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Management and control decision of energy intensity in logistics industry under the background of dual carbon strategy in China

Chongyan Li ✉ & Fuzhong Wang

In view of the rare research on energy intensity control in the logistics industry at home and abroad, this study constructs a research framework on the basis of analyzing the development status of energy intensity in the logistics industry, proposes the demand on management and control (M&C) and establishes the M&C mechanism, uses the mathematical model as the M&C tool, sets the corresponding parameters and implements the M&C decision on energy intensity in the logistics industry. The research shows that the energy intensity in China's logistics industry is still at a high level and needs to implement M&C. For the identified M&C objects, exponential model, difference model and linear model can be used to accurately control the energy intensity in the logistics industry, and decision maker can make decisions based on M&C. Finally, it is suggested that the Chinese government establish a decision-making service platform for energy intensity and carbon intensity control in the logistics industry, so as to promote the development of low-carbon logistics.

Keywords Logistics industry, Energy intensity, Energy conservation and emission reduction, M&C mechanism, M&C decision

More than a decade ago, a Chinese scholar proposed that"fog locks up half the sky, and there is no time to slow down the control of haze"[1]. When haze control became the expectation of millions of Chinese people, the Chinese government began to carry out supply-side reform of the energy industry in 2015, shut down heavy polluting enterprises for rectification, eliminated backward industries, vigorously supported the new energy industry, and provided effective help for haze control and carbon emission reduction by gradually expanding the use of low-carbon energy, reducing high-carbon energy consumption, and strictly controlling the emission of pollutants. In September 2020, China put forward the"carbon peaking carbon neutrality"strategy (dual-carbon strategy), which showed the Chinese government's long-term governing philosophy of energy conservation, carbon reduction and environmental protection. In order to develop green low-carbon industry and advocate green civilized life, China would gather the strength of the whole country in green development and low-carbon development in the future, and these would make contributions to human society.

The use of low-carbon energy is particularly important for China's dual-carbon strategy. Low-carbon energies mainly include wind power electricity, hydropower electricity, photovoltaic electricity, nuclear power electricity, natural gas, etc., with less carbon emissions. So far, the consumption of electricity and natural gas is less than 15% of China's total energy consumption, the high carbon energies such as gasoline, diesel, kerosene and coal, total of them account for a high proportion of energy consumption, their carbon emissions are large, which are the main cause of China's huge carbon emissions. In terms of total carbon dioxide emissions, China surpassed the United States in 2006, ranking first in the world. In view of the huge pressure to reduce carbon emissions, China accelerated industrial transformation and upgrading, and the control of carbon emissions in various industries became increasingly strict. Taking vehicle exhaust testing standards as an example, the standards were becoming more and more stringent. In 2006, the National II emission standards were implemented, and the National VI standards began to be implemented on January 1, 2019. From July 1, 2023, China fully implemented the National VI emission Standard 6b stage, prohibiting the production, import and sale of cars that do not meet the National VI emission standard 6b stage. It reflects that the high emissions of fuel vehicles were slowly being replaced by the new energy vehicles. In recent years, some countries such as Norway, Germany, France and others will begin to ban the sale of fuel vehicles in the future. The Chinese government will also be ready to

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draw up some fuel vehicles limited production schedule, in order to vigorously promote low-carbon new energy vehicles to meet the needs of market.

Logistics is very important in Chinese economy, due to the vast territory in China, the allocation of materials need logistics delivery between the east and west, and also between the north and the south, the energy consumption of the logistics industry ranks behind the industrial industry and is the industry with large energy consumption. In view of the huge energy consumption of the logistics industry and the implementation of China's dual carbon strategy, the road to lower carbonization of the logistics industry is the future development trend. However, at the beginning of the development of China's logistics industry, the extensive development mode led to low operation efficiency, and its mode maintained many years. In the meanwhile, the transport logistics mostly adopted traditional trucks with high emission and high pollution, which made the development of the logistics industry consume a lot of energy at the cost of high energy intensity of the industry. As China has entered a new stage of comprehensively deepening reform, a series of new reform policies in key areas have injected vitality and momentum into the Chinese economy. The flood of history is rolling forward, the new energy industry is the trend of The Times, China's new energy industry has been encouraged by policies and has been booming, the Chinese market continues to produce many kinds of new energy vehicles, and even export overseas. As a basic and strategic industry supporting China's economic development, the logistics industry has also entered a new stage in deepening structural adjustment, transformation and upgrading, and is benefiting from the development of the new energy industry. China's new energy vehicles (such as electric forklifts, electric trucks, etc.), natural-gas-powered trucks and ships have begun to be used in the logistics industry. Furthermore, electric forklifts and electric trucks can replace diesel forklifts and trucks, the use of electric vans in the"last kilometer"operation of logistics is also gradually increasing, and natural-gas-powered trucks and ships are also showing better economy in long-distance transportation. Although low-carbon energy technologies and equipments have not been popularized on a large scale, they have reduced the dependence of China's logistics industry on high-carbon energy.

Although the energy consumption in China's logistics industry has always been large, the discussion on M&C decision of energy intensity is rare, the establishment of M&C mechanism is full of challenges. Therefore, this paper is to establish the energy intensity M&C mechanism in the logistics industry, by setting a reduction range (M&C by objective reduction), selecting the model for M&C, and then making decisions. Finally, a M&C decision-making service platform should also be established, which facilitates the participation of all parties.

The rest of this study is organized as follows: the section"Literature review"summarizes the research gaps and contributions, the section"Logistics development and energy intensity"analyzes the development of logistics industry and its energy intensity, the section "Research framework and M&C mechanism" builds the research framework and puts forward the M&C mechanism, theoretical justifications for selecting models. The section"M&C processes and decisions"introduces detailed models solving, decision and decision-making service platform, the section"Conclusion"reports the main results and makes relevant suggestions.

Literature review

The development of logistics industry was affected by many factors, and some views emerged, such as the theory of economic pull. According to the theory, economy was the main reason for the development of logistics industry. In addition, the development of the logistics industry was also affected by capital, manpower, energy and other factors. In view of energy factors, there are some studies in this field.

The first branch is the influence from energy substitution, energy technology and energy structure. First, to vigorously develop biomass gas was conducive to carbon emission reduction. The market of biomass gas products should be explored[2]. The price of low-carbon energy was relatively cheap and very attractive, which was the power source of energy substitution[3], if the logistics industry used more low-carbon technology equipments, not only energy cost would fall, but also the operating cost of low-carbon technology equipment would fall in the foreseeable time period[3]. Second, low-carbon or carbonless energy technologies should be used. In order to achieve the constraint goal of limiting global average temperature rise to no more than two degrees Celsius by the end of the twenty-first century[4], proposed that China would need to invest more in low-carbon energy technologies[5–7]. examined that technological progress could also curb energy consumption or energy intensity. Third, energy structure played its role. The optimization of energy structure and the increase of the proportion of non-fossil energy had a stronger effect on carbon emission reduction in most sectors[8–10]. also showed that energy structure played an adjustment role in energy intensity. While[11] examined that the proportion rising of low-carbon energy was conducive to the decline of China's energy intensity.

The second branch is the influence from energy policy. In view of the low energy efficiency of South Africa's transport industry[12], suggested for the South African government to implement a policy to curb the energy demand of the transport industry, improve energy efficiency and solve the deteriorating environmental problems[13–16]. suggested that policies should stimulate the wide application of low-carbon technology and equipment in the transportation industry. In China, many policy studies are existed[17]. suggested that the transport industry needs to implement relevant policies to control the growing energy consumption. Since 2011, China's new energy automobile industry has been actively promoted and has developed rapidly, science and technology energy-saving started to be gotten attention[18], proposed that the government should vigorously promote the improvement of science and technology level of logistics industry, and further exert the inhibition effect of logistics development factors on carbon emission[19]. suggested that China should actively develop new energy, apply new low-carbon technologies, and adjust its industrial structure, so as to promote the development of China's logistics industry in the direction of low-carbon. Furthermore, some studies suggested that China should strengthen guidance, formulate energy-saving and emission reduction measures for low-carbon logistics industry, and encourage the development of low-carbon logistics[20,21]. After China's dual-carbon strategy was proposed in 2020, the logistics industry was acted as a large carbon emission industry, naturally had the responsibility to vigorously reduce emissions. Therefore, some differentiated policy suggestions appeared. First, low-carbon transport modes were recommended[22]. suggested that China should increase the proportion of low-carbon transport modes such as railways, strengthen measures to reduce the level of fuel consumption of traditional vehicles, promote new energy vehicles such as pure electric vehicles, and accelerate the implementation of smart transportation policies to help control the level of carbon emissions from transport. Second, carbon emission monitoring of industries was proposed[23]. suggested that Chinese management departments should pay more attention to the correlation of carbon emissions among industrial sectors from the perspective of economic circulation, and strengthen the carbon emission monitoring of industries with strong carbon correlation with the logistics industry. Third, a dynamic change assessment system should be established[24]. suggested that China should not only establish a long-term monitoring system for static carbon emission efficiency, but also build a dynamic change assessment system, so as to further develop the operation of the logistics industry towards low-carbon and efficient development. Fourth, new technologies and new energy should be used[25]. also suggested that China should strengthen its efforts to reduce carbon emission and promote the use of new technologies and new energy in the logistics industry.

Through the above analysis, there are management or policy mechanisms on energy problems, a detailed M&C mechanism research is hard to find. Therefore, it can be seen that there is insufficient research on energy intensity M&C decision in the logistics industry at home and abroad. There are research gaps: (1) lacks of an operable M&C mechanism on energy intensity. (2) lacks of discussion for a M&C decision-making service platform on energy intensity.

In this paper, the research contributions are as follows. First, this study focuses on establishing a M&C mechanism, proposes M&C models, and then applies them to the M&C decision of energy intensity in the logistics industry. Second, this study focuses on a M&C decision-making service platform, which can accelerate the formation of low-carbon logistics and innovative organization. There is rare existing literature in this field, which shows this paper has an important reference value.

Logistics development and energy intensity

Development of logistics industry

Since the beginning of this century, the logistics industry has been developing steadily in China. Taking its gross product as an example, the data from China Statistical Yearbook showed that it was 2184.2 billion yuan in 2011, and rose to 4,842.39 billion yuan in 2021, with a nominal annual growth rate of 8.287%, but after the price index was deflated(base period was 2011), the actual annual growth rate was only 1.14%. In the logistics industry development of other indicators, taking freight volume as an example, it was 36,969.61 million tons in 2011 and rose to 52,984.99 million tons in 2021, with an annual growth rate of 3.665%, while the volume of freight turnover rose from 15,932.36 billion tonnage kilometers in 2011 to 22,360.038 billion tonnage kilometers in 2021, with an annual growth rate of 3.447%. Obviously, among the actual gross product, freight volume and freight turnover of the logistics industry, the annual growth rate of freight turnover was the highest, as shown in Fig. 1.

The transport logistics is regarded as the main artery of economic development, if the logistics is not smooth, the economic development will be seriously affected. In Fig. 1, various indicators showed that China's logistics industry had made progress since 2011, which had strongly supported the rapid development of China's economy. The Chinese government needs a strong logistics industry that is both efficient and low-cost. In order to improve logistics efficiency and address the reduction of logistics costs in China's whole society, China has provided good transportation infrastructure construction to support the development of the logistics industry. In fact, the increase in value-added, freight transport volume and freight turnover in Fig. 1 confirmed that the logistics industry was indeed growing. In China's big market environment, the economic aggregate is huge, the product variety is wide, the logistics market has carried out a large number of freight tasks, accommodated a large number of employment personnel, and also promoted the healthy operation of China's economy.

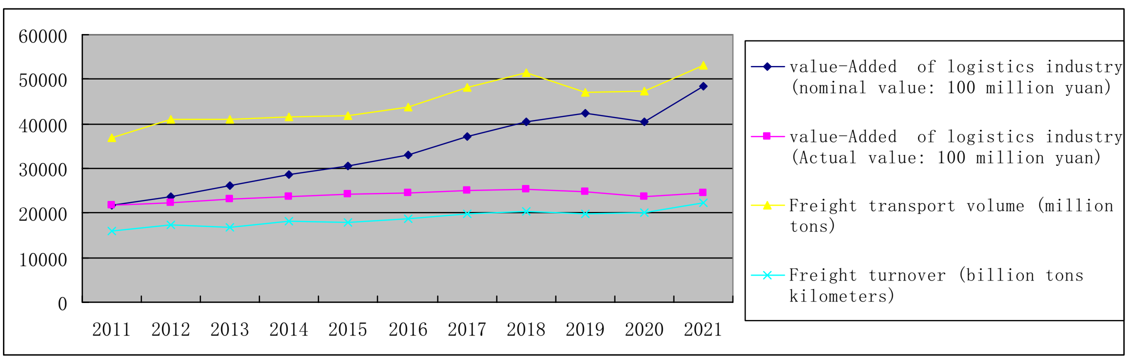

Fig. 1. Logistics industry development indicators Note: In China, it is generally believed that the Value-added of Transport, Storage and Post is the gross product of the logistics industry. All data in the paper are from China Statistical Yearbook.

Energy intensity of logistics industry

(1)Energy consumption.

In 2009, the logistics industry was included in China's"Ten Industrial revitalization Plan", showing that the industry had an important position in China. In China's 2024 Government Work Report, it mentioned the relevant policy policies such as"implementing actions to reduce logistics cost, speeding up the construction of the international logistics system, building smart customs, and helping foreign trade enterprises to reduce cost and improve efficiency", which pointed out the existing problems and development directions of China's logistics industry. The problem is that China still has high logistics cost, the development direction is to accelerate the construction of the international logistics system. One reason for China's higher logistics cost is its high energy consumption. From the perspective of energy consumption of the logistics industry, it was 296.9417 million tons of standard coal in 2011, and increased to 439.35 million tons of standard coal in 2021. The energy consumption during 2011–2021 is shown in Fig. 2.

During 2011–2021, the annual growth rate of energy consumption in the logistics industry is 4%, higher than the annual growth rate of 1.14% of the actual gross product of the logistics industry (as mentioned above), which indicates that the logistics industry consumed a large amount of energy, also created a relatively large amount of gross product, undertook a large number of freight tasks. However, from the perspective of the output level of the logistics industry per unit of energy consumption, the industry was extensive growth at the cost of consuming a lot of energy.

The absolute amount of energy consumption in China's logistics industry is relatively large. The reason is that with the continuous expansion of China's commodity circulation and international trade, the scale of logistics industry is also expanding. Energy consumption is involved in all aspects of logistics, such as packaging, circulation and transportation, packaging and storage, especially the transportation link, which is an important link of energy consumption in the logistics industry. Controlling the energy consumption of transport links or improving the energy efficiency of transport links will do more with less.

(2)Energy intensity.

In order to describe the movement track of energy efficiency of the logistics industry, energy intensity of the logistics industry should be analyzed, which is the ratio of energy consumption of the logistics industry to the gross product of the logistics industry, and its development trend is shown in Fig. 3.

As shown in Fig. 3, the overall nominal energy intensity of the logistics industry showed a downward trend during 2011–2021, but this trend did not really reflect the energy efficiency of the logistics industry. What was important was the actual energy intensity was the main issue. The actual energy intensity showed an overall upward trend, which indicated that since 2011, the extensive development mode of China's logistics industry at the cost of energy consumption had been used, but the actual energy intensity of the logistics industry had not been improved so far, it reflected the declining energy use efficiency of the industry.

Coal is rich and oil is scarce in China's energy system, and the logistics industry needs a lot of fuel oil which are from imports. Lack of oil in China results in higher prices of fuel (gasoline, diesel). In order to reduce the dependence on oil imports, Chinese government has vigorously promoted electric vehicles. In the past decade, China's electric vehicles have exploded growth, which is conducive to the reduction of energy intensity. In addition, the following practices are also helpful, such as using electric forklifts and electric trucks to replace diesel forklifts and diesel trucks as far as possible, using electric trucks for short distances and natural gas trucks for long distances are conducive to reducing the energy intensity of the logistics industry.

(3)Classified energy intensity.

The high carbon energy of the logistics industry includes gasoline, kerosene, diesel, etc., they are the main energies of the logistics industry. After the combustion of high-carbon energies, a large amount of carbon dioxide and other substances are emitted, which have great impacts on the environment and are not conducive to the completion of China's dual-carbon strategy. The actual value of classified energy intensity of China's logistics industry is shown in Fig. 4.

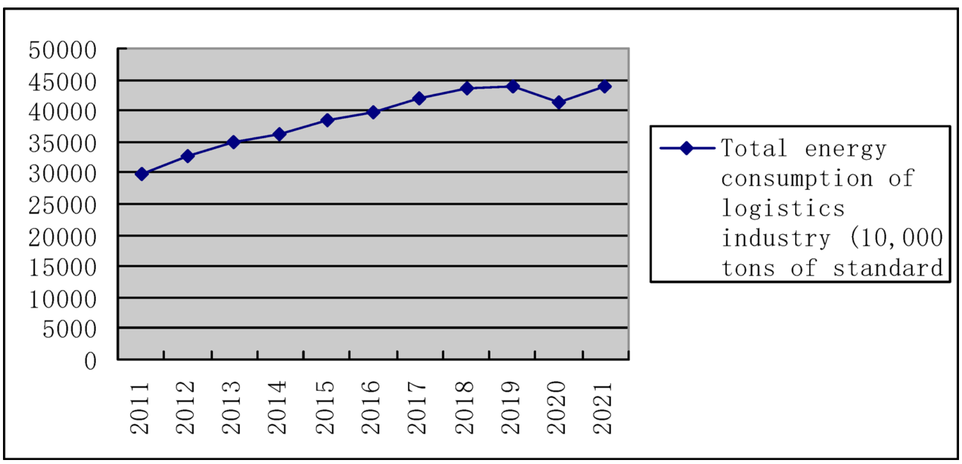

Fig. 2. Energy consumption of logistics industry.

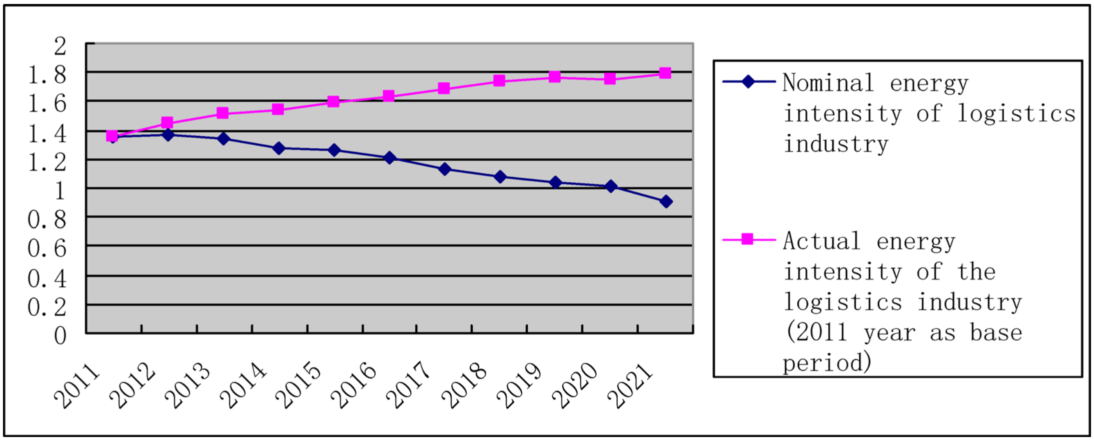

Fig. 3. Energy intensity of logistics industry (10,000 tons of standard coal/100 million yuan).

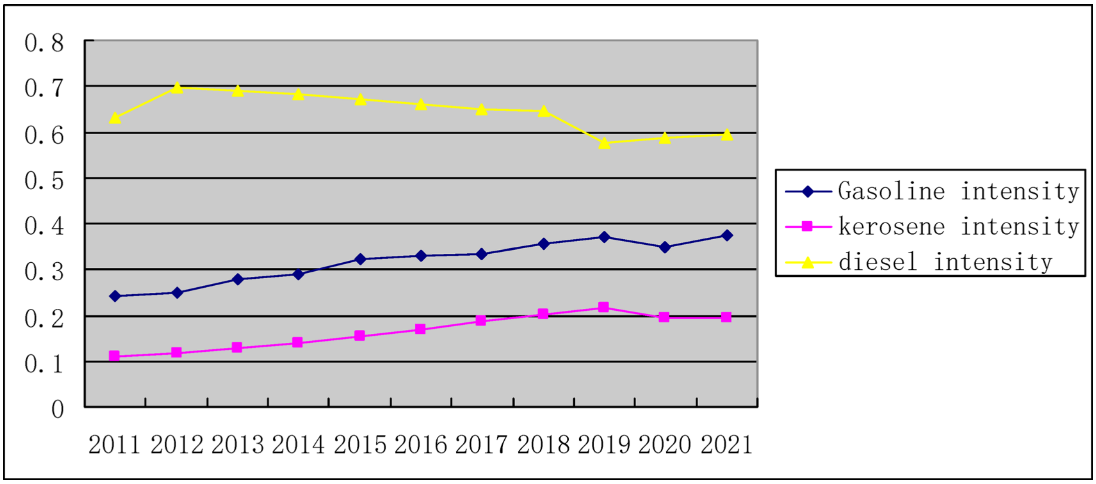

Fig. 4. Classified energy intensity of logistics industry (10,000 tons of standard coal/100 million yuan).

In Fig. 4, the development trends of gasoline, kerosene and diesel are different. From 2011 to 2021, the intensity of gasoline increased first and then decreased, while the intensity of kerosene and diesel generally increased. The reason was that gasoline price was more expensive than diesel price, the volume of diesel truck transportation was larger, and the transportation of trucks and ships all relied on diesel. In addition, the use of aviation kerosene was an important reason for the increase in kerosene intensity. High-carbon energy such as gasoline, kerosene, and diesel can be represented as an aggregate, which is a high-carbon energy aggregate and has been on the rise, as shown in Fig. 5.

Natural gas and electricity are clean and low-carbon energy, so China has encouraged to develop them. In 2011, natural gas consumption in China's logistics industry was 13.835 billion cubic meters, and in 2021 it rose to 36.631 billion cubic meters, with an annual growth rate of 10.23%. Electricity consumption rose from 84.842 billion KWH in 2011 to 199.302 billion KWH in 2021, with an annual growth rate of 8.92%. Obviously, the annual growth rate of electricity consumption was significantly smaller than that of natural gas, which was due to the promotion and application of natural gas-powered trucks and ships in the logistics industry, which accelerated the consumption of natural gas. Their energy intensities are shown in Fig. 6 below.

In Fig. 6, natural gas intensity and electricity intensity in the logistics industry shows an upward trend. This trend is expected to continue for a long time to come. China's natural gas deficit has been existed in recent years, with increasing the application of natural gas energy in the logistics energy system (such as transport power, distributed energy stations). China's electricity supply can meet the needs of production and life, so the logistics industry increases the use of power equipments is particularly necessary. Increasing the uses of electric vehicles (trucks, forklifts), all-electric logistics transportation projects, electric trailers, tractors and other equipments at port terminals, these will promote the process of technology and low-carbon in logistics industry.

For a long time, coal has been the main energy source in China, and the proportion of coal in total energy consumption was 68.5% in 2000, rose to the highest proportion of 72.5% in 2007, and then declined year by year, to 55.9% by 2021. The decline in the proportion of coal means that the proportion of other clean energy will increase, with the proportion of primary electricity and other energy sources rising from 7.3% in 2000

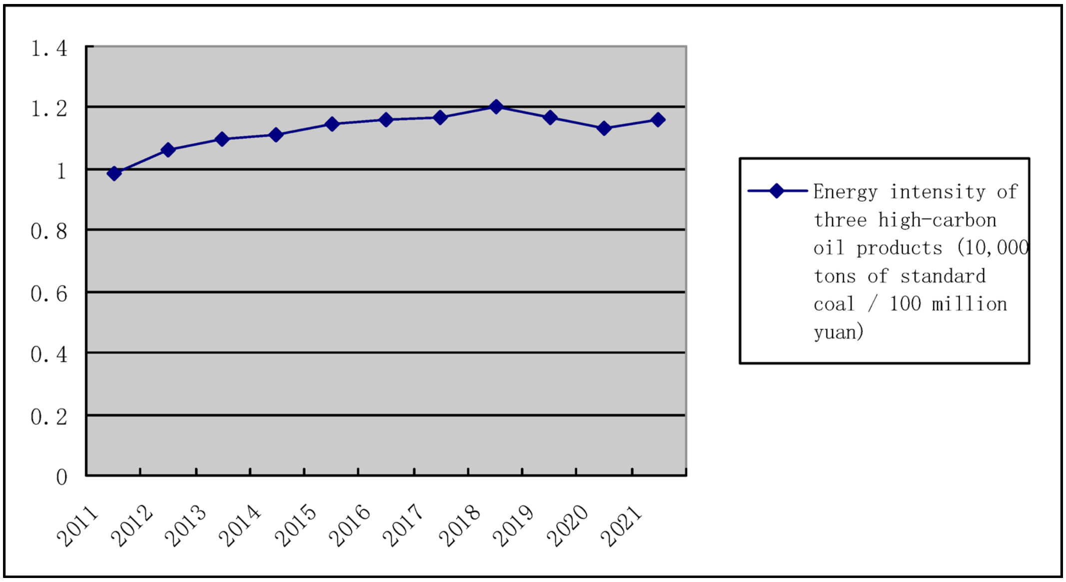

Fig. 5. The energy intensity of high-carbon energy aggregate.

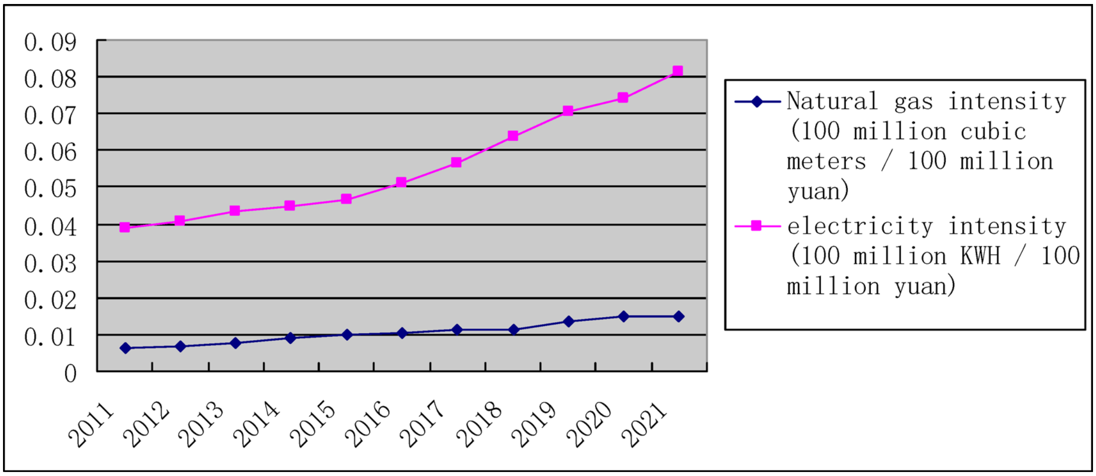

Fig. 6. Natural gas intensity and electricity intensity in the logistics sector.

to 16.7% in 2021, and the proportion of natural gas rising from 2.2% in 2000 to 8.8% in 2021, which is the fastest rising rate, due to inseparable from China's recent implementation of"coal to gas"in urban and rural areas. The situation in the logistics industry is different, the proportion of natural gas or electricity consumption in the logistics industry was also rising, respectively accounting for 3.6% and 2.09% in 2000, then the proportion changed to 10.5% and 1.81% in 2011, and the proportion changed to 9.71% and 2.34% in 2021. In general, during 2000–2021, the proportion of natural gas consumption increased rapidly in the early period and remained stable in the later period, while the proportion of electricity consumption decreased slightly in the early period and increased steadily in the later period.

Research framework and M&C mechanism

Research framework

The research framework of this paper is as follows: Firstly, the introduction introduces the implementation of China's dual-carbon strategy, and then introduces the changes faced by the development of logistics industry driven by low-carbon energy and new energy industries, that is, China's new energy vehicles (electric forklifts, electric trucks, etc.), natural-gas-powered trucks and ships have begun to be used in the logistics industry. Then, it analyzes the development of the logistics industry and the current situation of high energy intensity, proposes that the energy intensity of the logistics industry should be managed and controlled, and then proposes a M&C mechanism, which is applied to the energy intensity M&C of the logistics industry. This research is conducive to promoting the Chinese government to establish a decision-making service platform for energy intensity or carbon intensity M&C of the logistics industry, and can serve as a reference for government decision-making. The research framework is shown in Fig. 7 below.

In Fig. 7, Chinese government has responsibility to implement China's dual-carbon strategy, and this has significant meaning. Nowadays the world is under the greenhouse gas effect, so China has the necessity and responsibility to reduce carbon emissions, at the same time, China's economy will transition from extensive economic growth to green economic growth. All what Chinese government has done will contribute to our society. From this point of view, China's dual-carbon strategy is a driving force for the carbon intensity M&C of the logistics industry. Under the guidance of China's dual -carbon strategy, the use of low-carbon energy and government subsidies for new energy provide a further driving force, which is typically manifested in the decline of gasoline intensity and the increase of electricity and natural gas intensity. Other low-carbon energy sources (such as wind and nuclear) are not used on a large scale in the logistics industry, that is, the use of low-carbon energy is also selective. Low emissions of new energy vehicles and low prices of new energy are also driving forces. Just imagine, if the carbon emissions of energy are low and the price is high, it is not good for the promotion of application, precisely because the price of electricity and natural gas is controlled by the Chinese government, for the United States and Europe, China's one yuan per KWH of electricity (0.14 US dollars) in commercial electricity price is too cheap. After determining the implementation of energy intensity control in the logistics industry, the next step is to establish a M&C mechanism, and finally M&C application and decision-making are to be discussed.

M&C on energy intensity in the logistics industry

Demands of M&C

Although the Chinese government has not yet implemented direct M&C over the energy intensity of the logistics industry, there are indirect M&C methods in the form of limiting carbon emissions of transportation vehicles and piloting carbon credits. For example, to detect the exhaust gas of trucks, restricting the trucks with substandard exhaust emissions on the road is an effective M&C method. In addition, there are some logistics-related industries (such as aviation) also have carbon emission quota control. According to the European Union Directive 2008/101, the aviation industry was included in the EU carbon emission trading system, since 2012, all airlines (including foreign airlines) that flied in and out of the EU and on routes within the EU would be included in the carbon emission trading quota system, in other words, airlines would be allocated a certain amount of greenhouse gas emission credits. Large fines would be charged for exceeding the quota.

In foreign countries, there are some self-controlled logistics enterprises, such as the world famous logistics TNT Group planned to reduce the company's vehicle carbon dioxide emissions by half by 2025(Compare that to 2008). In China, there are also some companies (such as Hangzhou Tang Logistics) that used low-emission natural gas heavy trucks and electric forklifts to implement low-carbon operations in 2013. Compared with a diesel heavy truck of the same tonnage, the carbon emissions of a natural gas heavy truck could be saved by more than half. An electric forklift had almost zero carbon emissions compared to a diesel forklift. Not only that, some logistics enterprises in China have begun to implement low-carbon operations, according to the official website

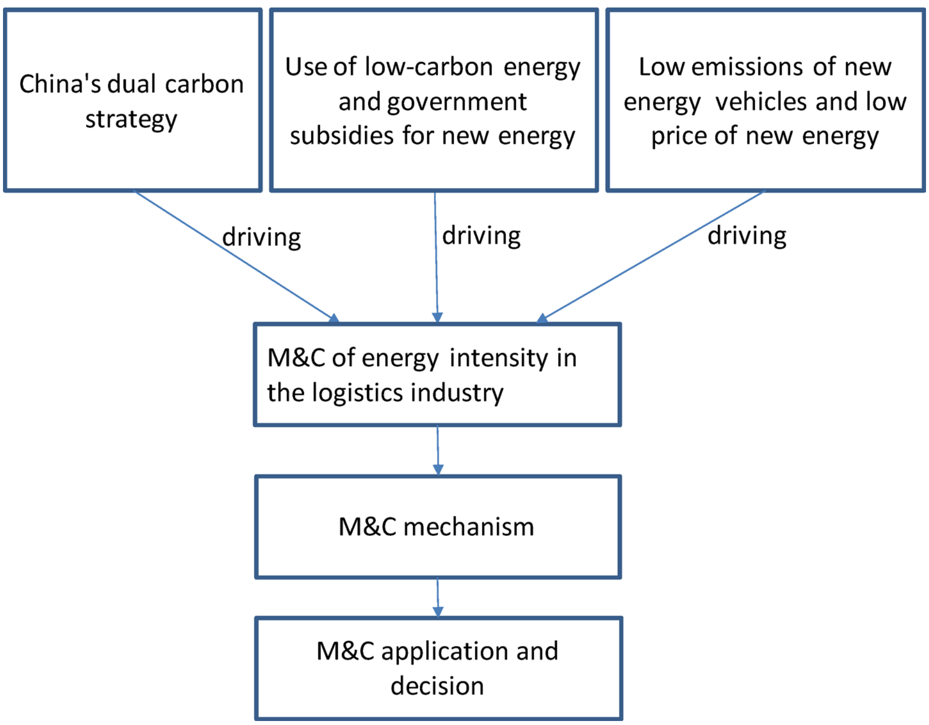

Fig. 7. Research framework.

of the Zhejiang Environmental Protection Department, the Huzhou Southern Logistics Terminal"air transport corridor"conveyor belt was completed in Zhejiang Changxing and put into trial operation in August 2018, which was the first"all-electric logistics"project to achieve all-electric transportation, warehousing, loading and unloading, and docking. The project was expected to reduce exhaust emissions by about 14,000 tons per year.

It can be seen from the above that more and more logistics enterprises with a sense of social responsibility have begun to actively implement low-carbon operations. The environmental protection departments of various provinces and cities issued a number of regulations and policies, such as the"Regulations on the Prevention and control of Air Pollution in Zhejiang Province", which indicated the goal and determination of carbon emission control. The logistics industry is a major carbon emitter. If logistics enterprises want to continue to consume a lot of energy at the cost of extensive operations, it will become difficult, because all kinds of vehicle and ship exhaust detection standards are getting higher and higher. At a time when China's central leadership determined to build a beautiful China, the government's control of carbon emissions would become increasingly strict. In view of the rising energy intensity in the logistics industry, resulting in a high carbon intensity, thus, a strong M&C demand is generated.

Construction of M&C mechanism

In order to implement a M&C process, it is necessary to build a feasible M&C mechanism. The general steps of M&C include: determine the M&C objects and objectives, select the M&C models, set the M&C parameters, M&C application and decision-making. Indeed, a good M&C mechanism should have not only a top-down hierarchical control mechanism, but also a bottom-up reverse hierarchical feedback mechanism. The top-down hierarchical control mechanism is conducive to the implementation of each step, and the bottom-up reverse hierarchical feedback mechanism is conducive to the correction of the result. Therefore, the M&C mechanism built in this study is shown in Fig. 8:

We will introduce the M&C mechanism according to Fig. 8:

(1) M&C objectives and objects.

During the 14th Five-Year Plan period (2021–2025), the main goal of China's modern energy system construction is to reduce energy consumption per unit of GDP by 13.5% in five years. For the logistics industry, the M&C objectives of energy intensity have been set by the paper as follows: a 13.5% reduction in 2021–2025, and a 27% reduction in 2021–2030. The object of M&C is the energy intensity in the logistics industry across national, regional and energy aggregation.

(2) M&C models (or methods).

As mentioned above, the energy intensity in the logistics industry has been generally on the rise, and the purpose of energy intensity M&C is to restrain its growth and strive to promote its adjustment. We propose four M&C models, as shown in Table 1.

Table 1 includes two exponential models, one difference model and one linear model, they can be used as general M&C models respectively, and the government can apply them to the M&C decisions of energy intensity in the logistics industry. At the aspect of model selection with empirical evidence, just like uniform falling motion or fast falling motion in physics, in order to better fit the actual data, the choice of model is goal-oriented. In the use process of three types of M&C models, the energy intensity value can be reduced quickly in the early stage by exponential models and difference model, but the linear model is to uniformly reduce the energy intensity value, the local governments can select one or multi- models to implement M&C according to

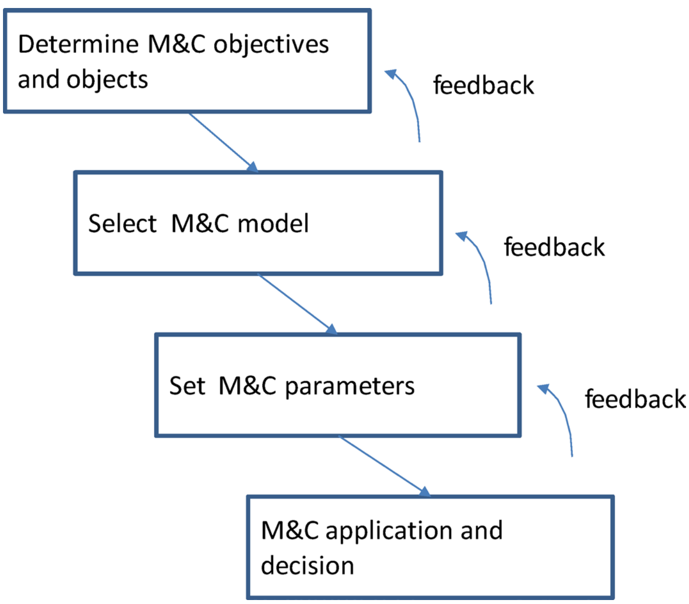

Fig. 8. M&C mechanism.

Model type	Model form	Regulatory factor	Parameter description	Other description
exponential model(M1)	$y_t = y_0 e^{at}$	e^{at}(a < 0)	t is time	It can be gradually adjusted according to time and proportion
	$y_t = y_0 \lambda^t$	$\lambda^t (0 < \lambda < 1)$	t is time	
Difference model[26] (M2)	$y_t = (1-\phi)^t (y_0 - \hat{y}) + \hat{y}$	$(1-\phi)^t$ $\phi(0 < \phi < 1)$	$\hat{y}$ is the long-term desire value, t is time	
Linear model(M3)	$y_t = y_0 + bt$	b(b < 0)	t is time	

Table 1. M&C models.

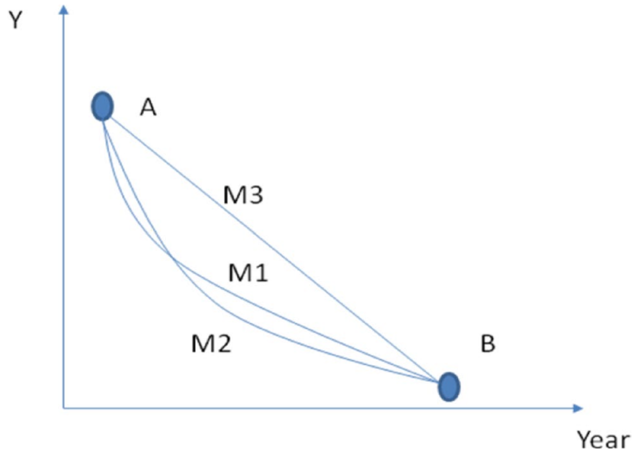

Fig. 9. The different performance of models under the same objective reduction.

their demands. Under China's dual-carbon strategy, to quickly or uniformly reduce the energy intensity value is of practical significance. The corresponding model parameter values will be set in the following part.

(3) Parameters of M&C models.

It is crucial to determine the parameters of the M&C models. Our preliminary idea is to do M&C on energy intensity of China's logistics industry during 2021–2025. In this way, we can get the first set of parameters, which can be used as a basis for further progress.

(4) M&C application and decision-making.

The above models are used to calculate, analyze and compare the energy intensity of the logistics industry in the range of national, regional and energy aggregate, so as to make corresponding M&C decisions.

Theoretical justifications for selecting models

At the aspect of model selection with empirical evidence, there are some studies in discussing the management and control in energy intensity, such as dynamic optimization or system dynamics in this field. In this paper, the nature of M&C is to reduce the energy intensity, just like uniform falling motion or fast falling motion in physics, the choice of model is goal-oriented in this paper. Under the same objective reduction, three types of models (exponential, difference, linear) can show one difference shown in Fig. 9. Furthermore, under the specified parameters, three types of models can also show another difference shown in Fig. 10[26]. found that the difference model belongs to progressive convergence. From the perspective of the nature of the models, in the short term, a larger long-term desire value can be given to the difference model, thereby achieving a rapid reduction to the specified target and better performance. If the time period is extended, then the exponential model has a stronger downward momentum in the early stage and a weaker one in the later stage, but the progressive convergent model (difference model) does not achieve a greater decline more quickly. On the contrary, the linear model performs most ideally over a long time period.

M&C processes and decisions

M&C by objective reduction

M&C by objective reduction means setting a reduction range for energy intensity, the objectives are a 13.5% reduction in 2021–2025 and a 27% reduction in 2021–2030, by the use the above models, the results are shown in Table 2 and Table 3.

As can be seen from Table 2 and Table 3, it is feasible to adopt the M&C models. For different models, the M&C data are all ideal, and the M&C values of energy intensity in the logistics industry gradually are decreasing from the peak in 2021, which shows good results.

Because the objectives for each model are a 13.5% reduction during 2021–2025 in Table 2 and a 27% reduction during 2021–2030 in Table 3, so the results in 2025 or 2030 are the same. However, the convergence speed in each model is different, faster convergence in the difference model, followed in exponential model and

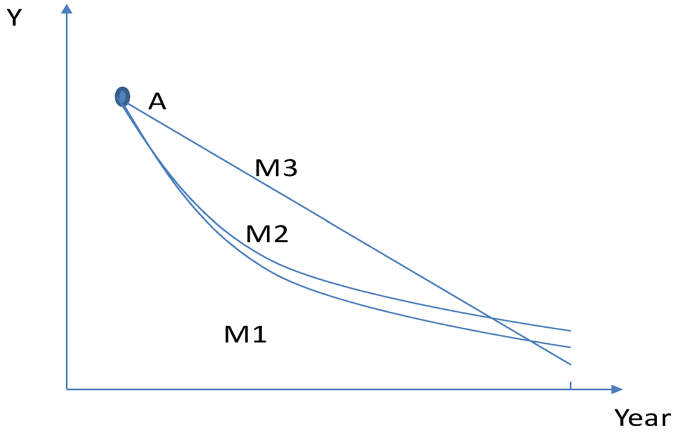

Fig. 10. The different performance of models under the specified parameters.

Year	Exponential model(M1) $y_t = y_0 e^{at}$, a = ln(0.865)/4 $y_t = y_0 \lambda^t$, $\lambda = 0.865^{1/4}$	Difference model(M2) $y_t = (1-\phi)^t (y_0 - \hat{y}) + \hat{y}$, $\hat{y}$ = 0.73*y_0, $\phi = 1 - 0.5^{1/4}$	Linear model(M3) $y_t = y_0 + bt$ b = −0.135*y_0/4;	Period overall objective
2021	1.795576	1.795576	1.795576	reduce 13.5%
2022	1.731641	1.718442	1.734975	
2023	1.669982	1.653580	1.674375	
2024	1.610519	1.599038	1.613774	
2025	1.553173	1.553173	1.553173	

Table 2. M&C by objective reduction on energy intensity from 2021 to 2025 (10,000 tons of standard coal/100 million yuan, base period was 2011). Note: The two exponential models export the same results. The determination of parameters is goal-oriented(a 13.5% reduction in 2021–2025), $y_t = y_0 e^{at}$, t = 2025–2021, a = ln (y_t/y_0)/t = ln (1–0.135)/4 = ln (0.865)/4. Similar in λ. The difference model is set a long-term desire value (a 27% reduction), $\hat{y}$ = 0.73*y_0, $y_t = (1 - 0.135)y_0$, ϕ can be calculate as $\phi = 1 - 0.5^{1/4}$. In the linear model, $y_t = (1 - 0.135)y_0$, b = −0.135*y_0/4;.

Year	Exponential model(M1) $y_t = y_0 e^{at}$, a = ln(0.73)/9 $y_t = y_0 \lambda^t$, $\lambda = 0.73^{1/9}$	Difference model(M2) $y_t = (1-\phi)^t (y_0 - \hat{y}) + \hat{y}$, $\hat{y}$ = 0.7*y_0, $\phi = 1 - 0.1^{1/9}$	Linear model(M3) $y_t = y_0 + bt$ b = −0.27*y_0/9;	Period overall objective
2021	1.795576	1.795576	1.795576	reduce 27%
2022	1.733874	1.673978	1.741709	
2023	1.674292	1.579829	1.687842	
2024	1.616757	1.506933	1.633974	
2025	1.56120	1.450492	1.580107	
2026	1.507551	1.406792	1.526240	
2027	1.455746	1.372957	1.472372	
2028	1.405722	1.346759	1.418505	
2029	1.357416	1.326476	1.364638	
2030	1.310771	1.310771	1.310771	

Table 3. Energy intensity M&C by objective reduction from 2021 to 2030 (10,000 tons of standard coal/100 million yuan, base period was 2011). Note: The two exponential models export the same results. In the difference model, the long-term desire value is set as 70% ($\hat{y}$ = 0.7*y_0), which is smaller than an overall objective 73% (reduce 27%). After $\hat{y}$ is set, $y_t = 0.73y_0$, ϕ can be calculate as $\phi = 1 - 0.1^{1/9}$. In the linear model, $y_t = (1 - 0.73)y_0$, $b = -0.27 * y_0/9$.

Year	Exponential model(M1) $y_t = y_0 e^{at}$, a = ln(0.865)/4 $y_t = y_0 \lambda^t, \lambda = 0.865^{1/4}$	Difference model(M2) $y_t = (1-\phi)^t (y_0 - \hat{y}) + \hat{y}, \hat{y}$ = 0.73*$y_0, \phi = 1 - 0.5^{1/4}$	Linear model(M3) $y_t = y_0 + bt$ b = −0.135*y_0/4;
2021	1.795576	1.795576	1.795576
2022	1.731641	1.718442	1.734975
2023	1.669982	1.653580	1.674375
2024	1.610519	1.599038	1.613774
2025	1.553173	1.553173	1.553173
2026	1.497869	1.514606	1.492573
2027	1.444535	1.482175	1.431972
2028	1.393099	1.454904	1.371371
2029	1.343495	1.431972	1.310771
2030	1.295657	1.412688	1.250170

Table 4. Energy intensity M&C by the specified parameters from 2021 to 2030 (10,000 tons of standard coal/100 million yuan, base period was 2011). Note: The two exponential models export the same results.

Year	Exponential model(M1) $y_t = y_0 e^{at}$, a = ln(0.73)/9 $y_t = y_0 \lambda^t, \lambda = 0.73^{1/9}$	Difference model(M2) $y_t = (1-\phi)^t (y_0 - \hat{y}) + \hat{y}, \hat{y}$ = 0.7*$y_0, \phi = 1 - 0.1^{1/9}$	Linear model(M3) $y_t = y_0 + bt$ b = −0.27*y_0/9;	Period overall objective
2021	1.163999	1.163999	1.163999	reduce 27%
2022	1.124000	1.085172	1.129079	
2023	1.085376	1.024139	1.094160	
2024	1.048078	0.976884	1.059240	
2025	1.012063	0.940296	1.024320	
2026	0.977285	0.911967	0.989400	
2027	0.943702	0.890032	0.954480	
2028	0.911273	0.873050	0.919560	
2029	0.879958	0.859901	0.884640	
2030	0.849720	0.849720	0.849720	

Table 5. M&C on high carbon energy intensity from 2021 to 2030 (10,000 tons of standard coal/100 million yuan, base period was 2011). Note: The two exponential models export the same results.

slower in linear model. The user of the model is the government agency, and the government decision-maker can selectively use one or more models, so that each model can meet the policy needs.

M&C by the specified parameters

M&C by specified parameters means that the specified parameters are given first. We take the parameters in Table 2 as the specified parameters (or set according to real demands), which have practical significance, but the results are different. Therefore, the models are run again and the results are shown in Table 4.

In Table 4, except for the small adjustment amplitude of the difference model (affected by the long-term desire value $\hat{y}$), the adjustment amplitudes of the exponential and linear model are larger, which indicates that if the adjustment is continued according to the specified parameters, both the exponential and linear model will give a larger reduction. The difference model will also work much better if the long-term desire value is modified to be smaller (we will modify the long-term desire value for this situation below). Therefore, in the M&C by the specified parameters, the convergence speed in each model is changed. According to the curve characteristics of the model, the difference model converges more in the early stage and less in the late stage. The exponential model converges more in the early stage and more in the late stage, while the linear model depends on uniform convergence and finally obtains the optimal convergence value.

M&C on high-carbon energies

(1) At the national level.

China is a country lacking in oil and gas, and it is also very necessary to do a M&C for the combined energy intensity of gasoline, diesel and kerosene, as shown in Table 5.

Table 5 is still controlled by the objective reduction of 27%, and the results obtained are also ideal. Because the objective reduction is the same as in Table 3, the convergence speed is also the same as in Table 3, and each model can meet the policy needs.

(2) At the regional level.

In order to facilitate the analysis, the energy intensity of the three major high-carbon oil in the logistics industry in each region in 2021 was calculated, as shown in the following Table 6.

serial number	Eastern, central and western regions	year	Region	Energy intensity on gasoline- -kerosene-diesel aggregate	serial number	Eastern, central and western regions	year	region	Energy intensity on gasoline--kerosene-diesel aggregate
1	1	2021	Hebei	0.472751	16	2	2021	Jiangxi	1.577075
2	1	2021	Tianjin	0.67647	17	3	2021	Gansu	1.626722
3	1	2021	Shandong	0.839132	18	3	2021	Chongqing	1.660166
4	3	2021	Inner Mongolia	0.959967	19	2	2021	Hubei	1.730108
5	3	2021	Shaanxi	0.965748	20	1	2021	Hainan	1.749532
6	2	2021	Shanxi	1.035515	21	3	2021	Guangxi	1.809572
7	2	2021	Henan	1.063794	22	1	2021	Beijing	1.883834
8	2	2021	Anhui	1.076081	23	3	2021	Sichuan	1.989678
9	1	2021	Jiangsu	1.159055	24	1	2021	Liaoning	1.997981
10	1	2021	Guangdong	1.231922	25	2	2021	Hunan	2.064742
11	1	2021	Fujian	1.256632	26	3	2021	Qinghai	2.247433
12	1	2021	Zhejiang	1.258048	27	2	2021	Heilongjiang	2.251233
13	2	2021	Jilin	1.328201	28	3	2021	Yunnan	2.338203
14	1	2021	Shanghai	1.346113	29	3	2021	Xinjiang	2.355823
15	3	2021	Ningxia	1.393422	30	3	2021	Guizhou	2.631334

Table 6. Energy intensity on high carbon oil by region in 2021 (10,000 tons of standard coal/100 million yuan, base period was 2011). Note: 1 denotes as the eastern province, 2 denotes as the central province, 3 denotes as the western province. Since the Chinese Bureau of Statistics does not provide the price index of the value-added of the logistics industry by region, the price deflator of the actual value-added of the logistics industry in the provinces here is the value -added index of the tertiary industry(Because the logistics industry belongs to the tertiary industry logistics industry), with a base period of 2011.

Year	Exponential model(M1) $y_t = y_0 e^{at}$, a = ln(0.73)/9 $y_t = y_0 \lambda^t, \lambda = 0.73^{1/9}$	Difference model(M2) $y_t = (1-\phi)^t (y_0 - \hat{y}) + \hat{y}, \hat{y} = 0.7^* y_0, \phi = 1 - 0.1^{1/9}$	Linear model(M3) $y_t = y_0 + bt$ b = −0.27* y_0/9;	Period overall objective
2021	2.631334	2.631334	2.631334	reduce 27%
2022	2.540912	2.453138	2.552394	
2023	2.453597	2.315167	2.473454	
2024	2.369283	2.208341	2.394514	
2025	2.287866	2.125630	2.315574	
2026	2.209247	2.061589	2.236634	
2027	2.133329	2.012005	2.157694	
2028	2.060020	1.973614	2.078754	
2029	1.989231	1.943889	1.999814	
2030	1.920874	1.920874	1.920874	

Table 7. M&C on high carbon oil energy intensity by objective reduction in Guizhou from 2021 to 2030 (10,000 tons of standard coal/100 million yuan, base period was 2011). Note: The two exponential models export the same results.

In Table 6, the energy intensity of the three high-carbon oil in the logistics industry ranges from 0.47 to 2.63. The lower the value, the higher the energy utilization efficiency of the logistics industry in the region, that is, the greater the output can be obtained with less energy consumption. On the contrary, the higher the value, the lower the energy utilization efficiency of the logistics industry in the region will be. We choose one of the largest energy intensity values (Guizhou, the others are omitted) for M&C, and the results are as shown in Table 7.

We have done a M&C for the high-carbon oil energy intensity for Guizhou's logistics industry. By setting an objective reduction of 27%, the energy intensity value will be reduced from 2.631334 to 1.920874. Because the high carbon oil energy intensity of Guizhou's logistics industry was the highest in 2021, it can also be set as an objective reduction of 30% or more, so that the M&C reduction is larger, which is conducive to Guizhou's faster promotion of low-carbon logistics industry. Furthermore, because the objective reduction is the same as in Table 3 or Table 5, the convergence speed and policy applicability are also the same as in Table 3 or Table 5. In order to facilitate the comparison, the operation was done again according to the specified parameters, and the results are shown in Table 8.

In the exponential and linear models in Table 8, the parameters we set are the M&C parameters from 2021 to 2025, and the M&C will continue according to the original parameters from 2026 to 2030. In the difference

Year	Exponential model(M1) $y_t = y_0 e^{at}$, a = ln(0.865)/4 $y_t = y_0\lambda^t, \lambda = 0.865^{1/4}$	Difference model(M2) $y_t = (1-\phi)^t(y_0 - \hat{y}) + \hat{y}$, $\hat{y}$ = 0.5*y_0, $\phi = 1 - 0.73^{1/4}$	Linear model(M3) $y_t = y_0 + bt$ b = −0.135*y_0/4;
2021	2.631334	2.631334	2.631334
2022	2.537640	2.531788	2.542526
2023	2.447282	2.439773	2.453719
2024	2.360142	2.354721	2.364911
2025	2.276104	2.276104	2.276104
2026	2.195059	2.203435	2.187296
2027	2.116899	2.136265	2.098489
2028	2.041522	2.074176	2.009681
2029	1.968830	2.016786	1.920874
2030	1.898726	1.963738	1.832066

Table 8. M&C on high carbon oil energy intensity by specified parameters in Guizhou from 2021 to 2030 (10,000 tons of standard coal/100 million yuan, base period was 2011). Note: The two exponential models export the same results, the parameters in Table 2 are used as the specified parameters, which are calculated from the decline of China's energy intensity per unit GDP as the specified parameters, and a small part of the specified parameters are slightly adjusted to measure the effect in Table 8. Furthermore, in the difference model, a more smaller long-term desire value is set as $\hat{y}$ = 0.5*y_0, $\phi = 1 - 0.73^{1/4}$.

model, the long-term desire value in 2025 is changed to $\hat{y}$ = 0.5*y_0 After comparing with different models in Table 8, we find that the M&C effect of the linear model is the best, which has the best convergence value. At the aspect of convergence speed and policy applicability, if the reduction target set for energy intensity is less than the long-term desired value level, the differential model will show better convergence speed in the early stage and slower convergence speed in the middle and late period, the decision maker can select different models based on real demands.

To sum up, the above models assume static parameters (e.g., fixed annual reduction targets or the specified parameters) to M&C the energy intensity. But every year or every time, the specified parameters may be re-adjusted according to actual situation, the M&C models can be applied to multi- scenario analysis under fixed annual reduction targets or policy shifts, etc.

Discussion on M&C decision

Based on the above analysis, it will be discussed at the national and provincial levels based on the roles of government, logistics enterprise and M&C platform:

At the national level, China's central government can control the energy intensity of the logistics industry as follows: M&C by objective reduction, M&C by the specified parameters. The former needs to set the objective, and then selects the relevant models for M&C. Although it is feasible to do a M&C by the latter, the parameters must be determined in advance, which needs to rely on the accumulation of experience or the parameters under the earlier M&C by objective reduction as a reference (or use new specified parameters). M&C on high carbon energies also needs to be operated by two above M&C methods.

At the provincial level, China's governments at all levels can make M&C decisions according to the energy intensity of the logistics industry in each region: Firstly, strict M&C should be carried out in the regions with high energy intensity of high-carbon oil in the logistics industry (value is greater than 2). All regions with the value greater than 2 are in the central and western provinces, where gasoline and diesel consumption are larger, and their road logistics play important roles, generating a large amount of high-carbon consumption. Secondly, regions with energy intensity of the high-carbon oil in the logistics industry should be focused on M&C (value is greater than 1.5 and less than 2).This includes three eastern provincial regions: Beijing and Hainan and the Liaoning. After analysis, it is found that the main reason is that Beijing's and Hainan's air transport enterprises consumed large amounts of kerosene, Liaoning consumed a lot of gasoline and diesel, they drove substantial increases in energy consumption. It also includes six provincial-level regions in central and western China, such as Jiangxi, Gansu, Chongqing, Hubei, Guangxi, Sichuan, which also consume more gasoline and diesel. Thirdly, general M&C should be carried out in regions where the energy intensity of the high-carbon oil in the logistics industry (value is greater than 1 and less than 1.5), and no special requirements should be made for regions (value is less than 1).

If the local government takes the energy intensity of the region as the benchmark, enterprises apply for energy intensity M&C in order to enjoy the government's green energy subsidies and avoid penalties for high carbon emissions. The M&C purpose of government is to determine whether enterprises are eligible to apply for subsidies or continue to strengthen a M&C over high-emission enterprises.

In the M&C of energy intensity, we continue to discuss the roles of stakeholders, a decision-making service platform should be established, as shown in Fig. 11.

In Fig. 11, there are mainly three types of roles, one is the government, the second is the logistics enterprise, and the third is the M&C platform of energy intensity in logistics industry. The government initiates the M&C objectives, logistics enterprises send the demands to M&C platform, and the government supervises

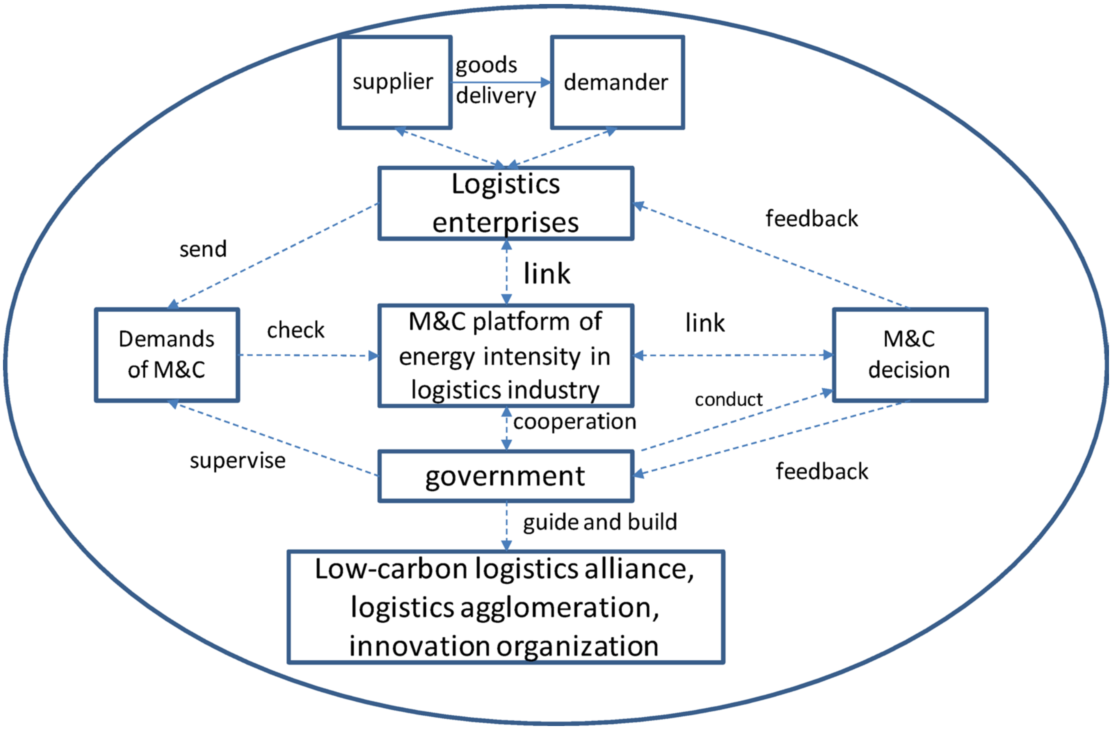

Fig. 11. A M&C decision-making service platform.

Roles	Aims	Behaviors or Actions
Logistics enterprises	(1)Apply for low carbon subsidies (2)Respond to the national dual-carbon strategy (3)Acquire more low-carbon logistics businesses (4)Obtain honor awards of low-carbon logistics enterprise	Apply for M&C based on benefit,development or survival principle
Platform	Conducts an intermediary business, a certain business fee can be charged	Inspects materials and qualifications from logistics enterprises, who meet the requirements will be submitted to the government for further review and decision-making (including the distribution of subsidies and honor awards)
Government	(1)Needs a low-carbon logistics industry (2)Realizes the upgrading of the logistics industry (3)Needs to implement a dual-carbon strategy	(1) Builds a low-carbon and technological logistics industry (2) Contributes to the implementation of the dual-carbon strategy (3)Reduces social logistics costs by low-carbon technology

Table 9. The roles, aims and actions of different stakeholders.

the demands on the M&C platform. The M&C platform cooperates with the government and accepts its guidance and supervision. The M&C platform receives the M&C demands (detailed business, products and various energy consumption records of the enterprise and the government subsidies applied for) from logistics enterprises, which are checked and supervised by the government, a M&C mechanism will be established, and a reasonable M&C process will be implemented according to M&C objectives. The operationalized feedbacks from logistics firms can be solved by the platform and the government, the former collects various types of demands and operationalized feedbacks, while the latter centralizes to approve the rational and legal demands and operationalized feedbacks. The roles, aims and actions of different stakeholders are shown in Table 9.

About the example applications in logistics, for instance, (1) Local governments measure the energy intensity of their regions in a certain future year based on three types of models, any model can be chosen. For example, Guizhou made a decision at 1.920874 (energy intensity) in 2030 based on the target value (Table 7). (2) Regarding the distribution decision-making of low-carbon energy subsidies in Guizhou, if the energy intensity of an enterprise is less than 1.920874, it meets the distribution conditions. The platform (Fig. 11) collects the number of enterprises that meet the subsidy distribution conditions, their output value and tax payments, and calculates the subsidy per unit of output value. Then each enterprise can obtain a certain amount of subsidies (less than the tax paid) based on its total output value. In terms of the low-carbon Enterprise Honor Contribution Award, the top 50 or 100 outstanding low-carbon enterprises will be established.

Suggestions for policy objectives or development measures to be adopted by Chinese governments at all levels are as follows.

(1) the M&C models are used by the local governments, if the energy intensity in the M&C models is higher than expected value, the V6 automobile exhaust emission standards must be implemented strictly. Furthermore,

Serial number	Provinces of high carbon energy intensity of the logistics industry	centralized region	Logistics joint development decision
1	Shanghai, Jiangsu, Zhejiang, Jiangxi, Anhui	Yangtze River Delta	The Yangtze River Delta (Shanghai, Jiangsu, Zhejiang) can make use of its strong logistics capacity, which can spill over and radiate Jiangxi, Anhui and other provinces, so as to avoid the vacancy of logistics capacity
2	Sichuan, Yunnan, Guizhou, Chongqing, Guangxi	Southwest region	Relying on Guangxi to access the sea, it is complementary with other mainland provinces in terms of logistics capacity, industry and resources
3	Hunan, Hubei	central region	Relying on Guangdong's logistics capacity, it spills over to Hunan, Hubei and Guangxi, with complementary logistics capabilities and complementary industries
4	Beijing, Liaoning	Circum-bohai Bay	Beijing-tianjin-hebei – Liaoning, logistics integration construction
5	Heilongjiang, Liaoning, Jilin	Northeast region	It is expected to open up the estuary of the Tumen River in Heilongjiang, and integrate logistics development with Liaoning, Jilin and eastern Inner Mongolia
6	Gansu, Qinghai, Xinjiang	Northwest region	Construct logistics alliance among Gansu, Qinghai, Xinjiang, western Inner Mongolia
7	Hainan	Southern region	It is an island, mainly develops tourism, consumes more aviation kerosene, but the total consumption is not large, can continue to maintain its own characteristics, and can also achieve win–win cooperation with neighboring provinces (such as Guangdong)

Table 10. Logistics joint development decisions among provinces with high carbon energy intensity.

the local governments should vigorously use electric trucks, electric forklifts, all- electricity logistics projects, etc., implement multimodal transport, accelerate the applications of natural-gas-powered trucks and ships, increase the use of electricity and natural gas energy-saving equipments, and increase the proportion of electricity and natural gas consumption in the logistics industry consumption, promote energy conservation and carbon reduction in the logistics industry.

(2) the local governments should implement alliance operations of logistics parks and logistics bases in provincial areas to enhance the output value of the regional logistics industry. Different models play important roles, the exponential model suggests faster adoption of EVs in high-intensity regions. The regions with high energy intensity should reduce energy intensity by various means such as energy saving and carbon reduction and increasing the output value of logistics industry.

(3) the local governments should give overall consideration to the construction of low-carbon logistics parks and large-scale low-carbon energy stations, and promote the development of low-carbon logistics by implementing energy substitution, energy saving building, energy saving tools or running on the enterprises, etc.

According to the location advantages of each province and the actual situation of high carbon energy intensity, the development decision-making suggestions of each province are shown in Table 10 below:

Conclusion

In the process of epoch-making industrial transformation and upgrading, the logistics industry has also shown many new changes, for example, more and more energy tools are widely used, and the trend of low-carbon logistics industry is becoming more and more obviously. Under China's dual-carbon strategy in the new era, carbon emission reduction is an urgent problem. In view of the fact that carbon emission has boosted global greenhouse gas effect, and the logistics industry is a major carbon emission, it is necessary to strictly save energy and reduce emissions. This paper takes the logistics industry's energy intensity M&C decision as the theme of research, through the above analysis, the main conclusions are as follows:

(1)The annual growth rate of energy consumption in China's logistics industry is relatively high, which is generally faster than the annual growth rate of the actual gross product of the logistics industry, resulting in the continuous rise of energy intensity, which is not conducive to energy conservation and carbon reduction. In order to control it, a M&C mechanism of hierarchical control and reverse hierarchical feedback is constructed.

(2) In order to better set reasonable reduction objectives for the energy intensity of the logistics industry, we propose a M&C by objective reduction, the general models are mainly constructed, which can make classified M&C decisions for the energy intensity of the logistics industry in different years and provinces respectively, and can accurately control the reduction in objects, because the M&C models can accurately converge.

(3) If it is necessary to control the energy intensity of the logistics industry for a longer period of time, it can also be implemented M&C by the specified parameters. It should be noted that the parameter values in each model can be set in advance (refer to the parameters in the M&C by objective reduction or use other specified parameters), and good results can also be achieved. It can be seen that each model has a strong universality, as long as the appropriate parameter values are set, accurate M&C can be carried out (such as for Guizhou province).

On the basis of M&C, China's central government should guide the development direction of the logistics industry through policies. Local governments (especially those in neighboring provinces) should give more consideration to hub zones and form industrial agglomeration areas in the construction of logistics parks, logistics bases and logistics centers, so as to realize the synergy between different industries in multi-provincial regions. For example, the energy intensity of the logistics industry in Guizhou and Yunnan is high, and for the neighboring provinces with strict M&C, the industrial coordination mechanism should be established, which is the pressure brought by M&C and is also an opportunity.

Based on the above research, we also believe that the Chinese government should strengthen the standardization and energy-saving operation equipment, such as in the combined transport of roads and railways, all freight equipments such as containers and pallets can be used as widely as possible in the transport of roads and railways, further improve the level of railway freight line electrification, and promote energy saving and carbon reduction in the logistics industry. The local governments should vigorously promote more energy efficient delivery vehicles, strengthen and improve the construction and operation of charging piles, enhance the low-carbon logistics infrastructure, so as to reduce the overall energy consumption of the logistics industry in various regions.

To sum up, this study can control the energy intensity of the logistics industry by constructing a M&C mechanism, selecting models as M&C tools and setting parameters of the models. This job is feasible and exercisable. In view of this study on energy intensity M&C for decision-making effect in the logistics industry is obvious. Therefore, we suggest that relevant government departments should make full use of the M&C mechanism and models of this study to serve the M&C decisions on energy consumption and carbon emission reduction in the logistics industry, so as to promote the development of low-carbon logistics and help the implementation of China's dual-carbon strategy.

In other areas, the Chinese government should continue to do the following jobs, (1)improve the quality of education and provide enterprises with high-quality workers, thereby increasing labor productivity; (2) increase the density of railway, road density and other high-quality transport infrastructure construction; (3) guide enterprises to implement the innovation of energy facilities and equipment. These initiatives are not only conducive to increasing the output of the logistics industry, but also beneficial to speed up transportation efficiency and reduce energy intensity, so as to promote energy saving and carbon reduction in the logistics industry.

The limitation in the paper includes the informationization construction of M&C platform of energy intensity, in future direction, we will study the use and informationization of M&C platform of energy intensity.

Data availability

Data is provided within supplementary information files.

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Chongyan LI: conceptualization, supervision, validation, methodology, software, writing—original draft, writing—review and editing. Fuzhong Wang: conceptualization, writing—original draft, writing—review and editing.

Declarations

Competing interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics approval
This work did not include any studies with human or animal participants conducted by all the authors.

Informed consent
Informed consent was not required as the study did not involve human or animal participants.

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