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Quantifying the Impact of Carbon Reduction Interventions and Incentive Mechanisms in Campus Buildings: A Case Study from a Chinese University

Li Xue [1], Hejun Xu [2,*], Zixuan Zhang [3] and Nan Li [4]

1 School of Management, Shenyang Jianzhu University, Shenyang 110168, China; xueli1965@sjzu.edu.cn
2 School of Civil Engineering and Architecture, Jiangsu University of Science and Technology, Zhenjiang 212013, China
3 School of Qilu Transportation, Shandong University, Jinan 250100, China; 202335497@mail.sdu.edu.cn
4 School of Business Administration, South China University of Technology, Guangzhou 510641, China; 202220132320@mail.scut.edu.cn
* Correspondence: 202300000210@just.edu.cn; Tel.: +86-17688413806

Abstract: With the development of sustainable cities, densely populated higher education institutions increasingly emphasize the sustainability of campuses and their impact on the environment. However, there is a lack of means to quantify emission reduction measures. This study aims to propose an evaluation framework that can quantify energy conservation and emission reduction measures and incentive policies. To this end, this study adopts a mixed methods approach, using questionnaires to assess the effectiveness of management and communication interventions and the impact of incentives on residents' willingness to participate in emission reduction efforts. The survey results show that although the support for the intervention measures is slightly higher than the average, specific measures such as adjusting dormitory lights-out time and providing sports equipment show superior emission reduction potential. Universities could reduce carbon emissions by about 560 tons per year without incentives and just using interventions. However, when incentives and interventions are combined, the university's annual emissions reductions are expected to increase to 800 to 1045 tons. Research also highlights the importance of understanding the relationship between occupant behavior, energy consumption, and building carbon emissions. By quantifying the impact of carbon reduction measures and incentives on the daily behaviors of residents, universities can more effectively implement sustainable campus strategies.

Keywords: sustainable campus; resident behavior; carbon emissions; incentive mechanism

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1. Introduction

Environmental changes caused by the rapid development of human civilization have gradually emerged in recent years. Exchanges between international trade, national economic structures, renewable energy consumption, and human capital will all have certain effects on carbon emissions [1]. Growing urbanization has accelerated and strengthened the impact of economic development on carbon emissions to a certain extent [2]. Building plays an important role in urbanization. As an energy-intensive industry, the construction industry contributes significantly to global energy consumption and carbon emissions [3]. In November 2022, the United Nations Environment Programme (UNEP) released the "Global Construction Industry Status Report 2022", which highlighted that in 2021, carbon dioxide emissions from the construction industry accounted for about 37% of global emissions. Carbon dioxide emissions during the operation period reached a record high of approximately 10 billion tons, an increase of around 5% year-on-year and 2% higher than the previous peak [4]. Reducing greenhouse gas (GHG) emissions and building sustainable cities and societies have become top priorities for governments and people around the world.

Universities are recognized as essential contributors to sustainable development [5]. The current series of studies on sustainable campuses often focus on increasing campus renewable energy production and reducing campus building energy consumption. Campus buildings are usually large in number and densely populated. For example, universities and other educational institutions in the European Union account for 16% of non-residential buildings [6]. At the same time, there are more than 3000 colleges and universities in mainland China, with 36 million students [7]. Students usually live in dormitory buildings on campus, so the dormitory buildings are endowed with significant characteristics, such as a large population density, intensive energy use, and relatively concentrated carbon emissions. According to previous studies, the average active-period student emits four times as much greenhouse gas as the entire population [8]. At present, the carbon emissions of dormitory buildings during daily use are often measured by energy consumption. For example, in a study on the full-cycle carbon emissions of Fuzhou University City, the energy consumption of the building in its use stage is based on average water and energy costs over the last five years [9]. In recent years, some scholars have begun determining the impact of people's energy behavior patterns on energy conservation and reducing greenhouse gas emissions through surveys and other methods. Zheng et al. applied Ecological Footprint Evaluation (EFE) and machine learning to comprehensively evaluate campus sustainability and students' carbon emissions, pointing out that changing existing high-carbon behaviors is crucial to low-carbon campus success [10].

The above studies explain the relationship between occupant behavior, energy consumption, and building carbon emissions. However, these studies have not analyzed in-depth the relationship between a specific type of behavior and carbon emissions. For example, universities in mainland China will lecture on low-carbon emission reduction almost every semester, including the location of energy output sources such as faucets, light switches, etc., and put up slogans such as "Save water and electricity." It is worth discussing which occupant behaviors these measures to reduce occupant carbon emissions will affect and how much influence they will have. Suppose the specific impact of these carbon reduction measures on the daily behavior of residents can be calculated. In that case, the school will undoubtedly be able to implement relevant, sustainable campus strategies more efficiently.

Individual carbon emission behavior can usually be explained by theories such as the Theory of Planned Behavior (TPB), the Norm Activation Model (NAM), the Value Belief Norm (VBN), and the Attitude-Behavior-External Conditions (ABC) model [11]. Among them, TPB assumes that individuals act intelligently based on available information and consider the meaning of their actions implicitly or explicitly. Therefore, if some incentive mechanisms related to higher education are combined with the implementation of resident-related emission reduction intervention measures, according to the discussion of TPB, rewards may promote residents' enthusiasm for emission reduction and achieve better results.

This research proposes an evaluation framework that can quantify the impact of interventions and incentive mechanisms to reduce carbon emissions in campus buildings. The framework will help obtain the final expected results under multiple incentives and provide guidance for sustainable campus construction. This article first reviews relevant research on campus carbon emissions. Subsequently, this study lists the various behaviors of residents and the improvement strategies and interventions for each behavior and determined the emission reductions of each carbon reduction intervention through questionnaires. Finally, this study obtained respondents' responses to the incentive mechanisms through a five-level scale survey and gave the expected emission reduction effects under various incentive combinations. This research can help campus administrators start with common behaviors in life, develop better emission reduction strategies and policy tools, and adopt more accurate and practical solutions to reduce carbon emissions in campus buildings.

2. Related Works

2.1. Campus Building Carbon Emission

The current calculation framework for campus carbon emissions during daily use is usually based on the Life Cycle Assessment (LCA) method. The specific calculation process uses the carbon emission factor method [12]. Therefore, as long as the calculated target energy consumption is obtained, the carbon emissions can be obtained directly. Existing research usually uses historical data and questionnaire statistics to get the energy consumption value of the target object. Larsen et al. calculated the carbon footprint of teachers and students of the Norwegian University of Science and Technology using 2009 financial account data [13]. The study focused on financial data and did not discuss related measures such as energy conservation and emission reductions. Huang et al. used the average annual energy consumption for the past five years as the basis for calculating the carbon emissions of Fuzhou University City during its use phase [9]. However, they did not consider the impact of the intervention. Leticia et al. calculated the university's carbon footprint by considering data on goods and services consumed by De Montfort University in 2008–09 [14]. Similarly, this study also mainly focused on the measurement of the carbon footprint and ignored the process of "how to reduce the carbon footprint." A study analyzed the greenhouse gas emissions of the University of Genoa (UNIGE) in Italy and Florida International University (FIU) in Miami, USA. It used campus building design and renovation models to reduce campus carbon emissions [15].

Statistical analysis is also widely used in practical research as an essential carbon emission assessment method. For example, Du et al. used statistical analysis methods to provide information on the behavior of residents in Hong Kong through a case study of a high-rise student apartment building, producing new data and new models [16]. A statistical analysis assessed energy use patterns in twenty-eight University of Johannesburg residence halls during the 2016 academic year [17]. A recent review of research identified the use of spatial planning and landscape, renewable and clean energy, energy systems, thermal envelopes, green transportation, management and control, human-related performance and intelligence, and other methods [18].

2.2. User Behavior of Building Energy

Once the value of energy consumption is obtained, the corresponding carbon emissions can be calculated. Some studies have shown that the energy use behavior of various occupants and buildings will affect energy consumption [19]. Li et al. found through a structured survey that 65% of student behavior was categorized as daily life, 20% as transportation, and 15% as academic activities such as learning [20]. There is a significant potential for substantial energy savings by changing the behavior of occupants with regards to energy consumption habits [21,22], and the energy consumption of the same house can vary by more than twofold depending on the behavior of the occupants [23,24]. A study created three behavior patterns (proactive, intermediate, and careless) to evaluate user interactions with air conditioning systems, lighting, natural ventilation, and internal shading devices. The results showed that the current user behavior is between intermediate and careless [25]. A review of research on the impact of occupant behavior on building energy consumption states that occupant behavioral efficiency is considered an effective and economical approach compared to retrofit techniques. However, future improvements in the classification, quantification, and validation of behavioral inputs are needed [26].

Research on building energy user behavior also includes social psychology and other behavioral aspects. Wang et al. summarized four classic behavioral theories and conceptual models, including TPB, in their study [11]. Si et al. used TPB to understand people's water-saving intentions [27], and Chen et al. used TPB to explain how individuals' intentions to participate in carbon reduction affect their final behavior [28].

2.3. Research Framework

Through the previous literature review, this study found that although teams have conducted relevant research on sustainable campus buildings, the research mainly focused on the calculation of carbon emissions on the campus as a whole. In other words, the current research focuses on "how much carbon is emitted" rather than "how to reduce carbon emissions". At the same time, most existing emission reduction strategies focus on building design and renovation. Although some research has pointed out that modifying occupant behavior is an effective and economical method, detailed behavioral input and quantification methods are lacking. Therefore, this study will focus on the changes in emission reductions from residents' behavior, aiming to explore the impact of interventions and incentives on carbon emission reductions for campus dormitory residents in combination with the TPB.

The specific research process is divided into three parts:

1. Using college students in Shenyang City, Liaoning Province, China as the data source, investigate their daily living behavior.
2. Design corresponding interventions for the above behaviors, investigate the respondents' acceptance of these carbon reduction measures, and then estimate the amount of carbon emission reductions under the intervention.
3. Based on the relevant policies of TPB and the university, design a corresponding incentive mechanism and investigate the respondents' willingness to implement intervention measures under the incentive mechanism, so as to understand the promotion and expected effects of various rewards on intervention measures.
4. The flow chart of this study is shown in Figure 1.

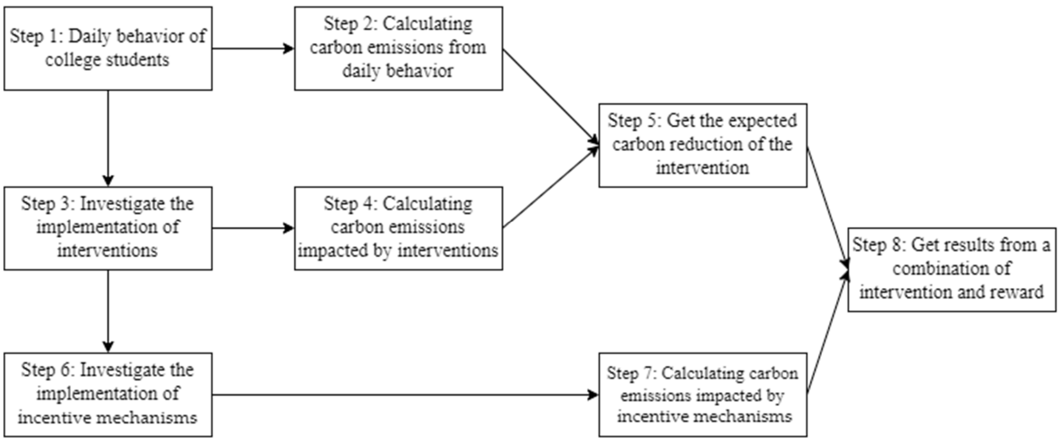

Figure 1. The flow chart.

3. Methodology

3.1. Daily Behavior of Residents

As mentioned in Section 2.3, this study first investigates the daily residential behavior of college students. The Hong Kong Environment and Ecology Bureau has developed an online carbon emissions calculator based on residents' daily behaviors in four aspects: food, clothing, housing, and transportation [29]. The calculator conducts a detailed survey of residents' clothing and shoe purchases, eating habits and consumption, energy consumption, and frequency of transportation. Based on various surveys conducted by this calculator, this study summarizes the daily behaviors of college students that produce carbon emissions, as shown in Table 1. This study is dedicated to quantifying the behavior of college students resident in dormitories, so their transportation travel is not within the boundaries of this study system, and so transportation is not involved in Table 1.

Table 1. Various behaviors of residents that generate carbon emissions.

Type	Activity
Clothing	Buying new clothes and shoes
Food	Frequency of eating red meat Weekly red meat consumption Number of prepackaged drinks purchased per week
Living	Electricity (in room) Electricity (public space) Water

3.2. Interventions

Based on the above-mentioned daily behaviors that generate carbon emissions and some regulations of university dormitories, this study set up various intervention measures. Among them, energy consumption in dormitories can be reduced through a series of measures from the perspective of managers, such as managers directly reducing the free electricity quota for each dormitory, further increasing the price of water- and electricity-consuming equipment in the building to reduce use, etc. This type of intervention is called "managerial intervention" in this study. Corresponding to this is "advocacy intervention", such as posting posters and holding lectures. Table 2 shows the various measures of the two major categories of intervention.

Table 2. Two categories of intervention.

Type	Interventions
Managerial intervention	Reduce the monthly free electricity amount for dormitories Reduce the monthly supply of garbage bags in dormitories Increase washing machine charging standards Increase dormitory electricity prices Charge for hot water in water room Increase charging standards for floor water dispensers Hair dryer and microwave oven charges Adjust dormitory lights-out time
Advocacy intervention	Provide sporting goods Conduct online lectures Post water and electricity conservation slogans in stairwells, corridors, and water rooms

3.3. Incentive Mechanism

Among the above-mentioned intervention measures, management-type interventions will inevitably reduce the quality of life of residents, while advocacy-type interventions are mostly a relatively common publicity method. Both types of intervention may not necessarily produce very good expected results. This study believes that incentives can motivate residents to accept these interventions to a certain extent and achieve a low-carbon lifestyle based on TPB. Based on the policies of each school, this study proposes twelve incentive mechanisms in three categories, involving students' spiritual honor rewards, material rewards, and academic rewards. Table 3 introduces the specific measures of these incentive mechanisms.

Table 3. Incentive mechanisms.

Type	Rewards
Honor rewards	Receive beautiful certificates and medals Complete a charity donation in the name of the winner and obtain an electronic certificate The deeds of the winners will be displayed in a prominent location (such as the corridor) for publicity The winners' deeds are publicized on the school and college's self-media platform
Material rewards	The winner can receive a cash equivalent to the energy reduction Winners can receive exquisite cultural and sports products The winner can get tokens or points, which can be used for daily consumption in school Cooperate with popular platforms to provide winners with interesting prizes (such as skins and heroes in Honor of Kings or League of Legends)
Academic rewards	The winner can get a school-level honorary title (plus one point for postgraduate admission) The corresponding score of the winner will get a full score at the end of the semester Winners can have priority to move into a four-person dormitory after the end of the school year Winners can participate in the research of low-carbon project teams and have the opportunity to publish high-quality papers

4. Data Analysis

4.1. Intervention Questionnaire Analysis

This study collected the influencing factors of students' carbon emission behaviors through an extensive questionnaire. After designing the questionnaire, the team used online social media and offline posters to promote the questionnaire to college students in Shenyang, Liaoning Province, China. Finally, 533 valid questionnaires were successfully collected. This study first used a five-point Likert scale to survey respondents' support for each intervention, with 1 being "very unsupportive" and 5 being "very supportive". The results showed that the average score of the five-level scale was 3.25, which was only slightly higher than the average, indicating that the respondents were not willing to participate in the intervention. The highest-scoring intervention, "Adjust dormitory lights-out time," also scored only 3.5 points. The scores for "Provide sporting goods", "Conduct online lectures", and "Post water and electricity conservation slogans in stairwells, corridors and water rooms" were all below 3.1. It can, therefore, be presumed that these interventions will have little effect.

After determining the main intervention measures of this study, this study combined the questionnaire survey with the students' living habits based on existing research. It estimated the carbon emission reduction of each measure.

4.1.1. Questionnaire Test

First, a reliability analysis was conducted on the questionnaire (all analyses in this study came from SPSSPRO). The results showed that the Cronbach's α coefficient value of the questionnaire was 0.989, indicating that the reliability of the questionnaire was very good.

Next, this study conducted a structural equation model analysis on the questionnaire. According to the two major types of intervention in Section 3, the measures of managerial interventions are set as factor 1 in the model, and the measures of advocacy interventions are set as factor 2. It can be seen from the calculation results in Appendix B and from the model path coefficient table that in factor 1, the significance p values of the second intervention to the eighth intervention in the management interventions and factor 2 are all

0.000, so the null hypothesis is rejected. At the same time, the standard loading coefficients are all greater than 0.4, which can be considered to have a sufficient variance explanation rate to indicate that each variable can be displayed for the same factor. In the same way, based on the fact that the significant *p* values of the second and third measures in the advocacy interventions are also 0.000, the null hypothesis is rejected. At the same time, the standard loading coefficients are all greater than 0.4. It can, therefore, be considered to have a sufficient variance explanation rate to indicate that each variable can be displayed for the same factor.

Finally, from the model path coefficient table, it can be seen that based on the paired term F1 -> F2, the significance *p* value is 0.000 ***, and being significant at that level, then the null hypothesis is rejected. Therefore, this path is effective, and its influence coefficient is 0.866.

In summary, the various intervention measures involved in the questionnaire are reasonably set and the data collected by the questionnaire are reliable, so further research can be conducted based on this questionnaire.

4.1.2. Managerial Intervention

Starting from question 2, this study analyzes the respondents' implementation level of each intervention measure one by one and then calculates the specific carbon reduction amount of each measure using the carbon emission factor method [30]. There are some measures that cannot be applied to all universities in Shenyang. For example, the price of electricity in public universities usually follows a unified standard, so the price of electricity in dormitories cannot be increased rashly. Finally, this study retained eight intervention measures in the carbon reduction estimation process. Several deleted measures can be used as a reference for universities to formulate subsequent policies. The carbon emission factors used in the study are shown in Table 4.

Table 4. Carbon emission factor [29,31].

Carbon Source	Unit	Carbon Emission Factor (kgCO_2e/unit)
Electricity	kWh	1.0826
Water	t	0.213
Laundry detergent	t	5930

First, the questionnaire indicated that nearly half of the students may or are very likely to reduce electricity consumption following a reduction in the monthly free electricity quota in the dormitory. When implementing electricity-saving related measures, 43.64% of the students would be willing to persist every week for more than four days. This could save about 0.1 kWh of power consumption per day and 1.8 kWh per month. According to the carbon emission factor, carbon emission reductions per person per month resulting from the intervention are 1.95 kgCO_2e.

Faced with a rise in the cost of operating the washing machines, the questionnaire found that 50.3% of students would choose to wash their clothes by hand as much as possible, and 32.12% would reduce their machine washing by at least once a week. Therefore, this research assumes that half of the students would reduce their machine washing frequency by three times a month, and the other half would remain unchanged. According to the instructions for the drum washing machines commonly used in the dormitory building, the power consumption of each standard washing process is 0.88 kWh, and the water consumption is 50 L. Therefore, this measure can reduce per capita electricity consumption by 1.32 kWh and per capita water consumption by 75 L. At the same time, reducing the number of machine washes will also reduce the consumption of laundry detergent. Calculated using 60 g of laundry detergent each time, the consumption of laundry detergent per capita will be reduced by 90 g per month after implementing this measure. Using the carbon emission factor method, the monthly carbon emission reduction of this measure can be calculated as 1.978 kgCO_2e.

A total of 75.15% of the students indicated that charging for hot water in the water room would prompt them to reduce excessive water use. The capacity of the thermos commonly used by students is 3 L. Based on this intervention, students were willing to reduce their water consumption to 1 L (six people in the dormitory use up two pots of hot water daily) and then reduce the amount of hot water by 0.5 L daily. According to the ratio obtained from the questionnaire, the per capita water savings after taking this measure is 0.375 L per day. The hot water room uses a stainless steel large-capacity water boiler with a rated power of 12 kW; the power consumption for boiling 100 L of water is about 12 kWh. Therefore, this measure could also reduce per capita electricity consumption by 0.045 kWh per day. After calculations, the monthly carbon emission reduction of this intervention is 1.46 kgCO_2e.

By raising the drinking water charge, the questionnaire suggests that 56.97% of the students would seek to reduce their water costs. After field research and one-on-one dialogue, this study found that each student would seek to reduce their water charge by about CNY 2 per week, calculated based on 0.35 CNY/L. Students willing to reduce their consumption of direct drinking water did so by 7 L of water per week (1 L of water per day). The average daily water reduction of all students was 0.5697 L. The total power of the direct drinking water dispenser in the dormitory building is 425W. It is operational 24 h a day because the power supply is used for filtering water. Therefore, this intervention will not affect the power consumption of the direct drinking water machine, regardless of whether the water is saved. The monthly carbon emission reduction of this measure is 0.0036 kgCO_2e.

The questionnaire shows that more than half of the students would use hair dryers and microwave ovens less than once a week if they were subject to a charge. In this study, half of the students indicated they would reduce their use of hair dryers and microwave ovens by 5 min a week. According to the rated power of the products, this measure can reduce per capita electricity consumption by 0.083 kWh per week. The action, therefore, has an carbon emission reduction of 0.36 kgCO_2e per month.

After adjusting the lights-off time inside the dormitory to midnight, an investigation showed that students went to bed about an hour earlier than before. This study estimates that the electricity consumption of equipment such as computers, mobile phones, and dormitory lights for college students is about 0.1 kWh per hour, and the monthly EPR of this measure is 3.25 kgCO_2e.

4.1.3. Advocacy Intervention

Educational advocacy measures generally include activities such as low-carbon lectures, courses, the provision of sporting goods, and the display of water-saving and electricity-saving slogans in stairwells, corridors, and water rooms. Such measures aim to show students specific low-carbon and related carbon emission behaviors and change their thinking. From a cultural point of view, this ideological education work guides students' carbon-saving awareness toward tangible measures to reduce carbon emissions and accelerate the promotion of low-carbon work.

According to the questionnaire, 48.48% of students would spend more than half an hour outdoors every day following the provision of sporting goods. This study assumes that half of the students exercise for half an hour daily; therefore, this measure could reduce electricity consumption per capita by 0.025 kWh, and the monthly carbon emission reduction is 0.81 kgCO_2e.

A total of 88.48% of students indicated that water- and electricity-saving slogans and conducting online lectures in stairwells, corridors, and water rooms could prompt them to reduce excessive electricity consumption. We surveyed the students after viewing sample banners and three low-carbon education lectures. The results showed that students actively reduced their excessive electricity consumption within the first week after the first lecture (see Figure 2). However, as time passed, some students began to ignore related carbon behaviors, and only 41.82% were willing to persist. Within 1–2 weeks of the second lecture, the students' low-carbon behavior continued to rise, and the rate increased to 71.52%, then slowly decreased to 45.45% over time. After the third lecture, student behavior began to decline after maintaining a slow growth and remained unchanged at 52.73%. Therefore, this study argues that 52.73% of students can adhere to the above-mentioned energy-saving habits, and this ratio is also used as the reduction factor for carbon emission reduction.

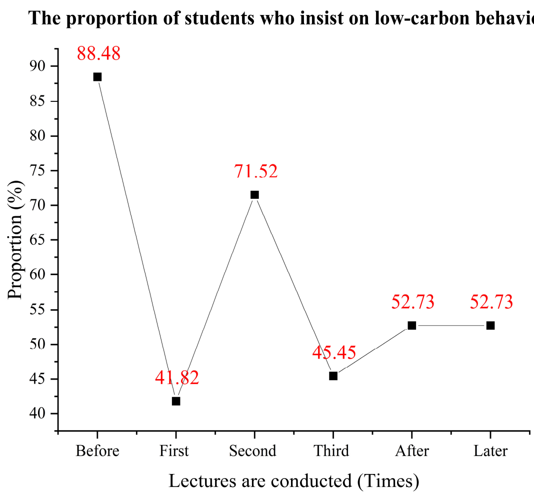

Figure 2. Energy conservation awareness after three lectures.

According to the results of the questionnaire and the simulation experiment, this study determined the specific carbon reduction per day for each intervention measure, as shown in Table 5.

Table 5. Carbon emission reduction of every intervention.

Activity	Saving Electricity (kWh)	Saving Water (L)	Saving Laundry Detergent (kg)	Reduction CO_2 (kge)
Reduce the monthly free electricity	1.8			1.949
Raise the washing machine charges	1.32	75	0.09	1.979
Charge for water room hot water	1.35	11.25		1.464
Raise the water fee		17.09		0.004
Adjust the lights-off time inside the dormitory	3			3.248
Hair dryer and microwave fee	0.33			0.357
Provide sporting goods	0.75			0.812
Posters and lectures		Reduction factor is 0.5273		
Total	4.508	54.491	0.047	5.174

4.2. Reward Questionnaire Analysis

This study set up a scenario: if the respondent, through his or her own efforts, ranks among the top in the dormitory building in terms of carbon reduction during that semester, he or she will be awarded the title of "Carbon Reduction Pacesetter." Under this assumption, the winners were surveyed on their satisfaction with twelve types of incentives in three categories. This study also conducted a survey using a five-point scale, with 1 indicating "very dissatisfied" with the reward and 5 indicating "very satisfied".

4.2.1. Questionnaire Test

First, a reliability analysis was conducted on the questionnaire. The Cronbach's α coefficient value was 0.962, indicating that the reliability of the questionnaire was very good.

Next, a structural equation model analysis was performed on the questionnaire. According to the three types of incentive mechanisms in Section 3, the model sets the four incentive measures of honor rewards as factor 1, the four incentive measures of material rewards as factor 2, and the four incentive measures of academic rewards as factor 3. It can be seen from the model path coefficient table that the confirmatory analysis based on factor f1 shows that the principal component composed of variables within this factor has a low level of explanation. The second, third, and fourth incentive measures in factor 2 and the significant p value of factor 3 are all 0.000, so the null hypothesis is rejected. At the same time, their standard loading coefficients are all greater than 0.4, which can be considered to have a sufficient variance explanation rate. It means that each variable can be displayed for the same factor.

Similarly, in factor 3, the significant p values of the second, third, and fourth incentive measures are all 0.000; then, the null hypothesis is rejected. At the same time, their standard loading coefficients are all greater than 0.4, and it can be considered that they have a sufficient variance explanation rate to perform various functions. Variables can appear for the same factor.

Next, from the model path coefficient table, we can see that based on the paired term f1 -> f2, the significance p value is 0.887. If it is not significant at that level, the null hypothesis cannot be rejected, and so this path is invalid. Based on the pairing term f1 -> f3, the significance p value is 0.887, and it is not significant at the horizontal level, so the null hypothesis cannot be rejected, and so this path is invalid. Based on the pairing term f2 -> f3, the significance p value is 0.000 ***, and it is significant at that level, so the null hypothesis is rejected, and so this path is valid, and its influence coefficient is 1.199.

In summary, the questionnaire has extremely high reliability, indicating that the data are relatively reliable. However, several measures of honorary awards are significantly different from the other two types of awards, and further analysis needs to be combined with the data.

4.2.2. Rewards Promote Intervention

Judging from the questionnaire data, the overall satisfaction level of respondents with honors and awards is low, and the highest score for "charitable donation" did not exceed 3.4 points. The other two types of rewards have higher scores, with the highest score 3.8 and the second highest score 3.79, both coming from material rewards. Academic rewards are relatively average, with all four measures reaching 3.6 points or above, which is higher than the overall average of 3.5.

Next, this study discusses the degree of implementation of intervention measures under incentive measures based on the degree of satisfaction with each incentive measure. The authors believe that in each incentive measure, respondents who chose "very satisfied" and "satisfied" will persist in implementing the intervention, while others will implement it in accordance with their proportion in the intervention questionnaire. This allows an estimate of the expected carbon reductions of the intervention based on each incentive. The results are shown in Table 6.

When the incentive mechanism is taken into account, even a low-scoring incentive can significantly increase the amount of carbon reduction per person per month. This is mainly because the previous interventions were only completed voluntarily by the respondents. After participating in the incentive mechanism, respondents who are satisfied with the reward will do their best to their reduce carbon emissions for the reward, and it is no longer based on basic consciousness and public welfare. Interventions, therefore, do not result in severe reductions. This is also consistent with the TPB mentioned many times in the literature review.

Finally, taking into account the length of schooling of college students (9 months per year) and the total number of students living on campus in various universities in Shenyang (general universities comprise mainly undergraduates, about 12,000 people), this study estimates that under the joint action of incentive measures and intervention mechanisms, an ordinary university can reduce carbon emissions by more than 800 tons a year, up to a maximum of about 1045 tons. If only intervention measures are taken into account, and only residents' voluntary efforts to reduce carbon emissions are considered, the university will reduce carbon emissions by approximately 560 tons per year.

Table 6. Incentive mechanism promotes carbon emission reductions.

Activity	Reduction Factor	Electricity Savings (kWh)	Water Savings (L)	Laundry Detergent Savings (kg)	Reduction CO_2 (kge)
Receive beautiful certificates and medals	0.737	6.743	79.956	0.069	7.726
Complete a charity donation in the name of the winner and obtain an electronic certificate	0.729	6.698	77.288	0.066	7.659
The deeds of the winners will be displayed in a prominent location (such as the corridor) for publicity	0.715	6.455	74.375	0.065	7.389
The winners' deeds are publicized on the school and college's self-media platform	0.728	6.479	76.968	0.069	7.440
The winner can receive a cash equivalent to the energy reduction	0.844	8.375	94.459	0.085	9.589
Winners can receive exquisite cultural and sports products	0.784	7.896	88.796	0.079	9.034
The winner can get tokens or points, which can be used for daily consumption in school	0.817	8.026	90.237	0.082	9.195
Cooperate with popular platforms to provide winners with interesting prizes (such as skins and heroes in Honor of Kings or League of Legends)	0.848	8.457	95.985	0.085	9.682
The winner can get a school-level honorary title (plus one point for postgraduate admission)	0.806	7.898	89.125	0.081	9.050
The corresponding score of the winner will get a full score at the end of the semester	0.839	8.266	92.201	0.084	9.468
Winners can have priority to move into a four-person dormitory after the end of the school year	0.827	7.903	90.963	0.082	9.067
Winners can participate in the research of low-carbon project teams and have the opportunity to publish high-quality papers	0.804	7.858	88.358	0.080	9.003

5. Discussion and Conclusions

Although the campus area of colleges and universities only accounts for 3–7% of the urban construction area, its dense population has become a severe challenge for sustainable urban development. This study proposed a series of methods to quantify the impact of various carbon reduction interventions in campus buildings on the occupants, as well as the role of incentive mechanisms in promoting these interventions. This study designed a questionnaire on intervention measures and a satisfaction survey on incentive mechanisms and calculated the carbon reduction amount of each measure and the expected value of each incentive mechanism based on the carbon emission factor method. Finally, it was concluded that the monthly carbon reduction of residents under intervention measures alone was 5.174 kgCO_2e. Among the multiple intervention measures, adjusting the dormitory lights-out time was expected to have the highest emissions reduction, which could reduce carbon emissions by 3.248 kg of CO_2e per month without considering discounts. The university's total annual carbon reduction was approximately 560 tons. After considering incentives, the monthly carbon reduction could reach 7.389 to 9.682 kgCO_2e, and the university's annual carbon reduction could reach 800–1045 tons.

The calculation results of this study can intuitively find the positive impact of incentive mechanisms, and the 12 incentive measures in this study can increase per capita carbon reduction to a certain extent. Among the measures, the average satisfaction with incentives such as honorary rewards was low, while the average satisfaction with incentives such as material rewards and academic rewards was higher. Therefore, we call on universities to consider supporting incentive measures, especially material and academic rewards, when formulating emission reduction policies. At the same time, even if incentives are not considered, various interventions can achieve a certain degree of carbon emission reduction. Therefore, we recommend that colleges and universities not only consider incentive measures but also adhere to implementing relevant intervention policies. In addition, this study's findings clearly reveal the carbon emission reduction potential of interventions and incentive mechanisms. However, forcing students to reduce carbon emissions through external forces is not enough. Creating a culture of sustainable development within the campus community will be more effective in achieving a low-carbon life. The authors plan to conduct a series of people-centered studies in the future to explore the core factors that influence people's formation of low-carbon values. Finally, the results show that electricity plays an important role in reducing carbon emissions. Therefore, the team recommends that universities adopt more targeted interventions or rewards for electricity-saving behaviors, such as addressing luminous lights on campus, that buildings use energy-saving products, and that air conditioning in public areas be set to a relatively higher temperature in summer.

This study also has certain limitations. First, the research sample was collected from college students in Shenyang City, Liaoning Province, China. This forms the geographical limitation of the research to a certain extent. For example, the university energy structure and residents' behavioral habits in tropical areas such as Hong Kong, Singapore, and Manila differ entirely from those of respondents in Shenyang. This study will be followed up with research teams from the City University of Hong Kong and the National University of Singapore to study the daily behaviors of college students in tropical areas. Second, the research objects of this study are limited to university dormitory buildings and resident behaviors. In fact, university teaching buildings, libraries, and office buildings all consume a lot of energy. Therefore, the team will explore the future role of campuses in sustainable cities and societies more fully. We have currently completed a study on carbon reduction for campus office buildings and are currently under review. Finally, this study focused on quantifying reward mechanisms but ignored students' perceptions of existing reward mechanisms. In future research, we will discuss incentives that are more popular among students and the possibility for students to increase their environmental awareness further through future studies.

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Data Availability Statement: The questionnaire data used in this study and related analysis results are presented in the Appendices A and B.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Survey on Intention of Carbon Saving Measures in Student Dormitories

Appendix A.1. Question 1: In order to Reduce Carbon Emissions, Your Support of the Following Interventions? [Matrix Scale Questions]

Questions\Options	Very Unsupportive	Not Supportive	Generally	Supportive	Very Supportive	Average Score
Reduce the monthly free electricity amount for dormitories	48 (9.09%)	71 (13.33%)	152 (28.48%)	187 (35.15%)	75 (13.94%)	3.32
Reduce the monthly supply of garbage bags in dormitories	45 (8.48%)	116 (21.82%)	155 (29.09%)	158 (29.7%)	59 (10.91%)	3.13
Increase washing machine charging standards	58 (10.91%)	71 (13.33%)	155 (29.09%)	171 (32.12%)	78 (14.55%)	3.26
Increase dormitory electricity prices	45 (8.48%)	61 (11.52%)	158 (29.7%)	174 (32.73%)	95 (17.58%)	3.40
Charge for hot water in the water room	42 (7.88%)	74 (13.94%)	149 (27.88%)	197 (36.97%)	71 (13.33%)	3.34
Increase charging standards for floor water dispensers	48 (9.09%)	81 (15.15%)	149 (27.88%)	187 (35.15%)	68 (12.73%)	3.27
Hair dryer and microwave oven charges	39 (7.27%)	65 (12.12%)	171 (32.12%)	181 (33.94%)	77 (14.55%)	3.36
Adjust dormitory lights-out time	26 (4.85%)	65 (12.12%)	149 (27.88%)	204 (38.18%)	89 (16.97%)	3.5
Provide sporting goods	61 (11.52%)	94 (17.58%)	197 (36.97%)	139 (26.06%)	42 (7.88%)	3.01
Conduct online lectures	55 (10.3%)	84 (15.76%)	207 (38.79%)	142 (26.67%)	45 (8.48%)	3.07
Post water and electricity conservation slogans in stairwells, corridors, and water rooms	61 (11.52%)	84 (15.76%)	200 (37.58%)	155 (29.09%)	33 (6.06%)	3.03
Subtotal	528 (9.04%)	866 (14.77%)	1842 (31.4%)	1895 (32.34%)	733 (12.45%)	3.25

Appendix A.2. Question 2: When the Monthly Free Electricity Amount in the Dormitory Is Reduced or the Electricity Price Is Increased, Will You Try to Save Electricity in the Dormitory as Much as Possible? [Single-Choice Question]

Options	Subtotal	Proportion
Very unlikely	48	9.09%
Impossible	74	13.94%
Generally	145	27.27%
Possible	194	36.36%
Very likely	71	13.33%
Number of valid entries for this question	533	

Appendix A.3. Question 3: When Implementing Power-Saving Measures, How Many Days per Week Are You Willing to Stick to Power-Saving Behavior? [Single Choice Question]

Options	Subtotal	Proportion
0	68	12.73%
1 day	68	12.73%
2 days	65	12.12%
3 days	100	18.79%
4 days	42	7.88%
5 days	48	9.09%
6 days	19	3.64%
7 days	123	23.03%
Number of valid entries for this question	533	

Appendix A.4. Question 4: When Reducing the Monthly Supply of Garbage Bags in the Dormitory, Will You Try Your Best to Avoid Unnecessary Garbage Generation? [Single-Choice Question]

Options	Subtotal	Proportion
Yes	320	60%
No	213	40%
Number of valid entries for this question	533	

Appendix A.5. Question 5: When Reducing the Monthly Supply of Garbage Bags in the Dormitory, Will the Amount of Garbage Be Reduced Every Month? [Single-Choice Question]

Options	Subtotal	Proportion
1–5 kg	287	53.94%
6–15 kg	142	26.67%
16–30 kg	48	9.09%
31–45 kg	26	4.85%
46–60 kg	13	2.42%
Or enter another quantity (kg)	17	3.03%
Number of valid entries for this question	533	

Appendix A.6. Question 6: When the Charging Standard for Washing Machines Is Increased, Will You Choose to Wash Clothes by Hand as Much as Possible? [Single-Choice Question]

Options	Subtotal	Proportion
Yes	268	50.3%
No	265	49.7%
Number of valid entries for this question	533	

Appendix A.7. Question 7: After Increasing the Charging Standard for Washing Machines, How Many Times a Week Will the Number of Machine Washes Be Reduced? [Single Choice Question]

Options	Subtotal	Proportion
0	152	28.48%
1	171	32.12%
2	136	25.45%
3	52	9.7%
4	6	1.21%
5	16	3.03%
Or enter the quantity (times)	0	0%
Number of valid entries for this question	533	

Appendix A.8. Question 8: After Charging for Hot Water in Bathrooms, Will You Reduce Excessive Water Use? [Single Choice Question]

Options	Subtotal	Proportion
Yes	401	75.15%
No	132	24.85%
Number of valid entries for this question	533	

Appendix A.9. Question 9: When the Charging Standard for Floor Water Dispensers Is Increased, Will You Reduce the Cost of Water Supply? [Single Choice Question]

Options	Subtotal	Proportion
Yes	304	56.97%
No	229	43.03%
Number of valid entries for this question	533	

Appendix A.10. Question 10: How Much Will Your Weekly Expenses Be Reduced after Increasing the Charging Standard for Floor Water Dispensers? [Single Choice Question]

Options	Subtotal	Proportion
0	149	27.88%
CNY 0.1–1	110	20.61%
CNY 1.1–2	145	27.27%
CNY 2.1–3	65	12.12%
CNY 3.1–4	58	10.91%
Or enter other quantity (yuan)	6	1.21%
Number of valid entries for this question	533	

Appendix A.11. Question 11: When Sporting Goods Are Provided, How Long Will Your Daily Outdoor Exercise Time Increase? [Single Choice Question]

Options	Subtotal	Proportion
0	84	15.76%
0–1 h	258	48.48%
1–2 h	139	26.06%
2–3 h	48	9.09%
Or enter the quantity (h)	4	0.61%
Number of valid entries for this question	533	

Appendix A.12. Question 12: When the Hair Dryer and Microwave Oven Are Charged for, How Much Will the Number of Times You Use Them per Week Decrease? [Single Choice Question]

Options	Subtotal	Proportion
0	168	31.52%
1	132	24.85%
2	165	30.91%
3	45	8.48%
4	19	3.64%
Or enter the quantity (times)	4	0.61%
Number of valid entries for this question	533	

Appendix A.13. Question 13: After Browsing Slogans or Lectures on Low-Carbon Energy Conservation, Are You Willing to Reduce Excessive Electricity Consumption? [Single Choice Question]

Options	Subtotal	Proportion
Yes	472	88.48%
No	61	11.52%
Number of valid entries for this question	533	

Table A1. Reliability analysis of intervention questionnaires.

Cronbach's α	Standardized Cronbach's α	Number of Items
0.989	0.989	11

Table A2. Table of factor loading coefficients.

Factors	Variables	Non-Standard Load Factors	Standard Load Factors	z	S.E.	p
F1	Question 1	1	0.996	-	-	-
	Question 2	0.789	0.904	4.627	0.171	0.000 ***
	Question 3	0.87	0.99	13.344	0.065	0.000 ***
	Question 4	0.94	0.975	9.118	0.103	0.000 ***
	Question 5	1.069	0.991	13.813	0.077	0.000 ***
	Question 6	0.978	0.99	13.022	0.075	0.000 ***
	Question 7	1.076	0.987	11.881	0.091	0.000 ***
	Question 8	1.156	0.979	9.857	0.117	0.000 ***
F2	Question 9	1	0.993	-	-	-
	Question 10	1.085	0.992	12.693	0.085	0.000 ***
	Question 11	1.106	0.991	12.182	0.091	0.000 ***

*** $p < 0.01$.

Table A3. Table of factor loading coefficients.

Latent Variables	Latent Variables	Non-Standard Coefficient	Standard Coefficient	Standard Error	Z	p
F1	F2	0.867	0.866	0.232	3.736	0.000 ***

*** $p < 0.01$.

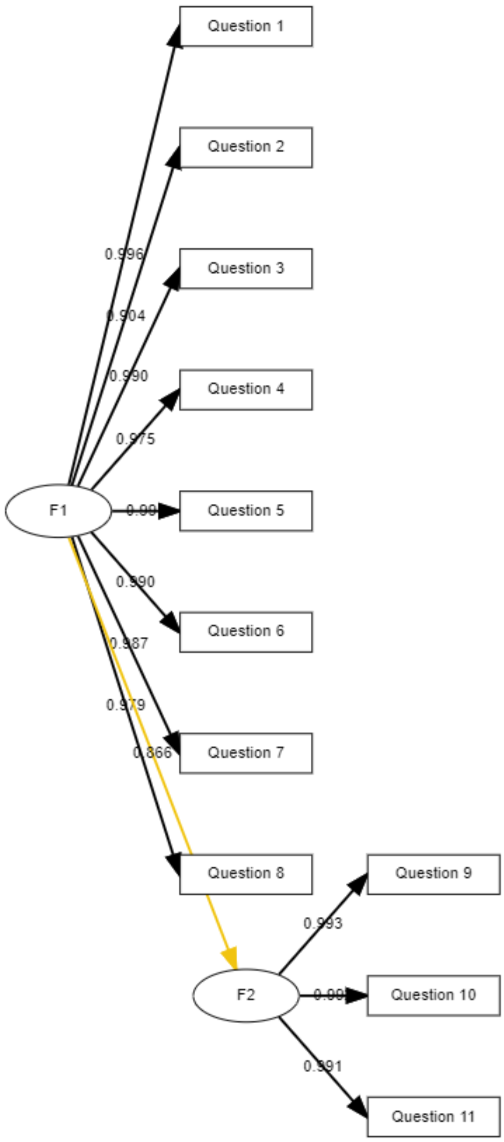

Figure A1. Structural Equation Model Path Diagram. The yellow arrow indicates the influence relationship between factors, and the black arrow indicates the influence relationship between a certain factor and its various components.

Appendix B. If You Live in the Dormitory, You Can Get Rewards for Low-Carbon Energy Saving

In dormitory life, the top resident in carbon reduction can get the title of "Carbon Reduction Model". Please express your satisfaction with the specific reward effect of this title. A score of 1 means very dissatisfied, and a score of 5 means very satisfied.

Questions\Options	Very Dissatisfied	Not Satisfied	Generally	Satisfied	Very Satisfied	The Average Score
Receive beautiful certificates and medals	84	116	96	130	107	3.11
Complete a charity donation in the name of the winner and obtain an electronic certificate	87	63	156	109	118	3.36
The deeds of the winners will be displayed in a prominent location (such as the corridor) for publicity	90	90	141	101	111	3.15
The winners' deeds are publicized on the school and college's self-media platform	85	84	138	134	92	3.12
The winner can receive a cash equivalent to the energy reduction	41	18	117	190	167	3.80
Winners can receive exquisite cultural and sports products	67	79	97	162	128	3.38
The winner can get tokens or points, which can be used for daily consumption in school	47	41	118	186	141	3.62
Cooperate with popular platforms to provide winners with interesting prizes (such as skins and heroes in Honor of Kings or League of Legends)	35	34	102	199	163	3.79
The winner can get a school-level honorary title (plus one point for postgraduate admission)	41	44	134	160	154	3.64
The corresponding score of the winner will get a full score at the end of the semester	45	40	97	170	181	3.75
Winners can have priority to move into a four-person dormitory after the end of the school year	48	51	96	167	171	3.68
Winners can participate in the research of low-carbon project teams and have the opportunity to publish high-quality papers	50	63	108	136	176	3.61
Subtotal	720	723	1400	1844	1709	3.50

Table A4. Reliability analysis of intervention questionnaires.

Cronbach's α	Standardized Cronbach's α	Number of Items
0.962	0.962	12

Table A5. Table of factor loading coefficients.

Factors	Variables	Non-Standard Load Factors	Standard Load Factors	z	S.E.	*p*
f1	Question 1	1	0.063	-	-	-
	Question 2	23.67	0.748	0.142	166.986	0.887
	Question 3	13.204	0.69	0.142	93.207	0.887
	Question 4	24.39	1	0.142	171.828	0.887
f2	Question 5	1	0.987	-	-	-
	Question 6	0.494	0.941	5.639	0.088	0.000 ***
	Question 7	0.829	0.985	9.426	0.088	0.000 ***
	Question 8	0.992	0.987	9.666	0.103	0.000 ***

Table A5. *Cont.*

Factors	Variables	Non-Standard Load Factors	Standard Load Factors	z	S.E.	*p*
f3	Question 9	1	0.914	-	-	-
	Question 10	1.204	0.993	4.828	0.249	0.000 ***
	Question 11	1.083	0.994	4.862	0.223	0.000 ***
	Question 12	0.897	0.941	3.895	0.23	0.000 ***

*** $p < 0.01$.

Table A6. Table of factor loading coefficients.

Latent Variables	Latent Variables	Non-Standard Coefficient	Standard Coefficient	Standard Error	Z	*p*
f1	f2	42.990	0.707	303.432	0.142	0.887
f1	f3	−14.539	−0.333	102.600	−0.142	0.887
f2	f3	0.861	1.199	0.203	4.243	0.000 ***

*** $p < 0.01$

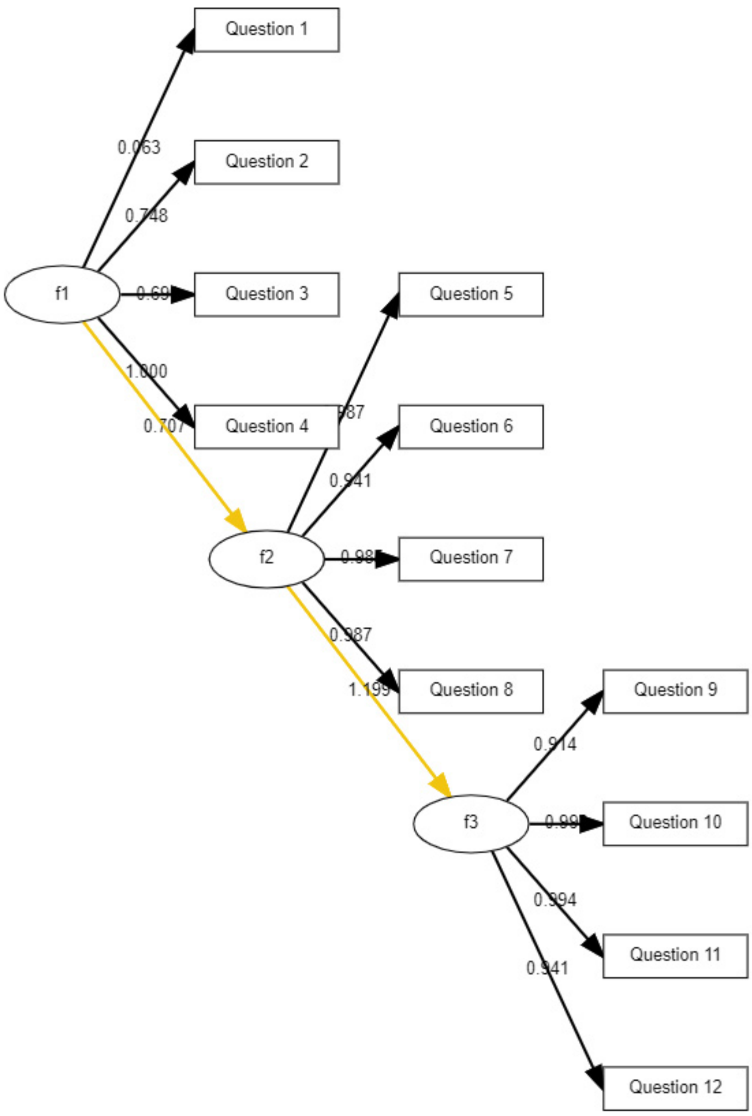

Figure A2. Structural Equation Model Path Diagram.

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