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Barriers to Green Implementation in Highway Construction in Cambodia: Identification of Root Causes

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ABSTRACT

Recently, infrastructure systems in developing countries have been substantially reformed, resulting in increased pollution to the environment from heavy equipment usage and construction operations that generate high emissions. Consequently, a green concept is necessary to address this issue. However, contractors and project owners involved in highway construction in Cambodia still encounter many barriers to the adoption of green concepts. This paper determined the differences between the perspectives of contractors and project owners on green concept adoption for Cambodian highway construction and sought to identify the root causes of high-impact barriers. A questionnaire was developed identifying 27 barriers covering 6 categories. Statistical analyses were undertaken of the data from 82 respondents who were professional contractors or project owners with experience in highway construction projects in Cambodia. The findings showed that the Training and knowledge and the Green material resource categories were high-impact for the project owners, while contractors identified Green material resource and Government management as high-impact categories. Identification of the root causes from the high-impact categories was developed using cause-and-effect diagrams to assist policymakers to comprehend the main root causes of barriers to the green concept. Competent solutions were suggested to assist the Cambodian community move toward greater sustainability.

1. INTRODUCTION

The entire industrial sector has argued over climate change and global warming, with operations in highway construction being considered as one of the vital issues regarding emissions [1-3] because they consume a substantial amount of materials and energy, as well as producing a large amount of waste [4]. To enhance environmental sustainability, the green concept has been recognized recently as a primary goal in the construction industry [5]. Green technology operations in the construction industry provide efficient protection against adverse environmental impacts by reducing emissions [6]. Nevertheless, the green concept cannot be accomplished easily as it faces many barriers from those involved in construction, especially contractors and project owners.

Many studies have investigated and summarized lists of obstacles and solutions to green concept adoption in specific areas. Shi et al. [7] conducted a survey in Shanghai, China with the major stakeholders of the construction industry to determine green concept adoption problems. As a result, a sustainability case was trialed in China's Agenda 21 at State Council 1994 to preserve the environment. In Singapore, the recognition of green construction was presented as a national priority [8]. Hence, industries have commenced selecting contractors with a combination of traditional and green concept knowledge and skills [9]. Some developing countries have expressed optimism regarding developing the green concept [10]. The industrial construction sector in Cambodia, one of the developing countries in Southeast Asia, has grown substantially based on the country's GDP statistics [11]. Nevertheless, practitioners of the highway construction industry in Cambodia seem inattentive to sustainability, as the practitioners' major priority regarding construction projects is net profit [12].

To achieve the goal of maintaining sustainability in highway construction, it is vital to understand the different perspectives of contractors and project owners regarding obstacles to green concept implementation. Without knowledge of green concepts and obstacles, it is onerous to come up with solutions and efficient regulations to implement sustainability [13]. The solutions and regulations of green technology adoption may not apply efficiency to suit the demands of contractors and project owners, even if the obstacles are addressed apart. Hence, the obstacles from contractors and project owners are necessarily separated for a detailed study. Investigating the root causes of obstacles using a cause-and-effect diagram can present the levels of detail much better by addressing the possible root causes of each obstacle through group categorization. An advantage of root causes identification is that it can easily seek potential solutions for the main barriers that happen in regions.

The purpose of this paper was to determine the differences between contractors' and project owners' perspectives toward sustainability in the Cambodian highway construction sector

and to search for root causes of high-impact obstacles. As a result, project owners and contractors should better comprehend the root causes of obstacles and also identify potential solutions. The finding of this paper will aid highway practitioners (mostly government agencies) in determining the critical obstacles, with their root causes, to adopting the green concept and further provide insight regarding potential solutions for the highway industry in Cambodia. The paper could also be useful for policymakers constructing future regulations to reinforce sustainability in Cambodia.

2. RESEARCH FRAMEWORK

The research procedure contained four important steps that are shown in Figure 1 and described below:

(1) A comprehensive literature review was conducted to identify the factors of obstacles to green technology adoption. Furthermore, a summary of published studies can help to identify research gaps and challenges.

(2) The questionnaires were developed and validated based on pre-interviewing experienced construction experts before distributing the final form to highway construction professionals for the collection of relevant data related to green concept adoption. The questionnaire provided a list of obstacles that were evaluated for their level of impact by the respondents, who also provided some feedback and recommendations.

(3) Statistical analysis was used to identify the high-impact obstacles and categories from the contractor and project owner groups. It also helped to interpret the different perspectives of both parties. Statistics can assist in analyzing, gathering, summarizing, and presenting the data simply and easily.

(4) A cause-and-effect diagram was created to find the root causes of the obstacles having the most impact on the groups. The root causes were identified from a comprehensive literature review and interviews with professional highway engineers in Cambodia. A cause-and-effect diagram can determine the sources of each main cause for the topic and build a structure to visualize the effects from the root causes.

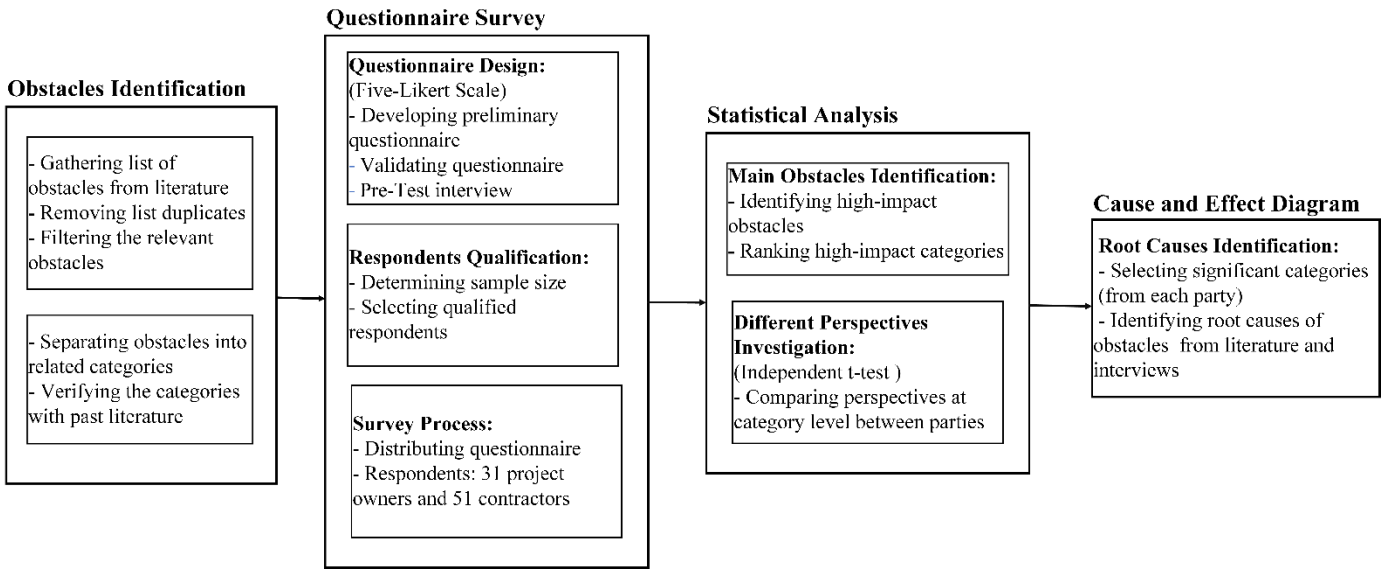

Figure 1. Research framework

3. IDENTIFICATION OF OBSTACLES

It is essential to have a literature review that enables a list of obstacles to be identified and categorized into groups. The obstacles to green construction have been listed in many studies. The obstacles were chosen that were relevant to highway construction and were most frequently mentioned in the literature. Published studies that have investigated the potential barriers to improving green construction were often based on surveys in different places to identify the most critical barriers. Chowdhury and Srabon [14] addressed 20 potential barriers in a survey to seek the different perspectives of laborers, contractors, and engineer groups in Khulna city, Bangladesh. The study showed that lack of knowledge, the lack of technology tools, and the lack of qualified engineers were significant barriers identified by the workers, contractors, and engineers, respectively. Powmya and Abidin [15] presented 12 obstacles to implementing green construction in Oman. That search identified the top-two barriers as the lack of demand for green construction and the lack of pressure by the government. Lam et al. [16] addressed the barriers and categorized them into groups, showing that green materials and tools was a vital category for green construction operations, with the failure of green construction being due to the unavailability of green material. Nusa et al. [17] identified financial issues as the main category in green construction, leading contractors to have uncertainty in selecting a green concept. The study also presented the issues of management skills from the government in setting up the regulations and motivating contractors to adopt green technology. Djokoto et al. [18] mentioned four primary categories of green adoption in Ghanian construction: lack of awareness, lack of government support, higher cost, and shortage of green material. The obstacles were addressed to make the green concept successful in Ghanian construction. Hwang and Ng [19] observed a specific category of obstacles related to knowledge and skills that affected green concept adoption. Their study identified the main barriers from the different perspectives of project managers, clients, laborers, and project teams. Another investigation focused on the greatest impact

factor of construction cost. In addition, that study indicated the relationship between project size and cost overrun to help project planners make more realistic decisions in developing highway budget estimates [20].

Table 1. Potential list of obstacles and categorization from literature

Category	Obstacle	Literature work [7]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]	[33]
Funding issue	1.1. Increase in primary project cost.	✔			✔	✔		✔		✔		✔		✔	✔					✔		✔
	1.2. High costs of green materials.	✔		✔		✔		✔			✔	✔							✔		✔	
	1.3. Project cost increase due to higher certification and designing.		✔															✔	✔			
	1.4. Capacity to deliver green materials for acceptable cost constraints.		✔							✔				✔			✔					
	1.5. Financial problem from project delay.			✔						✔												✔
Cooperation and attitude	2.1. Lack of interest from parties involved in projects.	✔	✔			✔			✔	✔	✔	✔	✔			✔					✔	✔
	2.2. Lack of awareness of green technology quality and performance.		✔		✔		✔							✔							✔	✔
	2.3. Lack of cooperation between contractors and subcontractors.		✔	✔			✔		✔	✔	✔	✔										
	2.4. Incomplete international agreements for emission reduction.								✔								✔					
	2.5. Lack of project owner's demand or interest.				✔			✔	✔	✔	✔	✔	✔			✔			✔		✔	✔
Green material resource	3.1. Unable to quantify actual quantity of green materials used.	✔		✔		✔						✔										
	3.2. Insufficient green material and no valid test.	✔			✔	✔			✔	✔		✔							✔		✔	
	3.3. Insufficient information and database.	✔				✔	✔	✔		✔	✔	✔		✔	✔		✔		✔		✔	✔
	3.4. Lack of research development center and facility.						✔					✔		✔					✔			

Table 1. Potential list of obstacles and categorization from literature (continued)

Category	Obstacle	Literature work [7]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]	[33]
Government management	4.1. Lack of inducement from government on green technology.	✔		✔	✔	✔				✔		✔				✔						
	4.2. High tax on green material in country.																✔		✔			
	4.3. Lack of financial support from government.		✔	✔			✔	✔		✔				✔					✔			
	4.4. Lack of green technology codes, regulations, and evaluation standards.						✔	✔		✔								✔				
	4.5. Lack of promotion or exhibition supported by government.	✔			✔	✔		✔		✔												
	4.6. No green reward, certificate, or recognition programs to contractors.						✔		✔												✔	✔
Time and schedule	5.1. Blocking green technology adoption due to short time and schedule.	✔				✔			✔			✔	✔									
	5.2. Adopting new green technology causes project delays.	✔				✔			✔	✔		✔										
	5.3. Long delivery time for green material from other countries.			✔						✔							✔		✔			
Training and knowledge	6.1. Lack of certification systems or training.				✔		✔	✔							✔				✔			
	6.2. Insufficient designing and technical expertise.	✔		✔		✔	✔	✔	✔	✔	✔	✔	✔	✔								✔
	6.3. High technological risks and danger.		✔						✔		✔	✔						✔	✔			
	6.4. Limited ability in using green technology methods.	✔		✔		✔	✔	✔	✔	✔		✔		✔			✔		✔			

Note: ✔ : represents identification of obstacles in the associated study, ▩ : represents identification of associated category for each obstacle

After gathering the list of obstacles, duplicated obstacles were combined. The list of obstacles was after careful review, the list was culled of obstacles not related to highway construction. Before actual data collection, the questionnaire was checked and reviewed using pre-test interviews with 10 experts to check its suitability and completeness. Experts with real-practice experience in this field were targeted to gather further information from the previously completed practice. The 10 skilled experts provided additional important obstacles and recommendations that reflected the Cambodian content based on their experience in utilizing green technology in highway construction. Most experts provided a similar point of view that Funding issues, Green material resources, and Government management were the critical barriers to green concept adoption in the Cambodian construction industry. All 10 experts agreed with the statement that more supportive effort from the government could presumably drive the positive status of the green practice in Cambodian highway construction. Then, the obstacles were separated into related categories that impacted green concept adoption based on verification with the literature.

Finally, the obstacles were identified and grouped into six categories: (1) Funding issue, (2) Cooperation and attitude, (3) Green material resource, (4) Government management, (5) Time and schedule, and (6) Training and knowledge. These six categories inclusively covered the 27 most-mentioned obstacles on green adoption and are shown in Table 1.

4. QUESTIONNAIRE AND DATA COLLECTION

The questionnaire was divided into two main parts: (1) respondent's profile, (2) impact level evaluation of obstacles. The first part of the questionnaire required respondents to provide general information on their work experience in the construction sector, while the second part sought the respondents' views on the level of impact of the 27 obstacles. The rating-scale technique was applied to show the level of impact of each obstacle. The level of impact for each item on the list of obstacles in the questionnaire was evaluated using a five-point Likert scale (0 = no impact, 1 = very slight impact, 2 = slight impact, 3 = quite an impact, 4 = strong impact, and 5 = extreme impact). Before actual data collection, the questionnaire was checked and reviewed using pre-test interviews with 10 experienced construction experts to check its suitability and completeness. Then, the questionnaire was revised according to these professionals' comments and feedback.

This research focused on both contractors and project owners, having experience in utilizing green technology in highway construction. Then, the total number of contractors from private highway companies and project owners from the Department of Public Works and Transportation in Cambodia who were familiar with the green technology was obtained. Since green technology in highway construction has just been recently initiated in Cambodia, the eligible respondents were relatively limited. These respondents were contacted to request their participation in the survey stage. Subsequently, 82 respondents were available to voluntarily disclose the essential information related to their previous experience. The questionnaire was sent out to 82 public or private contractors and project owners who each had more than 3 years of experience working in the highway construction industry in Cambodia. In addition, the respondents had fundamental knowledge and understanding of green concepts that ensured the respondent's ability to answer the designed questions. Google Forms was used to collect the data from all respondents. The respondents were divided into two groups: 51 contractors and 31 project owners. The results showed that 39 respondents had experience of more than 3 years, 26 respondents had more than 5 years, 11 respondents had more than 7 years, and 6 respondents had more than 10 years.

5. DIFFERENT PERSPECTIVE INVESTIGATION

The questionnaire survey was analyzed using the SPSS statistical software to identify different perspectives between the project owner and contractor groups. First, to show the reliability of the data set, a Shapiro-Wilk test was used to check the normality of the data collected. A significant level ≥ 0.05 proves that the data set is normal. Second, the mean value of each obstacle was calculated and ranked in each group. The standard deviation was also determined to identify the importance of obstacles having the same mean value. A smaller standard deviation was ranked higher. Third, an independent t-test was performed to determine whether categories of obstacles were significantly different between the two groups. The results are summarized in Table 2 that shows the different perspectives toward green technology adoption between the contractor and project owner groups. The results from the respondents indicated that most project owners considered the Training and knowledge and the Green material resource categories were the two most important for green concept adoption. The contractor group selected Green material resource and Government management as high-impact categories.

5.1 Contractor perspectives

For the contractor, the Green material resource category and the Government management category were the top-two categories that impacted contractors with similar mean values of 3.55 and 3.54, respectively. In the Green material resource category, the high-impact obstacle was the lack of research centers with an average value of 3.94. The contractor's perspective reflected that insufficient research work had been undertaken in Cambodia and this had a strong impact, because the precise information related to the green concept was not yet available. Many respondents expressed concern regarding insufficient green material being available in the market, as did the project owner group. In addition, databases and information were deficient. Both these obstacles with an average value of 3.43 seem to have the same strong influence on contractors. The materials and database needed to be acquired from other countries at a high cost and this required more time to be functional. The success of green concept adoption required cooperation from the government, as there was a perceived lack of support from the government to assist contractors with the correct goals for sustainable construction, as has been reported in another study regarding codes, regulations, information, finances, and promotion [18]. Most contractors considered that the government had tried to encourage construction projects to select green technology. However, the top management in government rarely provided supporting funds for applying the green concept. The lack of awareness from government can lead to the wrong guidance and support from government [18]. Similarly, Nusa et al. [17] noted in Malaysia the main barrier relating to government management was the shortage of policies in highway

construction, with a lack of control and effort by government to reinforce the green concept in that country. Besides the two high-impact categories mentioned above, other categories were influential to the contractors. Training and knowledge was ranked third, with an average value of 3.35. In addition, contractors faced difficulties with the way of using green technology, including designing and operating green equipment, so that this obstacle impacted them with an average value of 3.56. Other research reported that the lack of training regarding the green concept, meant contractors could not perform green actions well [7]. The uncertainty of using green technology leads to longer project delays, since unexpected issues can arise during the project operation. Similarly, Lam et al. [16] showed there were project delays and extra budgetary requirements caused by green technology operation. The extra budget was necessary when the primary cost of the project increased due to the use of green technology. This caused financial problem in green projects that directly inconvenienced contractors and project owners who consequently showed a lacking interest and awareness of the green concept, with green projects demand from related parties also being reduced.

5.2 Project owner perspectives

For the project owner, an average value of 3.34 from the Training and knowledge category was the highest rank among all six categories. The lack of knowledge regarding the green concept seemed to cause trouble in successfully applying green technology. The high-impact obstacle in this category was the limited ability of using green methods that substantially influenced project owners, with an average value of 3.80. The questionnaire indicated a lack of knowledge of green concepts from related parties in projects. Green concept education must be provided to any related stakeholders in construction projects so they can properly understand green technology in any stage of the construction. Hwang and Ng [19] identified a similar issue by identifying knowledge of the green concept as a critical barrier. Another obstacle in the current study was insufficient designing and technical expertise that had an average value of 3.54.

Table 2. Comparison of statistical results between groups regarding perspectives on impact level

	Obstacle	Project owners			Contractors			Difference between groups
		Mean	SD	Rank	Mean	SD	Rank	p-value
1	**Funding issue**	**3.13**		**4**	**3.13**		**6**	**0.984**
1.1	Increase in primary project cost.	3.06	0.96		3.41	0.94		
1.2	High costs of green materials.	3.35	1.01		3.50	0.80		
1.3	Project cost increase due to higher certification and designing.	2.87	0.95		2.94	0.92		
1.4	Capacity to deliver green materials for acceptable cost constraints.	3.12	0.84		3.11	0.86		
1.5	Financial problem from project delay.	2.96	0.91		2.88	1.07		
2	**Cooperation and attitude**	**2.58**		**6**	**3.15**		**5**	**0.030[a]**
2.1	Lack of interest from parties involved in projects.	2.54	1.05		3.09	1.17		
2.2	Lack of awareness of green technology quality and performance.	2.41	0.95		3.09	1.02		
2.3	Lack of cooperation between contractors and subcontractors.	2.41	1.17		2.98	1.22		
2.4	Incomplete international agreements for emission reduction.	2.77	1.49		3.19	1.18		
2.5	Lack of project owner's demand.	2.77	1.14		3.39	1.00		
3	**Green material resource**	**3.29**		**2**	**3.55**		**1**	**0.146**
3.1	Unable to quantify actual quantity of green materials used.	2.93	1.12		3.43	0.92		
3.2	Insufficient green material and no valid test.	3.16	1.21		3.43	0.94		
3.3	Insufficient information and database.	3.48	0.99		3.43	0.83		
3.4	Lack of research development center and facility.	3.58	1.25		3.94	0.78		
4	**Government management**	**3.13**		**3**	**3.54**		**2**	**0.026[a]**
4.1	Lack of inducement from government on green technology.	3.12	1.08		3.58	1.00		
4.2	High tax of green material in the country.	3.16	1.18		3.35	0.93		
4.3	Lack of financial support from government.	3.16	1.21		3.56	1.06		
4.4	Lack of green technology codes, regulations, and evaluation standards.	3.32	1.10		3.47	1.10		
4.5	Lack of promotion or exhibition supported by government.	3.06	1.06		3.56	0.92		
4.6	No green reward, certificate, or recognition programs to contractors.	3.00	1.26		3.56	0.98		
5	**Time and schedule**	**3.09**		**5**	**3.28**		**4**	**0.344**
5.1	Blocking green technology adoption due to short time and schedule.	2.96	1.19		3.39	1.02		
5.2	Adopting new green technology causes project delays.	3.03	1.19		3.05	0.98		
5.3	Long delivery time for green material from other countries.	3.29	1.13		3.39	1.04		
6	**Training and knowledge**	**3.34**		**1**	**3.35**		**3**	**0.970**
6.1	Lack of certification systems or training.	3.32	1.16		3.56	0.87		
6.2	Insufficient designing and technical expertise.	3.54	0.88		3.56	0.90		
6.3	High technological risks and dangers.	2.74	1.06		2.82	1.12		
6.4	Limited ability in using green technology methods.	3.80	0.87		3.45	0.92		

Note: [a] indicates a significant difference between mean values of owner's and contractor's perspectives at 95% confidence level (p-value <0.05).

Most project owners stated difficulty in choosing qualified contractors who could be responsible for a green project. Most contractors reported limited ability in using green technology in selecting materials and in the design stage. Similarly, Eisenberg et al. [34] identified the lack of experts in projects. Most contractors were unfamiliar with green technology systems and databases that was caused by a lack of training and certification of most contractors related to the projects [18]. That obstacle also impacted contractors with an average value of 3.32. Another critical category was Green material resource. The scarcity of research development was the highest impact obstacle in this category, with an average value of 3.58, showing that Cambodian research centers regarding the green concept are still lagging behind the efforts in other countries. Similarly, Sourani and Sohail [30] identified the lack of a research center for some information related to green technology use. Another obstacle was insufficient information and databases, with an average value of 3.48 that impacted project owners. Project owners also considered there was a lack of raw materials and databases regarding green technology, leading contractors to increase the bidding price in the initial stage of construction. Project owners said that most contractors always concerned about the high cost of green materials and databases. This issue led contractors to add extra expense to projects. Nevertheless, the Funding Issue and Government management categories impacted on project owners, with each having a mean value of 3.13. The disquiet of project owners to funding issues was important, since without a sufficient budget, some green projects are difficult to complete.

5.3 Comparison between contractor and project owner perspectives

Significant differences between the two groups appeared in the two categories of Government management and Cooperation and attitude. A contrasting idea between the parties was that most contractors mentioned the lack of responsibility from government to pursue green technology adoption, with insufficient databases from government leading to difficulties in the project phase. The information on each project from the government was not sufficient to help contractors process green operations. In contrast, the project owners disagreed, regarding the suitability of information and databases for projects. One government respondent also considered that all projects needed to follow a master plan developed according to international and national professional construction consultants before submitting the project plan to senior government management for approval. Thus, all databases and information should be provided to contractors during the construction phase. The reason for the disagreement on this issue seemed to be the lack of synergy between the two groups. Another issue was that some contractors required financial support from the government due to the expense of green materials and equipment. In reality, the lack of government funding was due to the complexity of procuring national funds from the Finance and Economics Ministry. Significantly different obstacles were also the lack of exhibitions and promotion of green technology and no reward and recognition program for contractors. The project owners from the government ministry said that both obstacles were unnecessary, while contractors preferred some rewards and certificates from the government to show their good standing in society when their companies chose to use a green concept. Most contractors also agreed on the need to have more workshops and exhibitions on green technology to educate people in the community to acknowledge the benefits of sustainability.

The two parties differed also in the category of Cooperation and attitude. Most project owners, who were government officials, stated about the perspective of contractors and their rejection of selecting a new concept for construction. Government staff said that most contractors preferred to seek more benefits and revenue rather than thinking about sustainable construction. Project owners seemed to consider obstacles in this category as having low impact, including lack of interest, lack of awareness of quality, lack of cooperation of contractors and subcontractors, and lack of client demand, while contractors considered these as high impact obstacles.

The contractors and project owners shared similar opinions regarding the other four categories of Funding issue, Green material resource, Time and schedule, and Training and knowledge. Based on the independent t-test, these four categories had similar but not significantly different mean values that represented common perspectives from both groups. Contractors and project owners noted there was an increase in the primary project cost when selecting green technology, as the green materials were costly to purchase and had added delivery costs as they were mainly sourced from abroad. Furthermore, the design requirements for green projects were higher than for conventional construction. All these factors resulted in green projects costing more than equivalent normal construction. For some green materials, there were inadequate valid testing procedures, standard codes, and databases that affected both parties, as they needed to spend time to discover available green markets in other countries, resulting in long delays. Most contractors and projects owners agreed on the need to provide more training and knowledge on the green concept to related stakeholders, so all related parties had sufficient understanding of the theory and practice of the green concept. Due to the low popularity of the green concept in the country, the knowledge of the people was limited, resulting in engineers not focusing on new green concepts in the construction sector.

6. IDENTIFICATION OF ROOT CAUSES

After identifying the significant categories of obstacles, the two highest impact categories from each group were selected to determine root causes and seek solutions to implement green concept adoption. Cause-and-effect diagrams were used to map root causes and solutions for most impact categories from various groups. The results in Table 2 show that the top-two categories for the contractor group were: (1) Green material resource and (2) Government management, while the top-two for the project owner group were: (1) Training and knowledge and (2) Green material resource.

The cause-and-effect diagrams included 14 obstacles from both groups, with the roots causes of each obstacle placed next to them. The root causes of obstacles were determined from a comprehensive literature review before interviewing two public and two private professional highway experts. Experts A and B from the contractor group were experienced highway engineers working in private construction projects with more than 20 years and 15 of experience, respectively. Experts C and D from the project owner group were government staff working in the Ministry of Transportation in Cambodia.

Expert C had around 25 years of experience with highway construction and was be a professor teaching civil engineering at a private university, while Expert D had 15 years of experience in highway construction. Root causes from the literature and interviews were merged to develop competent root causes diagrams. Root causes not related to highway construction were discarded from the diagrams. Finally, solutions and regulations to reinforce green technology adoption were proposed based on root causes. Figures 2-4 show the three root causes diagrams from the high-impact categories.

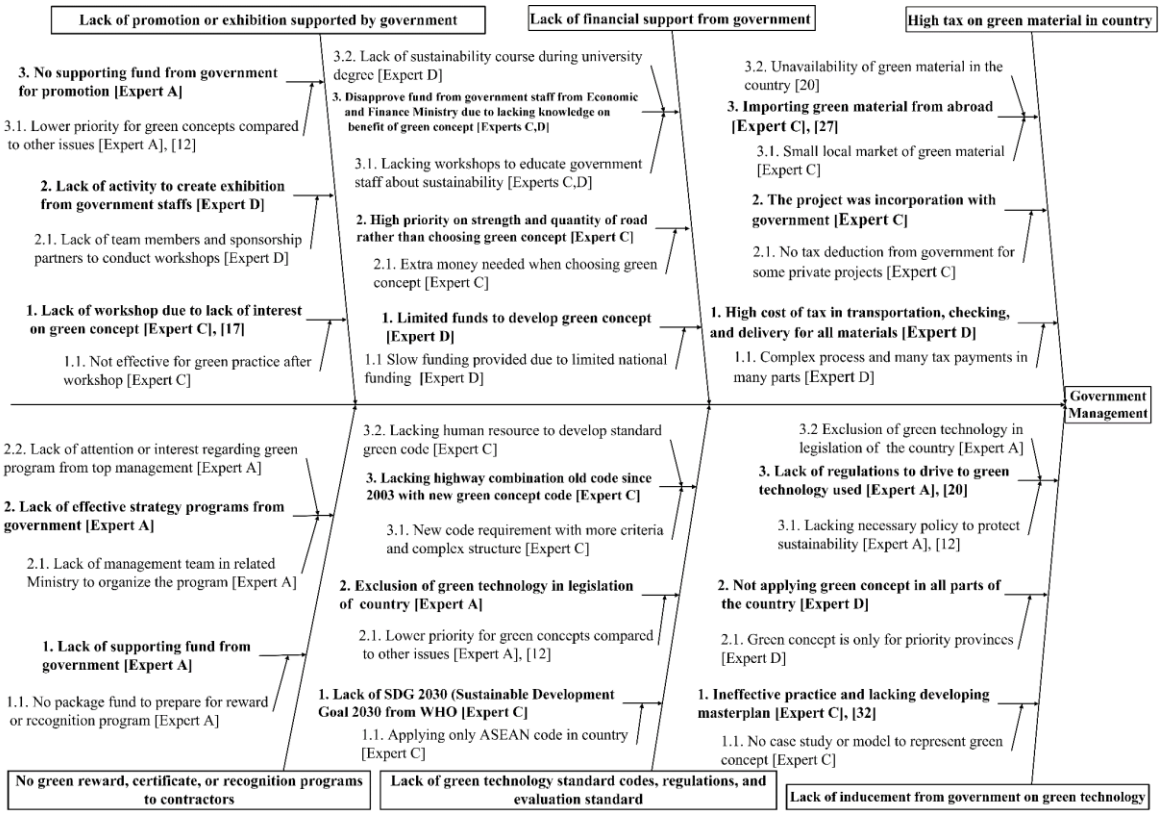

Figure 2. Government management cause-and-effect diagram

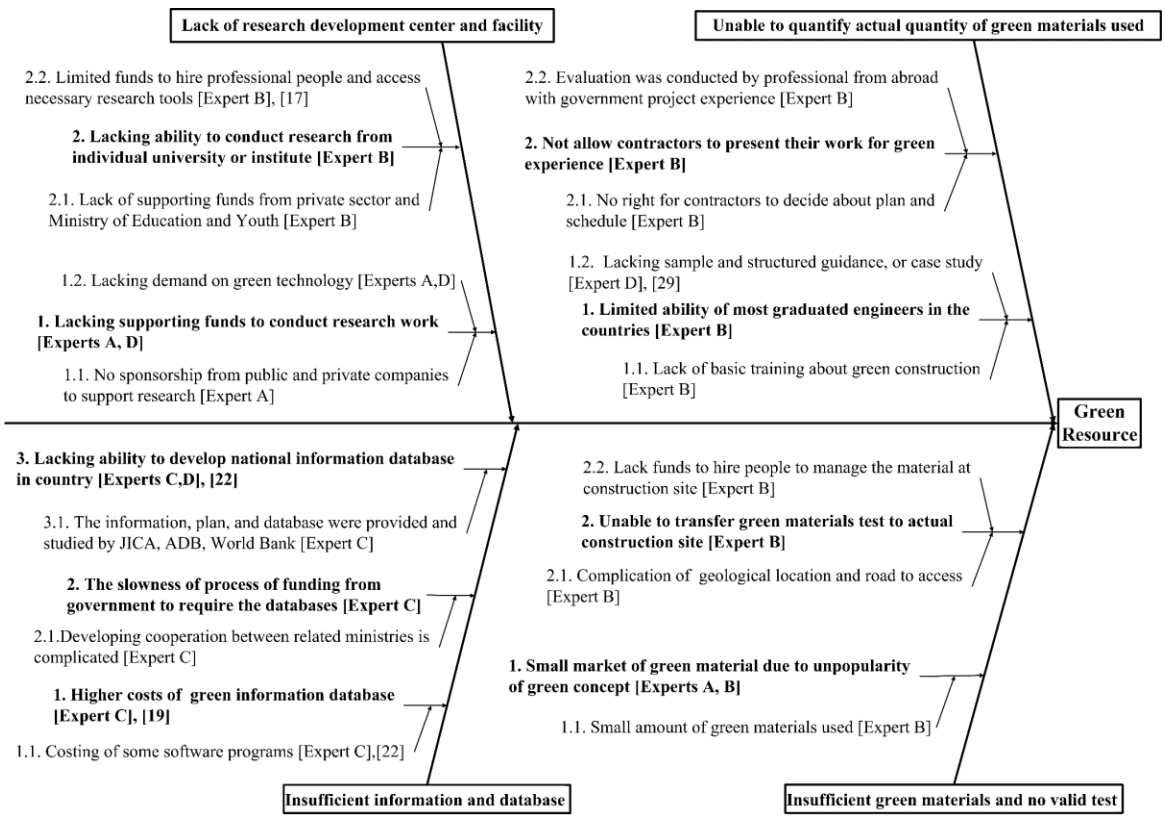

Figure 3. Green resource cause-and-effect diagram

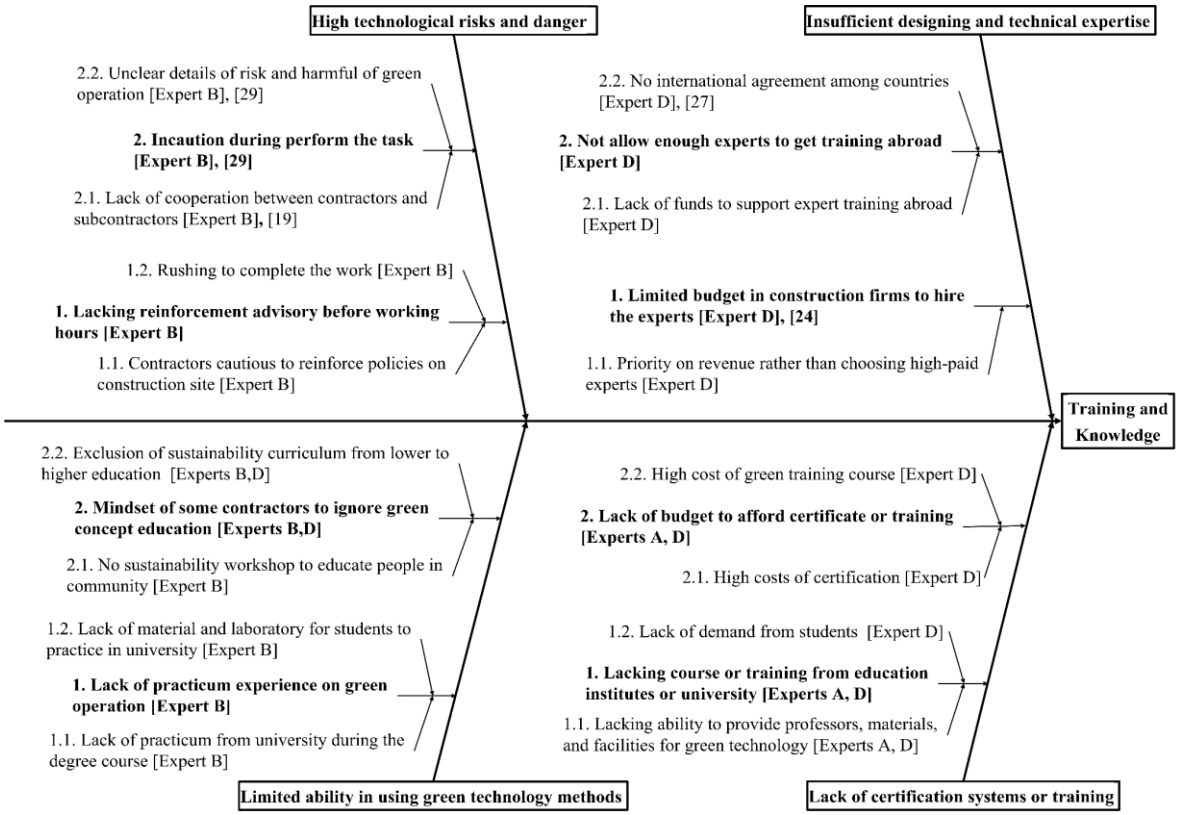

Figure 4. Training and knowledge cause-and-effect diagram

6.1 Contractor perspectives

Experts A and B from the contractor group expressed some opinions related to the reality of Cambodian highway construction. Both these experienced experts pointed out some main root causes that have led to green technology adoption failure.

First, the failure of green adoption was due to the lack of budget. Expert A provided some examples related to the root cause of the lack of exhibition and green rewards for contractors. The real problem behind those obstacles was the lack of a supporting budget. In addition, expert A identified other obstacles, such as the lack of a research center, or a green certificate that was also related to insufficient funding. Having a reasonable budget was a priority factor to push the green concept successfully. Expert A suggested related ministries and senior government officials should separate packaged funding to any part of construction by applying the green concept in the future. The lack of sufficient budget to hire professionals to conduct the research and acquire research facilities has led to the scarcity of research centers.

The other expert from the contractor group shared similar opinions. Expert B shared the idea of insufficient budget for improving green technology adoption. A long time and high cost are necessary to process step-by-step improvements to transform the education system to include the green concept in the school curriculum from lower to higher levels of education. Expert B proposed that the government allocate an extra budget to support the education system by providing students with more courses and training on green concepts. This would lead to the green concept being understood by all age groups in the country.

6.2 Project owner perspectives

Experts C and D who were government officials from the project owner group provided opinions toward the issues of green concept content in Cambodian construction industry.

Expert C expounded on the issue of cooperation between the contractor and government. To make the green concept process run smoothly, it was very important to request contractors to keep sustainability as a prime goal and not to focus too much solely on benefits. As a result, the government should play an important role in making the green concept successful and in solving other issues that arise in projects. Expert C added some ideas regarding insufficient budget allocation to proceed with the green concept throughout the country to offset the high cost of green concept projects and the current limited funding by the Cambodian government.

Similarly, expert D raised the lack of budget for developing the green concept. Expert D stated that in the Cambodian construction sector, the government was starting to consider the green concept and the smart city concept in prioritized provinces. However, the government attempts made it hard to understand the benefit of the green concept. Some new infrastructure was connected from province to province and was starting to apply the green concept. However, some projects could not apply the green concept due to limited government funding. As a result, the government needed to select priority projects and proceed step-by-step, following the “Rectangle Strategy”. Expert D suggested people in the community should cooperate closely with government to improve the green projects in the city. People who live in a region that applies green concepts will get more benefits in the future. Private companies that cooperate with the government regarding green concept projects should place greater effort on achieving the main goal of sustainability rather than thinking about revenue.

Table 3. Summary of similarities and differences from each expert's perspective

Suggestion	Perspective within-group		Perspective between groups
	Contractors	Owners	
Providing extra funds to support research work.	✔	N/A	N/A
Providing support budget for exhibition and reward	✔	N/A	N/A
Providing budget for data collection and mission from government	✔	N/A	N/A
Show high commitment to green practice	N/A	✔	N/A
Provide green knowledge to the lower education levels	✔	✔	✔
Create workshops to educate people in community about green concept.	✔	✔	✔
Provide training to educate contractors about green technology used.	✔	✔	✔
Provide authority for contractors to decide on matters	✔	×	×
Provide precise information and databases	✔	×	×

Note: ✔ similarity, x: difference, N/A: nothing provided

6.3 Comparison between contractor and project owner perspectives

Besides the perspectives within each group, 4 experts from both parties also shared the same opinions on the root causes. Experts A and B from the contractor group emphasized the importance of green concept knowledge. The green concept must be promoted initially at lower education levels, such as secondary school and high school, and then continue to the university degree level. This would assist people from younger generations to gain more knowledge and to understand the benefits of the green concept. In the future, the green concept will be an inevitable factor in society and people's lives. In agreement with the contractor group, experts C and D from the project owner group concluded the attitude toward the green concept was critical. Both these contractor experts mentioned that contractors and related workers from other ministries would accept green concept plans even if their costs were higher than for normal projects, since they understood the high value of the green concept. As a result, green knowledge had great potential to encourage green concept implementation by everyone in the community.

Both experts from the contractor group also suggested governments delegate the authority to contractors to decide and discuss initial planning before starting projects. Expert A stated that most projects always followed government decisions, including the bidding process, research mission, editing work, and penalties. In addition, expert B was concerned that in some provinces, his company had to allocate a high budget to collecting data, since the budget from the government was always delayed and had to pass through many parts of the ministry before getting to contractors. As a result, contractors needed to allocate their funds for this issue. Regarding this issue, expert C from the project owner group mentioned about contractors' work in the bidding process as they provided insufficient information and detailed pricing on each item. Some items and prices that contractors proposed were not suitable for projects, leading to some projects having problems in the future. Some contractors could not finish the work by the deadline and always requested extra time. As a result, government needs to authorize some essential tasks in the projects. A summary of the similarities and differences for the suggestions from the 4 experts is provided in Table 3.

7. CONCLUSIONS

The green concept is a vital idea to improve the construction industry and environment and to develop a future sustainable community. The identification of the root causes of critical obstacles on green technology adoption from the perspectives of both contractors and project owners can help to evaluate the real issues in the construction industry. The results indicated that the Government management and Cooperation and attitude categories were the two significantly different categories between both parties, with contrasting ideas presented in the survey. Nevertheless, the Training and knowledge and Green material resource categories were the top-two having the most impact according to the project owners, while the contractors considered the Green material resource and Government management categories were at the top of their list. Additionally, the root causes of obstacles using a cause-and-effect diagram presented the details of problems from the high-impact categories according to the perspectives of both contractors and project owners. This paper could be a key to highlighting issues for highway practitioners and government agencies to provide insight into essential solutions for the highway industry and to develop future regulations to reinforce sustainability in Cambodia. The findings of this research will shed light on the adoption of the green concept, which assists to increase awareness of the implementation of green technology in highway construction. In addition, this research contributes to an increasing number of future green practices in highway construction, where most construction stakeholders appear to be unfamiliar with the green concept. Then, further investigation can be conducted to strengthen the analytical results from this study. However, the study was based on real-world information from the Cambodian construction industry combined with a literature review. Additional respondents and data from other perspectives in developing countries are recommended to identify different perspectives on green concept adoption in the region.

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REFERENCES

[1] Avetisyan, H.G., Miller-Hooks, E., Melanta, S. (2012).

Decision models to support greenhouse gas emissions reduction from transportation construction projects. Journal of Construction Engineering and Management, 138(5): 631-641. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000477

[2] Limsawasd, C. (2017). GHG emission quantification for pavement construction projects using a process-based approach. Engineering Applied Science Research, 44(1): 27-33. https://doi.org/10.14456/easr.2017.4

[3] Limsawasd, C., Athigakunagorn, N. (2017). An application of discrete-event simulation in estimating emissions from equipment operations in flexible pavement construction projects. Engineering Journal, 21(7): 197-211. https://doi.org/10.4186/ej.2017.21.7.197

[4] Gambatese, J.A., Rajendran, S. (2005). Sustainable roadway construction: Energy consumption and material waste generation of roadways. Paper Presented at the Construction Research Congress 2005: Broadening Perspectives, San Diego, California, United States. https://doi.org/10.1061/40754(183)21

[5] Khun-anod, K., Limsawasd, C. (2019). Pre-project planning process study of green building construction projects in Thailand. Engineering Journal, 23(6): 67-81. https://doi.org/10.4186/ej.2019.23.6.67

[6] Geng, X., Wen, Y., Zhou, C., Xiao, C. (2017). Establishment of the sustainable ecosystem for the regional shipping industry based on system dynamics. Sustainability, 9(5): 742. https://doi.org/10.3390/su9050742

[7] Shi, Q., Zuo, J., Huang, R., Huang, J., Pullen, S. (2013). Identifying the critical factors for green construction–an empirical study in China. Habitat International, 40: 1-8. https://doi.org10.1016/j.habitatint.2013.01.003

[8] Gunawansa, A., Lutchmeeduth, B., Kua, H., Piana, V. (2011). Approaches to Climate Change Mitigation and Adaptation-the Cases of Mauritius and Singapore, 1-8.

[9] Somboonpisan, J., Limsawasd, C. (2021). Environmental weight for bid evaluation to promote sustainability in highway construction projects. Journal of Construction Engineering Management, 147(4): 04021013. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002005

[10] Morton, B. (2008). Analysing the implementation of sustainable public procurement policies. Paper Presented at the 3rd International Seminar on Public Procurement Asuncion, Barbara Morton Defra / Sustainable Procurement Ltd.

[11] Kang, Y., Jin, Z., Hyun, C., Park, H. (2018). Construction management functions for developing countries: Case of Cambodia. Journal of Management in Engineering, 34(3): 05018004. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000609

[12] Durdyev, S., Zavadskas, E.K., Thurnell, D., Banaitis, A., Ihtiyar, A. (2018). Sustainable construction industry in Cambodia: Awareness, drivers and barriers. Sustainability in Construction Engineering, 10(2): 392. https://doi.org/10.3390/su10020392

[13] Ng, S.T., Skitmore, M., Cheung, J.N.H. (2013). Organisational obstacles to reducing carbon emissions in Hong Kong. Habitat International, 40: 119-126. https://doi.org/10.1016/j.habitatint.2013.03.004

[14] Chowdhury, M.R.I., Srabon, M.R.T. (2018). Barriers to Adoption of sustainable construction practices in Khulna city. Paper Presented at the 4th International Conference on Advances in Civil Engineering 2018 (ICACE 2018): CUET, Chittagong, Bangladesh. https://www.kuet.ac.bd/webportal/ppmv2/uploads/1549947541139.pdf.

[15] Powmya, A., Abidin, N.Z. (2014). The challenges of green construction in Oman. International Journal of Sustainable Construction Engineering Technology, 5(1): 33-41. https://penerbit.uthm.edu.my/ojs/index.php/IJSCET/article/view/867.

[16] Lam, P.T., Chan, E.H., Chau, C., Poon, C., Chun, K. (2009). Integrating green specifications in construction and overcoming barriers in their use. Journal of Professional Issues in Engineering Education and Practice, 135(4): 142-152. https://doi.org/10.1061/(ASCE)1052-3928(2009)135:4(142)

[17] Nusa, F.N.M., Endut, I.R., Ishak, S.Z. (2015). Challenges of green highway concept towards implementation of green highway. Applied Mechanics and Materials, 747: 3. https://doi.org/10.4028/www.scientific.net/AMM.747.3

[18] Djokoto, S.D., Dadzie, J., Ohemeng-Ababio, E. (2014). Barriers to sustainable construction in the ghanaian construction industry: Consultants perspectives. Journal of Sustainable Development, 7(1): 134. https://doi.org/http://dx.doi.org/10.5539/jsd.v7n1p134

[19] Hwang, B.G., Ng, W.J. (2013). Project management knowledge and skills for green construction: Overcoming challenges. International Journal of Project Management, 31(2): 272-284. https://doi.org/10.1016/j.ijproman.2012.05.004

[20] Creedy, G.D., Skitmore, M., Wong, J.K. (2010). Evaluation of risk factors leading to cost overrun in delivery of highway construction projects. Journal of Construction Engineering Management, 136(5): 528-537. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000160

[21] Chan, A.P., Darko, A., Ameyaw, E.E., Owusu-Manu, D.G. (2017). Barriers affecting the adoption of green building technologies. Journal of Management in Engineering, 33(3): 04016057. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000507

[22] Hwang, B.G., Tan, J.S. (2012). Green building project management: Obstacles and solutions for sustainable development. Sustainable Development, 20(5): 335-349. https://doi.org/ https://doi.org/10.1002/sd.492

[23] Chan, A.P.C., Darko, A., Olanipekun, A.O., Ameyaw, E.E. (2018). Critical barriers to green building technologies adoption in developing countries: The case of Ghana. Journal of Cleaner Production, 172: 1067-1079. https://doi.org/10.1016/j.jclepro.2017.10.235

[24] Loosemore, M., Sunindijo, R.Y., Zhang, S. (2020). Comparative analysis of safety climate in the Chinese, Australian, and Indonesian construction industries. Journal of Construction Engineering and Management, 146(12). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001934

[25] Luthra, S., Kumar, S., Garg, D., Haleem, A. (2014). Barriers to renewable/sustainable energy technologies adoption: Indian perspective. Renewable and Sustainable Energy Reviews, 41: 762-776. https://doi.org/10.1016/j.rser.2014.08.077

[26] Aldossary, N.A., Rezgui, Y., Kwan, A. (2015). An Investigation into factors influencing domestic energy consumption in an energy subsidized developing

economy. Habitat International, 47: 41-51. https://doi.org/10.1016/j.habitatint.2015.01.002
[27] Chen, J.J., Chambers, D. (1999). Sustainability and the impact of Chinese policy initiatives upon construction. Construction Management and Economics, 17(5): 679-687. https://doi.org/10.1080/014461999371286
[28] Santos, G. (2017). Road transport and CO_2 emissions: What are the challenges? Transport Policy, 59: 71-74. https://doi.org/10.1016/j.tranpol.2017.06.007
[29] Selim, A.M., Saeed, D.M. (2021). Infrastructure projects for green cities between implementation challenges and efficiency indicators. Transport Policy, 5: 6. https://doi.org/10.13189/cea.2021.090208
[30] Sourani, A., Sohail, M. (2011). Barriers to addressing sustainable construction in public procurement strategies. Proceedings of the Institution of Civil Engineers-Engineering Sustainability, 164(4): 229-237. https://doi.org/10.1680/ensu.2011.164.4.229
[31] Stern, P.C., Gardner, G.T., Vandenbergh, M.P., Dietz, T., Gilligan, J.M. (2010). Design principles for carbon emissions reduction programs. Environmental Science and Technology, 44(13): 4847-4848. https://doi.org/10.1021/es100896p
[32] Williams, K., Dair, C. (2007). What is stopping sustainable building in England? barriers experienced by stakeholders in delivering sustainable developments. Sustainable Development, 15(3): 135-147. https://doi.org/10.1002/sd.308
[33] Zhang, J., Yang, Y. (2018). The challenges of Yunnan's engagement on sustainable highway infrastructure project in the context of belt and road initiative. Paper Presented at the 3rd International Symposium on Asian B&R Conference on International Business Cooperation (ISBCD 2018): October 20th, Kunming, China. https://doi.org/10.2991/isbcd-18.2018.59
[34] Eisenberg, D., Done, R., Ishida, L. (2002). Breaking down the barriers: challenges and solutions to code approval of green building: Development Center for Appropriate Technology Tucson, AZ.