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Carbon Footprint in Landscape Development Stages: A Life Cycle Approach

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Abstract: The study was designed to assess the performance of carbon at Malaysia. Landscape development plays an important role in the global carbon cycle. They produce a large proportion of CO2 emissions, but they also sequester and store carbon in our environment. The carbon footprint analysis is an established method for systematically quantifying carbon sinks and sources throughout the lifetime of goods and services. There are three stages of carbon contributors were identified through document review and expert's validation, which is construction stage, operation stage and maintenance stages. The paper presents the carbon footprint analysis of landscape development stages that was recently constructed in the permonade Percint 8, Putrajaya. Field measurement was conducted and the collected data were analyzed using SMART PLS (Partial least squares). Findings of the study highlighted that construction stage give the highest significant to carbon contribution with a path coefficient 0.748. The study also shows that the construction stage is the largest contributor due to the presence of a large number of facilities and activities in landscape developments compared to the maintenance stage. Particularly this is also related to the material and equipment used during the construction stage. The study suggested that the construction stage need to be considered when developing a sustainable landscape design. Finally, the recommendations on how to reduce carbon emissions in landscape development stages especially in Malaysia were highlighted.
Keywords: Carbon, landscape developments, sustainability, green, carbon footprint.

INTRODUCTION

Great interest has been shown in recent years in Malaysia's rapid economic development contributes to urbanization and shift in the global climate change issues. Unfortunately, such changes are not without disadvantages as urbanization leads to expansion of carbon outflows. It is all about 30 billion tons of CO2 enters the climate subsequently of human activity every year and the bulk of this phenomenon can be attributed to human daily life [1]. There is a developing declaration that will require a low carbon contribution that will influence all parts of society. At the worldwide atmosphere meeting in Cancun 2010 it was agreed that "developing nations ought to grow low-carbon advancement methodologies or arrangements" [2]. The world sustainable development conference in Kyoto has resulted in a legally binding agreement called the Kyoto Protocol. Through this effort, the industrialized countries have pledged to reduce their carbon emission toward world sustainability [3]. Although low carbon development has been implemented around the globe, Malaysia through the Ministry of Energy, Green Technology and Water (KeTTHA) aims for 40% GHG reduction for every GDP per capita year by year 2020. The objective is to decrease carbon outflow of up to 40% of GDP contrast with 2005 level. Practically, with all the fact, it is important to measure the carbon footprint especially focusing on our landscape developments. Research in carbon footprint has grown dramatically in the past and current decades, yet it is distinguished by multiplicity approach. This research expands to the landscape developments stages due to their large element and facilities. In order to have proper management, landscapes nowadays provide all the services such as information centers, supermarkets, cafeterias, restaurants, public transportation and recreational activities [4]. The entire element will emit carbon to the environment. The United States National Park Service (NPS) has also committed to reducing energy consumption and GHG emissions and has set to do so through its 2012 Green Parks Plan (GPP) [5]. The GPP was created in response to Executive Order 13514 Federal Leadership in Environmental, Energy and Economic Performance, and sets the target of carbon reduction by 2020, using a baseline of 2008 for all park operations (such as facility energy consumption and fleet operations). Hence, the key question of this paper was how to reduce our carbon emission in landscape development stages towards low carbon development in Malaysia.

CARBON FOOTPRINT AND LANDSCAPE DEVELOPMENT

Fundamentally, low carbon guides have been created by European countries such as the United Kingdom and Denmark, and as well as from Asian countries such as Japan and Singapore. Another initiative is the Transition Town development that connects with individuals at the group level to investigate how an option low carbon future could resemble [4]. Malaysia had contributed relatively high greenhouse gas (GHG) emission if compared to other Southeast Asian countries and the world average, due to its rapid urbanization and high economic growth. Even though the CO2 emission per capita is much smaller than most of the developed countries, Malaysia still rated in the third places in Southeast Asia countries, after Brunei and Singapore [6]. Carbon emission at is part of sustainable development in believed that carbon emissions can be decreased effectively without compromising the need of urban economic growth. Nevertheless, Yuan *et al*. [7] introduce a three stage concept of low carbon development that comprises the primary stage (low carbon economy), the developmental stage (low carbon society) and maturity stage (low carbon world). According to this model, green recovery is one of the initiatives towards enhancement low carbon development and can act as additional strategy is by identify the stages and elements in green space. Apart from all the policies exist, the recent Low Carbon Cities Framework and Assessment System [6] is developed to link the gap between existing policies of the government with many building rating tools currently available. Under the LCCF, the parameters were divided into four main categories which include urban environment, urban transport, urban infrastructure and building. Urban environment focusing on natural ecology, water body and biodiversity Green open spaces Number of trees.

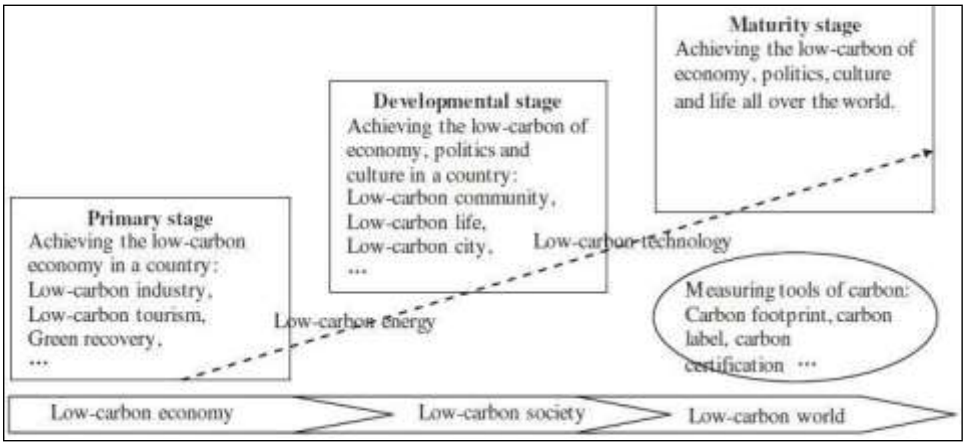

Fig-1: Three phases of low carbon development (Source: Yuan *et al*. [7])

In order to account for green recovery and the constant changes that are occurring over time, Pauleit and Duhme [8] suggested using life cycle assessment (LCA) for estimating the longterm environmental performance of landscape cover units and their essential technical components. LCA provides a framework for studying environmental impacts throughout the lifetime of goods and services [9]. LCA is clearly structured by an international standard, yet flexible for adapting to different applications. It is defined as a method to address potential environmental impacts, rather than a tool to predict absolute or precise environmental impacts [10]. Closely related to life cycle assessment is the carbon footprint analysis. The term "carbon footprint" is defined by Wiedmann and Minx [11] as "a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" but there is no consensus how it should be measured or quantified. This research followed the European Commission [12] guidelines, which define a carbon footprint as a sub-set of a complete LCA. LCA and carbon footprint are generally used in an industrial context but there are also applications from agriculture and forestry [13]. Sola *et al*. [14] conducted an LCA of the service sector energy usage of the Montjuic Park in Barcelona, Spain. The large park (450 ha) includes green space and services such as sport facilities. It is used to account for energy consumption of machinery and vehicles used by gardeners, electric lighting, and energy consumption taking place within the various service buildings. They also estimated the equivalent of emitted CO2 used for producing the energy.

MATERIALS AND METHODS

Currently, there are too many landscape developments in Klang valley. However, this study has been able to access Promenade Precinct 8, Putrajaya as the developers have provided the researcher to access the relevant information. Putrajaya is a planned model concept city and administrative capital of Malaysia. Being first of its kind in the region, it is built to reflect the country's commitment to green environment and to accommodate the growing size of the Malaysian federal government ministries and national level civil servants. The area is located 25km south of the capital city of Malaysia, Kuala Lumpur (Lat. 2°55' N, Long. 101°42'E). The selection of site is based on stages, since the site is available for the researcher for the purpose of data collection in all stages, the 12 zoning are thus involved in this study. This study was carried out measuring 5km long in the new federal administrative centre, Putrajaya, Malaysia. The major constructs involved in the research (construction, operation, and maintenance) and sub construct as shown in figure 2. For the purpose of this study, a set of data collection form was used to identify how much attributes that leads to carbon contribution to the area as shown in figure 3. The form consists of all sub construct and collected the data through zoning. A pilot study carried out in Zone 3. Zone 3 was chosen due to the fact that it has the number attributes to access carbon. The data collected from the pilot study is then used to determine the instrument's reliability. A Likert-scale measurement was employed to measure the carbon contribution. Later, a 5- point Likert scale as proposed by Jenkins [15] was being used. Given the substantial evidence of validity and reliability obtained from Jenkins [15], this study uses the suggested 5-point Likert scale. Table below illustrates the Likert-scale used in this field measurements study.

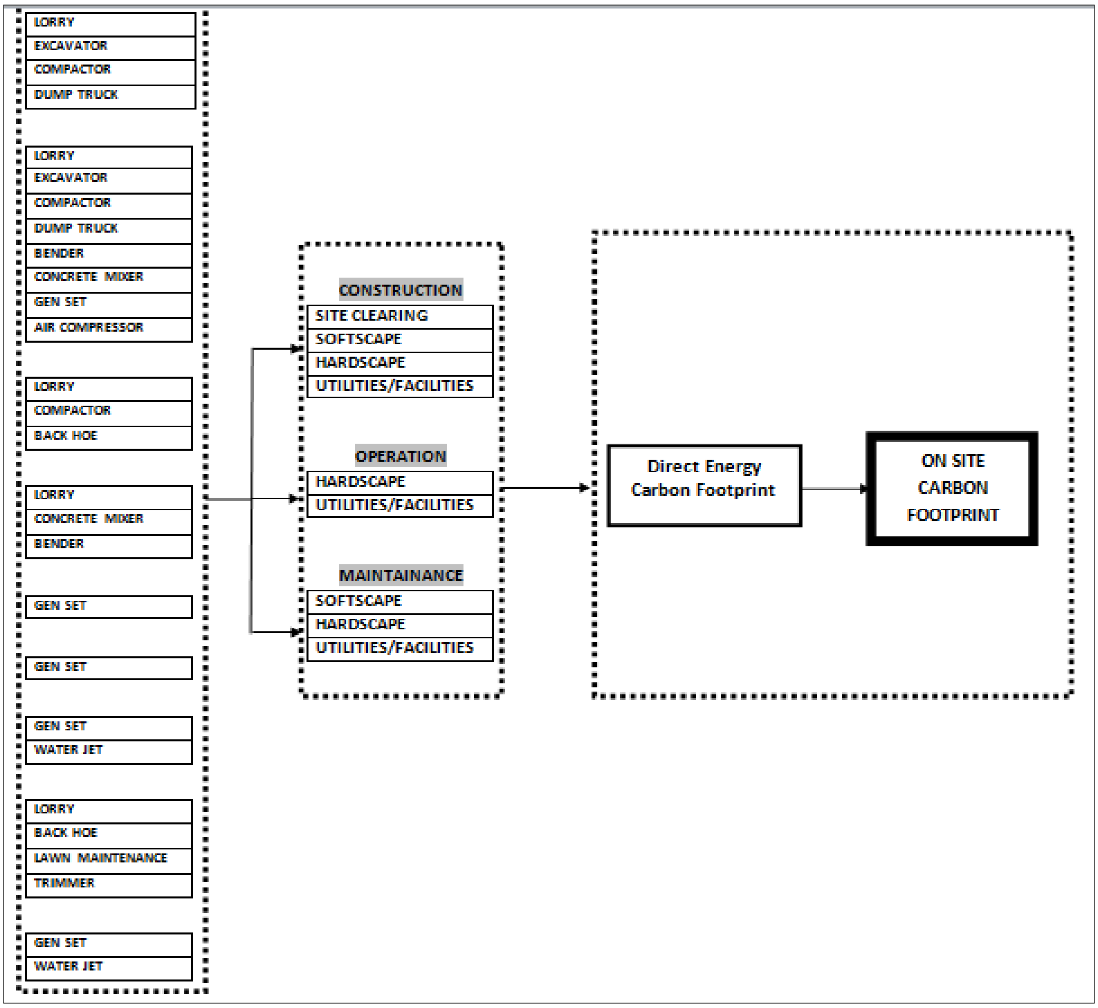

Fig-2: Landscape development stages

MONTH :..

STAGE	SITE CLEARING CONSTRUCTION				HARDSCAPE CONSTRUCTION								SOFTSCAPE CONSTRUCTION			UTILITIES CONSTRUCTION			OP H	OP U	HARDSCAPE MAIN		SOFTSCAPE MAINTENANCE				UTILITIES MAIN	
ITEM	LORRY	EXCAVATOR	COMPACTOR	DUMP TRUCK	LORRY	EXCAVATOR	COMPACTOR	DUMP TRUCK	BENDER	CONCRETE	GEN SET	AIR COMPRESOR	LORRY	COMPACTOR	BACK HOE	LORRY	CONCRETE M	BENDER	GEN SET	GEN SET	GEN SET	WATER JET	LORRY	BACK HOE	LAWN MACHINE	TRIMMER	GEN SET	WATER JET
WEEK	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28

Fig-3: Data Collection Form

Table-1: Likert-scale interpretations to measure carbon contribution

Scale	Attributed used
1	0-4
2	5-9
3	10-14
4	15-19
5	20-24

A life cycle based approach, consistent with the WRI Scope 1 GHG emissions inventory, was used as the basis for this carbon footprint [16]. Hillman *et al*. [17] have shown that three cross-boundary key urban materials (contruction, operation and maintenance) in addition to in boundary end uses of energy. We have considered all these activities in the Permonade Percint 8, Putrajaya footprint with some exceptions; only direct GHG emissions are calculated for different categories that are described in the supporting information. Difficulty in obtaining the most up-to-date and accurate data and lack of local parameters. However, this problem can be circumvented by utilizing suitable parameters that were already established in other countries. This inventory uses the latest emission (Defra) factors provided by the UK government's Department of Environment, Food and Rural Activities. These have been adopted by the GHG Protocol as emission factors and are updated on a regular basis Co2 diesel (2.6769 kg CO2e/litre) and Co2 petrol (2.3144 kg CO2e/litre). All GHG sectors were calculated according to the general equation.

Data were then analyzed using SEM-PLS and described in terms of percentage and frequency. SEM-PLS analysis is use to measure the correlations among the construct to determine the significant correlations among the three construct. The SPSS software is also being use to reveal any outliers in the data inputted, thus reducing the probability of including any data that may affect the subsequent statistical analysis namely, Structural Equation Modelling (SEM). Field analysis being carried out to further understand the results from this data collection. The purposes of this field analysis is to evaluate the relationship as follows:

- Relationship between carbon footprint and construction stage
- Relationship between carbon footprint and operational stage
- Relationship between carbon footprint and maintenance stage

RESULTS AND DISCUSSION

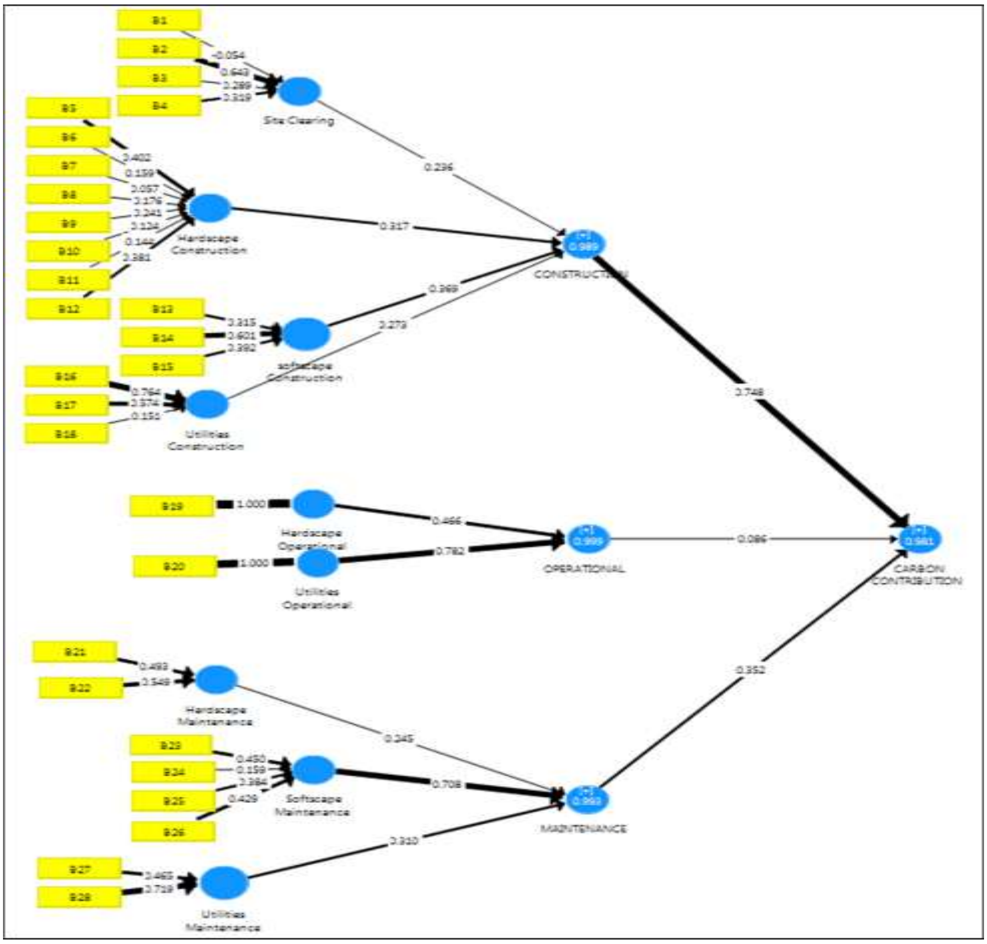

Fig-4: Relationship between carbon contributions

Relationship between carbon footprint and construction stage

Referring to Figure 4, the finding shows that construction phase has a significantly positive relationship with carbon contribution in which the β value reported is 0.874 and the t value reported is 3.407. The relationship between construct and sub construct namely site clearing, hardscape construction, softscape construction clearly showed that all four sub- construct have strong positive relationship. Hardscape construction was found to have the largest β value (0.352), followed by utilities construction (β=(0.305), site clearing (0.172), and subsequently softscape construction (0.183) with t values of 5.222, 5.210, 4.336, and 2.928 respectively. This shows that when site clearing, hardscape construction, softscape construction and utilities construction towards construction stage is high, the resulting carbon contribution will also be high. Hardscape construction is the biggest carbon contributor because it requires large amount of attributes to construct all the hardscape elements such as a walkway, gazebo, bench et cetera. Such process will also require transport vehicles such as lorry and truck, which uses diesel and petrol to power the machineries. The next largest carbon contributor is utilities construction. All parks have their own utilities such as lighting and these facilities also require the same attributes to construct. The third largest emission of carbon during construction that may be analyzed is site clearing. The findings have shown that site clearing factor has significant relationship with carbon contributions. As a part of construction stage, Site clearing will require the use of lorry, trucks, and others. All these will contribute to high amount of carbon to our environment. Softscape construction is found to be the least contributors of carbon during construction phase through the use of backhoes during the construction works.

Relationship between carbon footprint and operational stage

Structural model evaluation results show operational stage has significantly positive relationship with carbon contribution where the β value reported is 0.070 and the t value returned is 9.856. Sub construct environmental factors namely hardscape operational (β=0.588), and utilities (β=0.529) also have positive relationship with the major construct. Its significance t values with 97% confidence level are 5.535 and 13.493 respectively. This shows that operational contributes very minimal amount of carbon. Based on the results from field measurement, there is less attributes used at this stage compared to the construction stage.

Relationship between carbon footprint and maintenance stage

Maintenance stage also has positive relationship with carbon contribution. The significance between the maintenance stage and carbon contribution at 92% confidence is reported at β value of 0.509 and t value of 13.774. The relationship between maintenance sub constructs namely hardscape maintenance, softscape maintenance and utilities maintenance were found to be clearly positive; however, these relationships are not really strong compared to construction stage. Softscape maintenance (β=0.901) was found to have the strongest relationship with carbon followed by hardscape maintenance (β=0.258) and lastly utilities maintenance (β=0.133) with t values of 9.305, 8.001 and 3.148. These result also show that softscape maintenance contributes the highest amount of carbon to a park during the maintenance stage. Elements that are usually found at a park include trees, shrubs, lawn will requires a large amount of attributes such as trimmer, lorry, lawn machine et cetera for its maintenance work during this stage. All these attributes will contribute carbon to a park.

Table-2: Path coefficient on carbon contribution

Stage	Path coefficient, β	t value	p value
Construction	0.748	7.012	0.00
Operation	0.086	2.228	0.00
Maintenance	0.352	3.946	0.00

Table-3: Path coefficient on carbon footprint construct-sub constructs

Construct	Relationship construct -> sub-construct	Path coefficient, β	t value	p value
Construction	Construction-Site clearing	0.236	3.357	0.00
	Construction-Hardscape	0.317	3.743	0.00
	Construction-Softscape	0.369	5.039	0.00
	Construction-Utilities	0.237	2.220	0.00
Operational	Operational-hardscape	0.466	1.897	0.00
	Operational-Utilities	0.782	4.377	0.00
Maintenance	Maintenance-Hardscape	0.245	1.900	0.00
	Maintenance-softscape	0.708	6.187	0.00
	Maintenance- Utilities	0.310	2.697	0.00

Effect size

Table-5: Effect size

	Carbon contribution
Construction	23.374
Operational	0.323
Maintenance	4.143

From table 5, it was found that the most effective variable is construction stage (23.37), followed by maintenance stage (4.143) and operational stage (0.323). This shows that construction stage exerts more substantial effects on carbon contribution when compared to maintenance stage and operational stage.

Predictive relevance

Table-6: Q^2 value on field measurement

Dependent variables	Nilai Q^2
Construction	0.276
Operational	0.347
Maintenance	0.246

Referring to table 6 results, the Q^2 values for construct construction, operational and maintenance are 0.276, 0.347, and 0.246 respectively. These values are between 0.15 and 0.35; thus indicating that the model's possesses moderate level of relevance. The Q^2 values depend on relationships between variables that may influence carbon contribution. A medium-level Q^2 value is considered as sufficient for providing prediction of contribution of carbon to the environment.

Potential emissions reduction strategies to be considered

Our results show that the carbon footprint of landscape development is strongly influenced by the resulting management. Once hardscape and softscape is constructed, it is important to keep mortality low as possible. Manually maintenance can act as alternative to reducing emissions from using motorized equipment. As for lawns, reducing the mowing frequency lowers the associated emissions and produces a very different design effect hay meadow rather than turf. Healthy and robust tress should be selected for planting. The importance of choosing suitable tree species and maintaining them is a conclusion shared by Nowak *et al*. [18]. The selection of green machinery also can help in reducing carbon emission. From a physical standpoint, we point out some effective ways to further reduce carbon emission in landscape development, given the above data and results in order of potential for reducing the carbon footprint. We propose that, for the purposes of reduction tracking and as a basis for sustainable action, the targets of the landscape development stages should be translated into total life cycle GHG emissions instead of the absolute numbers, and should include key urban materials such as types of fuel. Limiting the number of landscape activity does not seem to solve the problem of reducing emissions in a global context. Reducing the number of landscape activity seems to go against the underlying principle of being more sustainable. The objective of the landscape development should reduce the impact of each stage towards low carbon community.

CONCLUSION

The carbon footprint analysis is a valuable tool for estimating the long-term environmental performance of landscape developments. We have shown that carbon footprint can be reduce from construction, operation and maintenance when choosing a design and maintenance plan that minimizes the use of motorized machinery and keeps tree mortality low. This study has taken into account three stages in landscape development. All factors have been linked to carbon contribution in order to provide scientific explanations. These explanations are important to provide information to important parties including designers themselves during landscape planning stage. The elements found in these studies do exist and plays important roles in carbon contribution. The findings also show that there is a direct and significantly positive relationship among all three stages with carbon footprint in landscape development. Thus, it is essential that certain afford being put during planning stage to identify elements that potentially to emit highest carbon, in order to ensure its reduction throughout the whole landscape lifecycle. The findings from this study are intact and confirmed through the evaluation from the field measurement. Hence, the presence of high number of attributes used will lead to high probability of construction, operation and maintenance which contributes to high level of carbon contribution to the atmosphere.

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