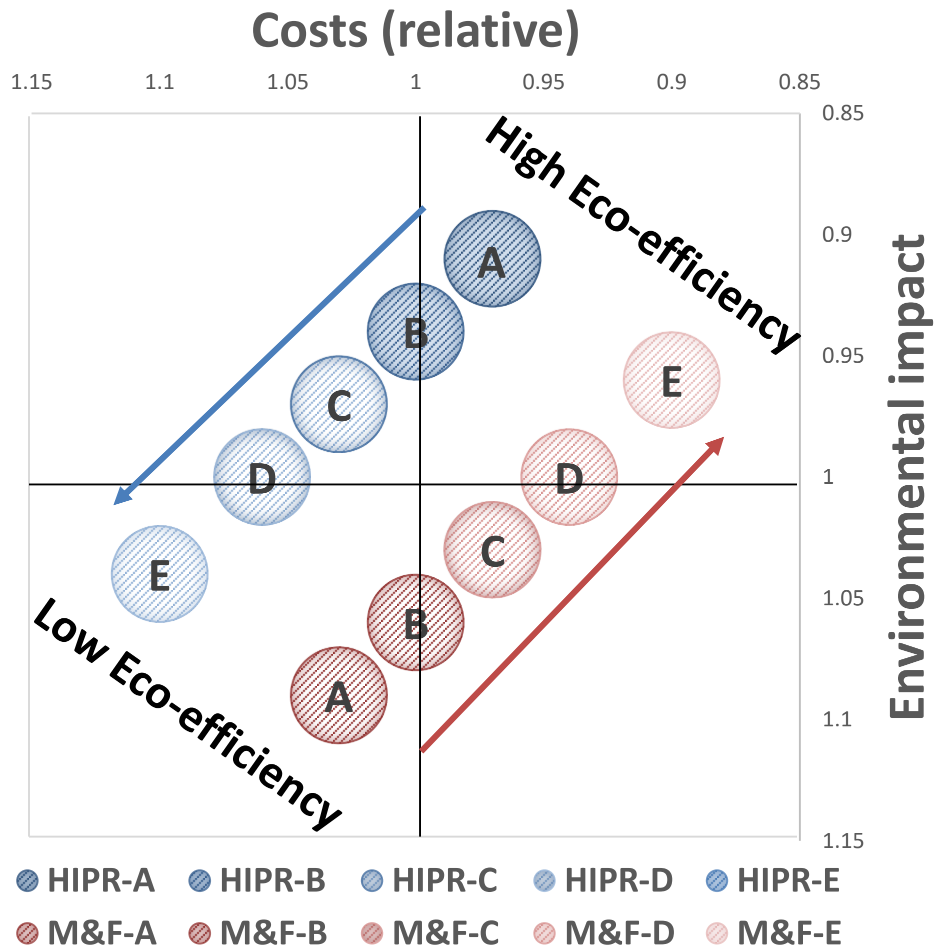


Service Life Sensitivity Analysis (2/3)

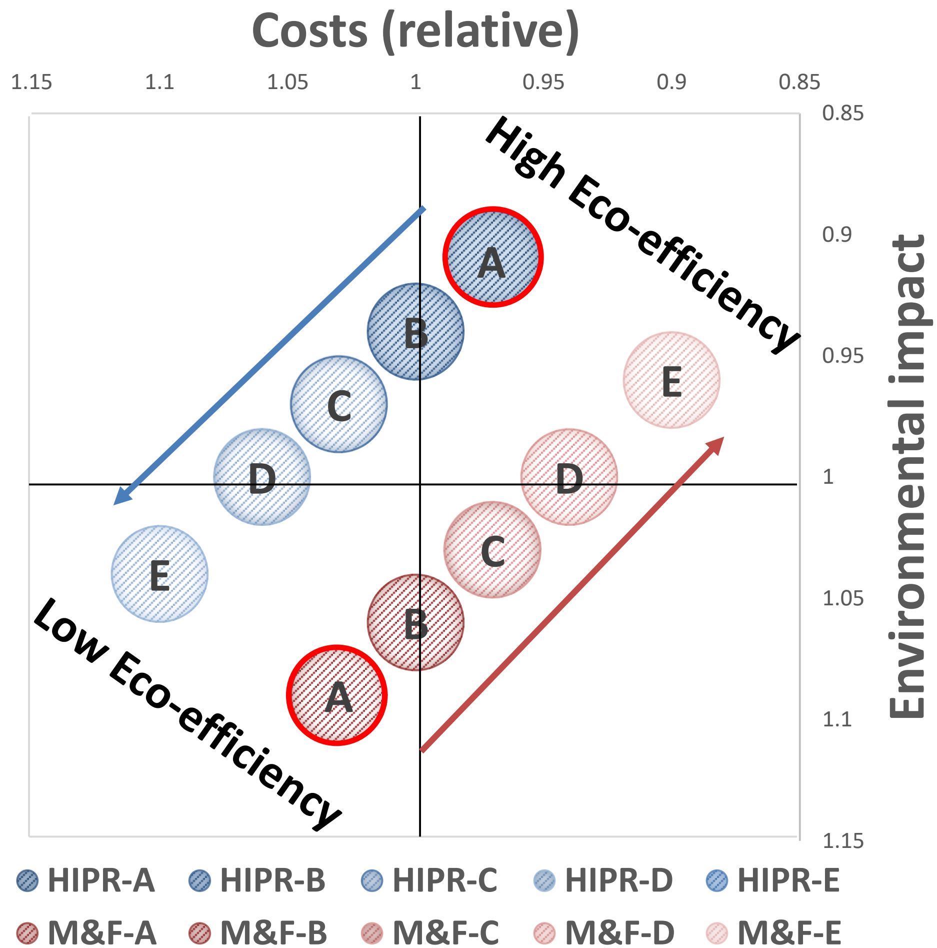




Service Life Sensitivity Analysis (3/3)

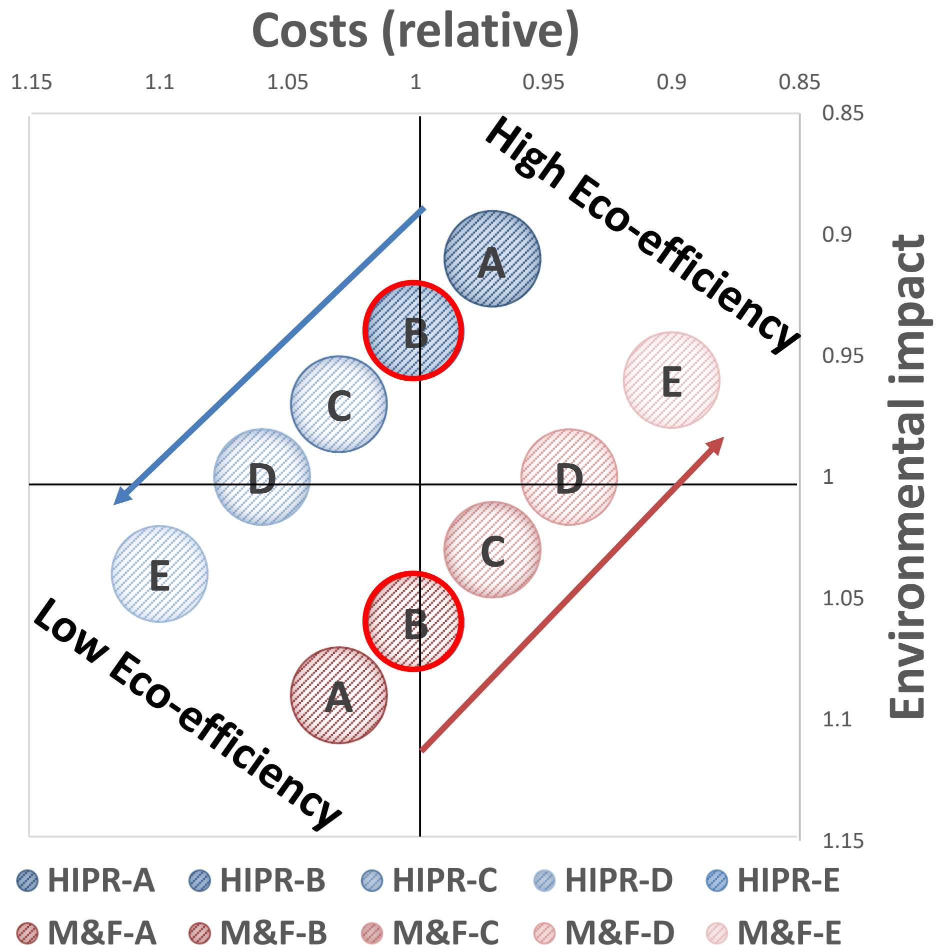


Service Life Sensitivity Analysis (3/3)



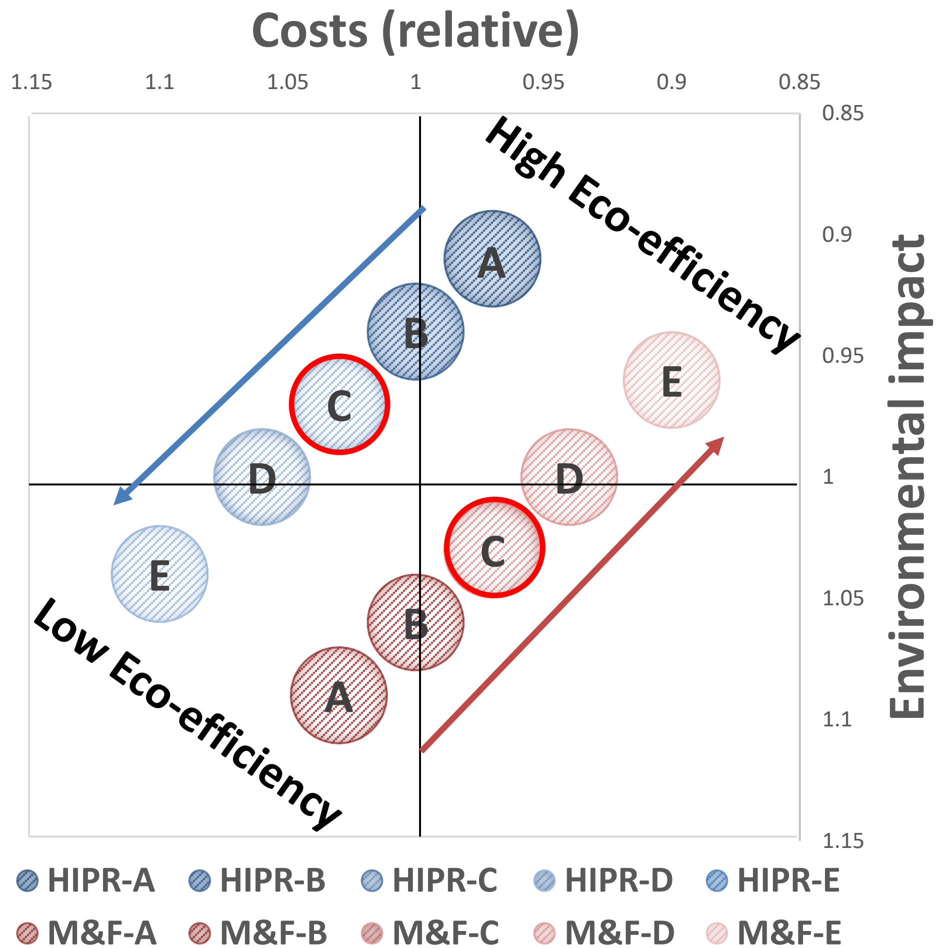
M&F	HIPR
15	15

Service Life Sensitivity Analysis (3/3)



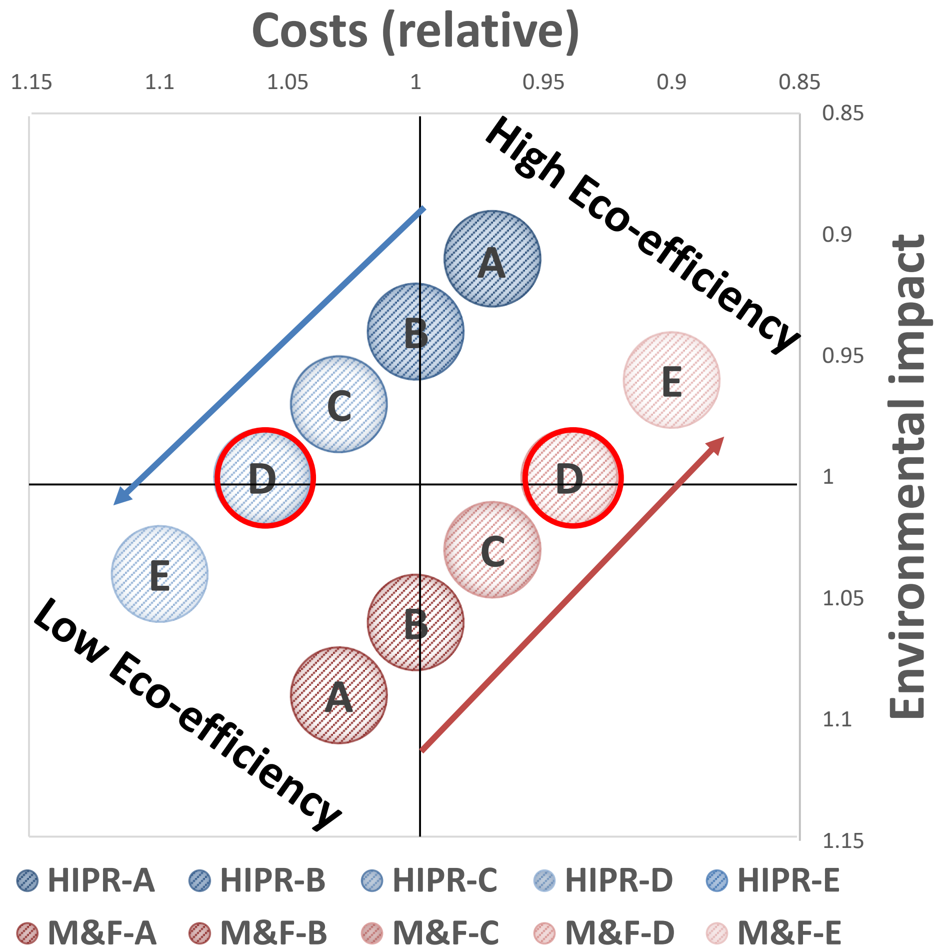
M&F	HIPR
15	14

Service Life Sensitivity Analysis (3/3)



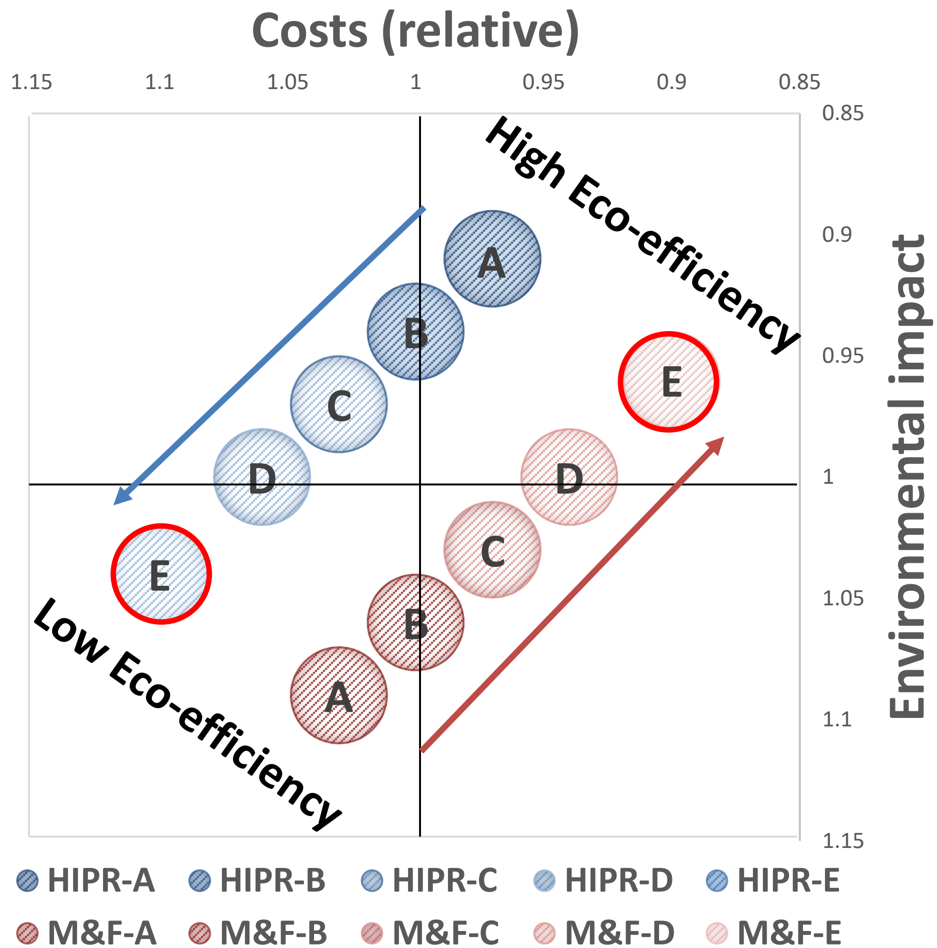
M&F	HIPR
15	13

Service Life Sensitivity Analysis (3/3)



M&F	HIPR
15	12

Service Life Sensitivity Analysis (3/3)



M&F	HIPR
15	11

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Conclusions

- In this project, the decreasing service life of HIPR witnesses its reduction of relative eco-efficiency compared with M&F techniques. For the presented case study, when the ratio of service life of two alternatives reaches **12/15** (**HIPR/M&F**), the M&F starts to show its advantages.
- EEA shows its high potential as an effective sustainability assessment tool for comparing asphalt pavement rehabilitation alternatives.
- Time period, region, system boundaries, transportation distance, crude source distribution, and treatment of refinery allocation will all affect the final eco-efficiency results. Therefore, further research is recommended on the sensitivity analysis about the effects of various factors to obtain more comprehensive results.

Thanks you!

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