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Investigating low-carbon transport options in Dhaka, Bangladesh

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A proSPER.Net Research Proposal

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1 Background

1.1 Sustainable Development

Sustainable development is vital for the future of humanity. With issues such as climate change and population growth, it is essential that adequate thought is given to the impacts and future viability of current developments. To facilitate action around sustainable development, the United Nations has developed seventeen Sustainable Development Goals (SDGs). They cover a range of issues that ultimately aim to end poverty, protect the planet and ensure that all people enjoy peace and prosperity (United Nations, 2017).

Sustainable development is a complex problem. The issues relating to the seventeen sustainable development goals (SDGs) are intrinsically linked, meaning progress made on one goal will often benefit other goals. Given the global population move towards living in megacities, the United Nations has acknowledged that 'Sustainable transport is essential to achieving most, if not all, of the proposed Sustainable Development Goals' (United Nations, 2017). In 2012, the United Nations released a document titled "The Future We Want" in which they state that "Sustainable transportation can enhance economic growth and improve accessibility. Sustainable transport achieves better integration of the economy while respecting the environment" (United Nations, 2012). Given the importance of sustainable transport in ensuring sustainable development, research in this area is critical. A literature search in March of 2018 found that factors impacting the development of low carbon transport have been investigated in most megacities. However, this information is lacking for the city of Dhaka in Bangladesh.

1.2 Dhaka's sustainable development issues

Dhaka has a major sustainable development issue. With a population over 18 million people, the capital of Bangladesh is not only one of the largest cities in Asia, but also one of the most polluted. As well as having major issues with water quality, it consistently ranks as the city with the worst air pollution in the world (Dhaka Tribune, 2018), presenting major public health problems. Despite this, carbon dioxide emissions have been increasing and this trend is not changing (C40 Cities, 2018). In the past decade the number of cars in Dhaka has doubled, compounding issues of air quality while also causing increased traffic congestion and making areas of the city nearly inaccessible during peak travel times. With the increasing population and severe cost of inaction, it is vital to investigate carbon reduction strategies to protect health in Dhaka. Furthermore, given the severity of the air pollution

problems and traffic congestion, it would seem pertinent to start with carbon reduction strategies within the transportation sector.

Many of the problems faced today could have been avoided if our cities were better designed and managed. Unfortunately for established megacities such as Dhaka, sustainable initiatives, such as green infrastructure, transport corridors for public and active transport and walkable suburbs, are having to be retrofitted to existing crowded spaces. Given the high cost of such actions, it is important that we research and collaborate with stakeholders on the planning of these initiatives to ensure they are effectively implemented.

2 Problem Statement

2.1 Research Question

The primary aim of this research is to answer the following research question:

1. What factors affect the move toward low carbon transport in Dhaka?

2.2 Objectives

To answer the above research question, several specific objectives have been

1. Characterize the carbon emissions of current and potential transport options in Dhaka
2. Identify factors affecting low carbon transport in Dhaka
3. Analyze the interrelations between economic, environmental and policy factors affecting low carbon transport in Dhaka
4. Provide recommendations on potential low carbon transport options for Dhaka

3 Methodologies

3.1 Methods for characterizing the carbon emissions of current and potential transport options in Dhaka

A systematic quantitative literature review will be conducted to identify the carbon emissions of current and potential transport options in Dhaka by systematically searching and categorising the relevant literature. We will seek to categorise and tabulate what researchers have suggested are the most important transport options and factors affecting low carbon transport. The Preferred Reporting Items for Systematic Review Recommendations (PRISMA) protocol (Moher, Liberati, Tetzlaff, Altman, & The, 2009) following the steps outlined in Pickering and Byrne (2014) will be used, as these have

been used successfully in a range of past studies (Ballantyne & Pickering, 2015; Guitart, Pickering, & Byrne, 2012; Roy, Byrne, & Pickering, 2012; Steven, Pickering, & Guy Castley, 2011). The approach seeks to be both robust and replicable, minimising potential biases that can occur in narrative reviews, and by being transparent in selecting and categorising the papers according to specific eligibility criteria (Petticrew, 2001). The approach documents (i) where, when, and by whom research was published; (ii) the geographical spread of the literature; (iii) types of methods used; (iv) types of subjects examined; (v) types of variables measured; (vi) different disciplines assessing the topic; and (vii) the types of results obtained (Guitart et al., 2012; Pickering & Byrne, 2014; Roy et al., 2012). The approach begins with the identification of a topic, in this case: "Methods for characterizing the carbon emissions of current and potential transport options and factors affecting low carbon transport". The second step involves database search and priority selection. The third step is content assessment and study selection. Finally, data collection processes are performed, extracting and handling data from within each paper for use in the review. Based on the result of this review, a list of most important transport option and factors affecting low carbon transports will be created. These results will be used later to analyse the interrelations between economic, environmental and policy factors affecting low carbon transports and also to provide recommendations on the transport options in Dhaka. Table 2 shows the review protocol, and Figure 1 shows the flow chart of the processes.

Table 1: Summary of the methods proposed to investigate Objective 1

Sub Objective	Data Collection	Sources of data	Data Analysis
Conduct a systematic literature review to identify the carbon emissions of current and potential transport options in Dhaka	Systematic Quantitative Literature review (PRISMA protocol)	Secondary data from literature	Meta-analysis

Table 2: Review protocol for the systematic literature review to identify the carbon emissions of current and potential transport options in Dhaka

Review step	Information collected
Title	Develop a working title
1: Research questions	1. What the methods were used regarding evaluation the carbon emissions of current and potential transport options, and factors affecting low carbon transport? 2. Where is there research on these issues, where was the research undertaken, who has undertaken the research and where was it published? 3. What evaluation techniques are there for assessing these issues? 4. What methods have been used to identify factors affecting low carbon transport?

	5. What most important factors were found out in the literature for inclusion in analysing the interrelations between various factors affecting low carbon transports?
2: Search terms used in electronic databases	The carbon emissions, potential transport options, factors affecting low carbon transport, recommendations on potential low carbon transport options, Methods for characterizing the carbon emissions
3: Electronic databases searched	• Google Scholar • Web of Science • ScienceDirect • SCOPUS
4: Search strategy and Initial selection	Author, Year, Title, Abstract, Key-words, Journal
5: Content assessment & Eligibility criteria	**Group 1 (all answers yes):** 1. Is the publication an original research paper'? (yes/no) 2. Are the objectives of the article clear? 3. Are the results related to the specific topic and research questions of this study? (yes/no) 4. The main findings of the study are clear? (yes/no) **Group 2 (at least one answer yes):** 1. Does the study evaluate the carbon emissions of current and potential transport options? 2. Does the study present a method used to identify factors affecting low carbon transport? 3. Does the study present a methodology for above issues? 4. Does the study present the most important factors affecting low carbon transport? 5. Does the study present the most important transport options to low carbon emissions?
6: Data collection process, cross-check and synthesis of results	**Basic data on the paper** Paper titles, Author, Journal, Year of publication, Study location **Methodological Information** Target area, Data collection method, Analysis Method, Unit of Analysis **Results** The most important transport options to decrease the carbon emissions The most important transport options to low carbon emissions Types of Factors

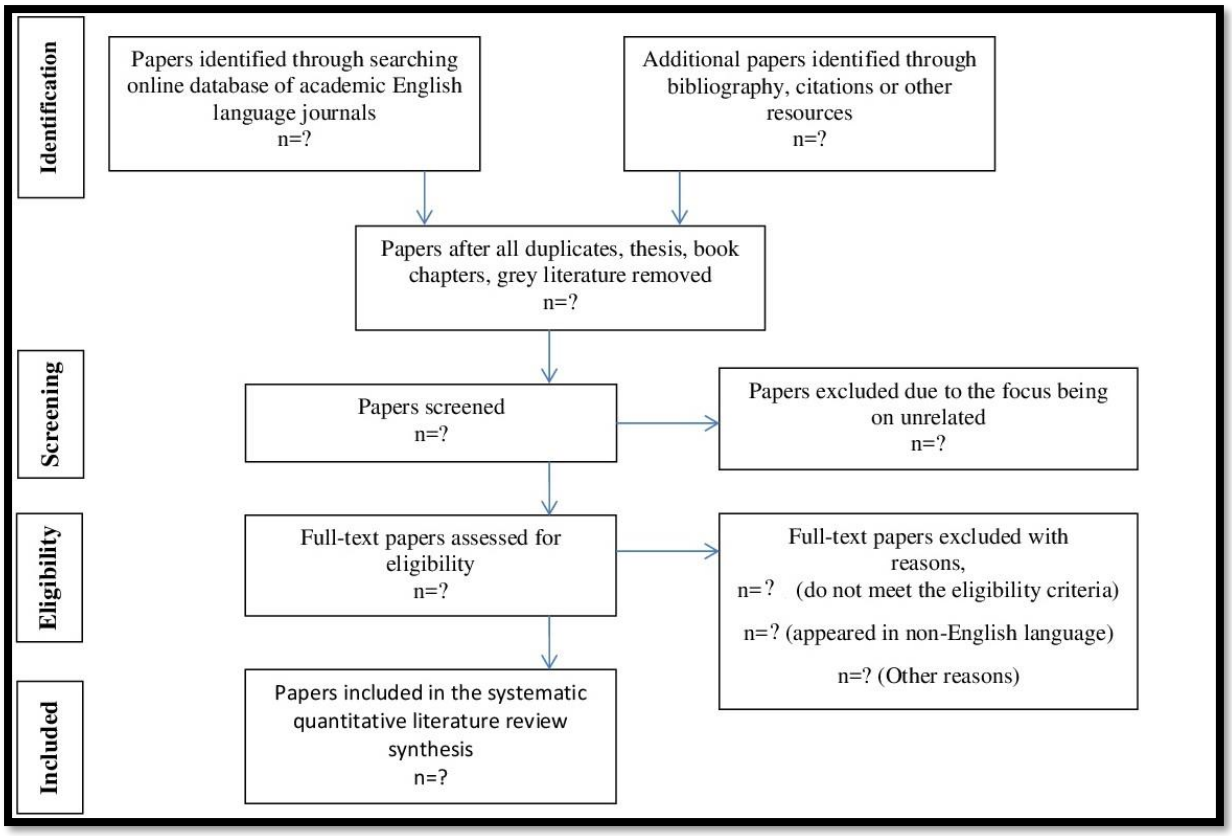


Figure 1: Flow chart of information through the different phases to compile the materials for a systematic quantitative literature review process based on PRISMA technique (Moher et al., 2009)

3.2 Methods for identifying the factors affecting low carbon transport in Dhaka

A Delphi process with a panel of experts will be used to develop a framework of the factors affecting low carbon transport in Dhaka. The Delphi technique is a process of deriving group consensus for any topic when the required information is not available using another systematic approach (Pikora, Giles-Corti, Bull, Jamrozik, & Donovan, 2003). In The Delphi technique, the group survey is an efficient and dynamic process. The main features of the survey in Delphi technique are an anonymous, written, multi-stage survey process and controlled feedback (von der Gracht, 2012). The aim of using this approach is to rank the factors in terms of which ones contribute most to low carbon transport and therefore should be included as main elements of the transport options from extensive list. Another aim is to develop a questionnaire that will be used to gain the citizen's perspective and preference of low carbon transport options.

The first round will be an online survey with key experts from relevant disciplines and the second round will be a workshop. The aim of first round is to gain primary experts' perceptions and to examine the content validity of the extensive list of potential factors affecting low carbon transport developed in the literature review. The draft of hierarchical framework obtained from the literature round will

be organized in form of questionnaire to be used for the second round. In the second round, the same experts who participated at the first round will be invited to attend the workshop activity of the study. They will be provided a sheet listing the revised set of factors affecting low carbon transport in Dhaka that emerged based on the results from the first phase of Delphi study "online survey". Then they will be asked to identify exactly which factors should be considered for Dhaka and which once should be removed. Experts will have opportunity to make changes to their previous decisions in the online survey in response to workshop debate. The relative importance of each factor will be determined by collating the results from the experts at this stage. After analysing the results, it will be decided whether there is a need for an additional round or the Delphi process should be stopped and the results finalised.

The main criticism of using the Delphi method is that standard analysis procedures have not uniformly been developed. Consensus measurement and stability can be considered the main goals and a valuable component of data analysis and interpretation of a Delphi study. Responses are considered in consensus when the answers among participants tend to converge with decreasing variability in scores. The consistency of responses between successive rounds of a study infers that responses are considered stable (Flanders, 1988; Seagle & Iverson, 2001). Various statistical procedures have been used on the data in a Delphi study to determine convergence of opinion and stability in Delphi studies. The most commonly used statistical methods of consensus measurement include for example means, standard deviations, medians, interquartile ranges, and a composite score (von der Gracht, 2012). The Wilcoxon matched-pairs signed-ranks test and Pearson Product-moment correlation coefficients have also been used in other Delphi studies for measuring the stability in responses between successive rounds (von der Gracht, 2012).

For this study, the data analysis will comprise of primarily descriptive statistics using a practical, non-parametric approach (von der Gracht, 2012). The following computation will be performed for data analysis: i) a composite score for each item will be calculated to rank order the items; ii) medians and interquartile ranges will also be calculated for each item in rounds one and two as measures of convergence of opinion and consensus measurement. The Wilcoxon matched-pairs signed-ranks test and Pearson Product-moment correlation coefficients for each round will also be calculated to further determine convergence of opinion and for measuring the stability between rounds.

A summary of the methods proposed to investigate objective 2 is presented in Table 3.

Table 3: Summary of the methods proposed to investigate Objective 2

Sub Objectives	Data Collection	Sources of data	Data Analysis
2.1: Economic factors 2.2: Environmental factors 2.3: Policy factors	Literature review Delphi process with expert panel	Literature review Experts	Consensus: Interquartile ranges IQR Composite Score Stability: Wilcoxon Matched-Pairs Signed-Ranks Test Intraclass correlation coefficient ICC
2.4: Citizen's perspective	Online & face-to – face street survey: Likert-type scales Open-ended questions	Citizens of Dhaka	Semi-quantitative Qualitative

3.3 Methods for Analyzing the interrelations between economic, environmental and policy factors affecting low carbon transports in Dhaka

The result from the literature review and Delphi process will provide the factors affecting the low carbon transport options in Dakka. The next step is to identify the most important relationships between these determined factors, summarized in Table 4.

Table 4: Summary of the methods proposed to investigate Objective 3

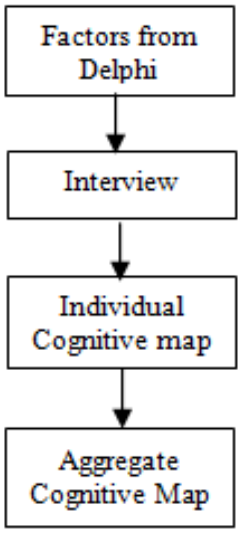
Sub Objectives	Data Collection	Sources of data	Data Analysis
3.1 Create a nexus to describe the interrelationships between the economic, environmental and policy factors	Literature review Delphi process with expert panel	Data collected in Objective 2	System Science approach (fuzzy cognitive map)

A system science approach will be used with a fuzzy cognitive map (FCM) approach to identify the interrelationships between the components of each factor. In general, a FCM is a knowledge-based soft computing method that produces a conceptual network or a graph that is used to describe system behaviors and edges that represent the causal links between nodes (Guiterez et al, 2017).

Giabbanelli, Weir and Mago (2012), explain that the model created using FCM can give the relationships between factors, and also the strength of these relationships. Papageourgiou (2014) states that a FCM is developed based on expert's experiences and can identify new knowledge or information about a system without empirical data. One benefit of FCM is that its pictoral display is easily understandable by the experts with minimal need for explanation or training (Giabbanelli, Weir and Mago, 2012). Based on the concept that has been provided by Glykas and Giabannelli (2012), the structure of FCMs are :

1. The FCM structure map is determined by nodes that have causality
2. The causal relation between nodes is marked by number 0 or 1 where 0 defines no causal relation between two nodes and 1 shows a causal relation between two nodes.
3. The causal relation also can be defined by (-1 , 0 , 1), where:

+ 1 is positive causal. This means if a quality in node A is higher or lower then a quality in node B will also be higher or lower; - 1 is negative (inversely) causal. This means that if a qualty in node A is higher then quality in node B will be lower; 0 means there is no causality.



The methodology to create FCM is modified from Guiterez et al (2017) to include 4 main steps. The only difference with the original method is the first step and how to gather data from the experts (Figure 2).

Figure 2: The proposed methodology to create a fuzzy cognitive map

The first step is defining factors described in part 4.2 using the Delphi Method. The output of this activity is a list of factors affecting low carbon transport options. The second step is to conduct interviews with experts to identify factors, indicators and inter-connections based on their expert knowledge. The interview is planned to involve around twenty experts with a variety of backgrounds such as environment, transportation, economy, etc. Experts with a variety of backgrounds such as education, government and industry will also be sought. Semi-structured interviews will be used to collect this data. The third step is to create the Fuzzy Cognitive Map based on each interview. The

output of this step is an individual fuzzy cognitive map for each expert. The last step is to create a main Fuzzy Cognitive Map. At this step, causal loop diagrams (CLDs) that represent a system will be created through the aggregation concept. Components will be chosen based on the rule of being identified by experts at least 3 times. The output of this step is to create a general Fuzzy cognitive map that represents the relation between factors affecting the low carbon transport options in Dhaka.

3.4 Methods to provide recommendations on the transport options for Dhaka

The purpose of this stage of the research is to provide recommendations for interventions to decrease the carbon output of Dhaka transport. In order to do this, a series of sub-objectives have been developed (Table 5).

Table 5: Summary of the methods proposed to investigate Objective 4

Sub Objectives	Data Collection	Sources of data	Data Analysis
4.1 Map the distribution of transport carbon emissions in Dhaka	Literature review	From Objective 1	Resample management (Arcgis)
4.2 Identify the hotspots of carbon emissions	Literature review	From Objective 1	Resample management (Arcgis) Grid analysis Autocorrelation analysis
4.3 Set different scenarios of transport options in Dhaka	Literature review	Experts Bureau statistics	Dynamic System modeling
4.4 Provide recommendations for the interventions/select the best scenario	Focus group with experts Secondary data	Experts Literature review	Priority analysis SWOT analysis

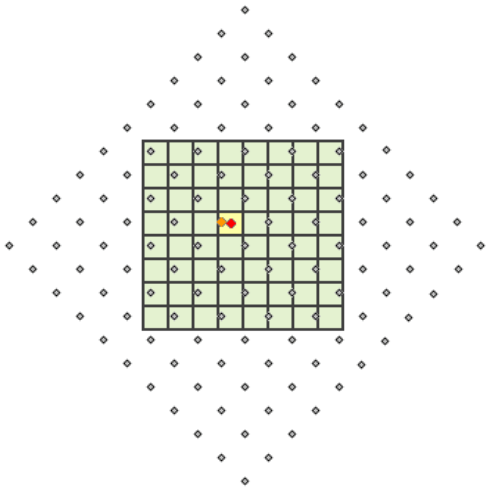
Sub-objectives 4.1 & 4.2: *Methods to map the distribution and identify hotspots of carbon emissions in Dhaka.*

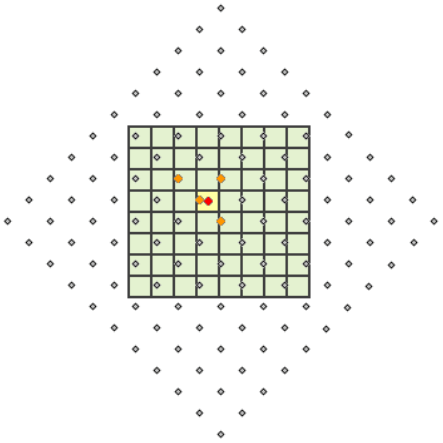
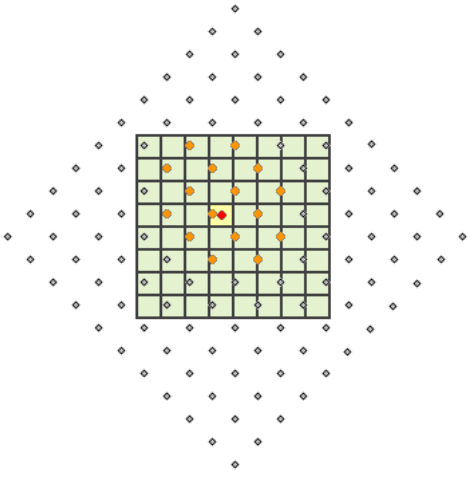
Resampling: To find the value each cell should receive on the resampled output raster, the center of each cell in the output must be mapped to the original input coordinate system. Each cell center coordinate is transformed backward to identify the location of the point on the original input raster. Once the input location is identified, a value can be assigned to the output location based on the nearby cells in the input. It is rare that an output cell center will align exactly with any cell center of

the input raster. Therefore, techniques have been developed to determine the output value depending on where the point falls relative to the center of cells of the input raster and the values associated with these cells. The three techniques for determining output values are nearest neighbor assignment, bilinear interpolation, and cubic convolution. Each of these techniques assigns values to the output differently. Thus, the values assigned to the cells of an output raster may differ according to the technique used.

Limitation: Bilinear interpolation or cubic convolution should not be used on categorical data since the categories will not be maintained in the output raster dataset. However, all three techniques can be applied to continuous data, with nearest neighbor producing a blocky output, bilinear interpolation producing smoother results, and cubic convolution producing the sharpest.

Table 6: Explanations of the three approaches for resampling

Nearest neighbor assignment	Nearest neighbor assignment is the resampling technique of choice for discrete (categorical) data since it does not alter the value of the input cells.  Once the location of the cell's center on the output raster dataset is located on the input raster, nearest neighbor assignment will determine the location of the closest cell center on the input raster and assign the value of that cell to the cell on the output raster. The nearest neighbor assignment does not change any of the values of cells from the input raster dataset. The value 2 in the input raster will always be the value 2 in the output raster; it will never be 2.2 or 2.3. Since the output cell values remain the same, nearest neighbor assignment should be used for nominal or ordinal data, where each value represents a class, member, or classification (categorical data such as a land-use, soil, or forest type). Consider an output raster created from an input raster that is rotated 45° in an operation and thus will be resampled. For each output cell, a value needs to be derived from the input raster. In the illustration below, the cell centers of the input raster are the gray points. The output cells are shaded in green. The cell being processed is shaded in yellow. In the nearest neighbor assignment, the cell center from the input raster that is closest (orange point) to the processing cell center (red point) is identified

	and assigned as the output value for the processing cell (shaded yellow). This process is repeated for each cell in the output raster.
Bilinear interpolation	Bilinear interpolation uses the value of the four nearest input cell centers to determine the value on the output raster. The new value for the output cell is a weighted average of these four values, adjusted to account for their distance from the center of the output cell. This interpolation method results in a smoother-looking surface than can be obtained using nearest neighbor.  In the following illustration, as in the previous one for nearest neighbor interpolation, the cell centers of the input raster are in gray points, the output cells are shaded in green, and the cell being processed is shaded in yellow. For bilinear interpolation, the four input cell centers (orange points) nearest to the processing cell center (red point) are identified, the weighted average is calculated, and the resulting value is assigned as the output value for the processing cell (shaded yellow). Since the values for the output cells are calculated according to the relative position and the value of the input cells, bilinear interpolation is preferred for data where the location from a known point or phenomenon determines the value assigned to the cell (that is, continuous surfaces). Elevation, slope, intensity of noise from an airport, and salinity of the groundwater near an estuary are all phenomena represented as continuous surfaces and are most appropriately resampled using bilinear interpolation.
Cubic convolution	Cubic convolution is similar to bilinear interpolation except that the weighted average is calculated from the 16 nearest input cell centers and their values.  The following illustration demonstrates how the output value is calculated for cubic convolution. The 16 input cell centers (orange points) nearest to the processing cell center (red point) are identified, the weighted average is calculated, and the resulting value is assigned as the output value for the processing cell (shaded yellow).

	Cubic convolution will have a tendency to sharpen the edges of the data more than bilinear interpolation since more cells are involved in the calculation of the output value.

Grid Analysis: The grid-level analysis is based on 1 km * 1km grid that covers the whole study area (Dhaka city). The gird will be created using Arcgis 10.2 software with the tool of Create Fishnet.

Autocorrelation analysis: The Spatial Autocorrelation (Global Moran's I) tool measures spatial autocorrelation based on both feature locations and feature values simultaneously. Given a set of features and an associated attribute, it evaluates whether the pattern expressed is clustered, dispersed, or random. The tool calculates the Moran's I Index value and both a z-score and p-value to evaluate the significance of that Index. P-values are numerical approximations of the area under the curve for a known distribution, limited by the test statistic. When the p-value returned by this tool is statistically significant (in this case, $p < 0.05$) the null hypothesis can be rejected.

The Moran's I statistic for spatial autocorrelation is given as:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=1}^{n} z_i^2} \quad (1)$$

where z_i is the deviation of an attribute for feature i from its mean $(x_i - \bar{X})$, $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features, and S_0 is the aggregate of all the spatial weights:

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} \quad (2)$$

The z_I-score for the statistic is computed as:

$$z_I = \frac{I - \mathrm{E}[I]}{\sqrt{\mathrm{V}[I]}} \quad (3)$$

where:

$$\mathrm{E}[I] = -1/(n-1) \quad (4)$$

$$\mathrm{V}[I] = \mathrm{E}[I^2] - \mathrm{E}[I]^2 \quad (5)$$

Figure 3: Overview of the autocorrelation analysis

Sub-objectives 4.3 & 4.4: *Setting scenarios and making recommendations for low carbon transport options in Dhaka*

Research outcomes from this research will be directed at:

- Dhaka Legislators
- Dhaka local government
- Dhaka Transport Co-ordination Authority (Including urban planners)
- Private sector (to guide investment)
- Academic researchers

To complete this phase of the research, the information gathered from each of the previous stages will be synthesized into a report which will be presented to the above stakeholders. In addition, members from each of the stakeholder groups will be invited to a workshop where the suitability and feasibility of these recommendations will be discussed and debated. Depending on the outcomes of this workshop, the report of recommendations may be revised and resubmitted to the stakeholders.

4 Research Plan Overview

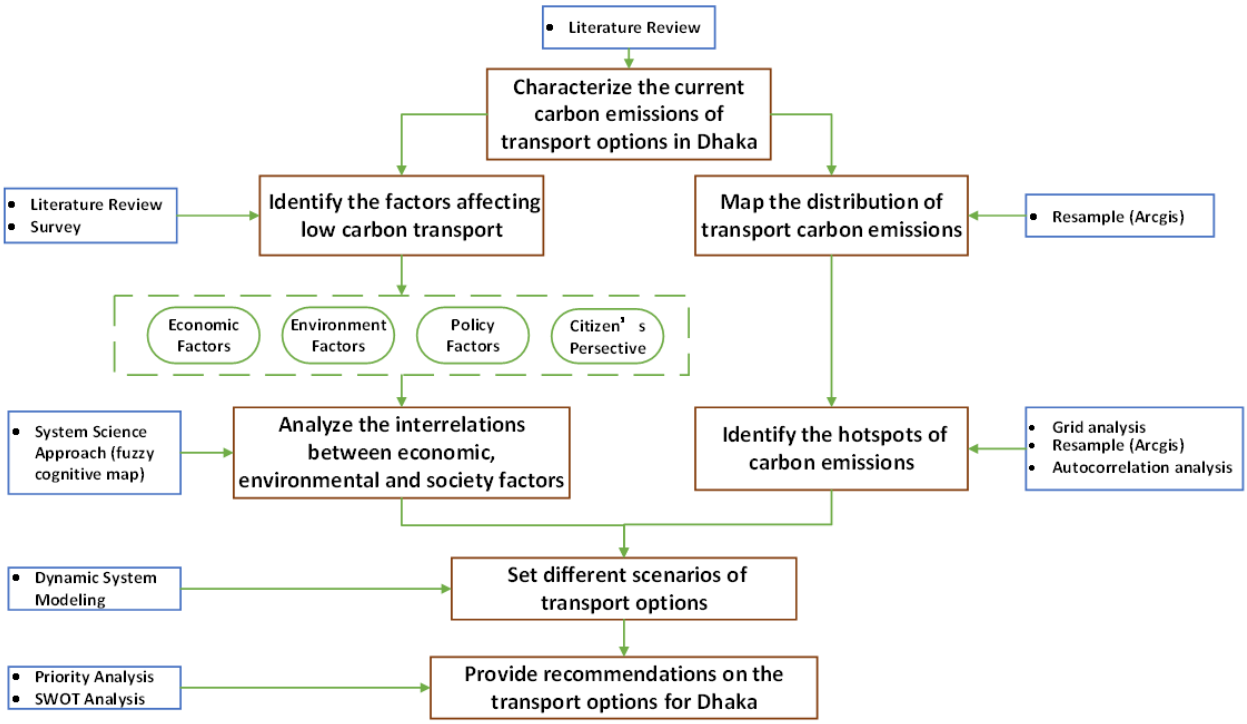


Figure 4: A schematic overview of the proposed research plan for investigating the low carbon transport options in Dhaka

5 Limitations

Limitations are an inherent part of any research. This research team recognises the importance of track record when conducting research and acknowledges that this is a limitation within this group, having not worked together before. To combat this limitation, the research group intends to schedule regular online video conferencing sessions and recruit a project manager with senior-level experience in research in the development of sustainable transport in south-east Asia. Another limitation is, due to the lack of empirical data in the research area, results of the expert panel may result in them basing their Delphi scores on strong personal or professional conviction or on guesswork rather than on their interpretation of published evidence. This may contribute to the lack of agreement between the experts in terms of the assignment of weights and thus, the inability of the Delphi study to produce consensus between the experts. A further limitation of the study may be the snow-ball method to identify potential members for the expert panel for the Delphi study may bias the results i.e., initial experts may only recommend other experts with similar backgrounds or beliefs. For the previous two limitations, this research team hopes to focus on a multidisciplinary approach to ensure that a wide variety of experts and factors are initially canvassed to reduce the likelihood of these limitations impacting the results.

6 Project Timeline

The primary outcome of this research is to investigate

Planned submission: March 2020		**Expected time to complete the project (months):**											
Project component	**Month:**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**
Literature review													
Data collection													
Data analysis/ model development													
Policy recommendations													
Write up													

Figure 5: Proposed timeline to investigate the low carbon transport options in Dhaka

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