Research on Multi-criteria Material Selection of Automobile in Full Cycle under the Background of Green Manufacturing

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Abstract. Under the background of the continuous strengthening of green manufacturing, the automobile industry, as a typical representative of the industry, will be an important battlefield for the green development of China's industry. In addition, with the emergence of new alternative materials for automobiles, the selection range of materials for automobile parts is gradually expanding. Literature from year 2009 until year 2019 were collected which is focused on related automotive material selection. It’s worth noting that the concept of “green manufacturing” was proposed in 2018. It is found that the selection criteria of automobile materials have been expanded from only focusing on mechanical properties to economic performance, technological performance and environmental performance. The multi-attribute material selection method is emerging because of the more complicated material selection caused by the increase of environmental attributes, which also brought manifest divergences in the selection of secondary indicators and the setting of weights. According to the practical application, the optimization measures related on the selection basis of secondary indicators and setting weights from the perspective of producers and consumers in the whole life cycle were proposed.

Keywords. Green manufacturing, Multi attribute material selection, Secondary index selection, Weight setting.

1. Introduction
By the end of 2018, China's car ownership has reached 240 million [1], which will reach 250 million in 2020 and 270 million in 2025 by conservative estimation [2-4]. Automobile industry is a resource intensive, energy intensive and environmental emission intensive industry. First, the production and manufacturing of automobiles need to consume a lot of materials. According to statistics, 25% of China's steel, 58% of rubber, 50% of glass, etc. are used in the automobile industry. In 2018, the total consumption of passenger cars reached 29.4397 million tons, mainly from the mineral resources represented by carbon steel, aluminum, magnesium, science, rare earth, platinum, etc. [4-6]. Energy consumption is required for automobile from raw material acquisition stage to recovery stage. According to statistics, the total electric power consumption of automobile production in China is 1.9 billion kwh in 2018 [6]. In various fields of oil consumption, the proportion of oil consumption in transportation field is nearly 50%, nearly 80% of which is consumed by automobile. However, China's dependence on imported oil has reached 69.84% in 2018 [5,7]. In addition, the exhaust emissions of fuel vehicles contribute 60% - 80% of the air pollutants in the first tier cities [8].

Facing the current situation of resource, energy shortage and environmental pollution caused by industrial development, "Green Manufacturing” has gradually aroused extensive discussion in
academia and industry. As early as 2008, the American manufacturing excellence Association put forward the concept of "Green Manufacturing" [9], most of the industrial developed countries have incorporated the ecological performance of industrial products into laws and regulations or directive documents, and built up green trade barriers. In recent years, sustainable development has become the transformation direction of China's manufacturing industry. In 2015, “Made in China 2025" officially issued by the State Council proposed that the manufacturing industry should transform from extensive manufacturing with serious resource waste and excessive pollutant discharge to green manufacturing and in 2017, Li Keqiang proposed in the work report of the government to firmly fight the "Blue Sky Protection Campaign", which highlighting the urgent demand for green manufacturing in China. Green material selection is one of the main contents of green manufacturing. With the continuous emergence of new high-performance and light-weight materials, the proportion of automobile materials has changed greatly in recent years. For example, the proportion of steel and cast-iron materials will change from 76% in 1975 to 54% in 2025, and the proportion of high-strength steel will change from 3% to 24% [11]. "The right material is used in the right place" has become the main development direction of modern automobile design and material application.

Under the influence of green manufacturing, the former single criteria material selection method is no longer applicable. Curtis and Walker (2001) believe that the balance between social, ethical, environmental and economic issues should be fully considered in the development of sustainable automobile products [12]. In recent years, scholars at home and abroad have made endless researches on multi-criteria material selection. It can be concluded that most of the researches have different opinions on the selection of secondary indicators and the setting of weight. On the basis of summarizing the related literature of automobile multi-criteria material selection at home and abroad, this paper puts forward the multi-criteria material selection scheme of automobile under the multi-perspective of the whole life cycle. The scheme divides the whole life cycle of automobile into five stages, discusses the rationality of weight setting systematically and scientifically from the perspective of producers and consumers, and puts forward the method of selecting secondary indexes according to the shape characteristics, structural characteristics and service conditions of parts, which provides reference for the later research. In addition, the later researchers can also quickly find the current secondary indicators and the methods of multi-criteria material selection from this paper.

2. Material Selection Index

Material selection is the basis and key of automobile design and manufacturing. The traditional methods of material selection mainly include empirical method and semi empirical method [13], that is, to judge and select according to the mechanical and technological properties of materials combined with their own subjective experience or according to the benchmarking results of similar products. This method is blind and can't meet the requirements of material selection in modern automobile manufacturing industry. In recent years, with the increasingly prominent problems of resources and environment, the concepts of "green manufacturing" and "sustainable development" have been paid more and more attention. "Made in China 2025" put forward the industrial green transformation and upgrading, and the 19th Communist Party of China (CPC) National Congress takes the high-quality development of manufacturing industry as the strategic policy [10]. Under the urgent top pressure of ecological design, the environmental properties of materials have become an important indicator of material selection in automobile design. In addition, with the increasingly fierce market competition, the economic performance of automobile material must be evaluated quantitatively. The research shows that more than 70% of the cost of automobile product life cycle came from the design stage [14]. Therefore, the economic properties have also become an important indicator of material selection.

The mechanical properties, technological properties, environmental properties and economic properties of materials have gradually become the focus of the research of automobile material selection at home and abroad, and can almost cover all aspects of material selection. However, these indicators are actually only the first-class indicators with guiding function, which are not comparable. Therefore, domestic and foreign scholars tend to focus on the second level indicators with
comparability. The second level index research on material selection by domestic and foreign scholars from 2009 to 2019 is shown in Table 1.

Table 1. The research on secondary index of material selection.

| Author & Year       | First-grade Indexes | Second-grade Indexes | Materials                        | Literature |
|---------------------|---------------------|----------------------|----------------------------------|------------|
| Michael D. Johnson, et.al (2009) | ○ ○ ○ ●         | Life cycle cost      | die-cast magnesium stamped steel | [15]       |
| J.D. Du, et.al (2010)          | ○ ○ ● ○         | Greenhouse gas emissions | Aluminum                     | [16]       |
| Feng Gao, et.al (2010)         | ○ ○ ● ○         | Greenhouse gas emissions | Aluminum                     | [17]       |
| Jindan Du, et.al (2010)        | ○ ○ ● ●         | Energy consumption cost | Magnesium                     | [18]       |
| Abdelraoof Mayyas, et.al (2011)| ● ● ● ●         | Density, Young’s modulus, Tensile strength, Total elongation n- Value, r- Value, Formability, Joinability, Paintability, Corrosion, CO2 Emission, Disposal, Price, Strength limit, Yield limit, Hardness and toughness, Heat treatment property, Processing technology, material cost, Processing cost, Recycling reusability, Environmental pollution, energy consumption, Disposal | Steel-BH, Steel-DP, Steel-HSLA, Steel-Martensite, Al-5xxx, Al-6xxx, Magnesium, Titanium, Carbon Fiber Reinforced Plastic, High Density Polyethylene | [19]       |
| Dandan Zhang, et.al (2011)     | ● ● ● ●         | No. 45 steel 40Cr ZG35CrMo 20CrMnTi HT200 | [13]       |
| Zhifeng Liu, et.al (2012)      | ○ ○ ● ○         | Life cycle environmental impact | Aluminum, Glass mat reinforced thermos-plastic, Mild steel | [20]       |
| Marta Herva, et.al (2012)      | ○ ○ ● ○         | Life cycle environmental impact | PET, PVC                       | [21]       |
| Ning Ding, et.al (2012)        | ○ ○ ● ○         | Greenhouse gas emissions | Aluminum Steel                  | [22]       |
| Prasenjit Chatterjee, et.al (2012) | ● ○ ○ ○         | Surface hardness, Core hardness, Surface fatigue limit, Bending fatigue limit, Ultimate tensile strength | Surface hardened alloy steel Carbonised, Carbonised steels, Nitrided steels Through hardened carbon steel | [23]       |
| Xuemei Qin, et.al (2013)       | ○ ○ ● ○         | Environmental impact, Energy consumption | Thermoplastic vulcanizate rubber | [24]       |
| Xige Wang,                  | ● ● ● ●         | Density             | BH Steel, DP Steel             | [25]       |
| Author & Year       | First-grade Indexes | Second-grade Indexes | Materials                                                                 | Literature |
|---------------------|---------------------|----------------------|--------------------------------------------------------------------------|------------|
| et.al (2013)        | M, P                | Young’s modulus      | HSLA Steel                                                               |            |
|                     |                     | Tensile strength     | Martensite Steel                                                         |            |
|                     |                     | Elongation rate,     | Al-5xxx, Al-6xxx                                                         |            |
|                     |                     | Formability          | Magnesium, Titanium                                                      |            |
|                     |                     | Joinability, Paintability | Carbon Fiber Reinforced Plastic                                         |            |
|                     |                     | Corrosion, CO2 Emission | High Density Polyethylene Carbon steel AISI 1015/3140                  |            |
|                     |                     | Disposal, Price      |                                                                          |            |
| Ahmad T. Mayyas, et.al (2013) | M, P, EN, EC | Density             | Dual phase steel                                                         | [12]       |
|                     |                     | Young’s modulus      | HSLA steel                                                               |            |
|                     |                     | Tensile strength     | Martensite steel                                                         |            |
|                     |                     | Total elongation     | Stainless steel AISI201/405                                              |            |
|                     |                     | Formability          | Aluminum alloy AA5005 AA5005/2424/6060                                   |            |
|                     |                     | Joinability          | AZ61 Mg alloy, Mg-Li                                                     |            |
|                     |                     | Paintability         | (12%) as cast                                                           |            |
|                     |                     | Shear modulus        | High strength carbon fiber S-glass fiber/epoxy composite                 |            |
| Juan Li, et.al (2015) | P                | Environmental effect | Aluminum alloy                                                           | [26]       |
|                     |                     | Energy consumption   | Cast iron                                                                |            |
|                     |                     | Resource consumption |                                                                          |            |
| Lei Zhang, et.al (2015) | P                | Environmental impact | PP+EPDM, PP+GF                                                           | [27]       |
|                     |                     | Resource consumption |                                                                          |            |
| Marco Raugei, et.al (2015) | P     | Life cycle environmental impacts | Al, Mg, Carbon fibre composites                                         | [28]       |
| Massimo Delogu, et.al (2015) | P     | Life cycle environmental impact, energy consumption | Polyamide composite Polypropylene composite                              | [29]       |
| Zhifeng Liu, et.al (2015) | P, P | Functionality aesthetics | PP+EPDM-T20, 45GrNi                                                    | [30]       |
| Qinglan Han, et.al (2015) | P, P | Cost                   |                                                                          |            |
| T. Warren Liao (2015) | P, P, P | Life cycle environment impacts and cost | Aluminum alloy High strength steel Stainless steel 17-4PH/410/440A/304 | [31]       |
| Boxue Sun, et.al (2016) | P, P | Hardness, Cost         | Ni-resist cast iron High-chromium cast iron Ni-hard cast iron Incone1600 |            |
| Wenlong Sun, et.al (2016) | P, P | Machinability          |                                                                          |            |
| Junfeng Shi, et.al (2017) | P    | Rating, Corrosion resistance |                                                                          |            |
|                     |                     | Hardness, Cost       |                                                                          |            |
|                     |                     | Machinability        |                                                                          |            |
|                     |                     | Rating, Corrosion resistance |                                                                          |            |
|                     |                     | Density, Elasticity modulus, Tensile strength, Yield strength, Poisson ratio, Extensibility, ADP, GWP, AP, POCP, HTP, Price | Steel Aluminum Magnesium | [32]       |
|                     |                     | CO2, CHx, NOx, PM2.5, Energy consumption, Cost | steell, aluminum alloy, magnesium alloy | [33]       |
|                     |                     | CO2, Energy consumption | Low-carbon steel, high strength steel, aluminum | [34]       |
It can be seen from table 1 that the first level indicators in the literature related to material selection studied since 2009 include environmental performance (the concept of "green manufacturing" was proposed in 2008). Life cycle assessment indicators have been applied in the secondary indicators of material selection, and most of the research has been refined to the resource consumption, energy consumption and pollutant emission in the full life cycle. Furthermore, in addition to the study of selecting materials only depending on environmental performance, other studies include economic performance. Although most of them only involve material cost or production cost, the existing research is gradually approaching the direction of life cycle cost. In the study of comprehensive selection of all-attribute materials including mechanical properties, technological properties, environmental properties and economic properties, the maximum number of secondary indicators can reach 24.

3. Material Selection Method
At present, the main research has taken the environmental performance of materials into account, and constantly studied its quantitative methods. The University of California, Berkeley, Carnegie Mellon University, Yale University and other research universities all regard life cycle assessment as the main research content of their green design and environmental management [35]. In the past ten years, an enormous amount of researches have been carried out to evaluate the environmental and economic properties of materials by means of life cycle assessment, so as to achieve the goal of green and economic material selection [36-38]. Life cycle assessment has gradually become an important means to define the environmental and economic properties of materials. However, environmental performance and economic performance are only two aspects of many properties of materials, which are one-sided. Therefore, in the context of green manufacturing, how to balance the complex multi-dimensional property relationship, so as to truly make the right materials to be used in the right place has aroused extensive research. The research on the multi-criteria material selection method of domestic and foreign scholars in 2010-2019 is shown in table 2.

| Author & Year | First-grade Indexes | Method | Materials | Literature |
|--------------|---------------------|--------|-----------|------------|
| Jindan Du, et al (2010) | ○ ○ ● ● | Life cycle assessment | Magnesium, Steel | [16] |
| Abdelraoof Mayyas, et al (2011) | ● ● ● ● | Life cycle cost | Steel-BH, Steel-DP | [19] |
| Jianquan Xu, et al (2019) | ● ● | Energy consumption, GWP, Production cost | Steel, Aluminum Magnesium | [36-39] |
| Author & Year          | First-grade Indexes | Method                                                                 | Materials                                                                 | Literature |
|-----------------------|---------------------|------------------------------------------------------------------------|---------------------------------------------------------------------------|------------|
| Dandan Zhang (2011)   | ● ● ● ● ●           | Process, The secondary fuzzy comprehensive evaluation method           | Al-5xxx, Al-6xxx, Mg, Ti, GFRP, HDPE, 45# steel, 40Cr                      | [13]       |
| Prasenjit Chatterjee, et.al (2012) | ● ○ ○ ○ ○      | Extended PROMETHEE II, Complex Proportional Assessment of Alternatives with Gray Relations, Organization, Rangement Et Synthese De Donnes Relationnelles, Operational Competitiveness Rating Analysis | Cast iron, Ductile iron, Cast alloy steel, Through hardened alloy steel, Surface hardened alloy steel, Carburised steels, Nitrided steels, Through hardened carbon steel | [23]       |
| Xige Wang (2013)      | ● ● ● ● ●           | House of Quality fuzzy VIKOR                                           | BH steel, DP steel, HSLA Steel, Martenistic steel, Aluminum 5xxx, 6xxx sheets, Magnesium sheets, Titanium sheets, Carbon Fiber Reinforced Plastic, High Density Polyethylene Carbon steel AISI 1015/3140, Dual phase steel, HSLA, Martensite steel, Martensite steel, Aluminum alloy AA5005/242/6060, AZ61 Mg alloy, MgeLi (12%) as cast Ti/3Al/8V/6Cr/4Zr/4Mo, Epoxy-carbon fiber, High strength carbon fiber/epoxy composite, S-glass fiber/epoxy composite | [25]       |
| Ahmad T. Mayyas, et.al (2013) | ● ● ● ● ●      | Principal Component Analysis, Preference Selection Index               | High strength steel, Aluminium alloy, Stainless steel 17-4PH/410/440A/304 | [12]       |
| Anhua Peng (2014)     | ● ● ● ● ●           | The Preference Ranking Organization Method for Enrichment Evaluations Life cycle cost | Tin-base bearing alloy, Tin bronze, Aluminum bronze, Aluminum base bearing alloy | [40]       |
| Qinglan Han, et.al (2015) | ● ●          | Life cycle assessment, Analytical Hierarchy Process                    | High strength steel, Aluminium alloy | [14]       |
| T. Warren Liao (2015) | ● ● ● ● ●           | Two interval type 2 fuzzy TOPSIS material                              | Stainless steel 17-4PH/410/440A/304 | [31]       |
| Author & Year          | First-grade Indexes | Method                                      | Materials                                      | Literature |
|-----------------------|---------------------|---------------------------------------------|------------------------------------------------|------------|
| Boxue Sun, et.al (2016) | ● ● ●               | Fuzzy matrix evaluation method              | Ni-resist cast iron, High-chromium cast iron, Ni-hard cast iron, Nickel 200 Monel 400, Inconel 1600 Steel Aluminium alloy Magnesium alloy | [32]       |
| Wenlong Sun (2016)    | ● ●                 | Life cycle assessment 3E method TOPSIS      | Steel Aluminium alloy Magnesium alloy          | [33]       |
| Xiaoxin Liu (2018)    | ● ● ●               | Grey correlation method Principal component analysis | 45# steel 40Cr 35SiMn 20CrMnTi HT200 | [35]       |
| Jianquan Xu, et.al (2019) | ● ●               | Target achievement method Multi-objective optimization method | Steel Aluminium alloy Magnesium alloy | [36]       |

It can be seen from table 2 that the current material selection methods are mainly divided into two types, one is weight dependent multi-criteria material selection method, the other is non weight dependent multi-criteria material selection method. It can be seen from table 2 that the current material selection methods are mainly divided into two types, one is weight dependent multi-attribute material selection method, the other is non weight dependent multi-attribute material selection method. According to the research on the literature before 2010 [40-41], most of the previous researches on the selection of multi-criteria materials adopt the weight dependent decision-making method, and the secondary indicators are subjective, among which the fuzzy comprehensive evaluation method is widely used. After 2010, the research on the weight dependent multi-criteria material selection method is still common, but there are improvements compared with the previous methods, such as: analytic hierarchy process, two-level multi-level fuzzy comprehensive evaluation method, fuzzy matrix evaluation method, two interval second type of fuzzy TOPSIS method, fuzzy compromise decision-making method, etc. These methods are mainly to improve the quantifiable and grading of secondary indicators.

At the same time, in order to avoid the uncertainty brought by weight and the compensation effect of decision-making, many scholars have carried out research on the multi-criteria selection method of non-weight relation dependence. For example, according to Zhang Shizhan, the preference index selection method can solve the material selection in the case of weight setting contradiction or uncertainty and Ahmad t. Mayyas used both the preference index selection method and the principal component analysis method to rank a series of candidate materials, and thought that the principal component analysis method was better than the emerging preference index selection method [12].

4. Discussion

4.1. Overview of Current Research

According to the research and analysis of 2009-2019, the problem of multi-attribute material selection was mainly divided into five steps.

Step 1: identify alternative materials.

According to the design requirements, a series of suitable alternative materials was selected. The
alternative materials can be new materials or feasible materials which was verified.

Step 2: determine and quantify the evaluation indicators.

According to the decision-making objectives, the evaluation indexes are determined, and the corresponding methods are adopted to quantify the evaluation indexes, which include the first level indexes and the second level indexes.

Step 3: make decision matrix.

The solution of multi criteria decision making problem starts from the establishment of decision matrix, the premise of which is that the evaluation index has been determined and quantified. Its form is as follows: let \( M_i \) (\( i = 1,2,3 \ldots n \)) is a series of alternative materials, \( W_{ij} \) (\( i = 1,2,3 \ldots , n; j=1,2,3,\ldots , n \)) is the weight value of a series of alternative materials relative to different indicators, \( C_j \) (\( j = 1,2,3 \), n) is a series of attributes or evaluation criteria, and \( X_{ij} \) is the value of alternative \( M_i \) under evaluation criteria \( C_j \). Based on the above assumptions, the decision matrix can be made as shown in table 3.

| Alternative materials | Weight | Non-weight | C₁ | C₂ | … | Cₙ |
|----------------------|--------|------------|----|----|----|----|
| M₁                   | W₁j    | x₁₁        | x₁₂| … | x₁ₙ|
| M₂                   | W₂j    | x₂₁        | x₂₂| … | x₂ₙ|
| …                   | …      | …          | …  | … | …  |
| M₄                   | W₄j    | x₄₁        | x₄₂| … | x₄ₙ|

It can be seen from table 3 that the main difference between the weight dependent multi-criteria material selection method and the non-weight dependent multi-criteria material selection method is whether the weight is considered in the decision matrix.

Step 4: standardization of each criteria decision data

In the multi-criteria problem, the different criteria of alternative materials need to be comprehensively compared and analyzed, while the units and orders of magnitude of different criteria are often different, and some criteria cannot be accurately quantified. Therefore, data standardization is mainly to solve the problem of incommensurability between attribute data.

In the process of standardization, all the research divides the selected evaluation indexes into benefit indexes (the bigger the attribute characteristics, the better) and cost indexes (the smaller the attribute characteristics, the better). Only part of the research considers the difference between the accurate number and fuzzy number of the indexes, and the fuzzy number was defuzzified by the center of gravity method. This paper only introduces the widely used process of standardization which does not consider the exact number and the fuzzy number.

Benefit indexes:

\[
R_{ij} = \frac{x_{ij}}{x_{ij}^{max}}
\]

where: the maximum value of the jth attribute can be represented by \( x_{ij}^{max} \).

Cost indexes:

\[
R_{ij} = \frac{x_{ij}^{min}}{x_{ij}}
\]

where: the minimum value of the jth attribute can be represented by \( x_{ij}^{min} \).

The final result is to convert each attribute value to a comparable value between 0-1.
Step 5: determine the optimal scheme

After getting the standardized values of each attribute, we need to determine the order of the alternative materials according to certain methods, which mainly include: fuzzy evaluation method, TOPSIS method, grey correlation degree method, AHP, PCA, preference index selection method, etc.

In recent years, some scholars have made a comparative study on the above methods. The research on the method of preference index selection is just in its infancy, which is not perfect, and the principal component analysis has obvious advantages.

4.2. Optimization Suggestions

According to the above analysis, there are two main difficulties in the research of multi-criteria material selection at present: one is how to select scientifically due to the wide range of secondary evaluation indexes; the other is which is better between weight dependent material selection method and non-weight dependent material selection method, and how to set the weight scientifically if necessary.

This optimization proposal is based on the closed-loop flow system of automobile material life cycle, as shown in figure 1. The idea of life cycle is mostly used to solve the problems with certain complexity and systematism. Recently, it is widely used to quantify the environmental attributes of products. The multi criteria decision making of materials is a highly complex and long-term systematic problem. In this paper, the whole life cycle of automobile is divided into five stages: raw material acquisition stage, parts manufacturing stage, vehicle assembly stage, use stage, scrap recovery stage. According to these five stages, the closed-loop flow process of materials is analyzed, and the solutions to the above three problems are explored.

4.2.1. Secondary Index Selection. The first is the selection of secondary indicators. Considering the comprehensiveness of primary indicators, it is recommended to select mechanical performance, technological performance, environmental performance and economic performance, while secondary indicators are the refinement of primary indicators. Among them, mechanical performance reflects the inherent properties of materials, which should be selected according to the structural characteristics, shape characteristics and service conditions of parts. For example, as a typical body outer panel, the shape features of the door outer panel are: symmetrical shape, smooth transition, small drawing depth, flat bottom and large volume. Its structural features are: it is difficult to arrange stiffeners or strengthening bosses, and its service conditions are: it is often affected by external loads, static loads include snow, artificial pressing or leaning, and dynamic loads include rain, etc. To sum up, in order to ensure its sufficient rigidity, dynamic and static dent resistance, and lightweight, the secondary index needs to consider density, impact strength, elastic modulus, yield strength and fatigue strength.

The process performance is mainly reflected in the manufacturing stage of parts and components, and also related to the performance of the material itself. Taking the door outer panel as an example, considering its appearance characteristics, structural characteristics and service conditions, it should have the characteristics of easy forming, riveting, painting, and corrosion resistance.

Environmental performance needs to take the full life cycle of the vehicle into account, and use the life cycle assessment method to quantify the environmental indicators which include greenhouse gas emissions, acidification effect, water eutrophication, energy consumption, resource consumption, etc.

Economic performance also needs to take the whole life cycle of the car into account. Using life cycle cost evaluation method, the cost of the five stages of life cycle of the car is calculated quantitatively, mainly including material cost, processing cost, assembly cost, use cost and recovery cost.

4.2.2. Weight Setting. For multi-criteria material selection, not all criteria are equally important at the current stage, so it is necessary to set weight. According to figure 1, the whole life cycle of a car should start from the perspective of the producer and the perspective of the consumer. It can be seen from the analysis that the environmental performance and economic performance need to cover the
whole life cycle of the vehicle. Therefore, when considering multiple criteria to select materials, the weight of environmental performance and economic performance depends on the perspective. The producer perspective will set the weight for the environmental and economic properties of raw material acquisition stage, parts manufacturing stage, vehicle assembly stage and scrap recovery stage, and the consumer perspective will set weights for the environment and economy attributes of the usage phase. Its comprehensive environmental and economic attributes are weighted average values of each stage.

Mechanical performance and process performance only need to be considered from the perspective of producer, and its index value can be quantified or obtained through expert scoring method. Therefore, it’s not necessary to set weight, the larger the index value, the better the performance.

![Closed loop flow system of automotive material life cycle](image)

**Figure 1.** Closed loop flow system of automotive material life cycle.

5. **Conclusion**

This paper analyzed the research on multi-attribute material selection in the past decade at home and abroad. It can be seen from the analysis that with the attention to green development, the importance of environmental properties of materials is highlighted. At present, four primary indicators have reached a consensus, and different researchers have different opinions on the determination of secondary indicators. In addition, some scholars at home and abroad have studied the non-weight dependent multi-criteria decision-making method in recent years, and they think that it can solve some problems such as the difficulty of setting the weights of some indicators, which leads to great differences in the setting of weights among scholars at home and abroad. Therefore, this paper focuses on the selection of secondary index and the setting of weight in multi-criteria material selection. Limited to the scope of this study, to study multi-criteria material selection methods, you can refer to the review articles related to multi-criteria material selection methods.

According to the analysis of previous studies, this paper summarizes the steps of multi-attribute material selection, determines the key steps that are prone to divergence in many studies, and puts forward the corresponding optimization ideas based on the whole life cycle theory. For the secondary index of mechanical performance and process performance, it should be selected in combination with the shape characteristics, structural characteristics and use conditions of the parts. The process performance should focus on the manufacturing stage of the parts. The secondary index of environmental performance and economic performance is relatively clear. The life cycle evaluation method can be used to select the concerned index. As for the setting of weight, this paper thinks that only the whole life cycle indicator like environmental performance and economic performance is needed, and from the perspective of producers and consumers, it is determined by the method of weighted average of each stage of the whole life cycle.

Although this paper puts forward optimization measures for the secondary index and weight
problem of multi-criteria material selection, due to the lack of experience database, it is just an example, not specific, and does not give a specific calculation method for the weight setting. In the future, it will pay more attention to the establishment of the secondary index database of mechanical performance, process performance, environmental performance and economic performance. Based on the experience, solidify the secondary indexes of the four primary indexes of the main auto parts, and establish the objective full cycle and diversified calculation formula.

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