

# Effect of Green Transformational Leadership and Organizational Environmental Culture on Manufacturing Enterprise Low Carbon Innovation Performance

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## ABSTRACT

Previous studies stated that low carbon innovation performance could be influenced by government regulations and the green market, which is the new trend of consumer consumption in the present time, mainly focusing on external factors. Before study augured that low carbon innovation performance could be driven by internal and external factors of cooperation such as institutional pressure, stakeholder pressure, and innovation resources. However, the study of green transformational leadership and organizational environmental culture on low carbon innovation performance is rare, especially in Chinese manufacturing, as well as the effect of influencing factors of TPB model: environmental attitude, subjective norm, and perceived behavior capability on low carbon innovation performance. Previous studies mostly used the TPB model for predicting individual behavior. This study established a theoretical model combining the TPB model with green transformational leadership and organizational environmental culture of Chinese automobile manufacturing on low carbon innovation performance. This study consists of two sections of research methodology: section 1 related to questionnaire design and data collection. We established a questionnaire and distributed it online, targeting responses from the managerial level working in Chinese automobile manufacturing. Eventually, 155 valid questionnaires were used for analysis. Section 2 involved data analysis using statistical software. Reliability and data validity was examined by reliability analysis and factor analysis. Correlations and convergent validity analyses were applied, and structural equation modeling was conducted to test the proposed hypotheses. The findings indicated that green transformational leadership, organizational environmental culture, and essential factors of TPB model; environmental attitude, subjective norm and perceived behavior capability positively affect low carbon innovation performance. In addition, the indirect effect of green transformational leadership was tested and found that organizational environmental culture and TPB factors mediated the relationship between transformational leadership and low carbon innovation performance.

**Keywords** Low Carbon Innovation Performance; Transformational Leadership; Revised TPB; Environmental Culture

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## 1. Introduction

Environmental issues such as global warming and climate change have gained heightened attention from society worldwide. Even though industrialization is beneficial for economic development, unrestricted usage of coal and fossil fuel has released excessive greenhouse gases that trap heat in the atmosphere and caused the global surface temperature to rise. This has caused a severe chain of effects on the earth like ice melting at the Earth poles, rising sea levels, affecting wildlife's habitat, and causing respiratory disease resulting from smog and air pollution. There will be a substantial risk of extreme weather, floods and droughts, Thus, reducing carbon emissions has become critical to mitigating the issue (Chen and Cai 2015).

Low carbon innovation will be the breakthrough point for carbon-neutral society and corporate and low carbon transition of corporate and industry. According to the book "Technology Transfer and Innovation for Low-Carbon Development" low carbon technology innovation in energy, industry, transport, and buildings can help reduce two-thirds of emissions by 2030 (Pigato 2020). Moreover, IEA's report explaining global CO<sub>2</sub> emissions by sector revealed that transportation is responsible for 25.92% of global carbon emissions in 2018. Later, Song et al. (2019) mention that about 18% of carbon emission comes from private car consumption. Therefore, the European Union sets different targets that limit carbon emissions from vehicles in its report and aims to cut 60 % of transport emissions by 2050 to become the first carbon-neutral continent globally. Corporate starts must take proactive initiatives to develop low carbon innovation products and improve their low carbon innovation performance in line with the global carbon reduction agreement to survive under stringent environmental goals and carbon emission targets. Automotive companies such as Ford, Volkswagen, Volvo, and Mercedes Benz are examples of companies that set environmental goals to decarbonize and produce low carbon or carbon neutral vehicles to mitigate climate change issues. Judging by the action taken by these companies, it is indisputable that these companies perceived low carbon innovation as an excellent alternative to cope with the climate change issue. Therefore, it is worth researching how low carbon innovation performance helps these companies achieve their environmental goal and the factor that drives them to voluntarily develop low carbon innovation.

As mentioned above in IEA's report, transportation is responsible for over a quarter of the world's carbon emissions. In another IEA report where transportation emission is divided into the mode, passenger road vehicles and road freight vehicles are responsible for almost three-quarters of total carbon emissions from the transportation sector (IEA 2019). Therefore, the government needs to encourage low carbon transition in the automotive industry to reduce transport emissions effectively. According to Transport and Environment's report, during the production of car and

battery, fuel and electricity production from driving, and carbon exhaust emission, new energy vehicles emits almost three times less carbon than conventional vehicles fueled by petrol and diesel (Transport and Environment 2020). This indicates that the automotive industry is one of the heavily polluting industries that harm the environment from production to vehicle distribution. New energy vehicles are the product of technology innovation specially designed to reduce emissions from the vehicle resulting from the development of advanced technology in the automotive industry. As vehicles are inseparable from human activity as transportation tools, developing new energy vehicles is essential for the country to mitigate climate change (Yuan et al. 2015; Du et al. 2018). Developing low carbon innovation performance among new energy vehicle corporate might be the key to sustainable business performance for other heavy pollution industries. This paper examine the factors driving corporate to develop low carbon innovation performance.

Previous studies show that green transformational leadership positively affects corporate green product development and green innovation and leads to positive environmental performance (Chen and Chang 2013; Singh et al. 2020). Besides, organizational environmental culture positively affects innovation and environmental performance of corporate (García-Granero et al. 2020; García-Machado and Martínez-Ávila 2019). However, these studies did not focus on the energy-intensive manufacturing. Besides, many researchers have investigated an individual's environmental attitude and behavior using the planned behavior theory. This paper studied from the perspective of the Chinese NEV manager who acts as a business decision-maker, also predicts low carbon innovation performance using TPB theory. Therefore, this paper suggests that green transformational leadership, organizational environmental culture, and TPB theory are applicable in the energy-intensive manufacturing. This paper aims to bridge the gap by exploring the factors contributing to low carbon innovation in the energy-intensive sector in China. The study is conducted using an integrated TPB theory model with green transformation leadership and organizational environmental cultures and their relationship towards low carbon innovation performance.

This paper consists of three research questions; the first research question is, does green transformation leadership affects low carbon innovation performance? The second research question is, does organizational environmental culture affects low carbon innovation performance? The third research question is can TPB predict an organization's low carbon innovation performance? According to environmental regulation, it is required to reduce carbon emissions. The company needs to take action to follow the rules. The especially automotive industry causes the majority of carbon emissions from the transportation sector. In contrast, many studies mentioned low carbon technology innovation as a tool for decreasing carbon emissions. However, at the company level, there is no evidence showing how low carbon innovation performance helps

companies achieve their environmental goal and factors that drive them to develop low carbon innovation performance voluntarily. Previous studies show that green transformational leadership positively affects corporate green product development and green innovation and leads to positive environmental performance (Chen and Chang 2013; Singh et al. 2020). In addition, organizational environmental culture positively affects innovation and environmental performance of corporate (García-Granero et al. 2020; García-Machado and Martínez-Ávila 2019). However, these studies did not focus on the Chinese manufacturer based on corporate green innovation. Thus, the effect of green transformation leadership and organizational environmental culture on low carbon innovation performance in Chinese auto-manufacturers are research motivation. Moreover, low carbon innovation performance is the output of the TPB model, concluding three critical factors; environmental attitude, subjective norm, and perceived behavior capability. This model is used for testing, adapting, and developing innovations. However, the TPB model is initially tested at the individual level. The TPB model of low carbon innovation performance at the company level is another reason that motivated this study.

This paper is organized as follows: Section 1 shows the research background and significance, research question, motivation, contribution, and structure. Section 2, related theories are conducted in the literature review and hypothesis development. While section 3 describes the method and hypothesis testing, including data collection, data description, and the result of the analysis, and section 4 is about the conclusion and discussion, the theoretical and practical implication of the research, and scientific contributions.

## **2. Theory and Hypothesis Development**

### **2.1 Influencing Factors on Low Carbon Innovation Performance**

Since global attention has shifted from economic development to sustainable development, reducing the incidence of environmental issues is deemed as the solution to sustainable economic growth. The energy environment economy has since gained a heightened interest from researchers worldwide. Research on the environmental topic has ranged from the causing factors of environmental issues, the possible solution to the problem, the role each level plays to alleviate the issue, etc. Since many researchers have provided a fundamental understanding of elements that positively affect the worsening of negative environmental externalities. It will be more effective to analyze the determinant factors that alleviate environmental issues to realize the carbon-neutral goal and create a sustainable economic(Chen and Cai 2015).

Low carbon innovation is an essential factor for corporate sustainable development, the critical element of sustainability of companies and countries is innovation. Low carbon innovation can

also be referred to as eco-innovation, environmental technology innovation, or green product innovation. These concepts have similarities that aim to reduce energy consumption, protect the environment, and save resources. Low carbon innovation performance focuses on reducing carbon emissions and improving energy efficiency (Xiaocheng 2012). Low carbon innovation performance is essential for a successful transition into a low carbon economy because reducing carbon emissions is one way to develop a low carbon economy (Luo and Tong 2011). Adopting environmental initiatives helps corporate to lower the cost of production and improve economic efficiency (Porter 1991).

Existing studies are helpful to understand the influencing factors of green technology innovation or environmental technology innovation, which can be summarized as follows: environmental policy-oriented institutional factors (Allen 2008; An et al. 2009), market consumer preference factors (Uyarra et al. 2016), corporate internal governance factors and stakeholder factors (Uyarra et al. 2016; Johnstone 2010). Jiang et al. (2020) revealed that executive environmental leadership positively moderates the internal and external driving factors of industrial companies' low carbon innovation performance, such as institutional pressure, stakeholder pressure, and innovation resources. Sezen and Cankaya (2013) investigated the effect of green manufacturing and eco-innovation on sustainability performance across companies in Turkey's automotive, chemistry, and electronic sectors. The findings show that green innovation has a significant positive effect on environmental and social performance, eco-process innovation has a significantly positive impact on corporate sustainability but no effect on eco-product innovation. Automotive, chemistry and electronics are heavy pollution industries that use none renewable resources and generate massive wastage and harmful emissions. Therefore, promoting and implementing eco-product and eco-process innovation should positively affect sustainability performance across corporate from different industries and sectors. However, little research has been done on the new energy vehicle corporate perspective, and Gong (2012) states that more than 50 percent of NEV model approved by China was not in production. Thus, this paper will bridge the gap by investigating the factors driving low carbon innovation performance in energy-intensive industries.

Previous studies also have investigated low carbon innovation performance from a few dimensions. Some explore the factors driving low carbon innovation performance. Lai et al. (2017) found that the main factor encouraging low carbon innovation performance is economic benefit and competitive advantage. Government regulation and government incentives both accounted for the second key factor, positive corporate image and corporate's environmental protection and social responsibility, ranked as the third factor. In contrast, other factors and consumers and market demand ranked fourth and fifth respectively. Cheng and Yao (2012) have conducted the impact of renewable energy technology on carbon reduction of carbon intensity.

Zhang et al. (2020) has investigated transport policies in Urumqi, China, and revealed that switching fuel was the most optimal policy to reduce carbon emission, but not omit the fact that the deployment of the electric vehicle will emit the minor emission consistent with Zhang et al. (2018). Low carbon innovation performance facilitates carbon reduction goals, and technological innovation such as electric vehicles may significantly reduce transport emissions through mass production and mass adoption. Therefore, it is essential to investigate the critical driver that motivates the energy-intensive industry to produce electric vehicles to urge low carbon transition in the whole industry by suggesting related policy to government and business.

The interdependence relationship between sustainability and innovation has been pointed out by Eccles and Serafeim (2013). Previous studies indicate that a company's sustainable performance and innovativeness are correlated. Bönnte and Dienes (2013) present that developing innovation in the company can enhance performance. At the same time, other researchers found that a company's innovativeness establishes its capability to implement sustainability planning and method in the company (VanBommel 2011). Gualandris and Kalchschmidt (2014) found that innovativeness increases the use of sustainable processes in the supply management of a company. Lintukangas et al. (2019) state that companies improving their green innovation will enhance the sustainable performance.

Economic sustainability assesses a company's performance is based on quantitative information such as the increase in sales performance, increase in the speed of launching new low carbon innovations, increase in the return of investment, expand the competitive market share and growth in the profitability ratio. These reports are usually available to stakeholders and the public after the corporate has successfully delivered a beneficial project for the environment and society. Moreover, the action of preventing the emission of harmful substances and reducing the damage to the environment. As the corporate actively play its role in protecting the environment, it will lead other corporations to do the same, thus indirectly benefiting society. Other examples of social sustainability also include improving the health and safety of the community while also controlling the infection of diseases. Also that helps develop the community's economy, providing more job opportunity, and sponsoring the community's environmental activity are also examples of social sustainability.

Many researchers have emphasized that innovation will be the breakthrough point in realizing carbon reduction (Chappin et al. 2020; Newton 2017; Uyarra et al. 2016). Therefore, this paper also perceives corporate especially from the energy-intensive manufacturing can gain sustainable growth by achieving environmental goals through carbon reduction with the aid and employment of low carbon innovation. However, as there is no universal agreement regarding the classification of environmental innovation, research about innovation generally has different names. Still, all

have similar purposes of ameliorating environmental externality, saving energy, and reducing carbon emissions and harmful substances. Chappin et al. (2020) provide an insight into factors influencing eco-innovation; research found that internal factors weigh more than external factors in influencing the adoption of innovation in these companies.

Even though this paper focuses on the different industry from Chappin et al. (2020) study, however, we agreed about the influencing factors that they has proposed and we categorized them into the following groups: government policy, corporate motivation, social influence, but added innovation capability which we argue that the external factors might have influence on corporate disposition toward low carbon innovation. This is due to corporate's decision and behavior is affected by factors such as limited resources and ability. Therefore, the corporate is more likely to develop low carbon innovation with higher innovation capability. We indicate this variable as the perceived behavioral capability in line with the theory of planned behavior by Icek Ajzek which represent the degree of ease or difficulty regarding desired behavior, or in other word meaning the perceived ability of the corporate about a behavior.

Government policy which includes environment regulation, support and subsidy and penalty and tax can facilitate the adoption of low carbon innovation in company. Corporate either adapt or phrase out operating under a stringent environmental ambience. With the government limiting the carbon emission standard, energy intensive industries are in great pressure to reduce their emission to avoid paying tremendous environment cost. The high investment cost often inhibits corporate low carbon innovation performance (Oberthür et al. 2020). Therefore, providing support and subsidy to this energy intensive manufacturing will positively affect the low carbon innovation performance. Chappin et al. (2020) and Li and Zeng (2020) also recognize this variable as an influencing factor of low carbon innovation in their study. This paper also realizes the significance of government policy, but we explore this variable from a different perspective via TPB theory.

Corporate motivation is also important in the development of low carbon innovation. Corporate's core objective is profit maximization. They will only adopt low carbon behavior if they perceive this behavior as profitable. As government introduces more environmental regulations, energy-intensive industries' profitability is affected by various environmental costs, even though investing in low carbon innovation might be followed with a high cost investment cost in the short run, however, it will be beneficial to these corporations in the long run. Chappin et al. (2020) study indicates that internal factors such as financial advantages, management promoting, and ethical responsibility significantly influence eco-innovation adoption. Adoption of eco-innovation by management promotion is an interesting finding. Therefore, this paper wishes to explore this relationship by investigating the role of green transformational leadership and environmental

culture in influencing the management to adopt low carbon innovation. However, differ as we examine financial advantages and ethical responsibility as antecedent in the TPB model.

External factors such as social influence play an important role in affecting low carbon innovation development. Corporate awareness of environmental issues like pollution, smog and greenhouse effect will more likely to feel the need of transforming their business into low carbon business operation. Therefore, they are more likely to develop low carbon innovation than those corporate who are not aware of environmental issues. Besides, influence from competitors and collaborators also might positively impact the energy-intensive manufacturing low carbon innovation. Accessibility to low carbon innovation help corporate to create a competitive advantage over other energy-intensive corporate. Driven by the economic benefit gained from creating competitive advantages, corporate is motivated to develop low carbon innovation to outperform its competitor. These stakeholders such as collaborators might sense this as a urge corporate to invest and develop low carbon innovation to compete with the competitor. In this paper, this paper examines influence from stakeholders such as government, competitors, suppliers, and consumers are being examined as the subjective norm in this paper.

One of the most important factors of adopting and developing new innovation is the technology, knowledge and resource capability. Even being motivated by various internal and external factors, it will be difficult to develop these innovations without sufficient resources, advanced technology, and knowledge. Therefore, this paper emphasizes this factor as innovation capability, and it is similar to the capability variable in TPB theory.

## **2.2 Green Transformational Leadership and Low Carbon Innovation Performance**

A leader is significant in a corporate. A leader leads, motivate, inspires, and supports followers. These roles of a leader became irreplaceable and helped the corporate-run new project or develop innovations more effectively and efficiently. This paper believes that leadership plays similar roles in energy-intensive industries as they transform and create low carbon innovation and recognizes this type of leadership as green transformational leadership. Therefore, this part will explain the concept of transformational leadership and green transformational leadership and how this type of leadership affects low carbon innovation performance in a corporate.

The transformational leader is a model of integrity and fairness, setting clear goals, having high expectations, encouraging others, providing support and recognition, affecting followers' emotions, influencing followers to look beyond self-interest, and inspiring followers to achieve the impossible following Bass. The theory of transformational leadership can be traced back to James Downtown in 1973. James Macgregor Burns explained the concept of transactional and

transformational leadership in 1978, and Bernard Bass extended the Burns' theory and identified the four factors of transformational leadership. The four factors are idealized influence, inspirational motivation, individualized consideration, and intellectual stimulation 1985 (Bryman, 2011). Burns (1978) defined transformational leadership as a process where political leaders and their followers raise one another to higher levels of morality and motivation. Then Bass (1985) referred transformational leadership as the influence of a transformative leader on followers by gaining trust, respect, and admiration from followers. Bass's work has provided a measurement for transformational leadership using a multifactor leadership questionnaire has been adopted by the researcher to investigate the role of transformational leadership in many different fields.

On the other hand, green transformational leadership is defined as the leader's action to deliver clear vision, inspiration, and motivation, support employees in the company, and fulfill the environmental goals (Singh et al. 2020; Mittal and Dhar 2016). Chen and Chang (2013) also refer to green transformational leadership as the leader's behavior that motivates employees to achieve environmental goals and inspires them to perform better than expected environmental performance. Employees learn from their leader; in another way, a pro-environmental leader will influence the employees to be pro-environmental. When green transformational leadership is present in the company, employees know the detailed plan, including the strategy to achieve and attain expected environmental performance. Therefore, employees are aware of their responsibility and receive motivation and inspiration from the leader, making them excited to perform beyond expectation and help the company achieve the set environmental goal.

Green transformative leaders who adapt to society and government pace have to encourage employees to develop environmental innovation. For a corporate to transform, it must note the social trend besides running a basic operating system. Especially after the 20th Century, the social movement reduces environmental costs and sustainability. Therefore, a good leader has to transform and motivate the employees to develop new environmental innovations. Thus, the role of green transformative leaders is being emphasized as one of their functions is to encourage the employee to achieve environmental goal. Besides, it is essential for every member within the corporate to transform for the corporate to be able to achieve a successful low carbon transformation. Therefore, a green transformative leader has to encourage and stimulate the organization's members and employees to think about green concepts and ideas. This way, they are more relatable and concerned with leader's new plan with promising environmental benefits which causes them to be more active and willing to work for the new plan.

The green transformative leader has to ensure all members agree with his decision and support him in achieving his plan that delivers improved environmental benefits. Teamwork and mutual agreement are important to a corporation. Therefore, to start developing a new project and

product or transform the business into low carbon, a leader has to be able to deliver a detailed plan and explain it to the employees. This kind of leader has to be able to excite the employees about the benefit gained from the plan, thus motivating employees to consider the possible outcome for their future generations.

Green transformative leaders always plan and willing to wait for a long time to witness the result of environmental projects or innovation. Innovation is time-consuming; it requires advanced knowledge and technology to develop innovation. Thus, leaders need to have a long-term vision to plan and explain different transformational projects and continuously encourage employees to work on new environmental innovations. Chen et al. (2014) investigate green transformational leadership positively affecting green performance. Singh et al. (2020) investigate how green transformational leadership through green human resource management affects green innovation and positively affects company environmental performance in 309 SMEs.

This paper suggests that green transformational leadership positively influences low carbon innovation performance. This is due to the manager usually being the one who sets the vision and develops a plan for the corporate. Hence, we assumed that a green transformative leader would provide a clear environmental plan for its employees to follow, thus encouraging them to achieve environmental goals and targets. Besides, we also perceived that green transformative leaders would stimulate employees' thinking of the green concept and consider their future generation. Thus, we searched for evidence from past research and found that our assumptions are theoretically supported.

Previous studies have stressed the importance of green transformation leadership as it can encourage employees to consider green innovation and affect employees to practice green innovation (Robertson and Barling 2013; Chen and Chang 2013; Mittal and Dhar 2016). Moreover, researchers suggest that the company practices and indulges green transformational leadership in encouraging and motivating employees to have a long-term environmental innovation vision and help achieve corporate green performance (Chen and Chang 2013) for sustainable development.

Based on the above literature, this paper suggests that green transformational leadership plays a similarly significant role in affecting corporate low carbon innovation performance in the energy-intensive manufacturing and proposes:

*H1: Green transformational leadership has a positive effect on low carbon innovation performance*

### 2.3 Organizational Environmental Culture and Low Carbon Innovation Performance

Organizational culture is a set of norms and values widely shared and held company throughout the organization (O'Reilly and Chatman, 1996; Guiso et al. 2015). Organizational environmental culture refers to green corporate capabilities, corporate ecological commitments, and corporate environmental philosophies (García-Granero et al. 2020). Organizational environmental culture “is a symbolic context about environmental management and protection within which interpretations guide behaviors and processes of members’ sense-making and set of values and norms describing how the company perceives the environmental variable” (Küçükoğlu & İbrahim Pinar 2015). Organizational environmental culture is concerned with environmental management and operational decisions that benefit the environment as an economical alternative in the corporate (García-Machado and Martínez-Ávila 2019).

There is a positive link between communications, corporate mission, values, and corporate performance. Corporate mission and value are essential as the former establishes a set of plans to achieve reach the future projection of the corporate, and the latter provides a set of norms and values for employees to follow. Both help corporate to enhance their business performance. A corporate that integrates social goals in the missions, and it is fundamental to creating competitive advantage. In their paper, Zhao et al. (2018) argue that corporate culture promoting innovation will increase employees’ creativity, develop new products, and find new alternatives. The findings support this argument showing that corporate cultures are positively linked to a corporate innovation output.

An organization with environmental culture is concerned with the quality of the environment, and it is operational activity’s impact on the environment. Thus, organizational environmental culture can motivate employees to protect the environment and consider every possible environmental impact in decision making. This may lead to corporate decisions to innovate low-carbon products and achieve sustainable performance. Organizational environmental culture will encourage its employees to act and perform without harming the environment and lead to a positive environment sustainable performance.

García-Granero et al. (2020) measure eco-innovation in 93 agri-food companies in southeast Spain by analyzing the relationship between environmental corporate culture and commercial orientation with the eco-innovation level of four dimensions. The results show that organizational eco-innovation is most important in agri-food companies, followed by marketing eco-innovation, process eco-innovation, and product eco-innovation. They also find a positive relationship between environmental corporate culture and eco-innovation in agri-food companies. Culture

shapes the fundamental values of a corporate, and its employees with act according to it. Another study-related by García-Machado & Martínez-Ávila (2019) which study the role of green culture on the environmental performance of 157 automotive companies in Mexico. Findings support that green culture directly affects green innovation and environmental performance, and green innovation also serves as a mediator of green culture to environmental performance.

Based on the above, this paper suggests that a corporate with organizational environmental culture should have a mission and values to protect the environment, environmental protection as the core value of the corporate, commitment to protecting and improving the environment, and invest in providing a better life for the future generation. Furthermore, corporate with organizational environmental culture thinks raw materials that do not pollute the environment are essential, worry about wasting resources, and consider the potential impact of new product development on the environment. Organizational environmental culture will affect employees to conduct environmental thinking and innovate to act according to the culture. This paper proposes that corporate environmental culture will affect low carbon technology innovation in the electric vehicle industry and presents the hypothesis:

*H2: Organizational environmental culture positively affects low carbon innovation performance.*

## **2.4 Theory of Planned Behavior (TPB) Model**

As mentioned before, this paper wishes to investigate the relation of low carbon innovation performance at the company level. Thus, the scope of the study has to focus on other factors influencing the corporate to enhance their low carbon innovation performance besides the factor of green transformational leadership and organizational environmental culture mentioned above. To achieve this study objective, this paper also includes the planned behavior (TPB) theory to predict the effect of motivational antecedents and control beliefs such as environmental attitude, subjective norm, and perceived behavioral capability on the corporate's low carbon innovation performance.

Icek Ajzen proposed the TPB in 1985; it is extended from the theory of reasoned action (TRA) which Fishbein and Ajzen developed in 1975. The theory of reasoned action (TRA) was developed to predict human behavior's intention through environmental attitude and subjective norm. The theory postulates the intention will lead to the act of behavior of interest. Initially, the development of TRA was inspired by Dulany's theory of propositional control (1968), which defines individuals forming conscious intention for selected responses. According to Dulany, behavioral intention is determined by the distribution of reinforcement, subjective reinforcer value, behavioral hypothesis, and motivation to comply. This theory assumes humans have volitional control for

behavior where individuals are assumed to own the ability to carry out particular behavior at will under an optimal situation.

The initial purpose of TRA is to predict human adoption of behavior. In his doctoral thesis, Fred Davis extended the model into the technology acceptance model (TAM) to predict human behavior associated with accepting new technology. The difference with TRA is that TAM added perceived ease of use and perceived usefulness, where the earlier refers to the degree of individual thinks adopting the new technology is easy and effortless. In contrast, the latter refers to the perception that adopting the technology will make task less complicated and more convenient. TAM was first used to predict the adoption of computers. Even the TAM includes a variable of perceived ease of use, but this refers to the effort associated with adopting technology that are already available. Hence, it is not suitable to apply to this paper that wishes to examine low carbon innovation development.

Perceived behavioral capability represents the important determinants that contribute to voluntary control of an individual toward the act of performing a behavior. However, TRA assumes an individual with behavior intention to have all the skill, resources opportunities, and technology needed to complete the behavior, but this theory has omitted the possibility that the individual does not have full volitional control to perform the behavior due to lack of resources and opportunity, even when an individual has intention to perform the behavior, the person might still face difficulty and obstacle in performing the act. Therefore, the theory of reasoned action, which claims that intention is an actual prediction of human behavior has limited prediction power using only the two belief constructs due to incomplete volitional control (Ajzen, 1991). Hence the TPB was introduced to overcome the limitation of the original theory by adding the variable of perceived behavioral capability to the foundation of TRA which only consists of environmental attitude and subjective norm. This is also why we choose TPB to predict low carbon innovation performance in energy-intensive industries.

In both theories, environmental attitude represents the degree of an individual's favorable or unfavorable environmental attitude towards the behavior. The higher the degree of favorable environmental attitude towards a behavior, the higher is the probability of performing that particular behavior, and vice versa the higher the degree of unfavorable environmental attitude for a behavior, the higher the chances that the individual would not perform the behavior. Environmental attitude toward the behavior is derived from the expectancy-value model where individual holds belief about a behavior's outcome. This type of belief is recognized as behavioral belief and an individual holds behavioral belief for a behavior that performing the behavior brings upon certain outcome and experience. Individual judges a behavior by evaluating all likely outcomes and value offered by the behavior. When the behavior offers more desirable outcomes

then individual will have a favorable environmental attitude for the behavior while the behavior offers more undesirable outcomes then the individual will form unfavorable environmental attitude for the behavior. Therefore, behavioral belief and subjective evaluation help to form an individual overall environmental attitude for a behavior of interest.

Many past studies have examined individual pro-environmental behavior such as eco-consumption, eco-social transportation, and eco-social conservation using TPB model. Wu et al. (2015) investigate local government employees' behavioral intention in adopting new innovative urban eco-land performance assessment model. The findings show that environmental attitude and subjective norm can explain local government employees' behavioral intention in adopting a new innovative urban eco-land performance assessment model. Recently, Jain et al. (2020) investigate construction and demolition waste recycling behavior of workers in construction sector in India and found that environmental attitude and perceived behavioral capability positively affect behavioral intention. The first study targets respondents are government's employees while the latter targets respondents are engineers, supervisors and small contractors. Results indicate that environmental attitude towards behavior affect environmental behavior adoption. We assume that positive environmental attitude for low carbon innovation can affect low carbon innovation performance in energy-intensive corporate.

This paper hence assumes corporate has a positive environmental attitude towards low carbon innovation that leads them to improve low carbon innovation performance. This paper has proposed a few positive environmental attitudes believes to have correlation with corporate low carbon innovation performance. These positive environmental attitudes motivate corporate to propose their plan of developing low carbon innovation for the corporate. As corporate thinks that low carbon innovation is able to expand new market for the corporate, they are more likely to push the development of low carbon innovation in the corporate. There is growing demand for low carbon innovation for environmental reason thus this is an opportunity for corporate to expand their market. Staying conservative will affect stakeholder's return as the business environment of energy intensive manufacturing is under great pressure due to stringent environmental regulation worldwide. However low carbon innovation in energy intensive manufacturing is still consider new and niche as not many corporate has the advanced technology and knowledge to develop and produce innovation that can replace the consumption of energy. This opportunity to expand the new market and to increase profit influence the corporate for having a positive environmental attitude to push the development for low carbon innovation. Corporate also positively perceives new low carbon product can enhance the competitiveness of the product in the market. All business must innovate to survive the fierce competition of the market unless the corporate is in the monopoly market. Various companies are available in the energy intensive manufacturing,

which means consumers can choose from various choices. A competitive product enhances the possibility of being purchased by consumer. Innovative product enhances the product competitiveness and also the profitability of the business.

Another positive environmental attitude for low carbon innovation is the environmental benefits provided by the product. Low carbon innovation can reduce the carbon emission that accelerates the climate change. Operating under nowadays' severe threatened environment condition means business needs to react to environmental issues to achieve long-term sustainability. Especially for these polluting industries like the energy-intensive manufacturing in this paper, they need to play their role in adapting to climate change by realizing low carbon transformation of the business model.

Long et al. (2017) describe environmental attitude towards the behavior as behavior belief and outcome evaluation either positive or negative and propose that the environmental attitude towards the environment is affected by organizational environmental behavior. It can be understood that if the company has positive evaluation outcomes for low carbon innovation performance, then the corporate has a high R&D in low carbon innovation performance such as the development of new energy car.

Furthermore, the subjective norm is defined as the viewpoints of other people who are important to an individual and influence his or her decision making, such as family and relatives, colleagues, associates or friends. Subjective norm is the social pressure one received whether or not to perform a behavior. Subjective norm is the influence of outsider opinion in one decision making. In short subjective norm can be understand as the opinion of others about the behavior. According to Ajzek, subjective norm is normative belief where important outsider thinks that the individual should perform or not perform a behavior, later describes this belief as injunctive and descriptive where injunctive refers to individual's perception of others opinion about a behavior while descriptive belief refers to the actual performance by important others. This construct of TPB similarly emphasizes the significance of belief in affecting individual's intention and behavior but differ at subjective norm is the perception of individual's regarding the degree of important others' opinion and pressure about a desired behavior. The degree of these opinion from important others is recognized as motivation to comply. Therefore, in TPB model subjective norm is obtained by multiplicative equation of normative belief and motivation to comply. Thus, the degree of agreement of important other about a behavior is the main determinant in subjective norm.

Based on previous studies, we noticed that individual's environmental intention and behavior can be predicted by subjective norm. Past research suggested that subjective norm is an effective prediction for environmental behavior and has significant effect on consumer's purchasing

intention on green product and green consumption. Subjective norm positively affects intention to visit green hotel and recycling intention (Chen and Tung 2010) and intention to adopt hybrid electric vehicles (Wang et al. 2017). Even though not many researches have researched on a corporate perspective, as corporate operates under the influence of stakeholder, we argue that subjective norm similarly has predictive power on a corporate's low carbon innovation performance, which will directly affect the low carbon innovation performance.

The existence of stakeholders and their influences on a business cause subjective norms to have a certain degree of control on the business decision. The opinion of outsider which are closely related to the corporate can influence the decision taken in a corporate. For instance, the government grants corporate permission to operate affect business decisions through establishing environmental regulations. Some common tools used by the government to ameliorate the severe smog pollution are carbon standard and carbon tax can affect corporate in the country to transform into more friendly to the environment. Manager is more likely to consider innovating vehicle running by electricity to avoid from paying tremendous amount of money for tax and to ensure not to violate the carbon standard. Competitive company and the collaborative company also have positive affect to a business. Corporate must respond to the action taken by the competitive company in order to stay competitive otherwise when the company loses its competitiveness, then it will be difficult for the company to survive. Thus, corporate must keep pace with competitor and develop low carbon innovation. Similarly, the collaborative company also affect company to develop low carbon innovation. Some companies have several collaborative companies for production therefore when the collaborative company managed to master the technology and skill to produce low carbon innovation thus will push the progress of low carbon innovation in the energy intensive corporate. Revenue and profit are gained when consumer purchases the product sold by the corporate. This makes the company analyze the consumer's liking as consumers only purchase product that has value to them. With the growing demand of low carbon product, company needs to adapt and innovate their product to attract these green consumers to buy their product.

In the original TRA model assumed individual has full voluntary control over their behavior however in fact individual's behavior is affected by various external factors. Therefore, TPB model is created as an extension of TRA model and perceived behavioral capability is added to the original constructs as control variable. Perceived behavioral capability is the perceived ease or difficulty of conducting the behavior (Ajzen, 1991); the degree of one's belief to perform a certain behavior (Ajzen, 2012). Perceived behavioral capability therefore is the degree of confidence one believes in themselves to perform a behavior by evaluating the perceived ease or difficulty of the behavior. Perceived behavioral capability evaluates an individual perception that how efficiently he or she can control that behavior. It is the function of accessible control beliefs

of individual's perceived requirements of the resources and opportunities to perform a particular behavior.

TPB model is not the first model that takes control variables in studying human behavior. Atkinson (1964) proposed the concept of expectancy of success and Bandura (1977) proposed the concept of self-efficacy. The first referred to how individuals perceive their likelihood of succeeding at a given task. The latter referred to how individuals rate their ability to overcome challenges to perform a certain task. Therefore, the concept of perceived behavioral capability is more similar to Bandura's concept of self-efficacy as individuals do not have complete volitional control over their behavior and will face various challenges and obstacles such as lack of knowledge, skill, resources, and opportunity to succeed in performing a task.

Perceived behavioral capability refers to whether the corporate considers low carbon innovation which is to develop low carbon innovation is easy or difficult. When the corporate has the knowledge and technology to develop and innovate, it will be easier for the corporate to start developing this 7vehicle vice versa if the corporate does not reach the minimum requirement of technology, it will be extremely difficult for it to develop and innovate low carbon innovation. In short, the corporate will be confident to develop and innovate low carbon innovation when they have perceived behavioral capability toward low carbon innovation. Even though the corporate has a higher level of perceived behavioral capability as the corporate has advanced skill, knowledge, and technology to develop and innovate, this does not mean that the corporate has the resource and ability to produce the vehicle. Therefore, whether or not the corporate can produce the vehicle is also considered one criterion to fulfill the perceived behavioral capability. Therefore, to overcome the problem of not having the production ability, the corporate has to cooperate with other companies for joint production, causing cooperative companies to become one of the criteria we assess as perceived behavioral capability in this paper.

Previous study applied TPB theory to explain on environmental innovation of Korean-owned company in China, the finding showed only perceived environmental behavioral control positively affect organizational environmental innovation (Long et al. 2017). However environmental attitude and subjective norm does not affect organizational environmental innovation. We argue that this unfavorable result is due to the difference across different industry and we propose that environmental attitude, subjective norm and perceived behavioral capability has a positive effect to low carbon innovation performance as follows:

*H3a: Environmental attitude positively affects low carbon innovation performance*

*H3b: Subjective norm positively affects low carbon innovation performance*

*H3c: Perceived behavioral capability positively affects low carbon innovation performance*

### 3. Method and Hypothesis testing

#### 3.1 Research Methodology

This research aimed to investigate factors of corporate low carbon innovation performance. The role of green transformational leadership, organizational environmental cultures was added to the existing TPB model of corporate low carbon innovation performance. A questionnaire is designed and used to collect primary data and analysis is done using statistical software. This paper consists two sections of research methodology: section 1 is about questionnaire design and data collection, section 2 is about data analysis using statistical software. Reliability and validity of data is accompanied by running reliability analysis and concompanyatory factor analysis. While, correlation analysis and structural equation modeling (SEM) is conducted to test the proposed hypotheses.

#### 3.2 Survey Design and Data Collection

A questionnaire is designed based on past literature. The first part of questionnaire is related to corporate information and individual demographic information such as gender, age, education level, and income level. When, the second part the respondents were asked to read statements and determine their degree of agreement. This paper implemented 7-point Likert scale for measurement, participant was asked to choose from 1 strongly disagree to 7 strongly agree over variables. The questionnaire items used in this study were developed and adapted based on the existing literature. Green transformational leadership has 5 items (Chen and Chang 2013). For example, “My leader encourages employees to achieve environmental innovation”, “My leader encourages employees to achieve environmental goals”, “My leader stimulates employees to have green low carbon thinking”, “My leader has a long-term ideal environmental vision (inspire with environmental plan)”.

Organizational environmental culture has 4 items. Example items are “Our organization has the mission and values to protect the environment”, “Environment protection is the core value of organization”. Environmental attitude has 4 items (Long et al. 2017). For instance, “Low carbon innovation product can explore new market”, “Low carbon innovation through new energy car can enhance product competitiveness”, “Low carbon innovation through new energy car can reduce air pollution”. Subjective norm has 5 items (Long et al. 2017) such as “The pressure of carbon standard by the government lead our corporate to develop Low carbon innovation product”, “Competitive company lead our corporate to develop low carbon innovation product”, “Green consumer pressure lead our corporate to develop low carbon innovation product”.

Perceived behavioral capability has 4 items (Long et al. 2017), Example are “Our corporate has the ability to develop Low carbon innovation product” and “Our corporate has the technology

and equipment to innovate low carbon innovation product”. The last variable is low carbon innovation performance which has 3 items such as “The sales performance of new technology product have increased in the auto industry”, “Our corporate has much better green paten in the auto industry”.

The questionnaire was distributed online from January 2020 to May 2020. The questionnaire was anonymous and participant was aware that the data was only used for research purposes, participation was on voluntary. 200 questionnaires were collected and 45 incomplete questionnaires was removed. Finally, 155 valid questionnaires or 77.5% of distributed questionnaires were used for data analysis.

The questionnaires were established and distributed online targeting response from managerial level working in Chinese manufacturing. A total of 200 questionnaires were distributed, leaving 155 questionnaires for the analysis. Demographic characteristics showed most responders were from companies with staffs between 501-1000 (55.5%), following by companies with 1001-3000 staffs (16.8%), 301-500 (12.9%), 101-300 (5.8%), more than 6000 (5.2%) and the last was companies with 3000 -6000 staffs (1.3%). Most of companies were state-owned enterprise 60% and 40% were Chinese-foreign-funded enterprise. Major gender of responders were females at 57.4% and 42.6% were males. The biggest amount of age was at the age of 31 to 40 (65.8%). 16.1% were at the age of 41 to 50. Above 50 years were 28 (18.1%). Most participants have period of working in present company between 3-4 years (41.3%). 23.2% has less than 1 year of working period. 2.13% has been working for 5 years and above and 14.2% has worked for 1-2 years. Considering monthly income, 19.4% receive less than 5,000; 5001-8,000 were 20.6%; 8,001-12,000 had the most participants at 40.0%. 6.5% of participants had monthly income in the rage of 12001-15000 and the monthly income more than 15,000 had 13.5%of participants. In terms of education, participants have degree at high school level were 19 (12.3%); 59 (38.1%) were in bachelor degree; Masters’ degree had 19 (12.3%) and PhD was 58(37.4%).

Table 1. Summary Statistics of Data

Variables	Categories	Frequency	Percentage
Company size	less than 100 staffs	4	2.6%
	101-300 staffs	9	5.8%
	301-500 staffs	20	12.9%
	501-1000 staffs	86	55.5%
	1001-3000 staffs	26	16.8%
	3000-6000 staffs	2	1.3%
	6001 and above	8	5.2%

Variables	Categories	Frequency	Percentage
The type of enterprise	State-owned	93	60.0%
	Chinese-foreign-funded	62	40.0%
Gender	Female	89	57.4%
	Male	66	42.6%
Age	30-39	102	65.8%
	40-49	25	16.1%
	Above 50	28	18.1%
Period of working	less than 1 year	36	23.2%
	1-2 years	22	14.2%
	3-4 years	64	41.3%
	Five years and above	33	21.3%
Monthly income	≤5000元	30	19.4%
	5001-8000元	32	20.6%
	8001-12000元	62	40.0%
	12001-15000元	10	6.5%
	>15000元	21	13.5%
Education	High School	19	12.3%
	Bachelor Degree	59	38.1%
	Master Degree	19	12.3%
	Ph.D	58	37.4%

### 3.3 Confirmatory Factor Analysis and Reliability Analyses

First of all, we tested the reliability of the variables. The result is shown in Table 2. Based on the reliability test, the Cronbach alpha for green transformational leadership is the highest one compared to other latent variables at 0.875. Organizational environmental culture is 0.793. Environmental attitude is 0.845, subjective norm is 0.752, the perceived behavioral capability is 0.835, and low carbon innovation performance is 0.829. The Cronbach alpha value of all variables is above 0.7, located in the acceptable range.

The average variance extracted (AVE) and composite reliabilities (CR) were conducted by AMOS. The results of validity and reliability analysis are presented in Table 2. The average variance extracted (AVE) of green transformational leadership is 0.652, organizational environmental culture is 0.58, environmental attitude is 0.580, subjective norm is 0.572, the perceived behavioral capability is 0.691, and low carbon innovation performance is 0.745. The composite reliability (CR) of green transformational leadership is 0.903, and organizational environmental culture is 0.838, environmental attitude is 0.845, subjective norm is 0.835, perceived behavioral capability is 0.894,

low carbon innovation performance is 0.897. The average variance extracted of all variables are over 0.545, and composite reliability of all variables is over 0.826, which are acceptable. The standard regression weights of different observable measurements are more than 0.59, which means different measurements have higher validity.

**Table 2.** The result of validity and reliability analysis

Latent Variables	Observable measurements	Standard regression weights	AVE	CR	Cronbach's $\alpha$
Green transformational leadership	GLD1	0.67	0.652	0.903	0.875
	GLD2	0.65			
	GLD3	0.68			
	GLD4	0.62			
	GLD5	0.71			
Organizational environmental culture	OEC1	0.73	0.580	0.838	0.793
	OEC2	0.73			
	OEC3	0.60			
	OEC4	0.78			
Environmental attitude	AT1	0.64	0.580	0.845	0.845
	AT2	0.62			
	AT3	0.74			
	AT4	0.78			
Subjective norm	SN1	0.88	0.572	0.835	0.752
	SN2	0.85			
	SN3	0.64			
	SN4	0.64			
	SN5	0.63			
Perceived behavioural capability	PBC1	0.66	0.691	0.894	0.835
	PBC2	0.93			
	PBC3	0.86			
	PBC4	0.93			
Low carbon innovation performance	LCIP1	0.85	0.745	0.897	0.829
	LCIP2	0.87			
	LCIP3	0.75			

### 3.4 Correlations and Convergent Validity Analyses

The correlation analysis results demonstrate that the relationship between green transformational leadership and low carbon innovation performance is positive and significant; the correlation

coefficient is 0.653. It means that there are strong positive relations. Similarly, there is a positive relationship between organizational environmental cultures and low carbon innovation performance at 0.604 correlation coefficient. While, 0.598 is the correlation coefficient of environmental attitude and low carbon innovation performance. In the same way, the subjective norm has a positive effect on low carbon innovation performance at 0.636. As well As, perceived behavioral capability has correlation coefficient of 0.632 on low carbon innovation performance. The correlation test results show that coefficients are more significant than 0.4 and less than 0.9. Furthermore, the variables of squared roots of the average variance extracted (AVE) are significantly greater than the correlation weights of each variable. On this basis, we can consider all the variables of discriminant validity as acceptable (See Table 3)

**Table 3.** The result of inter-variables correlations and convergent validity analyses

	GLD	OEC	AT	SN	PBC	LCIP
GLD	<b>0.808</b>					
OEC	0.562	<b>0.761</b>				
AT	0.691	0.563	<b>0.761</b>			
SN	0.581	0.709	0.581	<b>0.756</b>		
PBC	0.591	0.701	0.685	0.522	<b>0.831</b>	
LCIP	0.653	0.604	0.598	0.636	0.632	<b>0.863</b>

Note: N = 155, squared roots of AVE extracted are shown in boldface on the diagonal and variable correlations are below the diagonal.

### 3.5 Hypothesis Testing by Using Structural Equation Modeling (SEM) Analysis

This paper utilized the relationship between green transformational leadership, organizational environmental cultures, environmental attitude, subjective norm, and perceived behavioral capability with low carbon innovation performance. Structural equation model (SEM) analysis was performed to examine the proposed hypotheses in our study. In the model, the GFI is 0.811, CFI is 0.916, NFI is 0.831, IFI is 0.917 and RMSEA is 0.072. It denotes that the model is fit and has high explanatory power. The results of the estimation of the structural equation model are presented in Table 4. As can be seen from Table 4, the hypothesis testing results showed that green transformational leadership which is defined leader's action that encourages organization member and employees to achieve an environmental goal, innovate new environmentally friendly product, and reduce damage to the nature had a strong positive significant with low carbon innovation performance. Thus hypothesis 1 is accepted. Similarly, organizational environmental cultures that established a set of values related to environment protection and preservation have a positive,

strongly significant effect on low carbon technology innovation ( $\beta = 0.624, p = 0.000$ ); therefore, hypothesis 2 is accepted. The effects on low carbon innovation performance of three factors of TPB model; environmental attitude (H3a), subjective norm (H3b), perceived behaviour capability (H3c) was tested in this process. The result shows that environmental attitude and subjective norm has positive significant on low carbon innovation performance ( $\beta = 0.272, p = 0.006$ ;  $\beta = 0.144, p = 0.005$ ) thus H3a as well as H3b were accepted. While, perceived behaviour capability was the strongest influencer of TPB on low carbon innovation performance. Perceived behaviour capability has strong positive significant on low carbon innovation performance ( $\beta = 0.539, p = 0.000$ ).

**Table 4.** The results of hypothesis testing

Hypothesis Path		Estimate	S.E.	CR	p-value	Result		
H1: Green transformational leadership →Low carbon innovation performance		0.699	0.122	5.508	0.000	Accepted		
H2: Organizational environmental culture →Low carbon innovation performance		0.624	0.099	6.298	0.000	Accepted		
H3a: Environmental attitude →Low carbon innovation performance		0.272	0.100	2.728	0.006	Accepted		
H3b: Subjective norm →Low carbon innovation performance		0.144	0.052	2.779	0.005	Accepted		
H3c: Perceived behavioral capability →Low carbon innovation performance		0.539	0.068	7.921	0.000	Accepted		
Model	GFI	CFI	NFI	IFI	RMSEA	X <sup>2</sup>	df	X <sup>2</sup> /df
<b>Default model</b>	0.811	0.916	0.831	0.917	0.072	464.397	258	1.800

### 3.6 Mediating effect

In a company, it's well known that the role of leadership plays the most importance part in the company's strategy to reach the company's goals which this context focuses on environmental goals. Green transformational leadership relates to leading, motivating, inspiring, and supporting followers in environmentally friendly ways. Since a leader is in charge of inspiring change by motivating followers or employees in an organization shapes the new organizational culture. Therefore, it seems as if organizational environmental culture can be motivated by green transformational leadership then green transformational leadership affect low carbon innovation performance through organizational environmental culture. According to these reasons, the mediation test was conducted to extra test the indirect effect of green transformational leadership vie organizational environmental culture. As the model shown in Fig2.1

In addition, TPB model which basically was used in the individual level was extended to the user into the company level in this paper. As mentioned above, green transformational leadership was a huge influencer of a company's performance. The influence of green transformational leadership might affect every single part of a company including the company's environmental attitude, subjective norms, and perceived behavioral capability which were the factors of TPB model. The green transformational leadership motivates the company's environmental attitude through a strategy which creates the future vision and positions the company for achieving green goals. Then building an organizational system to deliver result based on the strategy by motivating, engaging, and communicating with employees them grooming employees for environmental attitude. So, the testing of the model which shown in Fig2.2 is conducted.

While, the subjective norm of a company was similar to stakeholders of a company. A stakeholder could be an individual or a group that holds a stake or an interest in an organization's activity. Stakeholders could be employees, suppliers or consumers, unions, legislators, banks, competitors, shareholders, etc., Achieving organization goals was run by stakeholders. In contrast, an organization's goal could be broken by stakeholders. It is in the charge of the leader to engage and communicate with stakeholders for reaching the organization's goals. Engaging and communicating were fundamental of every company and these were the process through leaders. The leader with green transformational leadership seems to influence stakeholders or, in another word, the subjective norm in TPB model then has a mediating effect on low carbon innovation performance. Accordingly, the indirect effect of green transformational leadership on low carbon innovation performance through subjective norms was tested following the model in Fig 2.3.

Moreover, perceived behavioral capability seems to be motivated by green transformational leadership. Since, perceived behavioral capability, in an individual level, refers to an individual's confidence in an individual ability to perform behavior. While, in the organizational level, it can refer to whether the corporate considers innovation is easy or difficult to perform. The execution of a company for ongoing success in green goals was built by the leader. Green transformational leadership of a leader shaped the cooperate perceived behavioral capability then gave effect on low carbon innovation performance. Therefore, there is a chance that perceived behavioral capability motivation of associated between green transformational leadership and low carbon innovation performance. The mediation effect was tested as shown in Fig 2.4.

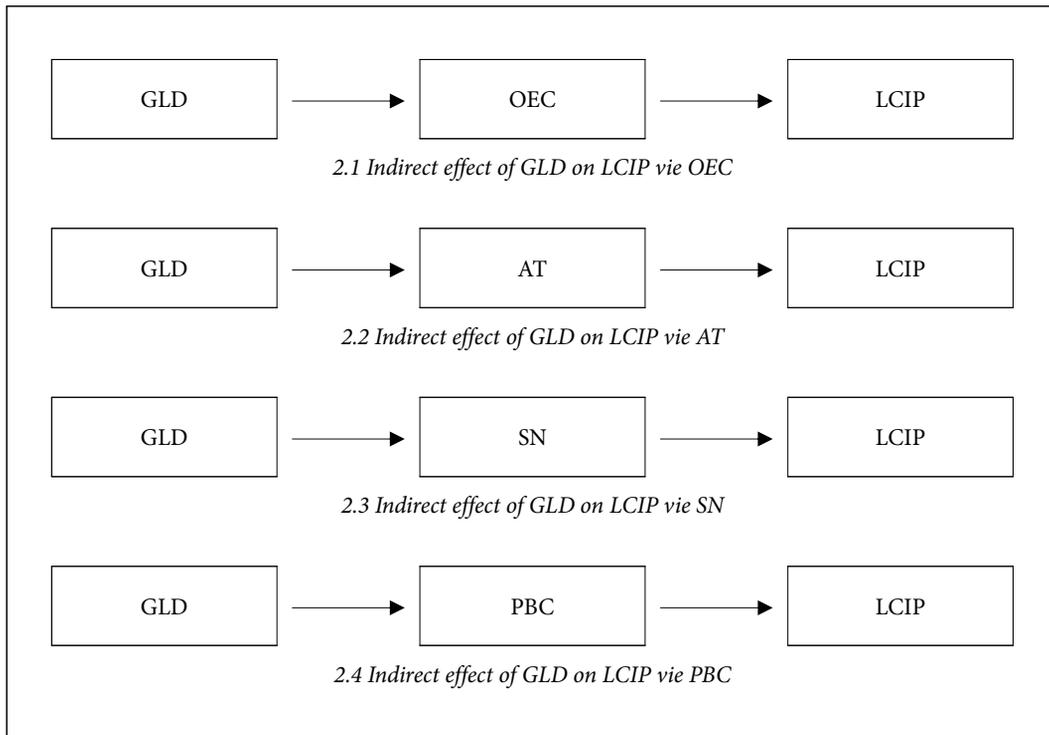


Figure 2. Mediation Effect of GLD on LCIP

To examine whether the effect of green transformational leadership on low carbon innovation performance have an indirect effect through organizational environmental culture environmental attitude, subjective norm and perceived behavioral capability. A bootstrapping approach is employed, a nonparametric resampling procedure that imposes no assumptions on normality of sampling distribution (Preacher and Hayes 2008). As shown in Table 5, green transformational leadership have a significant indirect effect on low carbon innovation performance via organizational environmental culture ( $\beta = 0.535$ ,  $p = 0.000$ ). In the same way as the indirect effect through environmental attitude, subjective norm and perceived behavioral capability ( $\beta = 0.427$ ,  $p = 0.000$ ;  $\beta = 0.470$ ,  $p = 0.000$ ;  $\beta = 0.392$ ,  $p = 0.000$ ). Consequently, green transformational leadership does not only have direct effect on low carbon innovation performance has been tested in hypothesis 1 of this paper but also have indirect effect and organizational environmental culture environmental attitude, subjective norm and perceived behavioral capability play role as mediator for the indirect effect on low carbon innovation performance.

**Table 5.** The results of mediation testing.

Mediation test	$\beta$	S.E.	C.R.	$\rho$ -value
GLD → OEC → LCIP	0.535	0.060	8.917	0.000
GLD → AT → LCIP	0.427	0.064	6.672	0.000
GLD → SN → LCIP	0.470	0.060	7.833	0.000
GLD → PBC → LCIP	0.392	0.072	5.44	0.000

#### 4. Conclusions and Policy Implications

This paper has examined factors of organizational low carbon innovation performance. The findings showed that green transformational leadership is positively correlated with low carbon innovation performance which consisted with Singh et al.(2020) as well as supported the study of Menguc et al. (2010) which stated that for initiating the environmental project of an organization, supporting from green leadership is needed. For a corporate that aims for a transformation, leadership is especially significance. According to institutional theory, organization was affected by three different institutional mechanisms; pressure from government regulations; pressure from the public; and pressure from leading companies (DiMaggio and Powell 2000).This is due to a leader uses his ability to influence its follower into working toward a common goal by providing guidance, support, planning, and also share the possible outcome and benefit. Green transformational leadership is proven to significantly affecting the low carbon innovation performance. Therefore, achieving green goal or environmental goal of a corporate, it need to train existing leader inside the corporation before assigning them for the role. In addition, when select a candidate to a company the candidate with green transformational leadership is important for considering.

Besides, organizational environmental culture has positive effect on low carbon innovation performance. This finding is consistent with previous literature regarding organizational culture and innovation (Yang et al. 2017; Gürlek and Tuna 2018). This findings is important as company realizes the need to transition into a low carbon business operation under the influence of increasing demand for environmental protection and preservation. Society and government influences company to develop low carbon innovation performance in order to achieve sustainability. Therefore establishing a set of environmental norm and value that form a common way of operating and communicating within the corporate ensure member and employee to think and act in a desirable way. Basically by establishing environmental culture within a corporate, the stakeholder gains a certain level of capability of that corporate pro-environment behavior, thus making the process to plan and develop new low carbon innovation performance easier.

Furthermore, this paper also applied Theory of Planned Behavior (TPB) model which includes three important factors; environmental attitude, subjective norm and perceived behavioral capability to predict low carbon innovation performance of corporate. The results indicated all three variables positively related to low carbon innovation performance behavior. Even though most previous research utilized the theory to predict individual's environmental behavior but this paper has confidence that corporate's environmental behavior can be predicted. The reasons were because a corporate follows a hierarchy order thus manager and leader's environmental attitude towards low carbon innovation performance will ultimately influence its follower action. Moreover, positive effect of subjective norm on manufacturing low carbon innovation performance could be explained by pressure from the public which was an institutional mechanism of the institutional theory. Pressure from the public or, in other words, normative isomorphism was similar to subjective norm of TPB model in company level. An organization was pressure from partners or beneficial to achievement of competitive advantage to adapt low carbon innovation performance. For instance, a company, which considers green their products and process, often choose to work with specific suppliers, provide green training, and even financial support (Agan et al. 2014). In addition, perceived behavioral capability which is a factor of TPB model has most significant on low carbon innovation performance which is agreeable with a previous study which stated that success on environmental innovations performance of an organization depends largely on the organization's capability (Cai and Zhou 2014).

The relationship between green transformational leadership and low carbon innovation performance can be in the form of direct effect and indirect effect. Focusing on indirect effect, this paper found out that organizational environmental culture and TPB model mediated the effect of green transformational leadership on low carbon innovation performance. The stated of organizational environmental culture mediate association between green transformational leadership influence and low carbon innovation performance which state that a leader is in charge of inspiring change by motivate followers or employees and the changing of people in an organization shapes the new organizational culture and the culture drove company performance. In addition, this study presented that TPB factors played mediating effect between green transformational leadership influence and low carbon innovation performance. Since, according to fundamentals of a company, strategy play role of creating the future vision and positioning the company for ongoing success and a leader is responsible for the fundamentals. The leader with green transformational leadership can motivate company's environmental attitude through strategy. Then, building organizational system to deliver result base on the strategy by motivating, engaging and communicating with employees them grooming employees for environmental attitude. While, subjective norm of a company or, in other words, stakeholders, is in charge of leader to engage and

communicate with for the objective of reaching the organization goals. Engaging and communicating were the process through leader. As well as, perceived behavioral capability, in organizational level, refers to whether the corporate considers innovation is easy or difficult to perform. The execution of a company for ongoing success in green goals was built by leader. Green transformational leadership of a leader shaped the cooperate perceived behavioral capability then gave effect on low carbon innovation performance.

#### 4.1 Theoretical and Practical Implications

Previous research has been focusing on the consumer purchasing intentions on low carbon innovation rather than corporate intention to produce these innovation and revealed that subjective norm such as policy and government incentives and environmental attitude such as perception and personality and consumer environmental concern (He et al. 2018; Okada et al. 2019; Wang et al. 2017; Li et al. 2019) are able to predict consumer's intention and behavior for low carbon innovation. On the contrary, we focused on a different point of view where we tend to investigate the factors for low carbon innovation performance. The results support our stand and hence we are able to provide some theoretical and practical contributions.

This paper has theoretical contributions as follow: (1) A model was created to investigate the factor of low carbon innovation performance. This paper managed to predict the corporate's low carbon innovation performance using an integrated TPB model with green transformational leadership and organizational environmental culture. The results showed that corporate's low carbon innovation performance is positively correlated with green transformational leadership indicating the important role of green transformative leader in successfully driving corporate to implement low carbon technology innovation. Organizational environmental culture also positively influences low carbon innovation performance showing environmental culture would stimulate corporate to act in a pro environmental way such as reducing waste and harmful substances while developing low carbon innovation performance for corporate sustainable's performance. Furthermore, environmental attitude, subjective norm and perceived behavioral capability also has a direct positive relationship with low carbon innovation performance. Moreover, (2) The effect of low carbon innovation performance is being investigated from three dimensions of sustainability: environment, economic and social. The relationship between corporate's low carbon innovation performance with business sustainability is measured from environment performance, economic performance and social performance and the results showed that low carbon innovation performance has the largest effect on environment sustainability and least effect on social sustainability.

In addition, this paper has practical contribution to corporate's manager and government as follow: (1) Green transformational leadership is positively correlated to low carbon innovation performance. Therefore corporate that needs low carbon transition in their business needs to train their manager to practice green transformational leadership in their work in order to help the corporate to achieve their low carbon transition sooner. (2) Organizational environmental culture is positively affecting corporate's low carbon innovation performance. Management can establish environmental culture in their corporate as this would ensure manager and employees to have environmental thinking and act in a pro-environmental way to reduce waste and develop low carbon innovation performance in response of government environmental regulation and carbon trading. (3) TPB theory can be applied to predict corporate's low carbon innovation performance. Therefore policy maker needs to encourage corporate to develop low carbon innovation performance by creating different type of environmental regulations and supportive actions that can impact on the subjective norm that will motivate corporate to adopt low carbon technology innovation.

#### **4.2 Scientific Contributions**

Previous studies indicate that the low carbon transition of the construction sector is mainly driven by profit and competitive advantage, government regulation and incentive, positive image, environmental protection and social responsibility and market and consumers demand respectively (Lai et al. 2017) while García-Machado and Martínez-Ávila (2019) suggest that environmental-related culture positively affected energy-intensive companies to transit into low carbon business by adopting green innovation. Thereafter low carbon transition led to positive environmental performance such as carbon reduction. This paper differs by examining the driving factors of Chinese manufacturers' low carbon innovation performance in a wider dimension. The first factor is green transformational leadership. Second is organizational environmental culture and three important factors of TPB theory; environmental attitude, subjective norm, and perceived behavior capability. In addition, this examination gave innovation of theoretical implication of the TPB model.

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## Authors Contributions

Liang Li: Conceptualization and writing, methodology, reviewing and editing, supervision. Joseph Fuseini: Writing-original draft; MeiXuen Tan: Original draft writing-review supervision and editing. Nuttida Sanitnuan: Original draft writing and editing.

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