Sustainable Framework for Vehicle Retrofitting

By ECOMOTIVE

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Agenda

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- Organisational Framework
- Product Definition and Specification
- Sustainable Design and Development
- Procurement
- Manufacturing
- Testing, Delivery, and Maintenance
- End of Life
- Implementation
- Conclusion

Organisational Framework

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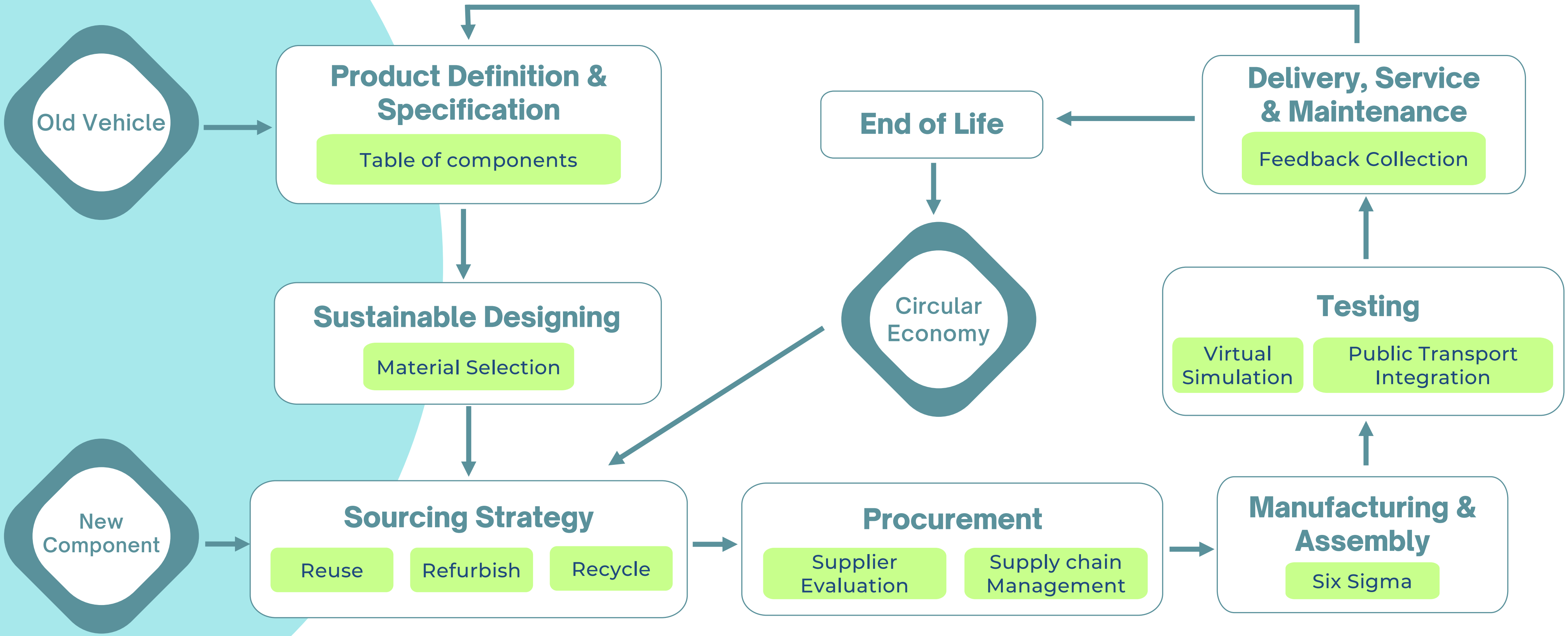

Product Definition and Specification

Table of Components

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Materials	Components	Quantity (MT)	Price (£/MT or £/L or £/m)	Average Emissions(CO2) / Material(MT)	Emissions/car (MT)
Aluminium	Body	0.35	1,400 to 1,950/Mt	14	4.9
Iron & Steel	Chassis, Body	1.7	675 to 900	2	3.4
Glass	Glass	0.05	375 to 750	0.65	0.0325
Plastics & Fibre	Battery, IU	0.25	600 to 1,500	3	0.75
Fabrics	IU	0.02	5 to 30 per meter	3.5	0.07
Rubber	Brake Pads, IU	0.02	1,125 to 1,875	3.5	0.07
Cathode (NMC)	Battery	0.007	15,000 to 22,500	10	0.07
Anode (Graphite)	Battery	0.003	3,750 to 7,500	7.5	0.0225
Lithium	Battery	0.0007	6,000 to 11,250	2	0.0014
Zinc	EM	0.003	1,875 to 2,625	2	0.006
Copper	Battery, EM	0.015	6,000 to 7,500	2	0.03
Paint	IU, EM	0.0003	10 to 40 per litre	0.3	0.00009

Metric Tons = Kilograms / 1000

- Battery contributes to 35-41% of the GHG emissions from EV production
- Manufacturing of Interior Upholstery contributes significantly to total GHG emissions

EM: Electric motor, IU: Interior Upholstery

Sustainable Design and Development

- Battery Chemistry Selection
- Material Selection for Battery Enclosure
- Interior Upholstery Material Selection

Battery Chemistry Selection

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Battery Type	Energy Density (Wh/kg)	Range (miles)	Lifetime and Degradation	Relative safety rating	Carbon Emission LCA (kg CO2eq)	Weight (Kg)	Relative Availability and Production Scalability	Cost ($/kWh)
Li-NMC	160-200	150-300	500-1500 Cycles	80	240	250-350	High (95)	150-200
Li-LFP	90-120	100-250	2000-5000 Cycles	100	166	250-400	Good (85)	170-220
Li-NCA	200-240	200-350	500-1500 Cycles	70	230	200-300	Moderate (75)	200-250
Li-S	300-500	250-300	500-1000 Cycles	60	146	200-300	Low (55)	300-400
Solid State Battery	400-500	300-400	2000-7000 Cycles	70	122	150-250	Low (55)	400-800
NiMH	60-120	80-150	500-1000 Cycles	70	300	300-400	Moderate (65)	140-150

Table: Selection Criteria

Battery Chemistry Selection

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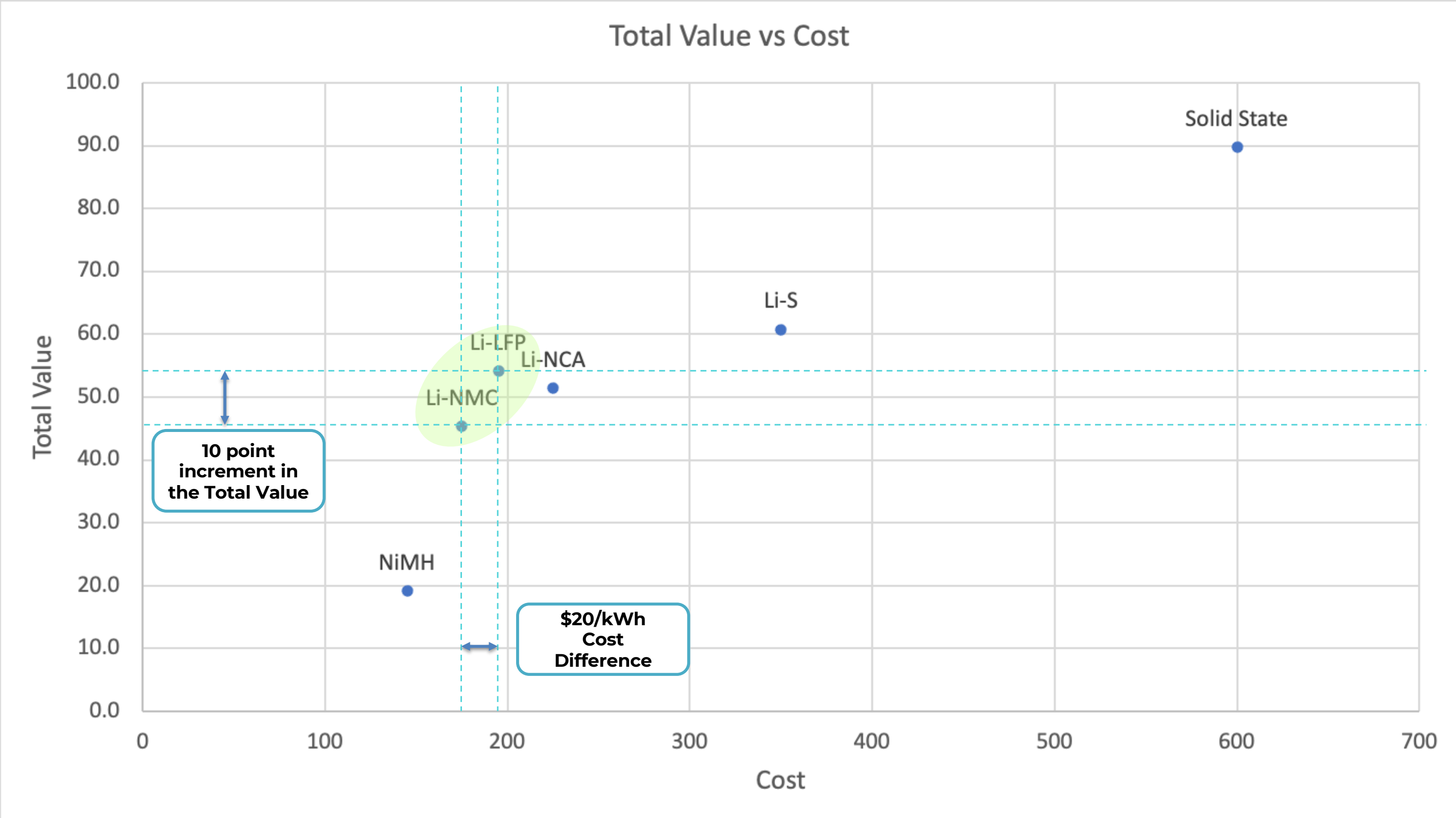
Criteria	Swing weights	Normalised weight
Energy density	70	0.1522
Range	70	0.1522
Lifetime and degradation	65	0.1413
Relative safety rating	75	0.1630
Carbon emission LCA	65	0.1413
Weight	60	0.1304
Relative availability	55	0.1196
Total Weight	460	1.0000

Table: Assigned Swing Weights

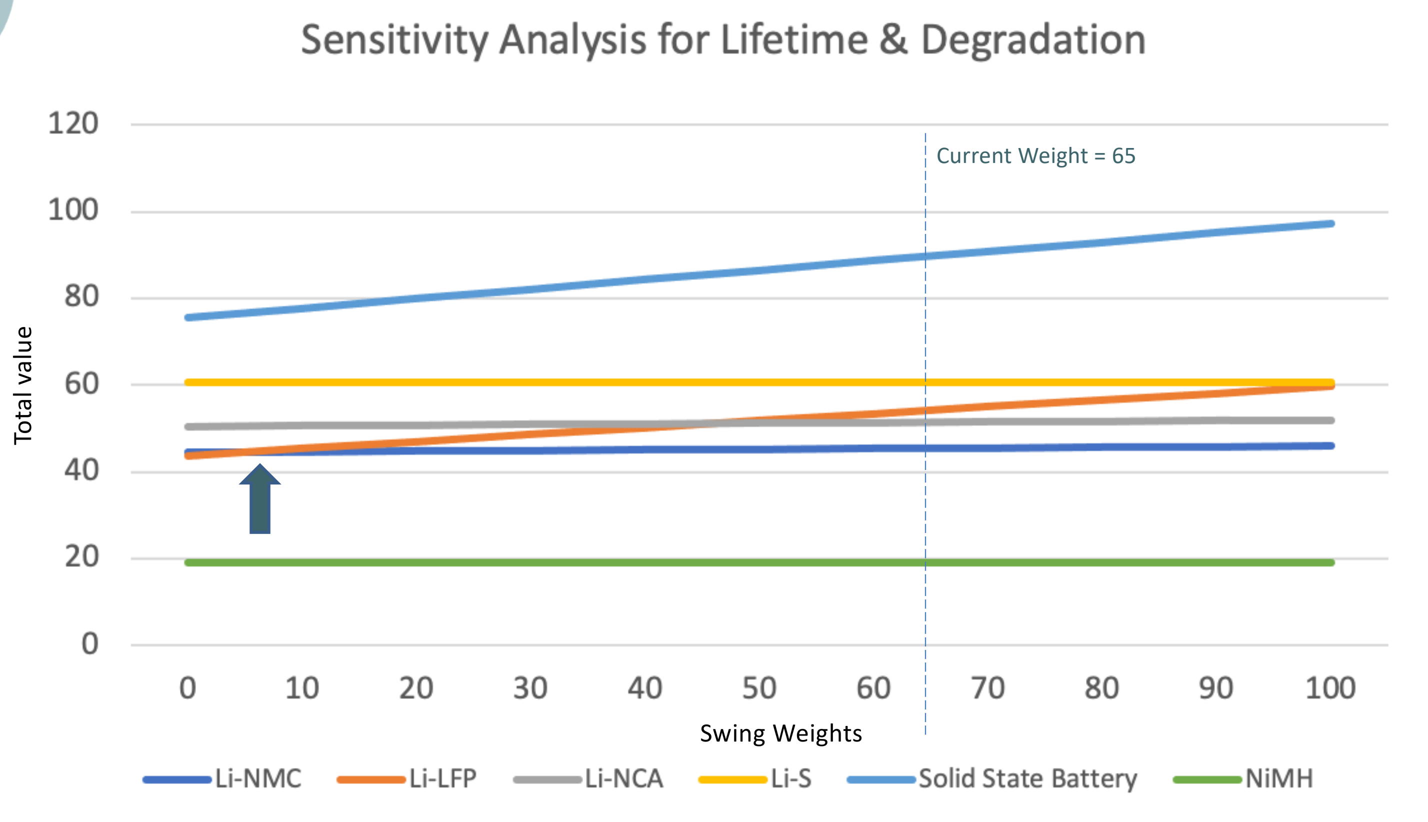
Battery Type	Energy Density	Range	Lifetime and Degradation	Relative safety rating	Carbon Emission LCA	Weight	Relative Availability and Production Scalability	Cost	Total Value
Li-NMC	25	46.8	6.7	80	33.7	33.32	95	175	45.4
Li-LFP	4.169	25.52	73.45	100	75.28	16.65	85	195	54.2
Li-NCA	36.116	68.07	6.7	70	39.32	66.65	75	225	51.4
Li-S	86.12	68.07	0	60	86.51	66.65	55	350	60.7
Solid State Battery	100	100	100	70	100	100	55	600	89.7
NiMH	0	0	0	70	0	0	65	145	19.2

Table: Normalized Value

Battery Chemistry Selection



Battery Chemistry Selection



Material Selection for Battery Enclosure

BATTERY ENCLOSURE BOX MATERIALS	Weight (kg/m^3)	CO2 (kg/kg material)	Durability	Longevity (years)	Cost (£/kg)
Hemp-based	650	1	3	7.5	2.625
Mycelium	300	0.3	2	10	7.5
Algae-based	300	0.35	1	3	15
Bio-derived Polyurethanes	600	1.75	3	12.5	4.875
Recycled Carbon Fiber Reinforced Plastics	1750	3	4	17.5	20.625
Wood	600	0.3	2	35	3.75
Bio-based Polyethylene Terephthalate (PET)	2500	1.5	4	15	1.5
Bio-based Polyamides	1200	1.5	4	17.5	3
Basalt Fiber	2850	0.5	4	40	6
Recycled Plastic	1000	1	2	27.5	1.25
Biodegradable Bioplastics	1000	0.5	1	2.5	3.5
Banana Fiber	600	1	3	10	9.375
Steel	7850	1.5	4	50	0.8
Aluminum	2700	1.75	3	50	2

Table: Selection Criteria

Fig. 1 Battery Enclosure Box

Durability
Low = 1
Moderate = 2
Moderate to High = 3
High = 4

Material Selection for Battery Enclosure

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Alternatives	Weight	CO2	Durability	Longevity	Total value	Cost (£/kg)
Hemp-based	95.39	74.07	74.07	10.53	64.8	2.625
Mycelium	100	100	100	15.79	80.0	7.5
Algae-based	100	98.15	98.15	1.05	75.6	15
Bio-derived Polyurethanes	96.05	46.3	46.3	21.05	53.8	4.875
Recycled Carbon Fiber Reinforced Plastics	80.87	0	100	31.58	49.8	20.625
Wood	96.05	100	33.33	68.42	77.9	3.75
Bio-based Polyethylene Terephthalate (PET)	70.97	55.55	100	26.32	61.8	1.5
Bio-based Polyamides	88.13	55.55	100	31.58	67.7	3
Basalt Fiber	66.35	92.59	100	78.95	83.7	6
Recycled Plastic	90.77	74.07	33.33	52.63	65.2	1.25
Biodegradable Bioplastics	90.77	92.59	0	0	51.3	3.5
Banana Fiber	96.05	74.07	66.67	15.79	64.7	9.375
Steel	0	55.55	100	100	60.1	0.8
Aluminum	68.33	46.3	66.67	100	69.2	2

Table: Selection Criteria

Attribute	Swing weights	Normalized Weights
Weight (kg/m^3)	80	0.2712
CO2 (kg/kg material)	85	0.2881
Durability	60	0.2034
Longevity (years)	70	0.2373
Total Weight:	295	1

Table: Assigned Swing Weights

Material Selection for Battery Enclosure

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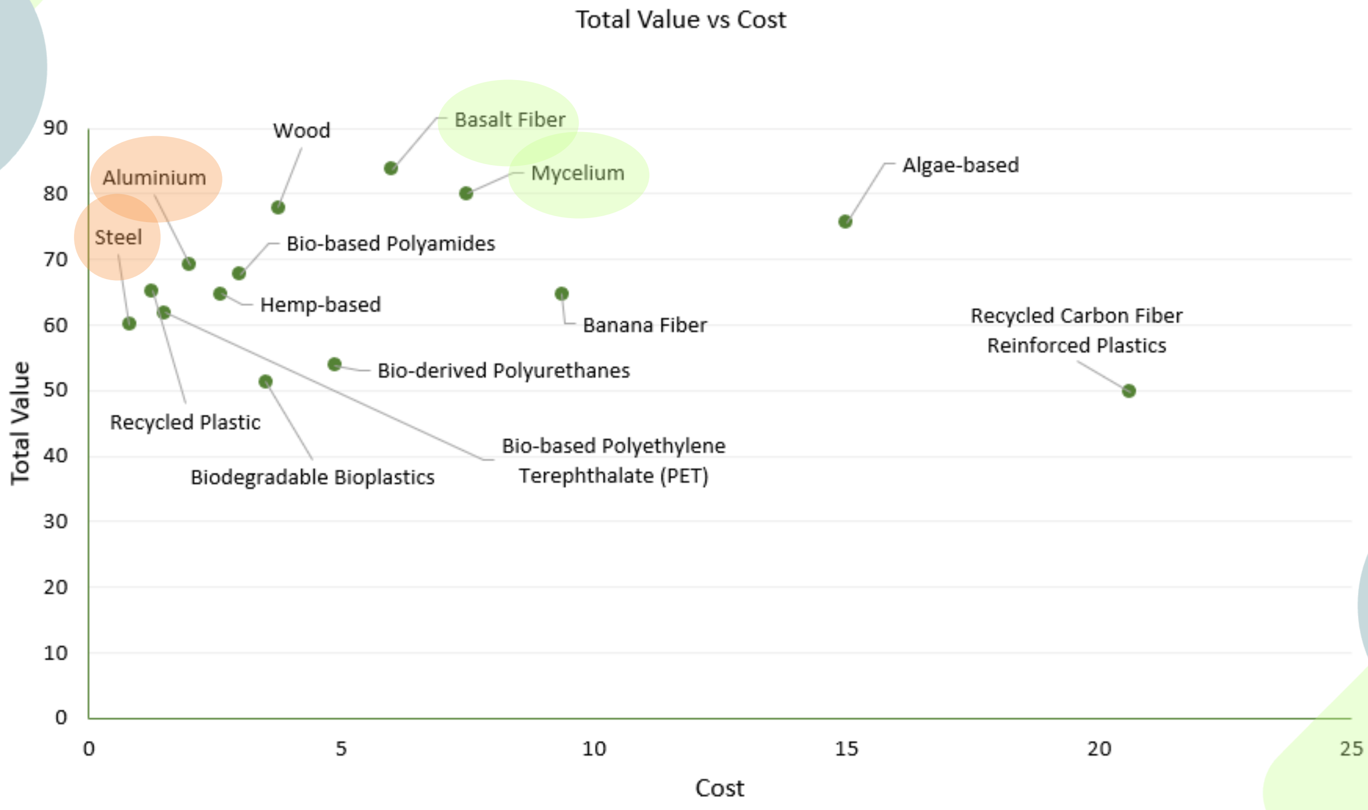

Interior Upholstery Material Selection

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	Materials		Life cycle assessments							Cost ($/kg)
		Longevity (years)	Acidification potential (kg SO2-eq)	Relative Human toxicity potential (0-most hazardous, 100-least hazardous)	Global warming potential (kg CO2-eq)	Relative Water Consumption (0-highest consumption, 100-lowest consumption)	Energy consumption (MJ)	Biodegradability		
Traditional Materials	PVC (Polyvinyl Chloride)	100	0.0062	0	1.9	90	55.5	NO		1
	PU (Polyurethane)	15	0.00885	20	3.084	60	101.5	NO		2.5
	PP (Polypropylene)	20	0.0043	30	1.6	80	73	NO		1
	PC (Polycarbonate)	10	0	35	5.6	50	112.95	NO		3
	ABS (Acrylonitrile Butadiene Styrene)	70	0.00658	40	2.354	70	95.34	NO		2
	PMMA (Polymethyl Methacrylate)	25	0.02935	45	8.21	75	116.14	NO		5
Sustainable Alternatives	Bio-PET (Bio-based Polyethylene)	35	0.013	60	2.1	5	60	NO		3.5
	Bio-PP (Bio-based Polypropylene)	15	0	65	2.4	0	42	NO		4
	PLA (Polylactic Acid)	15	0.0073	80	0.6	10	35	YES		3
	PHA (Polyhydroxyalkanoates)	3	0.016811	85	3.491	15	23.33	YES		3.5

Table: Selection Criteria

Interior Upholstery Material Selection

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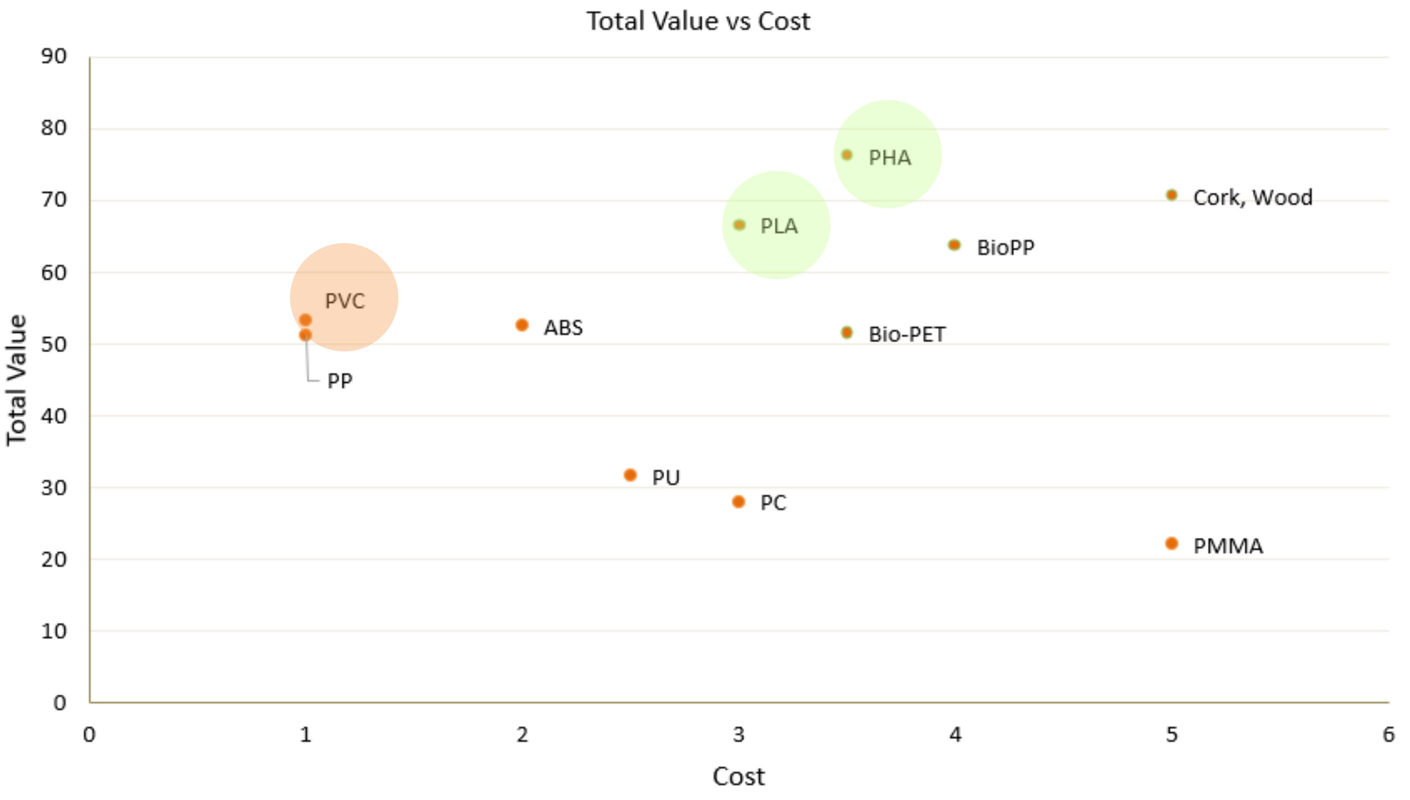
Attribute	Swing weights	Normalized Weights
Longevity	5	0.05
Acidification	5	0.05
HTP	20	0.18
GWM	30	0.27
Water	10	0.09
Energy	25	0.23
Biodegradability	15	0.14
Total Weight	110	1

Table: Assigned Swing Weights



Procurement

- Supplier Evaluation
- Green Supply Chain Management

Supplier Evaluation

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Suppliers	Transportation Emission (tCO2e)	Waste generation (metric tonnes)	Water Usage (gallons)	Carbon footprint (tCO2e)	Certifications (ISO 9001, ISO 14001, etc.)	Sustainability reporting	Transparency (%)	Cost ($)
Supplier 1	70	22000	200,000	200000	Yes	Yes	57	200000
Supplier 2	80	24000	250000	210000	No	No	60	320000
Supplier 3	200	23809	300000	215000	Yes	No	65	210000
Supplier 4	500	12998	350000	320000	Yes	Yes	30	340000
Supplier 5	180	31783	400000	280000	No	No	35	220000
Supplier 6	150	12000	210000	300000	No	Yes	89	230000
Supplier 7	100	21000	220000	190000	Yes	No	90	150000

Table: Selection Criteria

1 **Social**

2 **Economic**

3 **Environmental**

(UNEP, 2020)

Supplier Evaluation

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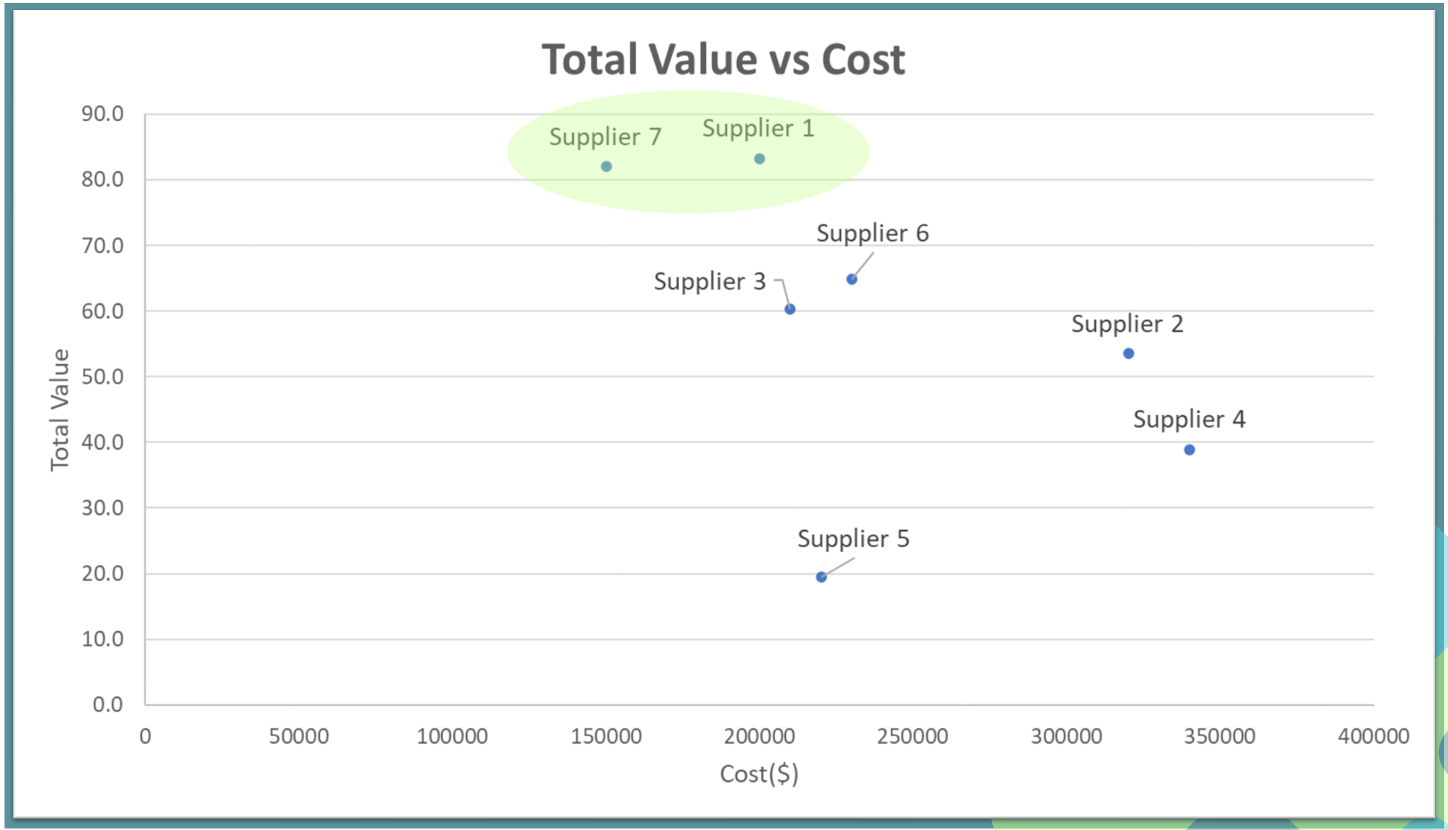
Attribute	Swing weights	Normalised weights
Transportation Emission	80	0.20
Waste generation	50	0.12
Water Usage	50	0.12
Carbon footprint	70	0.17
Certifications (ISO 9001, ISO 14001, etc.)	60	0.15
Sustainability reporting	40	0.10
Transparency	60	0.15
Total weight:	410	1.00

Table: Assigned Swing Weights



Green Supply Chain Management

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Strong Bargaining Power

- Stable relationship
- Vision alignment
- Seek expertise and resources

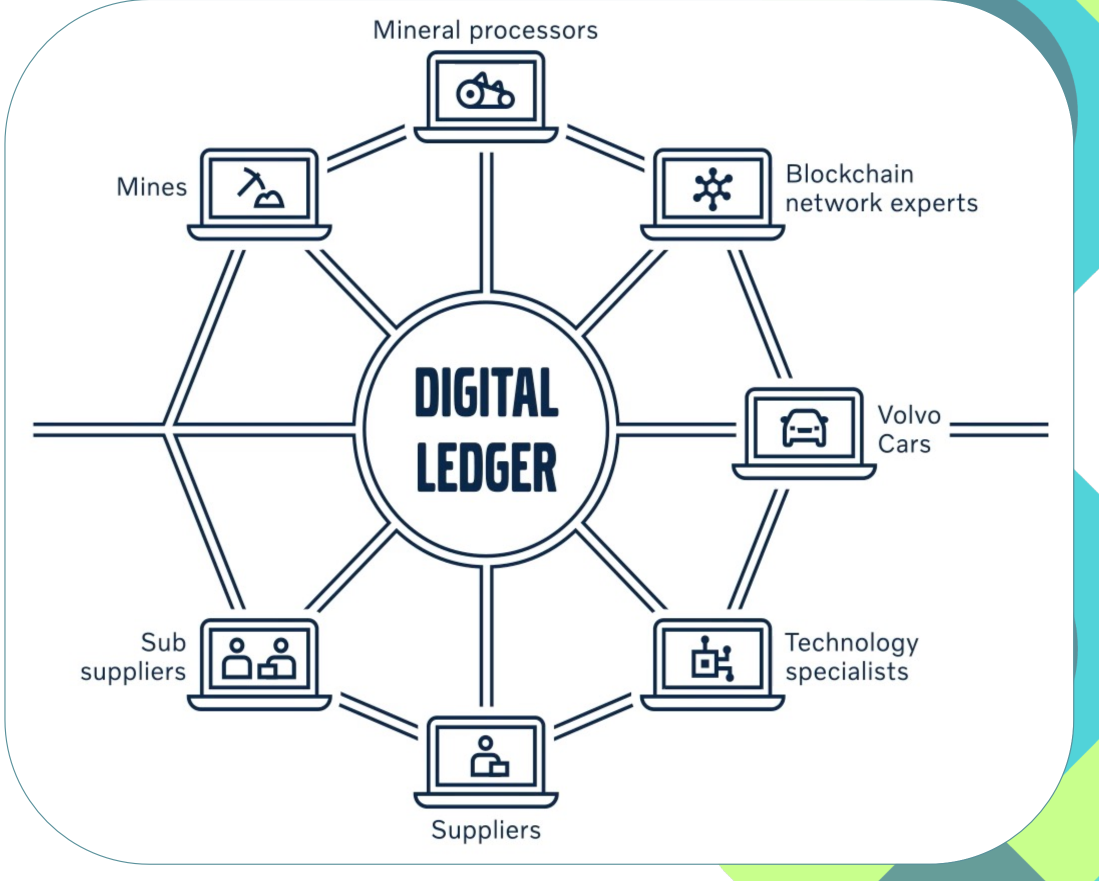
Low Bargaining Power

- Selective collaboration
- Personnel training
- Reward system

(Gutierrez et al., 2020)

Blockchain-based Traceability System

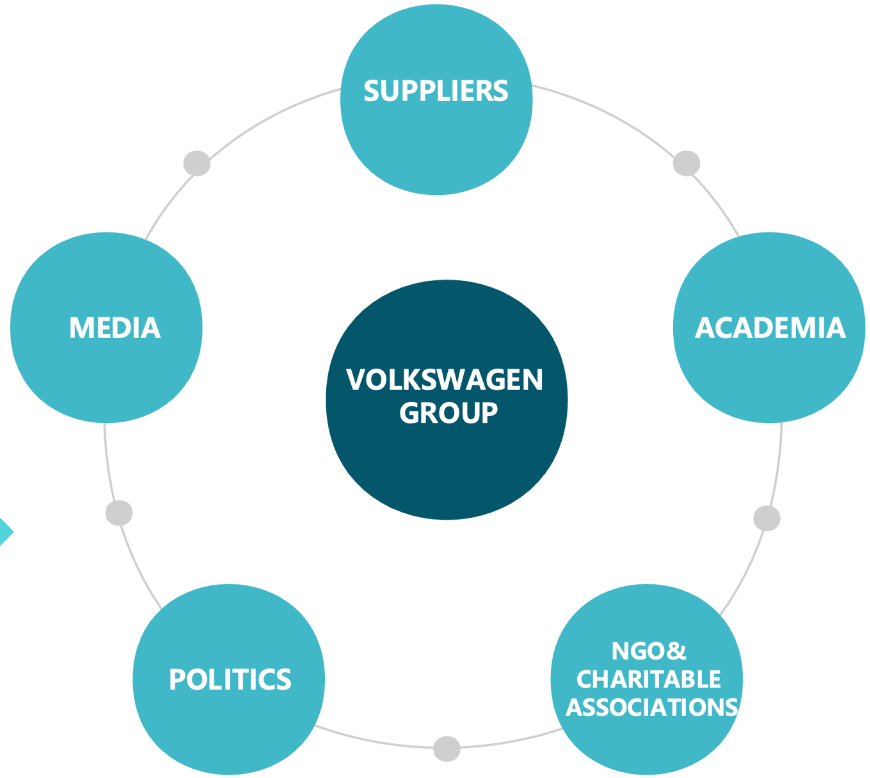
1. Mine site inspections
2. GPS Tracking
3. Entry & exit scanning
4. Time Tracking
5. Verified logistics providers



(Volvo Car, 2019)

Sustainability Steering Committee

- Discussion Panels
- Stakeholder Surveys
- International Cooperative Projects



(Volkswagen, 2020)

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Manufacturing

- Six Sigma
- Digital Twin
- Intelligent Immune System

Six Sigma（DMAIC）

Define: Enhance the sustainability of the vehicle cleansing process

Measure: PM emissions, material waste, noise pollution, and energy consumption

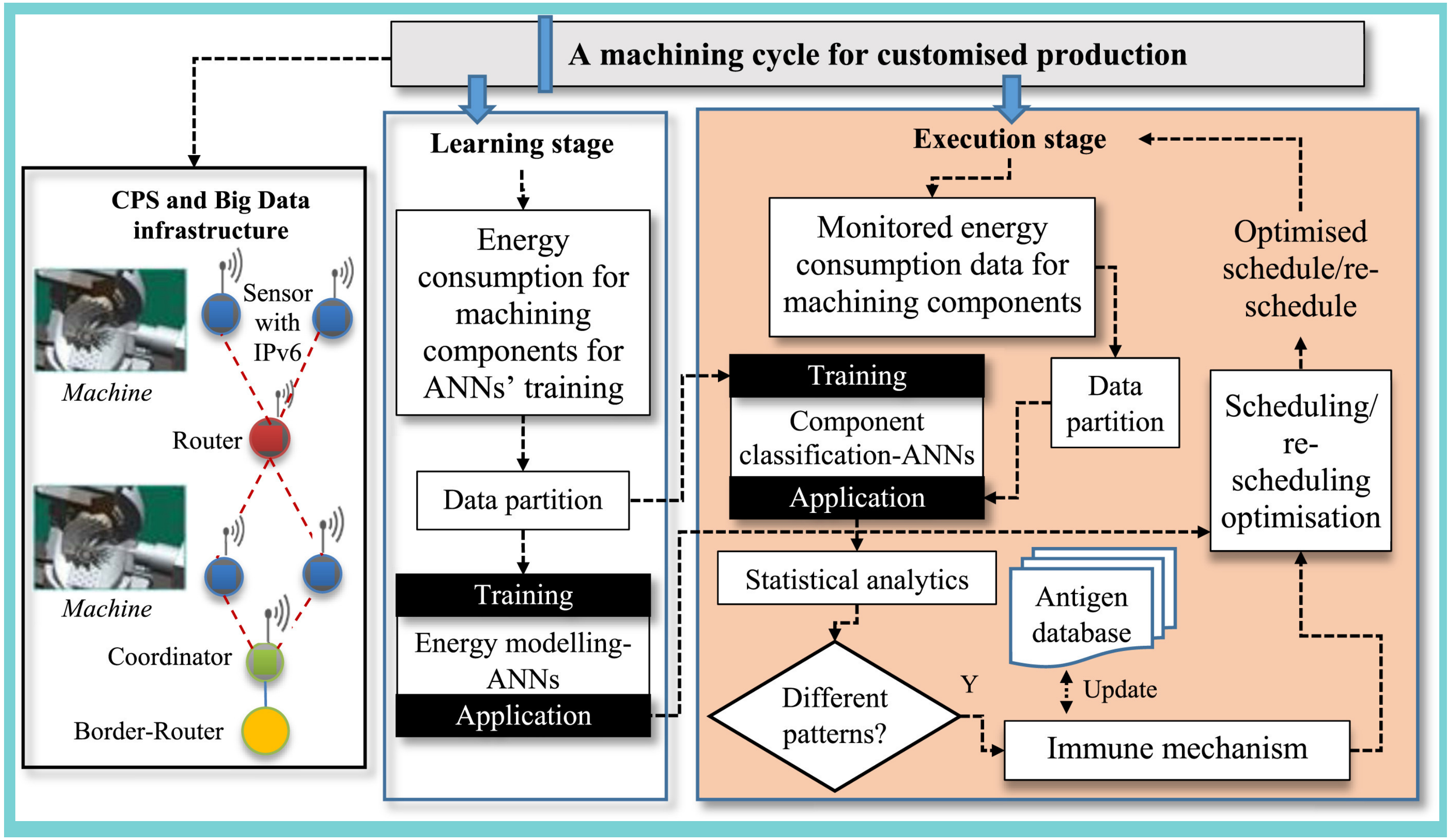
Analyse: High levels of air and noise pollution detected in current abrasive blasting process.

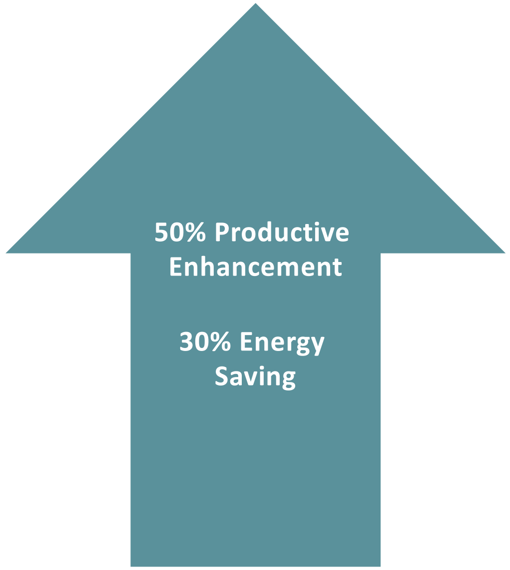
Improve: Changing to more sustainable blasting method such as bead blasting

Control: Maintaining the improvements by monitoring and controlling the process to ensure long-term stability

(Pankaj Kumar, 2023)
(Zulkarnain et al., 2021)

Intelligent Immune System





(Wang et al., 2018)

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Testing, Delivery and Maintenance

- Testing
- Delivery
- Maintenance

Testing, Delivery and Maintenance

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Testing

- Virtual Simulation
  (Springer India, 2017)
- Public Transport Integration
  (Shen, Zhang and Zhao, 2018)
- Battery Optimisation
  (You, Krage and Jalics, 2005)

Delivery

- Stakeholder Engagement
  - Customer education
  - Gather feedback and enhance the sustainability framework

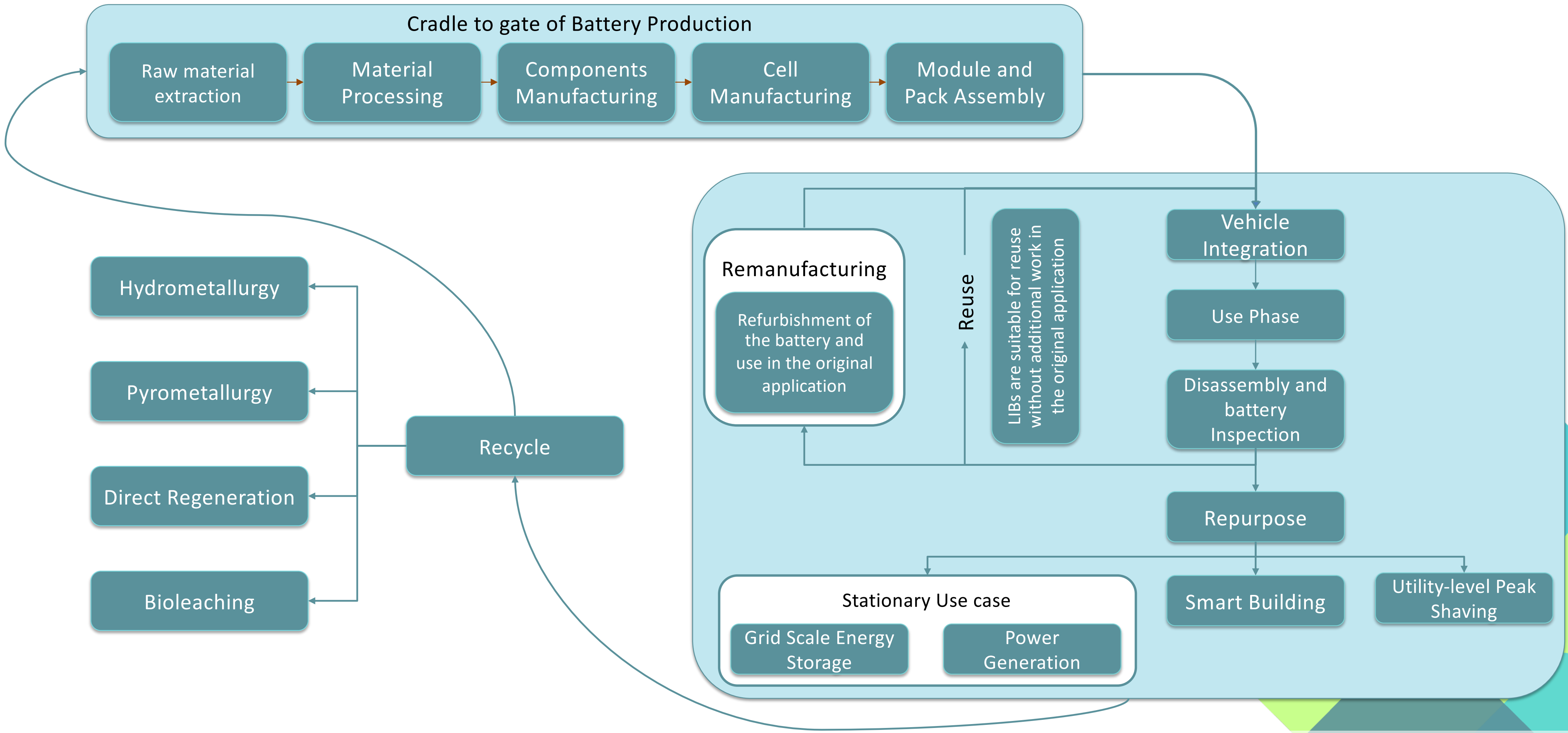
Maintenance

- Remote Diagnostic & Maintenance
  (Yang, Huang, and Lin, 2022).
  - Predictive Issue Identification
  - Maintenance Efficiency

End of Life

- Battery
- Interior Upholstery

Battery Framework



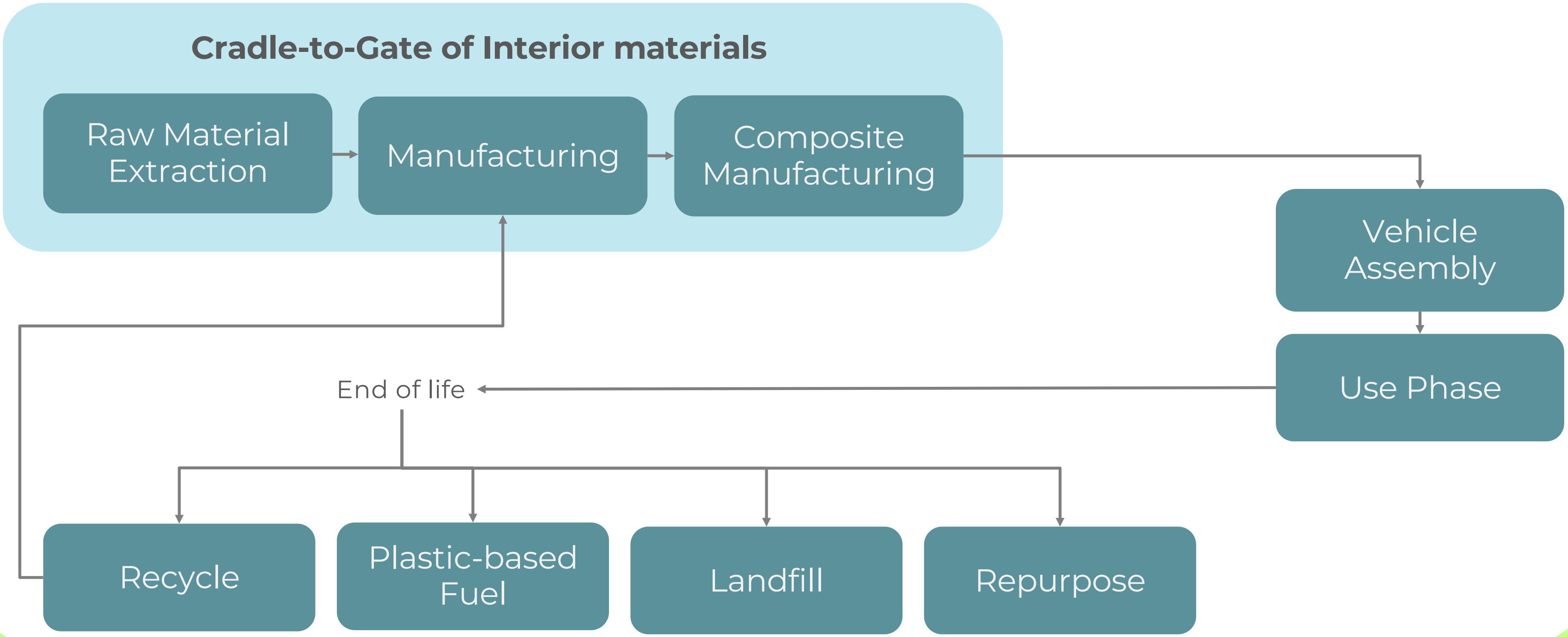
(Xia and Li, 2022; Yang, Huang and Lin, 2022)

Battery Passport

[GBA Battery Passport (Link)]

Global Battery Alliance (n.d.)

Interior Upholstery Framework



(Hermansson, Janssen and Gellerstedt, 2013)

Interior Upholstery End-of-Life Framework

Cradle to gate of Interiors Materials

Substituting **recycled PP** for virgin PP reduce
- 50% of CO2 equivalent
- 29% of water usage
- 78% of oil equivalent

Use Phase

The car door panels made of a mix of **bio-polyethene fossil-based polypropylene** materials improve energy consumption efficiency and reduce environmental impacts due to their low densities.

End of life

Substituting **recycling postconsumer HDPE and PET** for virgin HDPE and PET reduce
- 40–85% of non-renewable energy
- 25–75% of greenhouse gas emissions

(Yin et al, 2014; Bataineh, 2020)

End-of-Life stage

Materials from interior upholstery can take various routes once they come to end-of-life

Repurpose

Avoid going through many chemical processes

Recycle

- 8.4% of plastic waste were successfully recycled
- Put waste plastic through process to produce granulate and to produce new plastic product

Plastic-based fuel

Convert plastic into oil using method such as pyrolysis

Landfill

75.8% of plastic waste was landfilled

(Kumar Jha and Kannan, 2020; Chea et al., 2023; Jeswani et al., 2021; Li et al., 2022)

Framework Implementation

- Phased Rollout
- McKinsey Horizon Strategy
- Risk Analysis

Phased Rollout

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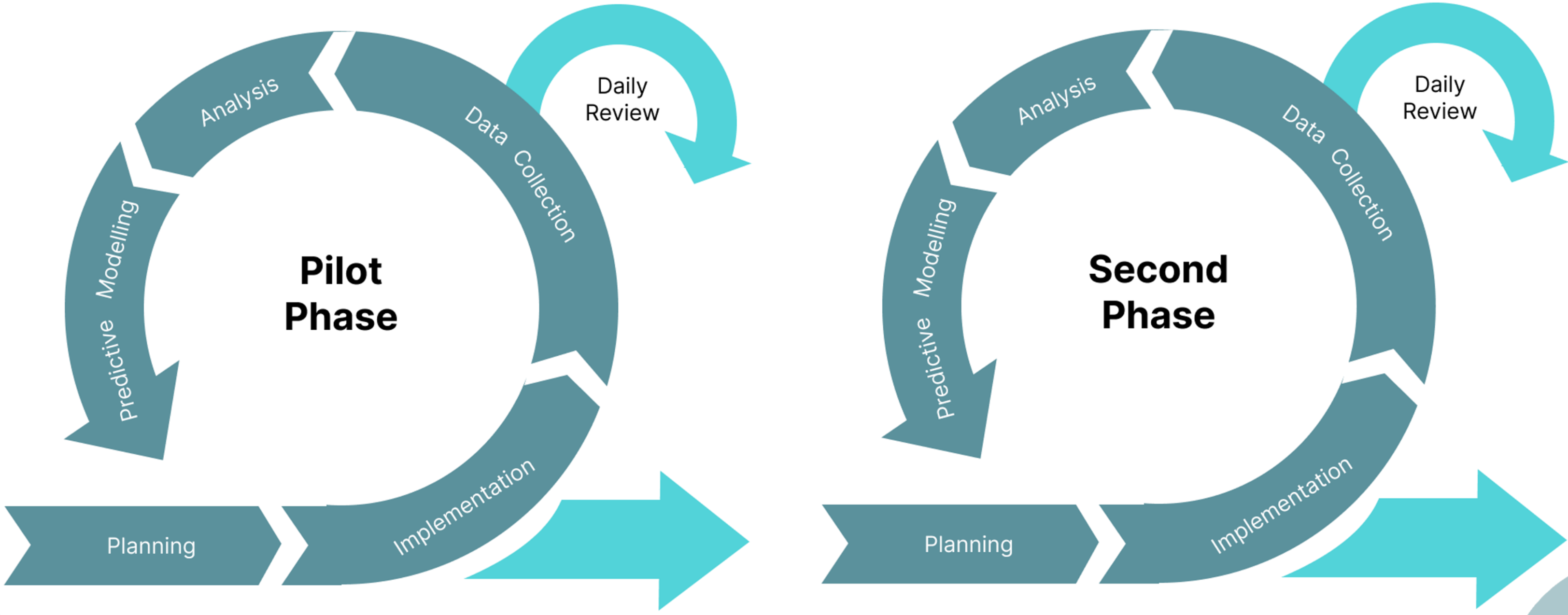

Iterative Approach / Continuous Integration

(DealHub, 2023)

McKinsey Horizon Strategy

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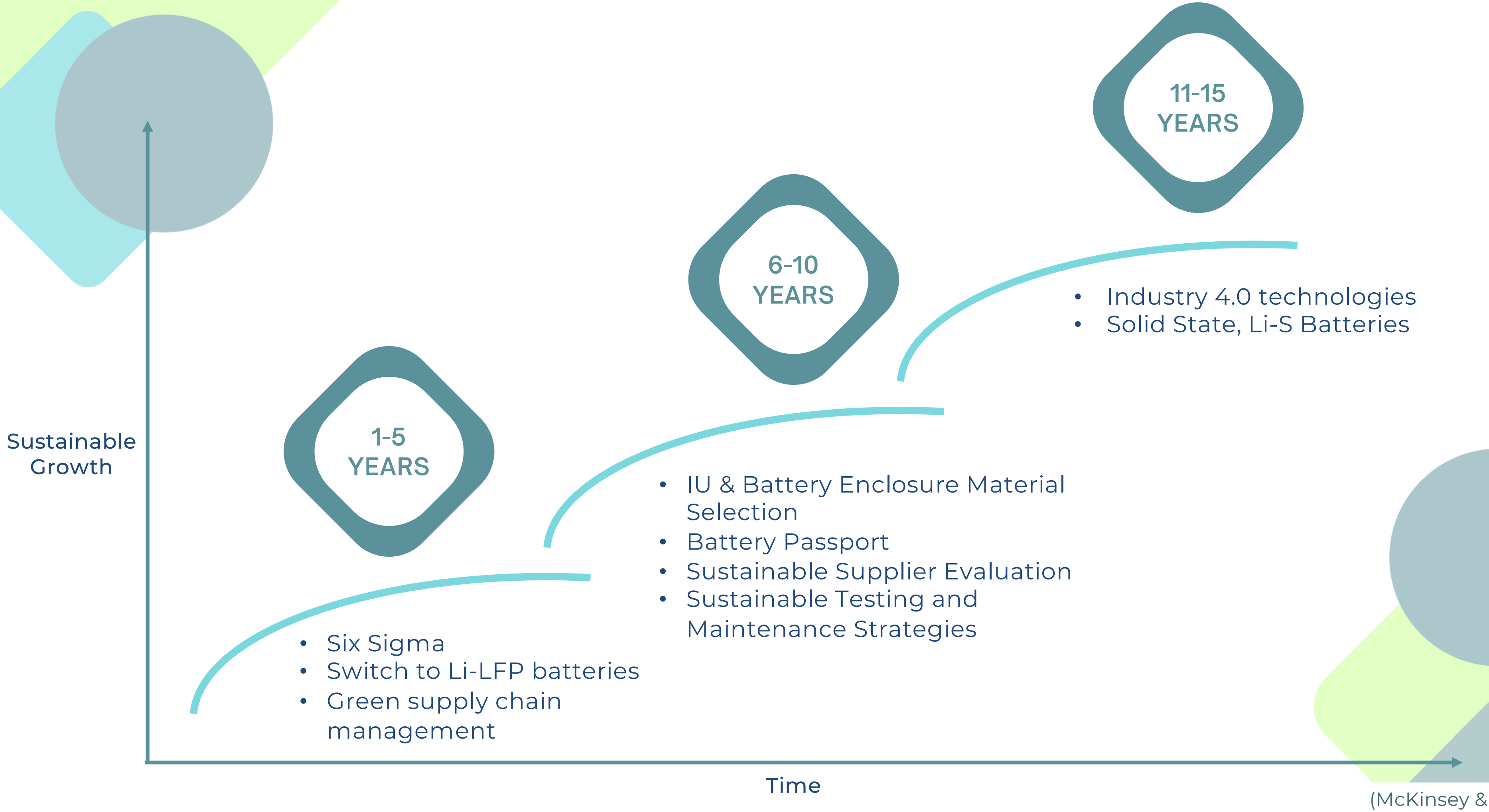

(McKinsey & Company, 2009)

Risk Analysis

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Risk No.	Risk Name	Low	Medium	High	Mitigation Action
1	SMART Analysis Decision-Making Tool			✓	• Validate data sources for analysis • Evolve data collection methods consistently
2	Supplier Data Collection		✓		• Partnering for standardised sustainability metrics Boost supplier education and training Optimise data collection and tracking.
3	Supply Chain Disruptions		✓		• Conduct thorough risk assessment before making supply chain changes. • Develop contingency plans for potential disruptions.
4	Regulatory Compliance	✓			• Monitor and adapt to regulatory shifts Design framework with future regulations in mind.
5	Technical Challenges	✓			• Perform feasibility studies and pilots Partner with experts to conquer technical barriers Gradually integrate methods for quality assurance.

Table: Risk Analysis

(Eichler, 2019)

Key Takeaways

- Seamless Emission Tracking System:
  - Across Products' Lifecycle
  - Quantify Environmental Impact at Each Stage
- Bolstering Environmental Understanding:
  - Aligns with Existing Sustainability Measures
  - Strengthening Link Between Innovation and Eco-Friendliness

Thank You...!

Q&A

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Appendix

Total Value Calculation

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Battery Comparison

Battery Type	Energy Density (Wh/kg)	Range (miles)	Lifetime and Degradation	Relative safety rating	Carbon Emission LCA (kg CO2eq)	Weight (Kg)	Relative Availability and Production Scalability	Cost ($/kWh)
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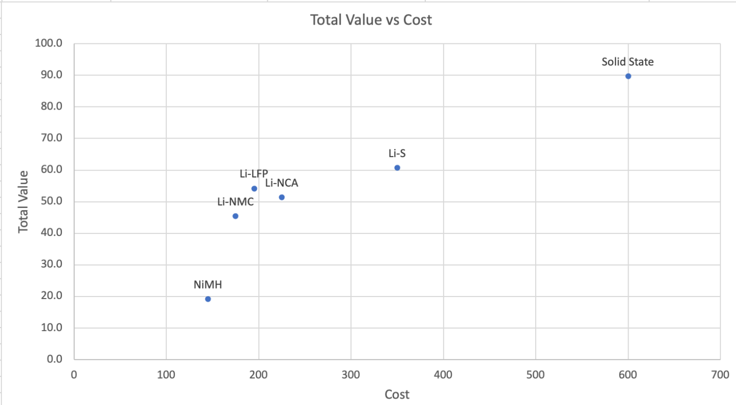
Li-NCA	200-240	200-350	500-1500 Cycles	70	230	200-300	Moderate (75)	200-250
Li-S	300-500	250-300	500-1000 Cycles	60	146	200-300	Low (55)	300-400
Solid State Battery	400-500	300-400	2000-7000 Cycles	70	122	150-250	Low (55)	400-800
NiMH	60-120	80-150	500-1000 Cycles	70	300	300-400	Moderate (65)	140-150

Battery Type	Energy Density	Range	Lifetime and Degradation	Relative safety rating	Carbon Emission LCA	Weight	Relative Availability and Production Scalability	Cost	Total Value
Li-NMC	25	46.8	6.7	80	33.7	33.32	95	175	45.4
Li-LFP	4.169	25.52	73.45	100	75.28	16.65	85	195	54.2
Li-NCA	36.116	68.07	6.7	70	39.32	66.65	75	225	51.4
Li-S	86.12	68.07	0	60	86.51	66.65	55	350	60.7
Solid State Battery	100	100	100	70	100	100	55	600	89.7
NiMH	0	0	0	70	0	0	65	145	19.2

Criteria	Swing weights	Normalised weight
Energy density	70	0.1522
Range	70	0.1522
Lifetime and degradation	65	0.1413
Relative safety rating	75	0.1630
Carbon emission LCA	65	0.1413
Weight	60	0.1304
Relative availability	55	0.1196
Total Weight:	460	1.0000



Total Value for Li-NMC = (Values of different criteria * Respective normalised weights)

= (B15*C25+C15*C26+D15*C27+E15*C28+F15*C29+G15*C30+H15*C31)

= 45.4

Linear Value Functions for different Criteria

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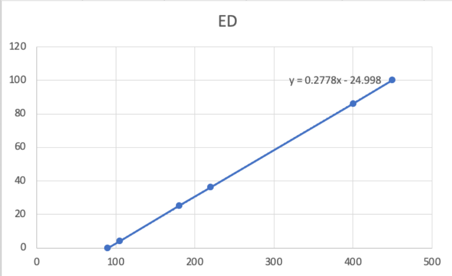
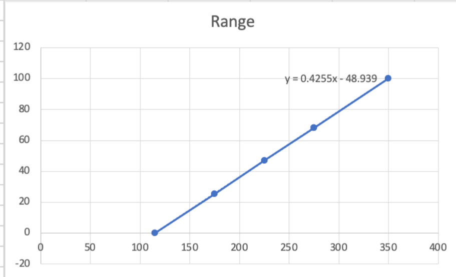
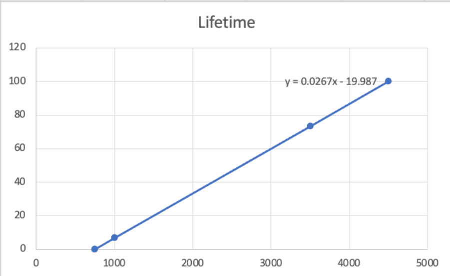
Energy Density	Rating
90	0
105	4.169
180	25.004
220	36.116
400	86.12
450	100



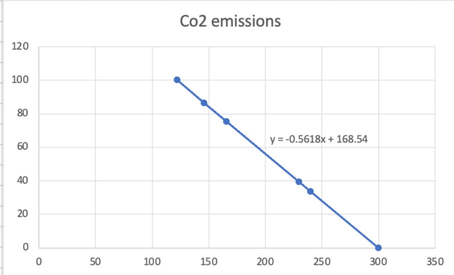
Range	Rating
115	0
175	25.5265
225	46.8015
275	68.0765
275	68.0765
350	100



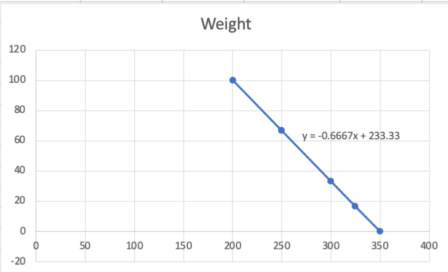
Lifetime	Rating
750	0
750	0
1000	6.7
1000	6.7
3500	73.45
4500	100



CO2	Rating
122	100
146	86.5172
166	75.2812
230	39.326
240	33.708
300	0



Weight	Rating
200	100
250	66.655
250	66.655
300	33.32
325	16.6525
350	0



Interior Upholstery Material Selection

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	Alternatives	Longevity (years)	Acidification	HTP	GWM	Water Consumption	Energy Consumption	Biodegradability	Total value	Cost
Traditional Materials	PVC	100	99.52485	0	74.1481	100	65.3	0	53.2	1
	PU	12.3707	99.22075	22.22	47.1208	66.66	15.8	0	31.6	2.5
	PP	17.5252	99.52485	33.33	77.6734	88.88	46.5	0	51.2	1
	PC	7.1262	100	38.85	37.72	55.55	3.4	0	28.0	3
	ABS	69.0702	99.27291	44.44	90.32	77.77	22.4	0	52.5	2
	PMMA	22.6797	96.756825	49.95	0	83.33	0	0	22.1	5
Alternative Materials	Bio-PET	32.9887	98.5635	66.66	70.035	5.55	60.5	0	51.5	3.5
	Bio-PP	12.3707	100	72.22	100	0	79.9	0	63.7	4
	PLA	12.3707	99.19335	88.88	89.4244	11.11	87.4	0	66.5	3
	PHA	0	98.1436	94.44	61.22	16.65	100	100	76.2	3.5
	Cork,Wood	48.4522	0	100	91.751	22.22	41.8	100	70.6	5

Attribute	Swing weights	Normalized Weights
Longevity	5	0.05
Acidification	5	0.05
HTP	20	0.18
GWM	30	0.27
Water	10	0.09
Energy	25	0.23
Biodegradability	15	0.14
Total Weight:	110	1

Battery Enclosure Description

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- Essential safety component for electric cars
- Provides secure battery housing with ventilation
- Efficient heat dissipation and temperature management
- Ensures battery durability and optimal performance

Blockchain-based Traceability System

- IBM is a leading technology company that provides blockchain solutions for various industries. They have collaborated with Walmart to bring transparency to the food supply chain and improve food safety.

- ARXUM, a German company that leverages cutting-edge blockchain technology to deliver a comprehensive and customized solution for modern industrial processes

- Size
- Complexity
- Type of transactions
- Number of transactions
- Level of security

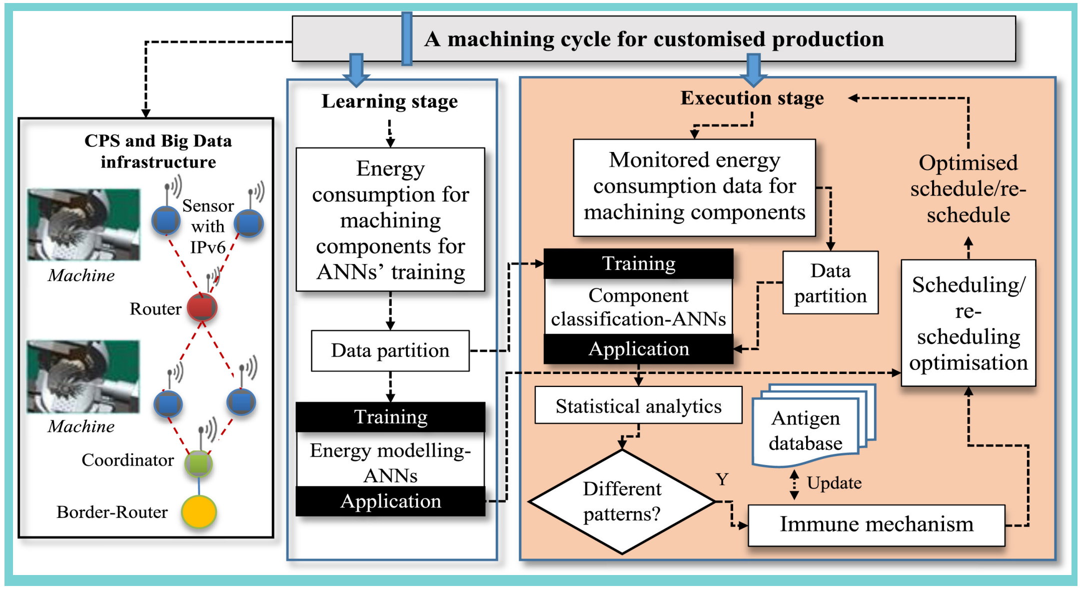
- Cost

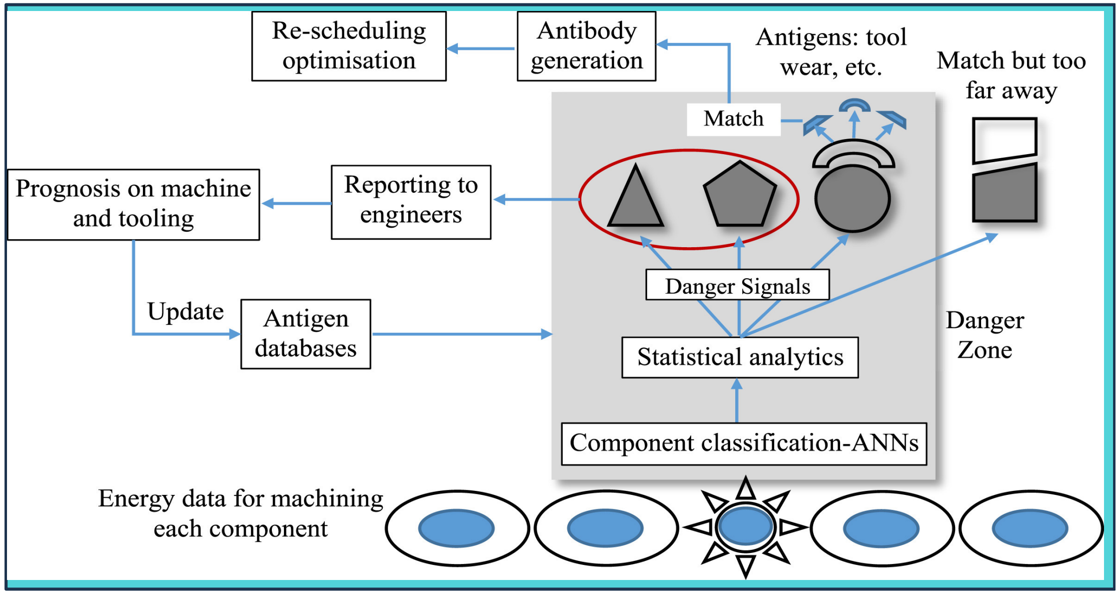
$100 each GB

$50,000 to US$100,000 per year

Intelligent Immune System

- Antigen databases: data characterising features of problems from machines (if any data doesn't match with pre-defined data, system with report to engineers for update)
- Danger signals: whether ene energy consumption data exceeds pre-defined normal energy consumption range
- Danger zone: each component has its won danger zone which defined the danger signal





Digital Twin

Process

Optimization

Worker Training

Continuous Improvement

References for IU Material Selection

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	Materials		Life cycle assessments								Cost ($/kg)
		Longevity (years)	Acidification potential ((kg SO2-eq)	Reference	Relative Human toxicity potential (0-most hazardous, 100-least hazardous)	Global warming potential (kg CO2-eq)	Reference	Relative Water Consumption (0-highest consumption, 100-lowest consumption)	Energy consumption (MJ)	Relative Biodegradability (0-least biodegradable, 100-most biodegradable)	
Traditional Materials	**PVC** (Polyvinyl Chloride)	100	0.0062	(Spierling et al., 2018)	0	1.9	(Spierling et al., 2018)	90	55.5	0	1
	PU (Polyurethane)	15	0.00885	(Franklin, 2022)	20	3.084	(Franklin, 2022)	60	101.5	45	2.5
	PP (Polypropylene)	20	0.0043	(Spierling et al., 2018)	30	1.6	(Spierling et al., 2018)	80	73	40	1
	PC (Polycarbonate)	10	0	(Kua and Lu, 2016)	35	5.6	(Kua and Lu, 2016)	50	112.95	55	3
	ABS (Acrylonitrile Butadiene Styrene)	70	0.00658	(Franklin, 2022)	40	2.354	(Franklin, 2022)	70	95.34	50	2
	PMMA (Polymethyl Methacrylate)	25	0.02935	(Mahmud and Farjana, 2020)	45	8.21	(Mahmud and Farjana, 2020)	75	116.14	60	5
Sustainable Alternatives	**Bio-PET** (Bio-based Polyethylene)	35	0	(Spierling et al., 2018)	60	2.1	(Spierling et al., 2018)	5	60	85	3.5
	Bio-PP (Bio-based Polypropylene)	15	0	(Spierling et al., 2018)	65	2.4	(Spierling et al., 2018)	0	42	80	4
	PLA (Polylactic Acid)	15	0.0073	(Spierling et al., 2018)	80	0.6	(Spierling et al., 2018)	10	35	100	3
	PHA (Polyhydroxyalkanoates)	3	0.016811	(Qiang et al., 2013)	85	3.491	(Qiang et al., 2013	15	23.33	95	3.5
	Cork and wood composites	50	0.905	(Silestre et al., 2016)	90	0.402	(Silestre et al., 2016)	20	77.3	90	5