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Discovering Thoughts, Inventing Future

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Carbonates, Present and Future of Petroleum Production

By Jhoan Jose Urdaneta

Introduction- Carbonates constitute the most abundant sediments and sedimentary rocks after terrigenous clastics. Carbonates are mainly formed by chemical, biochemical and biological processes, in contrast to sediments and rocks of terrigenous origin, which originate due to weathering and erosion of pre-existing material, arge percentage of carbonates are constituted in the marine environment, in coastal or tropical oceanic environments where clastic sedimentation is minimal or does not exist. These carbonates develop as reefs, platforms, atolls, banks, mounds, and ramps, as well as in the form of pelagic deposits in the oceans, for which a series of conditions is necessary, in the formation and accumulation of these sediments.

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Carbonates, Present and Future of Petroleum Production

Jhoan Jose Urdaneta

Introduction

Carbonates constitute the most abundant sediments and sedimentary rocks after terrigenous clastics. Carbonates are mainly formed by chemical, biochemical and biological processes, in contrast to sediments and rocks of terrigenous origin, which originate due to weathering and erosion of pre-existing material, arge percentage of carbonates are constituted in the marine environment, in coastal or tropical oceanic environments where clastic sedimentation is minimal or does not exist. These carbonates develop as reefs, platforms, atolls, banks, mounds, and ramps, as well as in the form of pelagic deposits in the oceans, for which a series of conditions is necessary, in the formation and accumulation of these sediments. In some lacustrine environments of tropical climate and lakes with high evaporation, carbonates will also form. Carbonates for their formation, either through direct precipitation or through organisms when building their shells and limestone skeletons, depend on the salinity and temperature of the water, the pH, the partial pressures of carbon dioxide, of dissolved oxygen, etc. The increase in salinity and temperature, the decrease in carbon dioxide, increase in oxygen and alkaline pH, favor the precipitation of calcium carbonate.

Image 1: Detritic Rocks: Conglomerates, sandstones, and kaolin shales (first). Utrillas Formation (Cretaceous), in Soria, Spain. Source: Geological and Mining Institute of Spain (IGME)

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Carbonate sediments and rocks contain more than 50% carbonate minerals, which are composed of CO3 2- and one or more cations. Calcite (CaCO3) is the most common mineral and the main component of limestone, followed by dolomite (CaMg (CO3) 2). Together these two minerals make up more than 90% of the rock-forming carbonate minerals during geological time. Limestones and dolomites can have varying amounts of quartz, feldspars, and clay minerals. In smaller quantities and locally, antigenic minerals such as chert, gypsum, anhydrite, and pyrite can be found. In recent carbonates, the common minerals are calcite and aragonite. Calcite is divided into calcite with high Mg (> 5% MgCO3) and calcite with low Mg (<5% MgCO3). Aragonite and calcite with high Mg are metastable and will invariably change to the stable form that is calcite with low Mg. These minerals are biochemically formed by some organisms, or by inorganic precipitation forming cement or constituents such as ooids and similarly occurred in the geological past. However, due to its condition of metastable minerals, Diagenetic changes will operate on aragonite and high calcium calcite, adapting a more stable form. Therefore all fossils with shells or skeletal parts, inorganic constituents and cements of these metastable minerals before the middle part of the Middle Pleistocene, will change to the stable form that is calcite with low Mg or simply calcite.

Image 2: Calcite is a form of calcium carbonate with the chemical formula, Source: British Geological Survey

In the sedimentary environments of modern carbonates, dolomite is not as usual as in the past since this mineral is constituted, by dolomitization processes from calcite, high magnesium calcite, and aragonite. However, the current models in which they are developing the dolomitization processes, such as areas of hypersaline lagoons, sabkhas areas of mixed meteoric and marine waters, among others, have allowed understanding, the processes and formation of the dolomites.

Diagenetic changes profoundly alter sediments and organisms formed by CaCO3. Most of these changes occur on the surface or by processes derived from it, during the early stages of burial. When the initial mineralogy is modified, the processes of lithification, formation of secondary cement, and transformation or creation of porosity manifest from the initial moment of deposition.

Carbonate minerals are found in numerous sedimentary environments, some terrestrial, but it is in tropical marine environments where they present a great abundance, both in the present and geological past, representing an excellent paleoclimatic indicator. Carbonate minerals are formed from carbonate saturated waters by biochemical processes developing the skeletal parts and shells of calcareous organisms, as well as by chemical precipitation of supersaturated waters forming concentric or radial laminations (ooids), and in environments with high evaporation or in the walls

of caves and caverns by rapid decrease of CO2 (stalactites and stalagmites).

Image 3: Stalagmites in Carlsbad Caverns National Park, New Mexico. Source: Peter Jones. https://www.britannica.com/science/stalagmite

Limestones and dolomites represent between 1/5 to 1/6 of the global sediments and sedimentary rocks, and these can be known, more than any other group of sedimentary rocks, about the geological evolution of the Earth's surface. The sedimentary particles and the depositional texture of the limestones are indicative of environments, facies, current energy, erosion factors, etc. Limestone fossils represent the evolution of organisms, paleoenvironments, paleoclimates, and changes in sea level, from the Precambrian to the present day. The chemical composition of limestone and dolomites and the content of fossils, indicate the physicochemical characteristics of fluids and the environment and the conditions of temperature, salinity, water depth, oxygenation, etc.

Carbonate classifications have more complexity than those used for clastic sediments such as sandstones. Textural characteristics or chemical composition, depositional texture, génesis, and recognition of the components are necessary for a good classification. The wide variety of porosities, origin, and modification of these, as well as their relationship with the initial depositional environments, and underground stages, create an inexhaustible topic of discussion in carbonates.

Using, isotopic measurements with oxygen used by calcareous organisms, mainly some species of planktonic foraminifera, paleotemperature values, and glaciation, and interglaciation states are obtained. In this way, sea level change curves have been developed, during the Tertiary and Quaternary.

Limestones and dolomites generally constitute aquifers, and hydrocarbon deposits, as well as deposits of zinc, lead, silver and mercury. As important hydrocarbon reservoirs, they represent approximately 50% of the world's basins. In the deposits of the Persian Gulf and in Mexico, most of the hydrocarbon deposits are stored in limestones and dolomites. There are also important reservoirs in the Lower Cretaceous in some regions of the United States (mainly in Texas), as well as in various Paleozoic calcareous facies in Canada and the United States. In North Africa, mainly Libya and Algeria, hydrocarbon deposits are found in carbonates, as well as in southern Russia. In Venezuela, most of the deposits correspond to sandstone facies, but important limestone and dolomite deposits are found in the Lower Cretaceous of the Maracaibo Lake basin, in front of Perijá and areas of tidal plains of the Barinas region (Cenomaniense). Some limestones can be used in the chemical industry as a source of CaO, as well as for cement production and use in the construction industry.

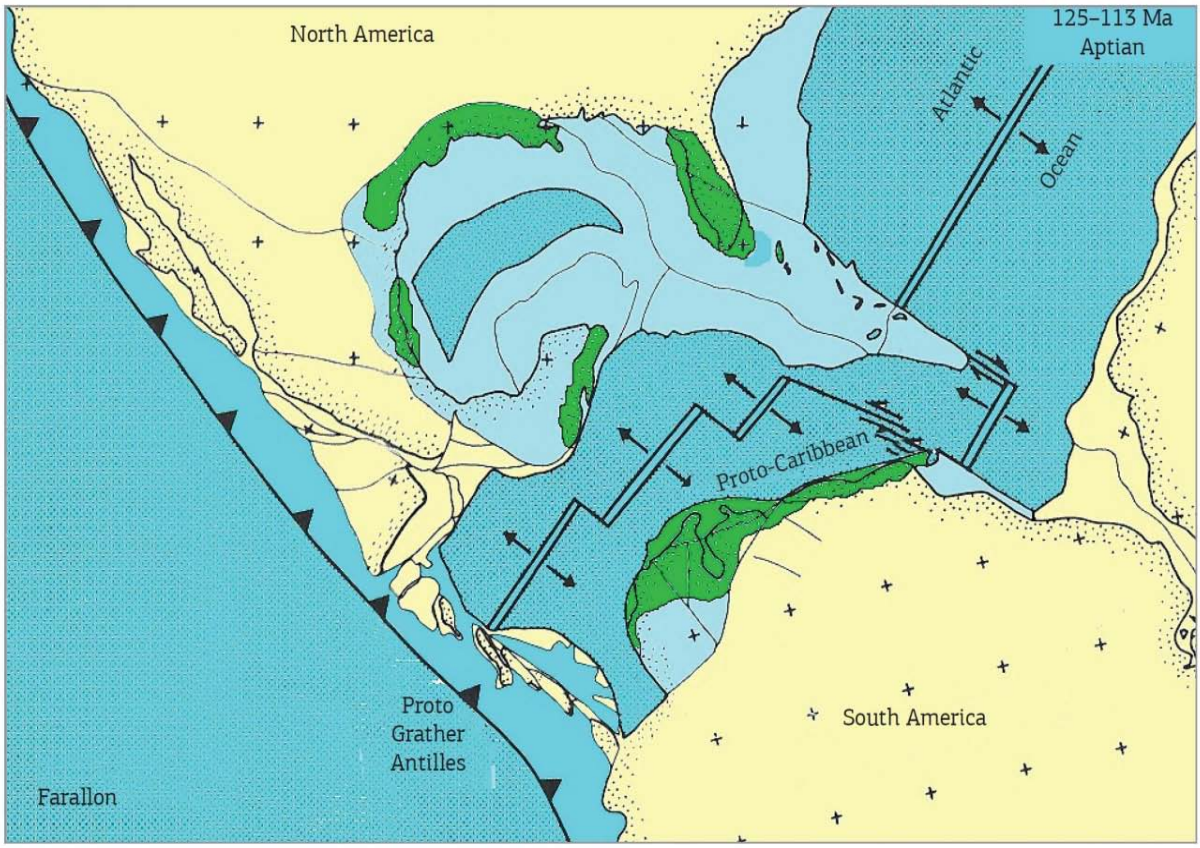

Image 4: Areas of carbonate platforms during the early Aptian (in green). In Venezuela, these carbonate systems were developed in the Maracaibo and Oriente basins. Part of these systems is also found in the East of Colombia, in outcrops and subsoil. Source: Brazilian Magazine of geology.

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The Method of Accounting for the Personality Factor of the Operator in the Ergatic System

By Valeri l. Z olotykh

Abstract- The article analyzes the phenomenon of the "human factor". As a result of the analysis, one of the tasks defined in the interests of solving the problem of managing the "human factor" is determined-the need to assess the impact of the "personality factor" of the operator participating in the management of the ergatic system on the safety of this system. In order to solve this problem, a method of formalizing the personality factor in an ergatic system is being developed.

Keywords: human factor; personality factor; ergatic system; human operator; special situation.

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The Method of Accounting for the Personality Factor of the Operator in the Ergatic System

Метод Учета Личностного Фактора Оператора В Эргатической Системе

Valeri I. Zolotykh

Золотых Валерий Иванович

Abstract- The article analyzes the phenomenon of the "human factor". As a result of the analysis, one of the tasks defined in the interests of solving the problem of managing the "human factor" is determined - the need to assess the impact of the "personality factor" of the operator participating in the management of the ergatic system on the safety of this system. In order to solve this problem, a method of formalizing the personality factor in an ergatic system is being developed.

Keywords: human factor; personality factor; ergatic system; human operator; special situation.

Аннотация- В статье проводится анализ феномена «человеческий фактор». В результате проведенного анализа определяется одна из задач, поставленная в интересах решения проблемы управления «человеческим фактором» - необходимость оценки влияния «личностного фактора» оператора, участвующего в управлении эргатической системой, на безопасность этой системы. С целью решения поставленной задачи разрабатывается метод формализации личностного фактора в эргатическоф системе.

ключевыеслова*: человеческий фактор; личностный фактор; эргатическая система; человек-оператор; особая ситуация.*

Метод формализации личностного фактора в эргатической системе

Системы, связанные с деятельностью человека, называются искусственными. В данном случае нас интересует система, которую человек создает в самом процессе труда для получения общественно-необходимого продукта. Такая система называется *эргатической системой* (от греч. "эргон" - работа) [1-4]. В зависимости от характера продукта труда они могут быть производственными, информационными, транспортными и т.п.

Термин «эргатическая система» впервые был принят в 1960 г. на первом конгрессе Международной федерации по автоматическому управлению с целью обозначения систем, включающих человека, который функционирует в совокупности с комплексом технических средств. Позднее содержание данного понятия расширилось. Эргатическая система (далее ЭС) - это любая система, работающая с участием человека.

Одним из видов технической ЭС является система «человек-машина». Особенности системы «человек-машина»:

1. Относится к классу сложных динамических систем, т.е. состоит из взаимосвязанных и взаимодействующих элементов различной природы.
2. Характеризуются целеустремленностью. Человек как часть данной системы ставит цели, определяет задачи и выбирает средства их реализации. Поэтому система способна получать одинаковые результаты различными способами.
3. Обладает адаптивностью. Система изменяет режим функционирования в соответствии с новыми условиями.

Таким образом, особенности системы «человек-машина» определяются способностью человека к правильному решению задач по управлению техническим устройством.

Существует несколько оснований классификаций ЭС.

- В зависимости от числа действующих в них людей различают моноэргатические (один оператор) и полиэргатические (несколько человек) системы.
- В зависимости от соподчиненности операторов в системе выделяют ЭС первого, второго и более высоких порядков. Например, система второго порядка имеет два этажа управления, на первом из которых оператор работает с техническим устройством, а на втором – оператор кроме работы с техническим устройством осуществляет руководство действиями первого оператора.
- По типу взаимодействия человека и машины различают системы непрерывного взаимодействия (например, система «экипаж – воздушное судно») и системы эпизодического взаимодействия (например, система «человек-компьютер»).
- По функциональному критерию ЭС разделяют на детерминированные (действующие по жесткому алгоритму) и недетерминированные, в которых появление тех или иных событий, а следовательно, и осуществление деятельности оператора имеет вероятностный характер.

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Имеются и другие критерии классификации ЭС, их число и разнообразие постоянно растет, что затрудняет попытки создания единой классификации.

Представление о современной моноэргатической системе схематично показано на рисунке 1.

Результатом функционирования ЭС выступает эргатическая функция. Эргатическая функция – сложная функция управления, составной элемент которой – человек-оператор. Е.А. Климовым выделены эргатические функции, которые являются основой для различных видов трудовой и профессиональной деятельности. Сама эргатическая функция определяется в [5] как «любое уменьшение неопределенности связи элементов внутри эргатической системы и ее связей с внешними обстоятельствами, рассматриваемыми с точки зрения тех целей, ради которых эта система создана, т.е. – это любая трудовая функция (функция эргатической системы)».

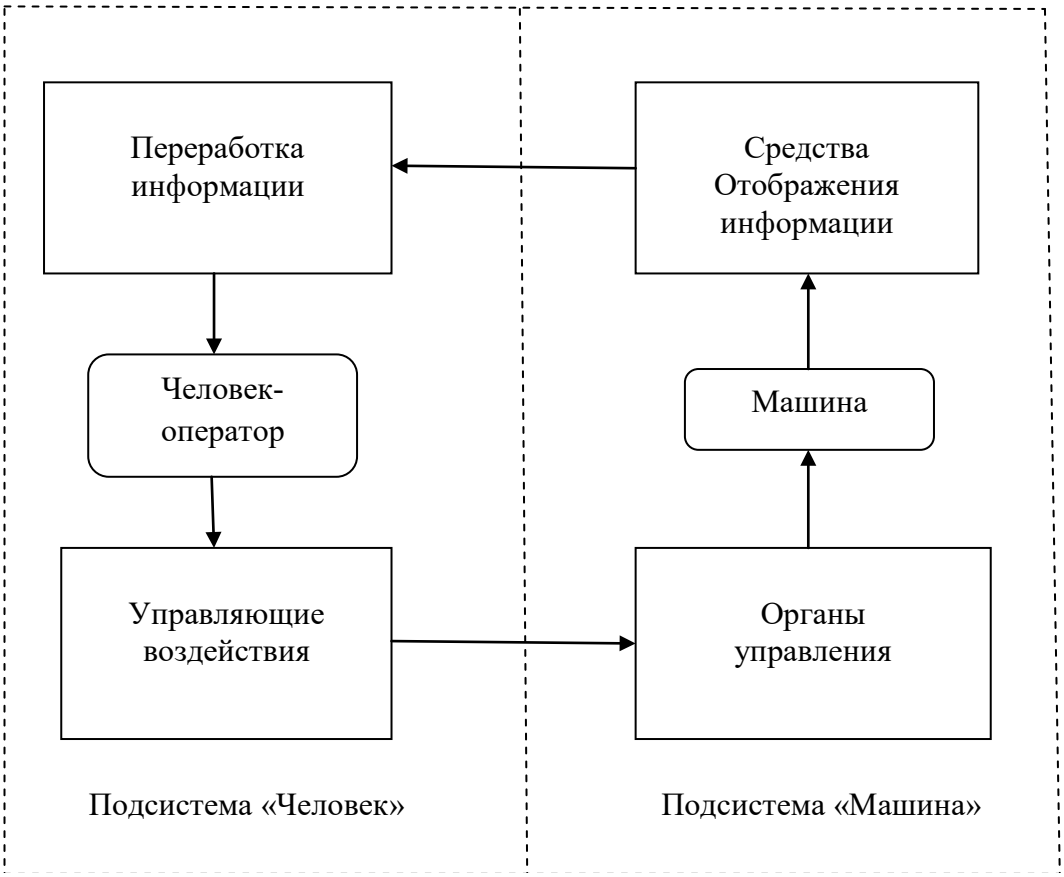

Рисунок 1: Схема моноэргатической системы

Одной из важнейших эргатических функций в [5] выделена защита ЭС от помех и разрушений. Ввиду того, современная ЭС – это человеко-машинная система, при функционировании таких систем для реализации этой функции необходим учет человеческого фактора (далее ЧФ), то есть выделения аспектов, связанных с присутствием человека.

В данном случае необходимо рассматривать ЧФ в аспекте личностного фактора (далее ЛФ) человека-оператора. Под «личностным фактором» будем понимать набор физиологических и психологических возможностей и ограничений, присущих конкретному специалисту – индивидууму, представляющих собой потенциальную угрозу безаварийному функционированию ЭС.

В общем случае трагические события, причины которых обусловлены проявлениями ЛФ человека-оператора в ЭС, развиваются, как правило, по одному из двух путей развития ситуации:

- ошибочное решение, ставшее следствием неполной или искаженной информации о состоянии ЭС или низкой квалификации, которое приводит к неверным поступкам, которые, в свою очередь, становятся причиной развития или углубления аварийной ситуации;
- несанкционированные действия, которые расцениваются как преступные, ведущие к аварии или катастрофе.

Можно ли спрогнозировать и предотвратить негативные проявления социально-психологических аспектов, связанных с участием человека в управлении техническими системами? Иными словами, возможно ли «обуздать» ЛФ? Над решением этой проблемы пока без особых положительных результатов работают

ученые многих стран на протяжении векового отрезка истории развития технического прогресса. В последнее время проблема влияния ЛФ на безопасность функционирования технических систем рассматривалась рядом исследователей [6-13]. Суть одной из задач, поставленной для решения обозначенной выше проблемы, заключается в необходимости численной оценки или учета влияния ЛФ человека, участвующего в управлении ЭС на безопасность этой системы. В таком аспекте проблема ЛФ широко не рассматривалась.

Прежде, чем приступить к решению поставленной задачи, необходимо определить, что такое безопасность ЭС, ведь именно безопасность ЭС необходимо обеспечивать при ее функционировании.

Главной целью системы безопасности является сохранение целостности ЭС в процессе функционирования в результате защиты системы от воздействия внутренних и внешних угроз. Для удобства назовем угрозу ЭС термином «опасный фактор». В настоящей статье под *безопасностью любой эргатической системы понимается защищенность системы от воздействия опасных факторов, которая позволяет обеспечить целостность системы в процессе ее функционирования по предназначению.* Под защищенностью следует понимать способность ЭС противостоять опасным факторам с сохранением возможности функционировать по предназначению в штатных и нештатных ситуациях. Данное определение дает возможность установить прямую зависимость между состоянием системы в процессе функционирования и воздействием на нее опасных факторов.

Необходимо отметить, что безопасность или защищенность ЭС достигается в результате функционирования системы безопасности в двух контурах:

1. Система обеспечения безопасности ЭС, главной целью которой является создание необходимых условий для безаварийного функционирования ЭС по предназначению;
2. Система управления безопасностью функционирования ЭС, предназначенная для компенсации влияния воздействия опасных факторов на состояние ЭС в процессе ее функционирования по предназначению.

В настоящей статье речь идет об обеспечении безопасности ЭС. Очевидно, для того, чтобы достичь главной цели обеспечения безопасности ЭС, необходимо выявить все опасные факторы, потенциально угрожающие безаварийному функционированию ЭС и устранить их, если это реально возможно, или минимизировать их влияние на состояние ЭС до начала процесса функционирования ЭС по предназначению.

При решении задач защиты ЭС от опасных факторов, связанных с ЛФ человека-оператора возникает необходимость учета влияния ЛФ каждого конкретного индивидуума, выступающего в роли оператора в конкретной ЭС, будь то самолет, электростанция, поезд, буровая установка и т.д.

Представим абстрактную ЭС в виде модели, изображенной на рисунке 2, где ЭС – система «человек-машина»;

*ЧО*i – i-тый человек-оператор, участвующий в управлении ЭС;

n – количество операторов, допущенных к управлению данной ЭС.

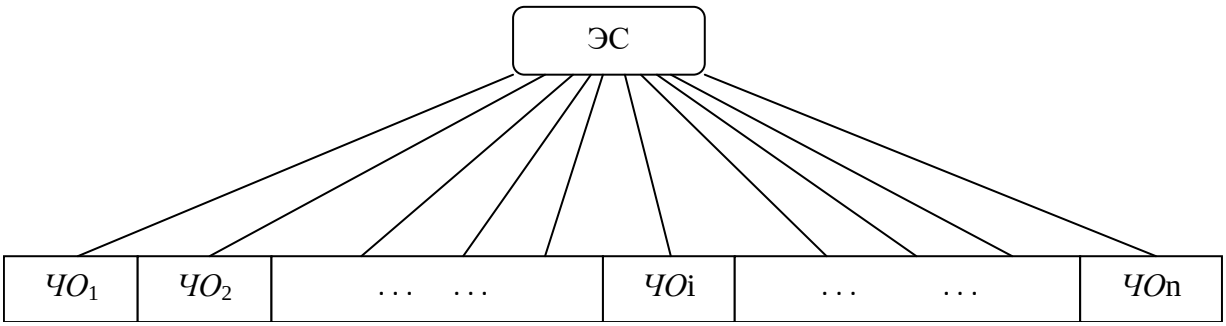

Рисунок 2: Модель абстрактной эргатической системы

В качестве оператора в ЭС могут выступать только штатные специалисты. Отсюда следует, что размерность n – конечна, поэтому задача по выявлению угроз системе, обусловленных ЛФ – решаема.

Учет влияние на состояние защищенности ЭС опасных факторов, связанных с личностью конкретного человека-оператора, как главного элемента ЭС, определяет необходимость разработки дополнительных критериев оценки уровня обеспечения безопасности ЭС, которые позволят объективно учесть влияние на безопасность системы показателей, связанных с такими явлениями, как:

– возникновение особой ситуации по вине человека-оператора (здесь под особой ситуацией понимается

любая нештатная ситуация, перерастание которой в аварийную возможно предотвратить только своевременными, чаще всего неординарными действиями);
- ошибочные действия или бездействие при управлении ЭС;
- иные проявления недостаточного профессионализма при управлении ЭС;
- проявления недисциплинированности при управлении ЭС;
- иные несанкционированные действия при управлении ЭС;
- факты отстранения от управления ЭС;
- нечестность (сокрытие фактов возникновения особой ситуации) и т.д.

Для того, чтобы учесть влияние данных показателей на уровень обеспечения безопасности ЭС и увеличить количество достоверно известной информации о состоянии защищенности ЭС, потребуется применить интегральный показатель, определяющий суммарную величину угроз состоянию ЭС со стороны ЛФ конкретного человека-оператора. Назовем этот показатель термином «суммарный показатель опасности человека-оператора».

Итак, *суммарный показатель опасности человека-оператора – это показатель, характеризующий потенциальную угрозу безопасности эргатической системы со стороны «личностного фактора» конкретного человека-оператора.* Численное значение суммарного показателя опасности человека-оператора ($K_{оч}$) напрямую зависит от негативных проявлений ЛФ конкретного индивида, задействованного в управлении ЭС. Очевидно, что влиять на величину $K_{оч}$ все перечисленные выше проявления ЛФ.

Для того чтобы вывести формулу $K_{оч}$, необходимо определить набор существенных для безопасности системы показателей потенциальной угрозы безопасности предстоящего этапа или цикла функционирования ЭС(показателей опасности K). Сумма значений показателей опасности даст величину, которую мы назвали «суммарный показатель опасности человека-оператора» – $K_{оч}$.

$$K_{оч} = K_1 + K_2 \ldots + K_i \ldots + K_n, \qquad (1)$$

где $K_{оч}$ – суммарный показатель опасности человека-оператора;

K_i – i-тый показатель опасности ЭС со стороны ЛФ человека-оператора;

n – количество определенных показателей опасности.

Зададим диапазон изменений величины суммарного показателя опасности человека-оператора в определенной n области показателей K: величина $K_{оч}$ может изменяться от 0 до 1. При $K_{оч} = 0$ угрозы состоянию ЭС со стороны ЛФ человека-оператора отсутствуют, при $K_{оч} = 1$ угрозы состоянию ЭС со стороны ЛФ человека-оператора определяются как максимально возможные.

Для удобства использования введем новый показатель, характеризующий человека-оператора, как источника потенциальных угроз безаварийному функционированию ЭС. Назовем этот показатель термином «уровень безопасности человека-оператора». Используя $K_{оч}$ при определении величины уровня безопасности человека-оператора ($U_{чо}$), мы получаем возможность учитывать влияние проявлений ЛФ человека-оператора на обеспечения безопасности ЭС. Для удобства применения численная величина уровня безопасности человека-оператора должна быть обратной численному значению суммарного показателя опасности человека-оператора. При максимальном значении $K_{оч} = 1$, уровень безопасности человека-оператора должен приобретать минимальное значение $U_{чо} = 0$. И наоборот, при минимальном значении $K_{оч} = 0$, уровень безопасности человека-оператора должен приобретать максимальное значение. Переведем в проценты значение, обратное значению $K_{оч}$ и представим значение уровня безопасности человека-оператора в виде выражения (2):

$$Uчо = (1 - Kоч)\ 100\% \qquad (2)$$

где $U_{чо}$ – уровень безопасности человека-оператора;

$K_{оч}$ – суммарный показатель опасности человека-оператора.

Очевидно, что величина $U_{чо}$ может меняться от 0% до 100%.

Далее для разработки метода формализации ЛФ в ЭС потребуется использовать введенный в употребление суммарный показатель опасности человека-оператора ($K_{оч}$).

$K_{оч}$ является показателем, величина которого напрямую зависит от негативных проявлений ЛФ конкретного человека-оператора. Для того, чтобы вставить в формулу (1), конкретные величины, необходимо:

1. Определить набор показателей потенциальной угрозы безопасности ЭС (показателей опасности K);
2. Обоснованно определить величину каждого показателя потенциальной угрозы безопасности ЭС, представленного в виде показателя опасности K.

Для того, чтобы сформировать набор показателей потенциальной угрозы состоянию ЭС со стороны ЛФ человека-оператора, необходимо применить экспертные методы.

На первом этапе наиболее целесообразным является метод опроса. Важным условием получения достоверных оценок при применении методов экспертных оценок является формирование экспертной группы, т.к. от компетентности, креативности, конформизма, самокритичности экспертов зависит

объективность и справедливость результатов экспертизы.

Опрос экспертов следует провести в два тура. Первый тур проводится в очной форме, индивидуально, способом интервьюирование-анкетирование. Основной задачей интервьюирования является определение наиболее существенных показателей потенциальной угрозы состоянию ЭС со стороны ЛФ человека-оператора. В ходе опроса следует делать упор на опыт опрашиваемых.

При проведении второго тура следует применить групповой вид экспертного опроса, в ходе которого ранее опрошенные индивидуально эксперты, в процессе совместной дискуссии вырабатывают консолидированную позицию в отношении угроз состоянию ЭС со стороны ЛФ человека-оператора. В результате опроса экспертов должны быть определены существенные, с точки зрения большинства экспертов, показатели потенциальной угрозы безопасности ЭС со стороны ЛФ человека-оператора.

На втором этапе определенные, в результате экспертного опроса, показатели угрозы безопасности ЭС подвергаются процедуре субъективного шкалирования с применением шкалы Лайкерта. Это необязательно, но может быть целесообразным в том случае, если в результате рассогласованности мнений экспертов было определено неоправданно завышенное количество показателей.

Следующим этапом будет определение численной величины каждого определенного показателя, названного показателем опасности.

Причинно-обусловленные явления, признаки которых не поддаются точной количественной оценке, называют атрибутивными признаками. К числу таких явлений относятся проявления ЛФ человека-оператора, поэтому наибольшую трудность представляет обоснование весовой доли каждого показателя опасности. Для решения этой задачи следует использовать метод экспертных оценок, в частности метод парных сравнений.

Методом парных сравнений определяется относительная значимость или весовая доля каждого определенного показателя опасности, иными словами, устанавливается степень влияния каждого показателя потенциальной угрозы со стороны ЛФ человека-оператора на состояние ЭС. Полученные численные величины, определяющие весовые доли каждого показателя опасности переводятся в проценты с таким расчетом, чтобы в сумме все определенные показатели давали 100%.

Следующим этапом будет определение текущих значений каждого показателя опасности в зависимости от зафиксированных фактов проявления того или иного негативного проявления ЛФ человека-оператора при управлении ЭС, определенные, как показатели потенциальной угрозы состоянию ЭС. Для решения этой задачи необходимо использовать экспертные методы, в частности метод опроса и метод бальных оценок.

Применение метода опроса компетентных экспертов позволит определить сколько фиксированных значений должна иметь величина того или иного показателя опасности в зависимости от количества зафиксированных фактов проявления оцениваемого показателя ЛФ человека-оператора.

Затем определяется максимальное значение, которое может принимать оцениваемый показатель опасности. С учетом того, что максимальная величина $K_{оч} = 1$, и имея полученные весовые доли каждого показателя опасности выраженные в процентах от максимального значения $K_{оч}$, получим максимальное значение оцениваемого показателя опасности в виде десятичной дроби, которое будет кратно полученному процентному эквиваленту оцениваемого показателя.

Затем методом бальных оценок, определяются значения оцениваемого показателя опасности в зависимости от количества зафиксированных фактов проявления оцениваемого показателя ЛФ человека-оператора.

Затем, путем опроса компетентных экспертов, определяется срок влияния факта проявления оцениваемого показателя ЛФ человека-оператора на величину соответствующего показателя опасности.

Подобным образом следует определять значения каждого показателя опасности в зависимости от фактов проявления соответствующего показателя угрозы состоянию ЭС со стороны ЧФ оператора. Определенные, таким образом значения каждого показателя опасности в сумме дадут численное значение суммарного показателя опасности $K_{оч}$, которое будет изменяться от 0 до 1.

Подставляя в формулу (2) полученное значение $K_{оч}$, вычисляем текущее значение уровня безопасности человека-оператора $U_{чо}$.

Завершающим этапом будет разработка критериев оценки влияния ЛФ человека-оператора на состояние защищенности ЭС. Для этого целесообразно использовать цветовую шкалу $U_{чо}$ (см. рисунок 3):

зеленый	желтый	синий	оранжевый	красный

Рисунок 3: Цветовая шкала значений уровня безопасности человека-оператора

При переходе к номинативной шкале (шкале наименований) красному цвету соответствует категория «уровень безопасности оператора $U_{чо}$ совсем не соответствует требованиям, предъявляемым к безопасности ЭС. Недопустимо».

Оранжевый цвет – «уровень безопасности оператора $U_{чо}$ в основном не соответствует

требованиям, предъявляемым к безопасности ЭС. Условно допустимо».

Синий цвет – «уровень безопасности оператора $U_{чо}$ не в полной мере соответствует требованиям, предъявляемым к безопасности ЭС. Допустимо».

Желтый цвет - «уровень безопасности оператора $U_{чо}$ в основном соответствует требованиям, предъявляемым к безопасности ЭС. Вполне допустимо».

Зеленый цвет – «уровень безопасности оператора $U_{чо}$ в полной мере соответствует требованиям, предъявляемым к безопасности ЭС. Допустимо в первую очередь».

Затем необходимо распределить значения $U_{чо}$ по цветовой шкале. Для решения этой задачи следует применить метод экспертных оценок, в частности бальный метод или метод непосредственной оценки.

Таким образом, получив возможность определять численное значение $K_{оч}$ в зависимости от фактов проявления ЛФ человека-оператора, и выработав критерии оценки степени влияния данного показателя на безопасность ЭС, в зависимости от численного значения $U_{чо}$, мы получили метод формализации личностного фактора в эргатической системе. Этапы полученного метода показаны на рисунке 4.

Рисунок 4: Этапы метода формализации личностного фактора в эргатической системе

В основе метода формализации личностного фактора в эргатической системе лежат следующие принципы:

- *Принципы факторного анализа.* Главными целями факторного анализа являются: 1) сокращение числа переменных (редукция данных) и 2) определение структуры взаимосвязей между переменными, т.е. классификация переменных;
- *Принцип иерархической композиции.* Используется для определения приоритетов в наборе определенных атрибутивных признаков в отношении предмета исследования.
- *Принцип парных сравнений.* Заключается в том, что все элементы задачи (признаки) сравниваются попарно по отношению к воздействию на предмет

исследования, то есть определяется вес или интенсивность каждого элемента (признака).

Полученный метод является универсальным инструментом, позволяющим разработать методику оценки влияния ЛФ оператора применительно к любой конкретной эргатической системе.

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Molecular Zoning of Eocene and Miocene Age Deposits, North of Maracaibo Lake Basin

By Eng. Jhoan Jose Urdaneta

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Keywords: fingerprint, biomarkers, pristane, phytane, star diagram.

I. Introduction

The Maracaibo Lake Basin has the most economically important oil fields for the Western Venezuelan Region, which are composed of several wells that produce oil from deposits located at different stratigraphic levels of Cretaceous and tertiary age. The data and samples that were analyzed and studied were sampled at the wellhead, using the methodology learned from the Zuliano Institute of Technological Research (INZIT).

The results obtained from these analyzes allowed to show the presence of crude oils with different geochemical characteristics indicating the origin of organic matter, depositional environment, degree of maturity, API gravity and the possibility of several alteration processes within the reservoir. Among the main processes of degradation of an oil can be mentioned: biodegradation, water washing, thermal alteration, among others. Also, the differences detected would point to a lack of communication between several compartments that have been isolated between them and, consequently, have followed different lines of structural and compositional evolution.

Finally, the molecular parameters of the crude oils of interest were determined, through analysis of biomarkers extracted from crude oil by gas chromatography coupled to mass spectrometry, this in order to mitigate the molecular uncertainty between the deposits.

a) Geographic Location

The study area is located northwest of the Bolivarian Republic of Venezuela, within the Maracaibo Oil Basin, which has an estimated extension of 47,705 km2. To the west-northwest, the basin is bounded by the foothills of the Sierra de Perijá; to the east-northeast by the western foothills of the Serranía de Trujillo; to the southeast by the Andean foothills towards the Motatán River; to the north and imaginary delimited by a line on the border between the states Zulia and Falcón and by the geological line of the Falla de Oca-Ancón. The lines mentioned above are quite arbitrary in the physiographic and geological sense, but they actually correspond to the geo-economic nature of the oil basin as such. At the local level, the study was prepared in Block I belonging to the Lagomar Production Unit of the Maracaibo District, which is located in the north-central part of Lake Maracaibo, occupying an area of 242,324 km2 and being divided into flank East and west flank. Specifically, the study area, called VLA0016 / VLA0033, whose size is approximately 11,888 km2, corresponds to Lagunillas Field and is located in the north-central area of El Pilar in Block I of Lake Maracaibo. Area VLA0016 / VLA0033 structurally limits the west due to a normal type fault with the Urdaneta Lago Production Unit, to the east with the Lama-Icotea Fault, to its north part with an arbitrary limit of the Medium Pink Production Unit and to the south with two faults that are intercepted at the level of the same member Santa Barbara. Table 2 shows the UTM coordinates that delimit the study area and Figure 1 shows the geographical location of Area VLA0016 / VLA0033.

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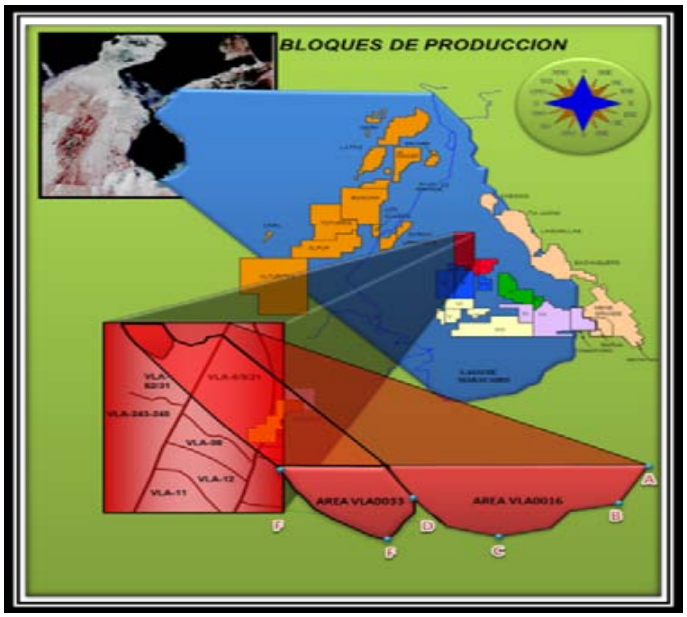


Illustration 1: Geographic Location of the Study Area. Area VLA0033 / VLA0016 in Block I of Lake Maracaibo, Venezuela.

b) Methodological Framework

The investigation of this work is descriptive and interpretive. The universe of samples analyzed was 9 wells distributed in areas VLA0016 and VLA0033 of Block I Lagunillas field of the Maracaibo Lake Basin, with emphasis on medium and light crudes from the area (9 Wells), thanks to the fact that they were achieved Perform a greater number of analyzes. It involved the sampling of these wells of the Lagomar Production Unit (U.P. Lagomar).

In the first place, we proceeded to search and compile all the information available regarding previous studies and bibliography. The samples were subjected to SARA analysis (separation of the saturated, aromatic, resin and asphalt fractions), to subsequently analyze the aromatic and saturated fractions through gas chromatography coupled to mass spectrometry in order to quantify relative the biomarkers present in the oil, in order to characterize and simulate the deposits.

c) Results and Discussion

The results obtained in this investigation, through the processing, analysis and interpretation of the data thrown by the population of crude oils studied, were carried out through a geological study of the area, and its subsequent sampling at the wellhead, which were subsequently analyzed in the laboratory, in order to determine the geochemical characterization of the crudes in the area.

d) General Characteristics of Crude

The marine crudes of the Maracaibo Lake Basin, coming from wells completed in different deposits of the geological column of this basin, have been generated mostly by the La Luna Formation.

According to the general composition of the crude oils (saturated hydrocarbons, aromatic hydrocarbons and resins+asphaltenes), the percentage of saturated hydrocarbons in relation to API gravity can also provide maturity trends, the higher the saturated content, the lower the aromatic and more asphaltene resins; hence the crudes become lighter crudes like those in this study.

Geochemical analyzes carried out on the samples of crude oil from Tertiary deposits included SARA analysis, gas chromatography coupled to mass spectrometry of the Saturated and Aromatic fractions to review the concentration and distribution of biomarkers of these hydrocarbons.

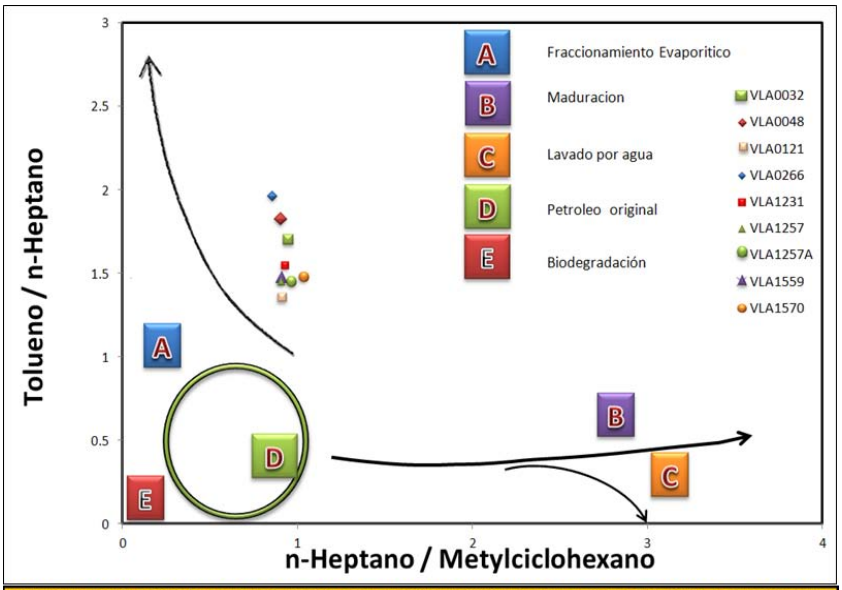
II. Relationship of Paraffinity vs. Aromaticity of Thompson (1988)

The characterization, correlation and classification of hydrocarbons is established based on their origin, degree of maturity alteration within the reservoir such as biodegradation, evaporative fractionation water washing, and hydrocarbon mixtures, for this reason the methodology proposed by KF Thompson is proposed (1988), which is based on the evidence that the light fraction of some crude oils that contain very high concentrations of aromatic compounds and naphthenes, while the proportion of n-alkane compounds is low.

Thus, the terms aromaticity are defined (Toluene / n-C7), which is related to evaporative fractionation, and paraffinicity (n-C7- / Methylcyclohexane), a value that increases with the maturity of the crude. The graph proposed by Thompson allows classification of light and condensed

crudes according to the type of alteration: evaporative fractionation, maturity, water washing and biodegradation.

In this graph, the direction of the arrows indicates a tendency of increase in the process or that the process is more advanced, for example, in the study area crudes, they are being affected, by an alteration of evaporative fractionation, located in zone A, on the other hand it also shows a good maturity, but as the evaporative fractionation process occurs, residual crudes tend to increase aromaticity, in zone A, while if the light fraction migrated is analyzed, an increase in The paraffinity.



CARACTERIZACIÓN GEOQUÍMICA DE LAS ARENAS B DEL VLA0016/VLA0033 Y BASAL LA ROSA DEL VLA0006, DEL BLOQUE I DE LA UNIDAD DE EXPLOTACIÓN LAGOMAR DE LA CUENCA DEL LAGO DE MARACAIBO.

RELACION DE COMPUESTOS	POZOS DEL AREA DE ESTUDIO							
Tolueno / n-Heptano	VLA0032	VLA0048	VLA0121	VLA0266	VLA1231	VLA1257	VLA1559	VLA1570
	1;70580402	1;83285652	1;36039403	1;96891433	1;55451925	1;45635028	1;7696649	1;48189273
n-Heptano / Metilciclohexano	VLA0032	VLA0048	VLA0121	VLA0266	VLA1231	VLA1257	VLA1559	VLA1570
	0;56947824	0;89784546	0;90791122	0;55640589	0;58184432	0;53963417	0;56331998	1;03343242

Illustration 2: Relationship of Paraffinity vs. Aromaticity

III. Paraffin ratio to Aromaticity Determination of Correlation and Transformation of Crude oil According to Halpern (1995)

Looking for the differences in the data of the C7-compounds of unaltered oils compared to biodegraded crude oils of the same family, interaction relationships were constructed in order to emphasize the differences.

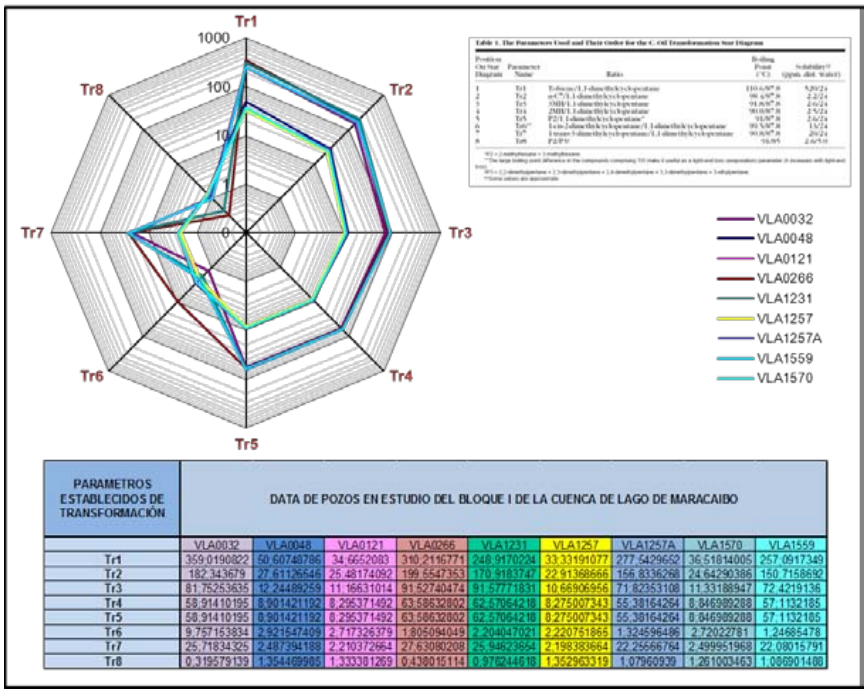
Parameter Tr1 measures the decrease in toluene which is compound C7; more soluble in water, and therefore it is useful to determine the alteration (water wash). The remaining relationships measure biodegradation and the susceptibility of the compounds involved decreases counterclockwise towards the Tr8 relationship, that is, the more resistant and stable relationship with biodegradation. The Tr6 parameter is composed of compounds that differ significantly in boiling points, so it turns out to be a parameter more resistant (less susceptible) to transformation than the smaller Tr parameters. Consequently, parameter Tr6 is very useful for measuring evaporation caused by inappropriate handling of samples and probably by fractionation-migration effect, in both cases the parameter will increase its value. On the other hand, the star diagram to determine correlations between oils is formed by relationships that are resistant or stable to the transformation processes and that are related to the origin of the crude oils. This means that relationships are virtually invariant within the same family, but that they show significant changes between the crude oils of different families.

The C1 to C5 ratios can be used to monitor evaporation or fractionation-migration between samples of the same family. The C1 ratio has a difference in boiling temperatures of -6 between the numerator and the denominator and should decrease with evaporation, while the C5 ratio has a difference of +8 and therefore must increase.

The star diagram for the transformation of crudes based on the high percentage of toluene for compound C7, indicates that the crudes under study do not show water wash disturbance, of the nine (9) samples, only VLA1257 wells were differentiated, VLA0121, VLA1570 and VLA0048 for presenting a lower value of toluene in the Tr1 peak, not being affected by this type of alteration. However, it can be inferred that the total of the samples analyzed (8) show alterations

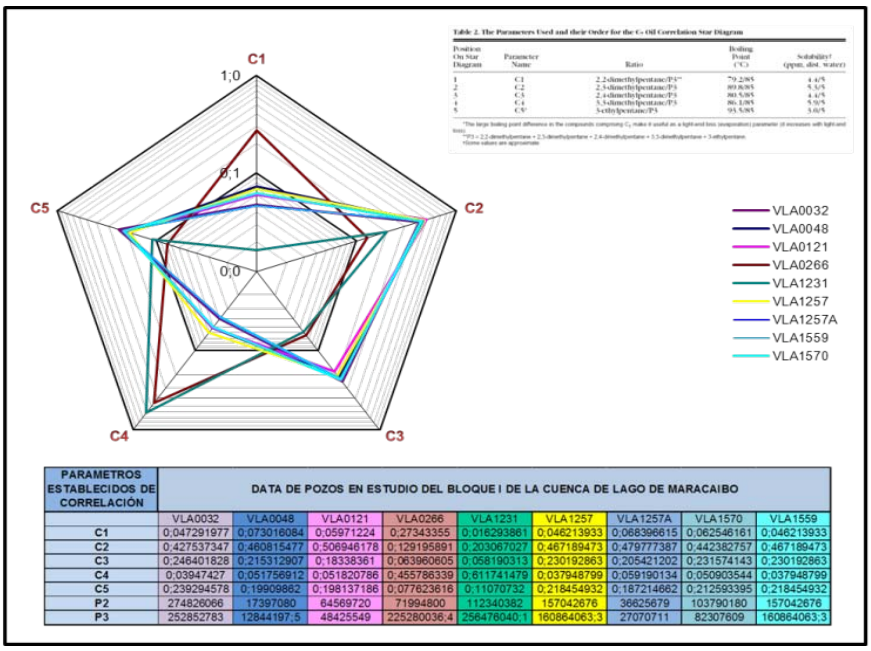
due to evaporative fractionation. Parameter Tr6 affects all crudes of the analyzed wells, except for well VLA0266, which presents a different alteration process associated more with a fractionation-migration alteration, due to the resistance it opposes with respect to the rest of the crudes.

The star diagram to determine correlations of crude oil as stated by Halpern (1988), shows that the samples in studies exhibit a similar profile, coupled with this, it is necessary for parameter C1 in all crude oils except for wells VLA0266 and VLA1570, differ from the others, this being an indication of a possible fractionation - migration, where other authors associate it with a poor handling of the sample during its preparation, additionally the hydrocarbons under study have a high degree of maturation and biodegradation.



PARAMETROS ESTABLECIDOS DE TRANSFORMACIÓN	DATA DE POZOS EN ESTUDIO DEL BLOQUE I DE LA CUENCA DE LAGO DE MARACAIBO								
	VLA0032	VLA0048	VLA0121	VLA0266	VLA1231	VLA1257	VLA1257A	VLA1570	VLA1559
Tr1	359.0190822	50.60748786	34.6652083	310.2116771	248.9170224	33.33191077	277.5429652	36.51614005	257.0917349
Tr2	182.343679	27.61126546	25.48174092	199.5547353	170.9183747	22.91368666	156.8336266	24.64290386	150.7158692
Tr3	81.75253635	12.24489259	11.16631014	91.52740474	91.57771831	10.66906956	71.82353108	11.33188947	72.4219136
Tr4	58.91410195	8.901421192	8.295371492	63.58632802	62.57064218	8.275007343	55.38164264	8.846989288	57.1132185
Tr5	58.91410195	8.901421192	8.295371492	63.58632802	62.57064218	8.275007343	55.38164264	8.846989288	57.1132185
Tr6	9.757153834	2.921547409	2.717326379	1.805094049	2.204047021	2.220751865	1.324596486	2.72022781	1.24685478
Tr7	25.71834325	2.487394188	2.210372664	27.63080208	25.94623864	2.198383664	22.25666764	2.499951968	22.08015791
Tr8	0.319579139	1.354469965	1.333081269	0.436015114	0.976244618	1.352963319	1.07960939	1.261003463	1.086901488

Illustration 3: Halpern star diagram (1988) to determine crude oil transformation

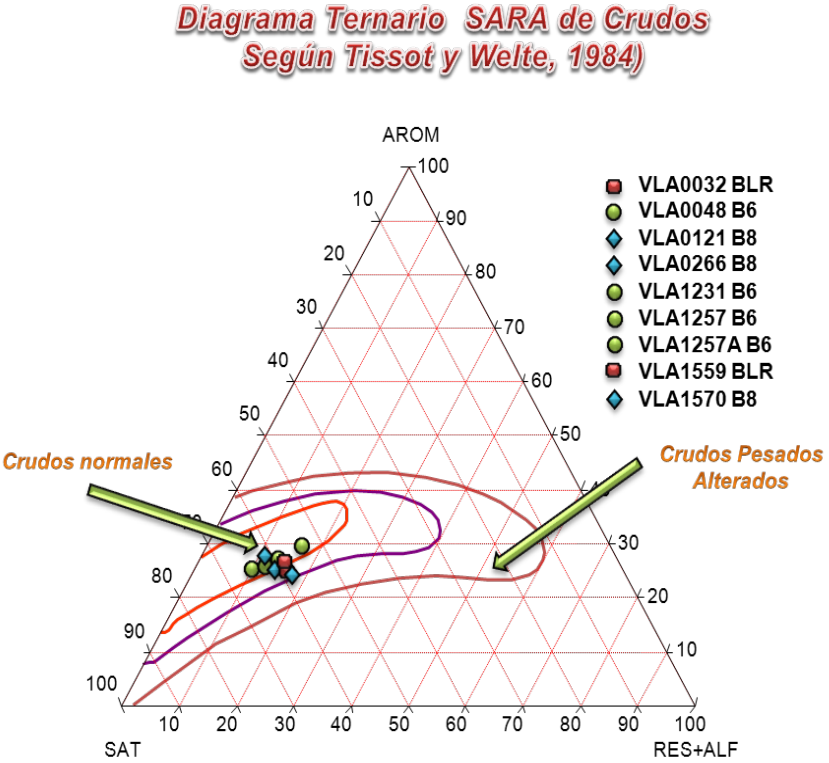


PARAMETROS ESTABLECIDOS DE CORRELACIÓN	DATA DE POZOS EN ESTUDIO DEL BLOQUE I DE LA CUENCA DE LAGO DE MARACAIBO								
	VLA0032	VLA0048	VLA0121	VLA0266	VLA1231	VLA1257	VLA1257A	VLA1570	VLA1559
C1	0;047291977	0;073016084	0;05971224	0;27343355	0;016293861	0;046213933	0;068396615	0;062546161	0;046213933
C2	0;427537347	0;460815477	0;506946178	0;129195891	0;203067027	0;467189473	0;479777387	0;442382757	0;467189473
C3	0;246401828	0;215312907	0;18338361	0;063960605	0;058190313	0;230192863	0;205421202	0;231574143	0;230192863
C4	0;03947427	0;051756912	0;051820786	0;455786339	0;611741479	0;037948799	0;059190134	0;050903544	0;037948799
C5	0;239294578	0;19909862	0;198137186	0;077623616	0;11070732	0;218454932	0;187214662	0;212593395	0;218454932
P2	274826066	17397080	64569720	71994800	112340382	157042676	36625679	103790180	157042676
P3	252852783	12844197.5	48425549	225280036.4	256476040.1	160864063.3	27070711	82307609	160864063.3

Illustration 4: Halpern star diagram (1988) to determine crude correlation

IV. Ternary Diagrams to Recognize Geochemical Crude Classes

The results obtained in the analyzes of the composition of the crudes based on their solubility (SARA) and the ternary diagram derived from them, are shown in Figure 5, it is observed that the grouping of data corresponding to all the crudes of the wells studied, they mostly enter the classification of normal crudes, as referenced, The SARA composition for the sands under study, are mainly of paraffinic origin (saturated), and it could be indicated that these crudes because they are at greater depth have a greater maturity level than the raw ones in the shallowest arenas of adjacent areas.



POZOS	% SATURADOS	% AROMÁTICOS	% RESINAS	% ASFALTENOS	% RES+ASF
VLA 0032	59;55	24;17	15;69	0;59	16;28
VLA 0266	59;18	24;62	15;90	0;30	16;20
VLA 1231	59;70	26;69	13;23	0;38	13;61
VLA 1257	54;36	28;68	16;35	0;61	16;96
VLA 1559	59;60	25;13	14;81	0;47	15;28
VLA0048	62;52	25;05	12;2	0;23	12;43
VLA0121	61;55	27;06	11;12	0;27	11;39
VLA1257A	65;29	24;55	10;06	0;1	10;16
VLA1570	61;33	24;35	13;79	0;53	14;32

Illustration 5: Ternary diagram of the SARA fractions (saturated, aromatic, resins and asphaltenes) with information on the raw materials of the study area

V. Relationship Between Pr / n-C17 and F / n-C18

In general terms, the relations between isoprenoids are parameters that define the type of contribution of organic matter since a ratio of Pr / Ph less than 1 indicates environments of anoxic deposits and conversely, relations of Pr / Ph greater than 1 indicate environments oxides or disóxicos. If these relationships exceed the value of 3 it is already considered a clear land contribution. When analyzing the data, it is observed that all the samples have a Pr / Ph ratio of less than 1. According to this relationship, an origin of the marine organic matter can be inferred with some contribution of terrestrial organic matter.

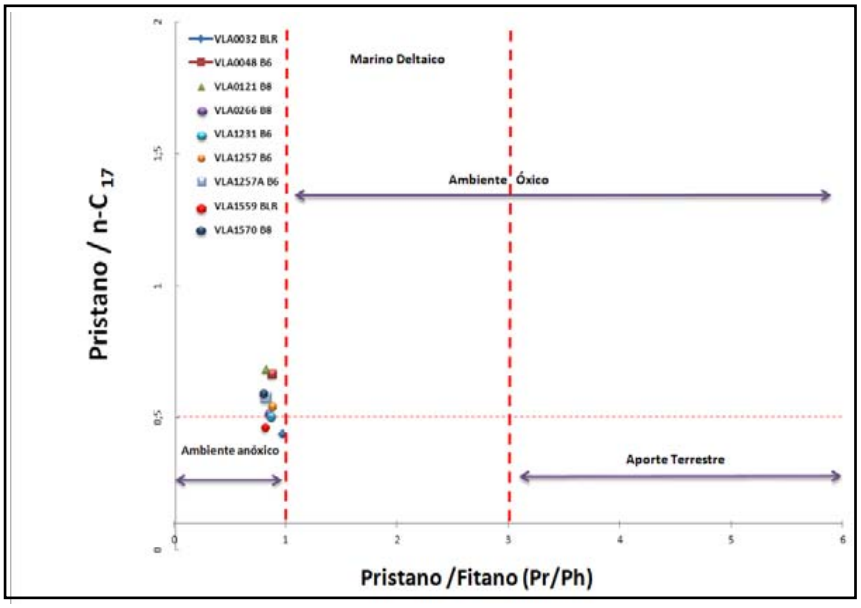


Illustration 6: Pr / Ph vs. Relationships Pr / nC17 of the crudes of the study area

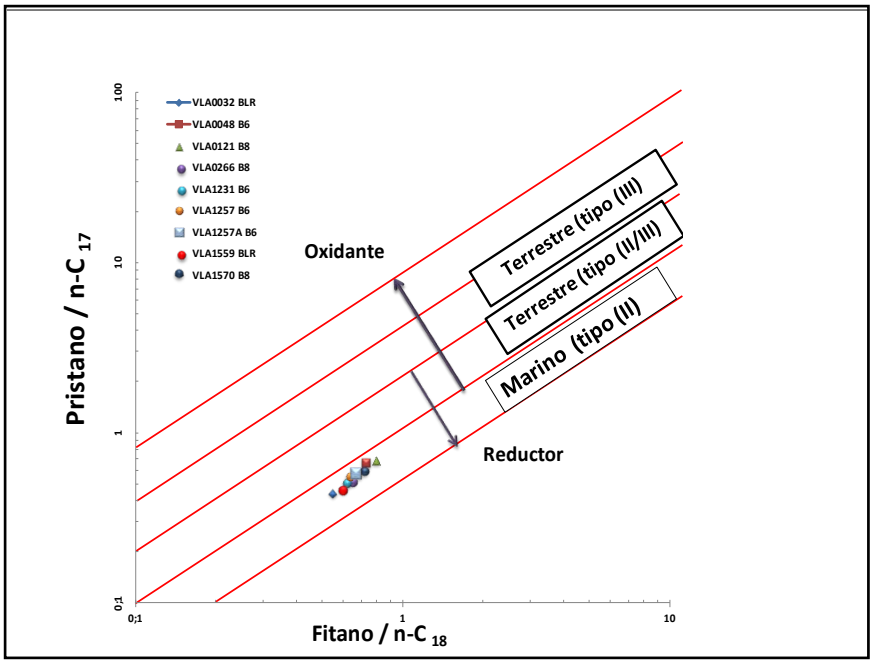


Illustration 7: Pr / Ph vs. Relationships Pr / nC17 of the crudes of the study area

On the other hand, the relation Pr / nC17 vs. Ph / nC18 according to Hunt, (1996), also shows values lower than one, which is particular to an organic matter of marine type in conditions of reduction which is attributed to a state of maturity developed, characteristic of the crudes of the area.

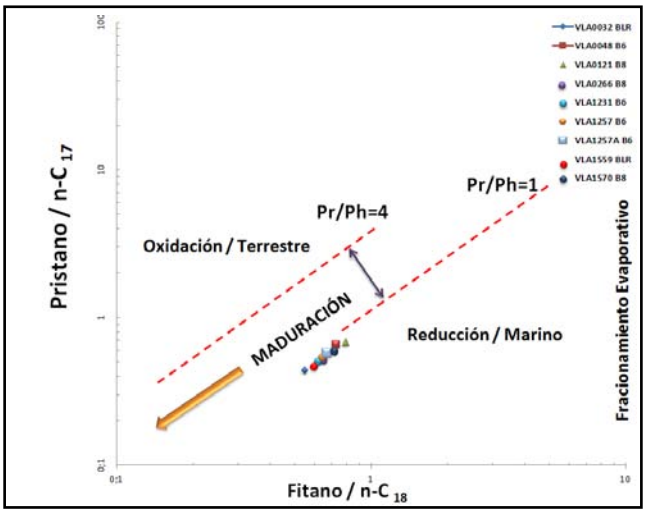


Illustration 8: Pr / nC17 vs. relationships. Ph / nC18 of the crudes of the study area

The bimodal distribution of n-alkanes reveals contribution of marine organic matter, and the Pristano / Fitano ratio indicates conditions of reduction. This is attributed to the advanced state of thermal maturity of the samples. The CPI (Preferential Carbon Index) markers confirm that it is in the presence of a mature oil with possible mixtures, according to Escobar (2007).

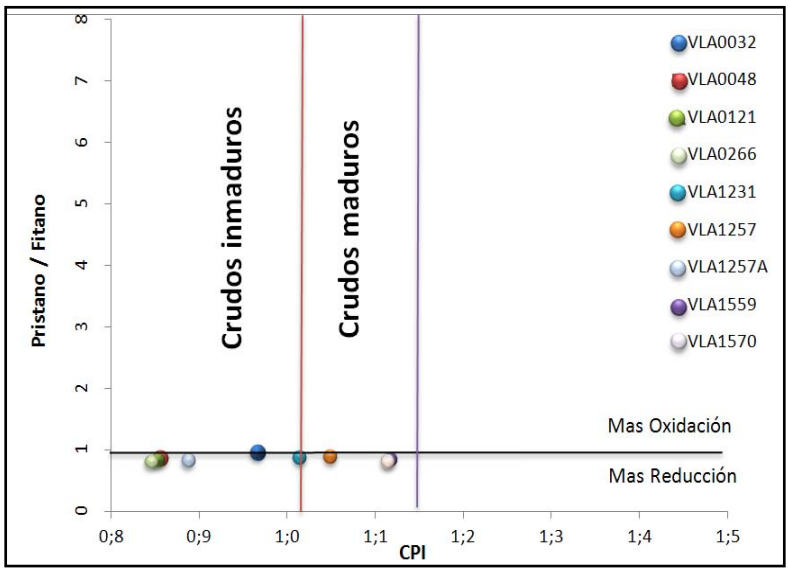


Illustration 9: Pr / Ph vs. Relationships CPI of the crudes of the study area

VI. Thermal Maturity

The Ts / Tm ratios are frequently used to determine the degree of maturity. As the degree of maturity increases, Tm increases while Ts remains constant. An increase in the Ts / Tm ratio would indicate an increase in the degree of evolution (Philp, 1985).

If we look at the values of Ts / Tm, they present values of 0.47 and 0.55 respectively. Characterizing the samples as relatively mature. However, Ts and Tm also depend on the type of organic matter, Ts and Tm are biomarkers that are characterized by their resistance to biodegradation.

That is why the application of the Ts / Tm ratio as an indicator of maturity should be used wisely, since the oil that has the highest ratios may have suffered some type of biodegradation, while abnormally low relationships may show a provenance. of a carbonaceous mother rock.

Crudes from the area of interest under study have a wide range of maturity where the Ts parameters (Ts + Tm) vary between the values of 0.41 to 0.55. In graph 34, it is observed that the relation Ts (Ts + Tm) presents a definite tendency to increase the API gravity of the crudes, the anomalous relationship of maturity Vs API Gravity that the study crudes present, probably the result of some cause of fractionation-migration type alteration as observed in previous results, and these also a good thermal maturity of hydrocarbons as the values grow.

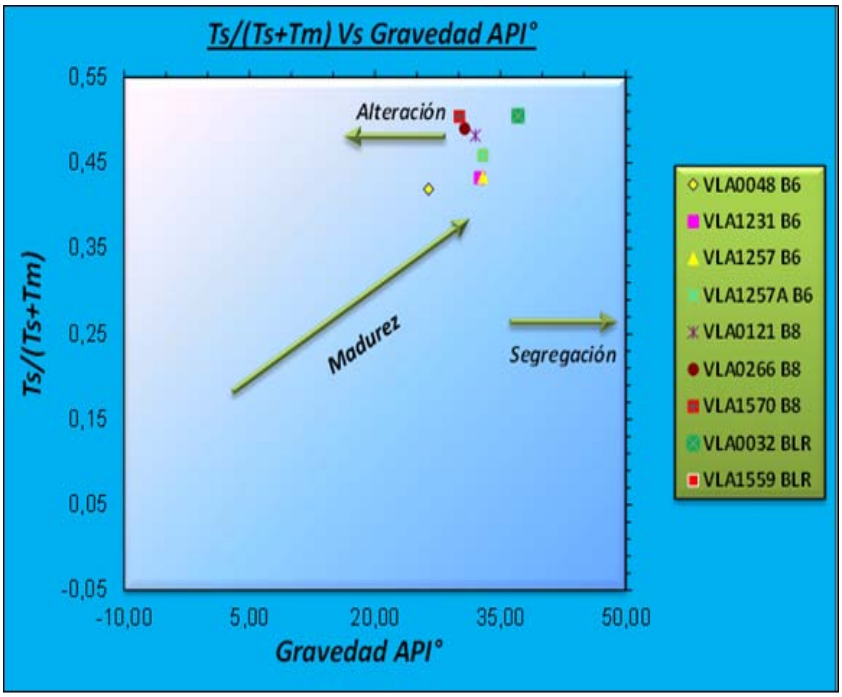


Illustration 10: Relationship of the Hópanos with the diagenesis of the crudos in the area of study

Integrating the information of the related crudes, it can be observed that the crudes have good maturity induced by the gradual burial of the generating rocks of the Formation La Luna, Gómez and Urdaneta (2013).

In this way, a significant amount of light crudes in the Maracaibo Basin have been generated at a relatively late stage of generation. However, it can be seen that biodegradation has also affected some light crudes specifically those of Sands B in the study area.

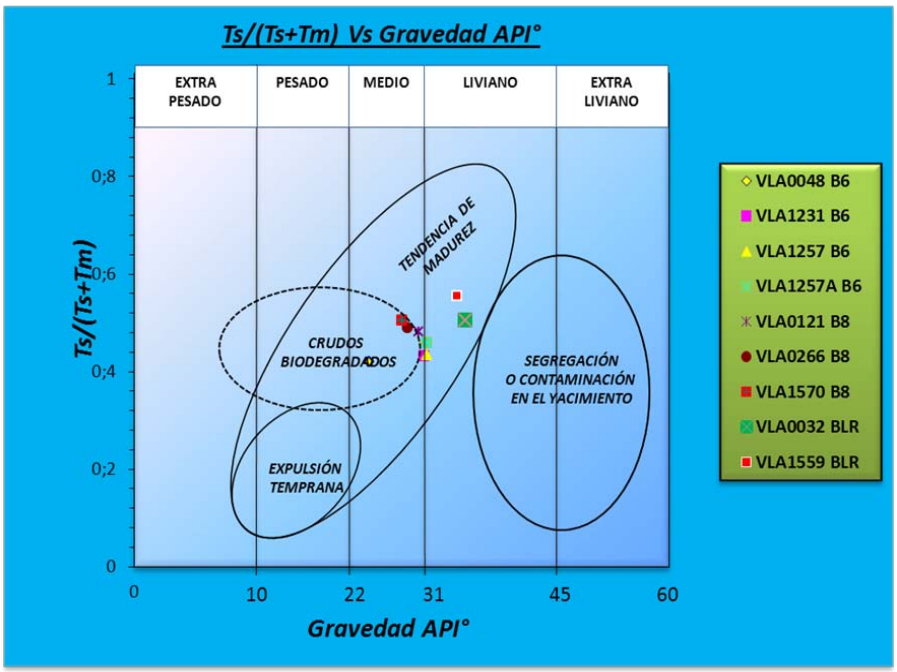


Illustration 11: Generalized relationship between API Gravity and the maturity of the crudes of the study area, using the parameter Ts / (Ts + Tm)

Another parameter used to determine the level of maturity is the methylphenanthrene index (MPI-1). This index is based on the distribution of methylphenanthrene and its methylated counterparts. These can be derived from steroids and triterpenoids originally present in the biological starting material; or they may originate from phenanthrene methylation reactions. The isomers that are more stable from the thermodynamic point of view are, 2, 3 methylphenanthrene, versus 1, 9 methylphenanthrene, according to Peters et al., (2005). They also serve to estimate the percentage of vitrinite reflectance calculated, since it has been observed that they have a linear relationship, according to Peters et al., (2005). As the following illustration shows, all the samples studied have a vitrinite value of approximately equal 1, which are mature samples and that all of them are within the oil generation window.

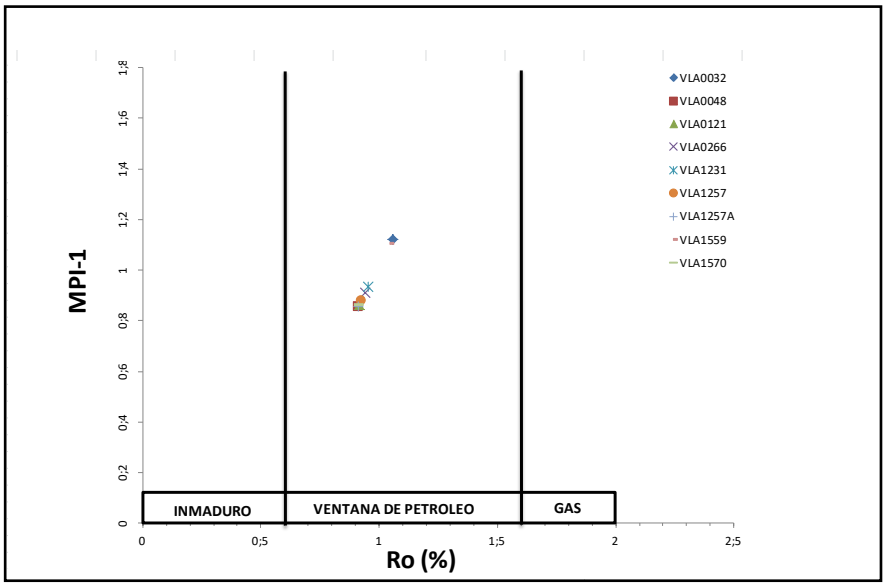


Illustration 12: Relationship between the methyl-phenanthrene index and the value of vitrinite

VII. Conclusions and Recommendations

- Through the C7OCSD, the fingerprint of the crude oil was differentiated in each of the samples from the area of interest, with molecular differences between them.
- Through C7OTSD, a high percentage of toluene is shown, indicating that the crudes have not been altered by water washing, indicating a progressive biodegradation.
- Crudes of interest show a good maturation, also indicating that they have a contribution of terrestrial organic matter.
- The MDBT compound shows a stepped shape to the right, indicating origin of siliciclastic crude.
- Serosity value vs. Pristano / Fitano is> 1 which indicates marine origin.
- The analysis of hopanoids indicates precursor abundance of marine origin.
- The Toluene / n-Heptane ratio shows that our crudes were affected by evaporative fractionation.
- The application of organic geochemistry as an alternative tool to the traditional PLT and SPT, allows an effective and low-cost approach in the monitoring of joint production of wells in the area, eliminating the mechanical intervention of the well.
- The geological study should be reviewed to validate if there are failures that prevent the mixing of crude in the Deposits.
- The geochemical study should be extended to other areas with the purpose of further development of the field.
- Take pure samples of the Deposits to characterize and determine possible areas of coalescence.
- It is recommended to calibrate with the results obtained in the study and confirm the geological model of the area.
- It is advisable to carry out an isotopic study of gases to complement and have a greater characterization of the Deposits.
- Chemostratigraphic studies are recommended to make this study more robust.

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Precision Agriculture in a Coffee Crop to Monitoring its Environmental Variables

By William Ruiz Martinez & Roberto Ferro Escobar

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Keywords: *agriculture, internet of things, cultivation, wireless sensor network, xbee module, zigbee standard.*

GJRE-J Classification: *FOR Code: 091599, 090799*

Strictly as per the compliance and regulations of:

Precision Agriculture in a Coffee Crop to Monitoring its Environmental Variables

Agricultura De Precisión Aplicada En un Cultivo De Café Para Monitorear Sus Variables Ambientales

William Ruiz Martinez [α] & Roberto Ferro Escobar [σ]

Resumen- Este artículo presenta la aplicación del Internet de las cosas (IoT), como herramienta tecnológica para el desarrollo de una red inalámbrica de sensores con el objetivo de monitorear un conjunto de variables ambientales que inciden en el cultivo y producción del café. Se presenta el diseño lógico y físico de los dispositivos, además se plantea la futura implantación de la red de sensores en un área determinada, en un futuro desarrollo se plantea la recopilación de información de las variables ambientales propias de dicho cultivo para ser comparada con una serie de parámetros ya establecidos, lo que posibilitara al cafetero observar el comportamiento de dichas variables en un espacio de tiempo y establecer la generación de alertas o advertencias cuando estas mediciones se encuentren fuera de los rangos establecidos. Mediante el desarrollo del estudio se pudo evidenciar la complejidad que implica el cultivo del café debido a sus diferentes variedades.

Palabrasclave: *agricultura, internet de las cosas, cultivo de café, red de sensores inalámbricos, modulo xbee, estándar zig bee.*

Abstract- This article presents the application of the Internet of Things (IoT), as a technological tool for the development of a wireless sensor network with the objective of monitoring a set of environmental variables that affect the cultivation and production of coffee. The logical and physical design of the devices is presented, in addition the future implantation of the sensor network in a given area is proposed, in a future development the collection of information of the environmental variables of said crop is considered to be compared with a series of parameters already established, which allows coffee to observe the behavior of variable variables in a period of time and establish the generation of alerts or warnings when these measurements are outside the established ranges. Through the development of the study it was possible to demonstrate the complexity that coffee cultivation implies due to its different varieties.

Keywords: *agriculture, internet of things, cultivation, wireless sensor network, xbee module, zigbee standard.*

I. Introduccion

Las Políticas de apoyo al sector agrícola en nuestro país no han sido las más ideales a lo largo de los años, por lo tanto, el apoyo del gobierno específicamente a los caficultores a través de los organismos acreditados no cubre todas las expectativas inicialmente propuestas y casi siempre se diluyen en buenas intenciones, pactos incumplidos y acuerdos mal administradas y gestionados que en muchos casos son un reflejo de los intereses regionales de los políticos de la época.

Debido a esta serie de problemas de índole político, mencionados anteriormente y otros de naturaleza técnica, el sector cafetero se enfrenta a una serie de problemas a la hora de optimizar los procesos de cosecha y producción, ya que, durante muchos años este sector, como dijimos anteriormente, no ha recibido la atención necesaria del estado. Colombia tiene un enorme potencial agrícola que no se explota adecuadamente debido a una planificación deficiente y una ejecución peor, el apoyo del gobierno es muy escaso o inexistente y los precios de los insumos son demasiado altos. Los intereses con los que se presta dinero a los caficultores terminan desalentando la inversión en este importante sector, obligándolos a diversificar o, en casos extremos, a abandonar el cultivo del café. No podemos ignorar el importante papel que desempeña la tecnología en muchos sectores y la agricultura no es ajena a ellos, ya que, con sus procesos de introducción, como la siembra y la producción de café, se puede mejorar y automatizar mejorando la rentabilidad de ellos.

Es por eso que un sector como el café y la introducción de tecnología en ciertos procesos del mismo, tiene el potencial de traer nuevos horizontes a la productividad del país, además de generar innumerables beneficios orientados a los procesos de siembra y producción de ciertos cultivos (Pinto Rios, 2015).

La agricultura de precisión abarca múltiples prácticas relacionadas con el manejo de cultivos y cultivos, árboles, flores, plantas, etc. Entre las aplicaciones más interesantes está el control de plagas y enfermedades. Mediante sensores ubicados estratégicamente, parámetros tales como la temperatura y la humedad relativa del suelo, la temperatura y la humedad de las hojas, la radiación solar se puede monitorear para detectar rápidamente situaciones adversas y establecer los tratamientos apropiados. La gran ventaja del uso de esta tecnología

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es la detección oportuna y la aplicación óptima de pesticidas, solo en aquellas áreas donde es realmente necesario(Martinez Fernandez, Ordieres, Martinez de Pison, & Gonzalez, 2009).

Uno de los principales problemas que surgen actualmente es como monitorear los cultivos en forma adecuada, ya que tecnológicamente hablando no existe un monitoreo y control constante de las variables ambientales que afectan el desarrollo de los mismos, desde el proceso de siembra hasta la obtención del producto final. De esta manera, la agricultura de precisión hace su aparición permitiendo que se pueda aplicar en cualquier tipo de cultivo, siempre que haya una variabilidad espacial (espacios utilizables), independientemente del área donde se quiera llevar a cabo.

"De acuerdo con (Siavosh Sadegian, 2008), es posible llevar a cabo la adaptación de aspectos específicos dependiendo de cada sistema productivo, teniendo en cuenta, variables como: clima, temperatura, humedad, tipo de suelo, material genético y sistema de gestión".

Colombia es conocida por producir el mejor café blando del mundo. Su producción, según informes emitidos por la Federación Nacional de Cafeteros, que es la entidad que representa a los productores a nivel internacional, ha crecido en un 26% en comparación con 2011. Lo que lo convierte en el tercer mayor productor mundial de granos de café, la federación ha promovido en compañía de los cafeteros aspectos como: La renovación de cultivos, la siembra de cafés especiales y orgánicos, entre otras estrategias para incentivar el cultivo del grano (Urbano, 2013).

Por esta razón, proponemos el prototipo de una red inalámbrica de sensores, aplicando el concepto del Internet de las Cosas (IoT) para establecer un conjunto de mediciones, alertas y controles para mejorar la producción y la calidad en un cultivo de café.

A través del diseño y desarrollo de este sistema de sensores, se le ofrece al agricultor tradicional una herramienta invaluable de tecnificación agrícola, que le permite aumentar sus beneficios económicos, la reducción del impacto ambiental y, por lo tanto, la mejora de su calidad de vida, de otro El punto de vista de la agricultura de precisión tiende a obtener un producto de mayor calidad con la conocida optimización de los recursos y funciona como un elemento predictivo para evitar posibles pérdidas de cutivos debido a la falta de gestion,supervision y acción oportuna.

II. Materiales y Métodos

a) *Metodología de Investigación*

Este proyecto lo podemos clasificar como de investigación aplicada con un enfoque cuantitativo, ya que basa en la recolección y envió de datos de un conjunto de sensores a una plataforma Web para ser almacenados, analizados y comparados con un conjunto de parámetros previamente establecidos, posteriormente se configurara un sistema de alertas para que el caficultor puede realizar la toma de decisiones respecto al manejo del cultivo, se ha planteado el desarrollo de la investigación, teniendo en cuenta las fases y actividades propuestas en la figura 1.

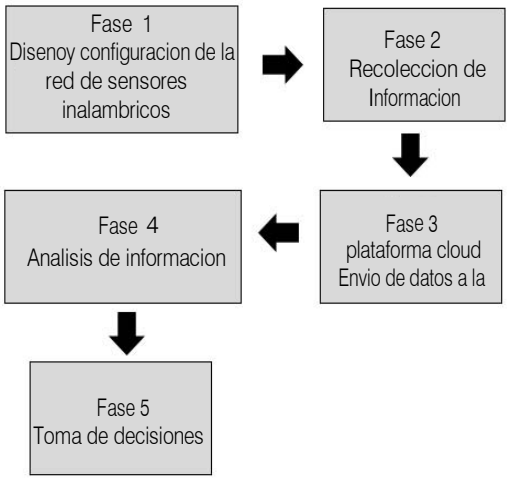

Figure 1: Fases del proyecto (Fuente: Autor)

b) *Componentes de la red de sensores*

De acuerdo con (National Instruments Notas Tecnicas, 2009), una red de sensores inalámbricos (Wireless Sensor Network) es una red inalámbrica que consiste en dispositivos distribuidos espaciados autónomos utilizando sensores para monitorear condiciones físicas o ambientales. Un sistema WSN incorpora un Gateway o puerta de enlace, que provee conectividad inalámbrica como complemento de redes cableadas y nodos distribuidos. El protocolo inalámbrico que seleccione depende en los requerimientos de la aplicación. Algunos de los estándares disponibles incluyen radios de 2.4 GHz basados en los estándares IEEE 802.15.4 o IEEE 802.11 (Wi-Fi) o radios propietarios, los cuales son regularmente de 900 MHz.

De acuerdo con (Villon Valdiviezo, 2009), los componentes o elementos de una red de sensores inalámbricos son:

Sensores: En el caso de los sensores, estos dispositivos se encargan de tomar la información del medio donde se encuentran y las convierten en señales eléctricas que son entregadas a un sistema de control, eventualmente pueden ser de cualquier tipo y permiten medir cualquier tipo de variable que queramos medir (luz, temperatura, viento, presión y humedad entre otras).

Actuadores: Los actuadores son dispositivos que siguiendo las órdenes del sistema de control realizan una serie de acciones que repercuten o tienen

incidencia en el mundo real (Ej. Apertura de una válvula, cierre de una membrana, encendido de un bombillo).

Nodo sensor: Toman los datos recolectados por el sensor a través de sus puertos de datos y envían la información a la estación base. Un nodo sensor tiene que contar con un procesador de consumo reducido, así como de un transceptor radio con la misma característica, a los que hay que agregar un software optimizado para que requiera pocos recursos, haciendo el consumo aún más restrictivo. Así, pues, un nodo sensor, dotado de una pequeña batería del tipo AAA o botón, puede tener una autonomía de hasta dos años.

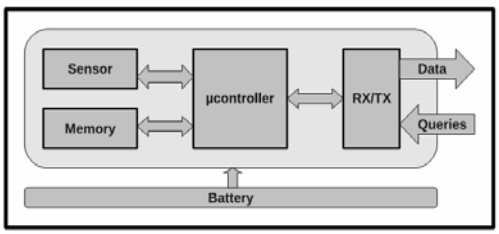

Figure 2: Arquitectura de un nodo sensor (Fuente: NEC)

Nodos intermedios: O los denominados "routers", son dispositivos encargados de extender el alcance de la red, rodear obstáculos a la transmisión sin hilos y proveer rutas alternativas para el tránsito de mensajes que se envían al Gateway (Components 101, 2019).

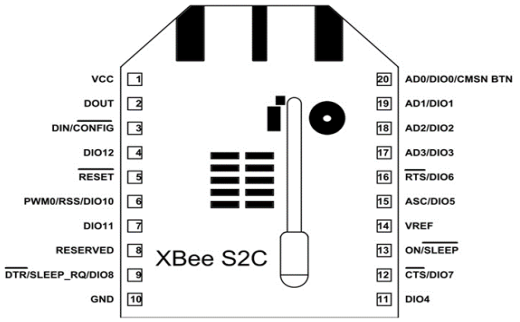

Figure 3: Modulo XBee (Fuente: Components 101)

Gateway: Este dispositivo es clave en el sistema ya que permite servir de interfaz entre la plataforma de aplicación y los nodos que conforman la red, además de permitir el acceso entre el sistema y los entornos, ya que permite manejar diferentes tipos de protocolos, además posee la capacidad de operar en las capas superiores del modelo OSI (Transporte, sesión presentación y aplicación), permitiendo realizar la conversión de protocolos para interconectar redes con protocolos de alto nivel diferentes.

Red inalámbrica: Medio de transmisión de la información, típicamente se basa en el estándar 802.15.4 (ZigBee).

La estación base: Es la encargada de conectarse a los nodos de coordinación o intermedios para recolectar los datos de la red, generalmente está conformada por un PC o un sistema embebido de visualización.

Figure 4: Funcionamiento de un Gateway en una red inalámbrica de sensores (Fuente: NEC)

c) Estándar de comunicación inalámbrica

Para el desarrollo del proyecto se encontraron varios estándares que cumplían las características y condiciones necesarias, pero se seleccionó el protocolo o estándar ZigBee 802.15.4., más que todo por factores económicos, a continuación, relacionamos algunas de sus aspectos más importantes:

De acuerdo con (Ramirez C, 2012), la Alianza ZigBee (ZigBee Alliance) está formada por una asociación de industrias que trabajan en conjunto para desarrollar normas y productos. ZigBee es el nombre de la especificación de un conjunto de protocolos de comunicación inalámbrica de alto nivel, para su utilización en aplicaciones de radiodifusión digital de bajo consumo, con base en el estándar IEEE 802.15.4 de redes inalámbricas de área personal (Wireless Personal Área Network o WPAN). La tecnología ZigBee está integrada en una amplia gama de productos y aplicaciones para los consumidores de tipo comercial, industrial y gobierno.

La idea principal sobre la que se ha desarrollado ZigBee ha sido la facilidad a la hora de implementarlo en un sistema de control, o lo que es lo mismo, se busca que de una manera sencilla y rápida se pueda desarrollar un sistema robusto y duraderofácilmente integrable en una red inalámbrica destinada a la supervisión y el control. Por este motivo, ZigBee pretende cumplir los siguientes requisitos:

- Alta fiabilidad
- Bajo costo
- Bajo consumo
- Es un estándar abierto
- Altamente seguro

En consecuencia, para poder satisfacer todos estos puntos, ZigBee se va a caracterizar por las siguientes características:

- Baja capacidad de transmisión, en torno a 250 Kbps, que nos permitirá desarrollar sistemas de muy bajo costo.
- Protocolo sencillo, pudiendo ser implementado sin ningún tipo de limitación en sistemas micro controladores de 8 bits.
- Muy bajo consumo energético permitiendo que la fuente de alimentación del sistema pueda durar años

d) Arquitectura de la red de sensores

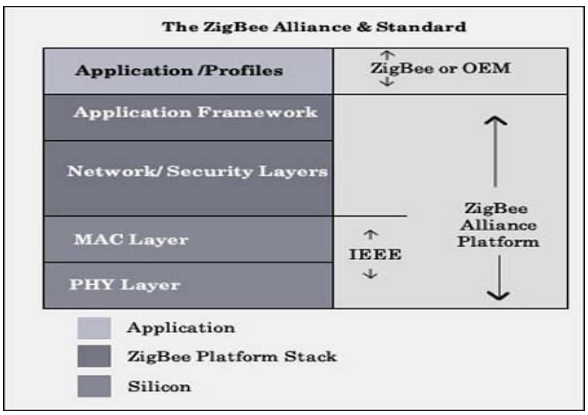

Figure 5: Pila de protocolos para el estándar IEEE 802.15.4 (Fuente: IEEE)

La Figura 6. muestra la arquitectura propuesta para la red de sensores, cuyo objetivo es monitorear un cultivo de café. El terreno para el estudio propuesto consiste en un lote de café con un área equivalente a una hectárea, que se encuentra en una finca cafetalera de la región. Los nodos sensores son responsables de monitorear variables ambientales tales como: temperatura y humedad del suelo, temperatura ambiente e incidencia de lluvia mediante el uso de un medidor de lluvia.

También vemos en la figura una puerta de enlace, cuya función es enviar la información recopilada por los nodos del sensor al nodo coordinador que es responsable de establecer la comunicación con la unidad central integrada por una computadora con conexión a Internet que se encargará de cargar la información recibida en un sitio en plataforma Ubidots para su procesamiento y posterior análisis.

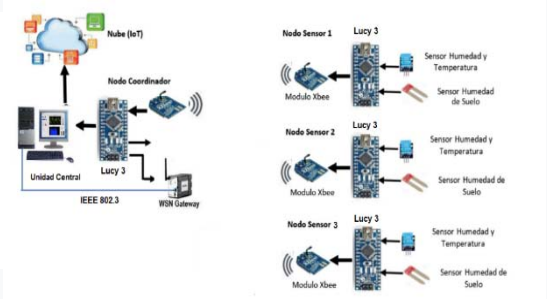

Figure 6: Arquitectura propuesta para la red de sensores (Fuente: Autor)

e) Plataforma Cloud Ubidots

Como se planteó anteriormente para el caso específico de este proyecto, en el apartado del almacenamiento y procesamiento de los datos provenientes de los sensores, este proceso se va a realizar a través de una plataforma Cloud, llamada Ubidots, a continuación ellos mismos se encarga de definir que son: "Ubidots es una plataforma de Internet de las cosas (IoT) que permite a las empresas crear aplicaciones IoT que convierten los datos de los sensores en conocimiento práctico y aplicable. Ubidots es un recurso eficiente y económico para integrar el poder de IoT en su negocio o proyecto de investigación" (Klotz, 2017).

Las principales características de la plataforma son:

- Capacidad para publicar los datos del dispositivo sobre una API REST.
- Flexibilidad, ya que permite a sus usuarios mezclar diferentes flujos de datos y presentarlos en esta plataforma.
- Disponibilidad ubicua, debido a que está basado en la nube.
- Seguridad basada en mecanismos incorporados en la plataforma de Ubidots (autenticación mediante API o tokens).

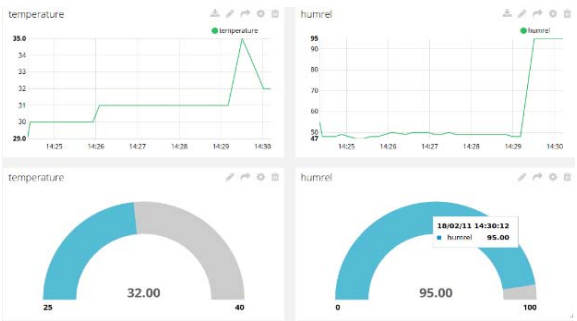

Figure 7: Visualización del comportamiento de 2 sensores en la plataforma Ubidots (Fuente: Ubidots)

f) El café y sus variables ambientales

En este apartado pretendemos dar a conocer una serie de variables de tipo ambiental que de un modo u otro inciden en la siembra y cultivo del café y posteriormente en su futura producción, veamos cada una de ellas a continuación:

Temperatura: La zona óptima para el cultivo del café arábico se encuentra entre 19 y 21.5 grados centígrados. En climas fríos, donde la temperatura media es menor de 19 grados centígrados, las variedades de café se desarrollan menos, su producción es menor y la cosecha se distribuye a lo largo del año. En climas calientes, donde la temperatura media es mayor de 21.5 grados centígrados, la vida productiva del cafeto es más corta, la cosecha más temprana y más concentrada. El ataque de la roya es

más severo y se incrementan plagas como la broca y el minador (Cafe de Colombia, 2010).

Lluvias: Se considera apropiada para el cultivo una cantidad de lluvia comprendida entre los 1.800 y los 2.800 milímetros anuales, con una buena distribución en los diferentes meses del año. Se requieren por lo menos 120 milímetros al mes. Periodos de mucha lluvia favorecen la presencia de enfermedades como el mal rosado y la gotera. El exceso de lluvias también puede afectar la floración del cafetal, disminuyéndola o dañándola. Si se presentan sequías excesivas, las hojas del cafeto pueden caerse por falta de agua y se puede incrementar el ataque de plagas como la arañita roja, el minador y la broca.

Humedad del aire o humedad relativa: Este componente del clima presenta altas variaciones entre el día y la noche. En la zona cafetera el aire es normalmente húmedo.

El suelo para el cultivo: El suelo es esencial para el cafeto porque le facilita el anclaje y le proporciona el agua y los nutrimentos necesarios para su crecimiento, desarrollo y producción. Tiene su origen en la desintegración y descomposición lenta de las rocas, causada principalmente por la acción del agua, la temperatura y los vientos. En algunas regiones estos procesos se acompañan de cenizas provenientes de los volcanes. Con el paso del tiempo las partículas formadas se mezclan con los residuos de animales y vegetales en descomposición, dando origen al suelo o capa vegetal (Ramirez, Victor Hugo;, 2011).

g) Resultados y discusion

Se pudo observar que la plataforma Ubidots brinda un ambiente grafico ameno e intuitivo, para todo tipo de procesos, como creación de parámetros para ser comparados con las mediciones enviadas por los sensores.

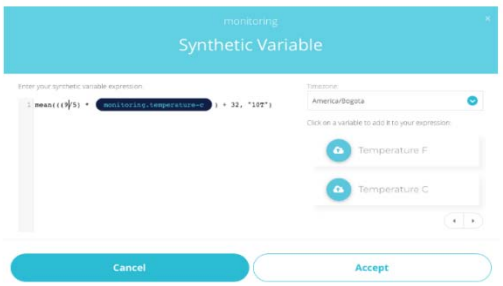

Figure 8: Definición del parámetro de humedad en la plataforma Ubidots (Fuente: Ubidots)

En las figuras 9. Y 10 se pueden visualizar las mediciones de la variable temperatura enviadas por un grupo de sensores, a la plataforma, pudiéndose establecer valores mínimos, máximos y promedio de un cultivo en una fecha y hora determinada.

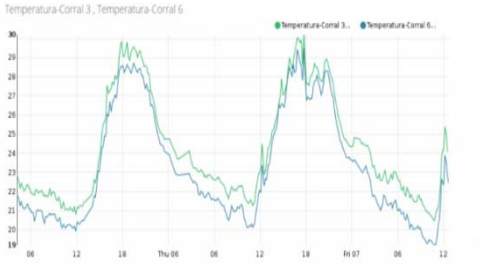

Figure 9: Visualización de datos de un sensor enviados a la plataforma (Fuente: Ubidots)

Figure 10: Visualización de datos de un sensor enviados a la plataforma en una fecha y hora especifica (Fuente: Ubidots)

Se comprobó que las tarjetas programables Lucy 3 que tiene cada uno de los nodos del sensor cumplen con efectividad las tareas encargadas, entre otras el recibir los valores enviados por cada uno de los sensores, procesar dichos datos y enviarlos al módulo de comunicación.

Se desarrollaron pruebas de distancia para determinar el rango máximo de los módulos inalámbricos Xbee -Pro S2C para garantizar una transmisión de datos confiable sin pérdida y atenuación de la señal, encontrando que el rango máximo está dentro del límite establecido de 100 metros en campo abierto.

h) Conclusiones

El manejo del cultivo de café es bastante complejo teniendo en cuenta la variabilidad de especies, terrenos y condiciones específicas de las variables ambientales que finalmente afectan el proceso de producción y la calidad final del grano.

El desarrollo e implementación de redes inalámbricas de sensores ahora es más factible debido a los bajos costos con los que se obtienen componentes como: sensores, tarjetas programables y módulos de comunicación, lo que lo hace rentable para los cafeteros teniendo en cuenta que con hardware y software de código abierto para lo cual no hay necesidad de pagar licencias.

La tecnificación del agro y en especial el cultivo del café, es viable siempre y cuando haya compromiso por parte de las entidades encargadas de promover el

grano, los caficultores y las empresas encargadas de ofrecer las soluciones tecnológicas a precios acordes con la realidad de dicho sector en el país.

El internet de las cosas (IoT), esta demostrando ser una tecnología de gran eficiencia en procesos agrícolas, ya que sus dispositivos son precisos y fiables en la toma de mediciones de variables ambientales de cualquier tipo de cultivo.

Las plataformas Cloud como Ubidots permiten almacenar datos enviados por los sensores, pero además prestan servicios de análisis de información y posterior envió de alertas o informes al usuario, sobre situaciones anómalas.

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Lens Coplanar System Application based on Lateral Refraction and Reflection of Polarized Light

By Lázaro J., Miranda Díaz

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A linearly polarized light beam over a lens will be reflected and refracted following the lines curves resulting from the interception of a plane of polarization with the sphere lens surface, keeping the orientation of refraction and reflection inside the plane of polarization.

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A linearly polarized light beam over a lens will be reflected and refracted following the lines curves resulting from the interception of a plane of polarization with the sphere lens surface, keeping the orientation of refraction and reflection inside the plane of polarization. Only looking at the lens laterally this effect is significant, and a lens behavor is like lateral analyzers if the polarization plane of the polarized light incident over the lens is rotated, and two pairs of fans on opposite edges to diameter are forming, get out to both sides of the lens. The resulting beams will take place at opposite ends to the diameter of the lens and it has the higher intensity, so that this phenomenon is noticeable only by observing the lens laterally and placing parallel to the optical axis Based in the principle that in the spherical surface of a lens fit n circles of radius r, and n is inversely proportional to r, then each circle is a lens itself. If a beam of light is projected in one of these areas, the phenomenon is expressed lateral side and the light get out diametrically opposite to the incident linearly polarized light get in, the lens acting as a waveguide for the light beam polarized. Demonstration that a polarized light over a lens will be reflected and refracted following the interception of the plane of polarization with the spherical lens surface, maintaining the orientation of refraction and reflection within the plane of polarization and it can be used for measurement of a polarized plane rotation. Now if we rotate the polarization plane of polarized light beam, not the lens, then, also changes the direction of the rays reflected and refracted as they remain within the plane of polarization of light.

Keywords: polarization, rotation, plane, lens, reflection, reflection, polarized light.

I. Background

Algebra properties of geometrical shapes are made to manifest when a linearly polarized light beam incident on a lens, such as the intersection between a plane and a spherical surface, a polarized light beam is electromagnetic waves and oscillate in planes parallel to each other in the same direction. When this planes affect orthogonally on the spherical surface of a convex lens, the light is reflected and refracted without leaving the plane which belongs at, in Figure 1 shown only the central portion of the lens for a better understanding. By rotated the polarization plane of polarized light beam, changes the direction of the rays reflected and refracted because they most remain within the plane of light polarization.

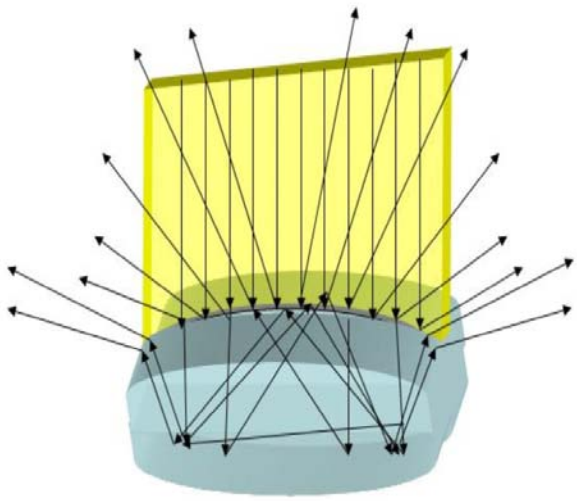

Figure 1: Refraction and reflection of polarized light in a convex lens

Now, we will put the lens over horizontal surface and a beam of polarized light incident in its geometrical centre, with the polarized plane oriented vertically to us, we can see a brightness circle inside the lens (Fig.1a), and what is that circle? It is light; light get out laterally from the lens. And why it is so brightness, because we are front of the polarized plane of the beam. With the polarized plane oriented parallel to us, the circle disappears, why, because there are two beam of light get out of the lens 90^0 from us to booths lens sides and parallel to our position, then we can not see the light. Let's consider that these two positions are *extremes positions* and between those positions, the circle change in intensity, decreasing while the polarized plane of beam is rotated up to be parallel to us.

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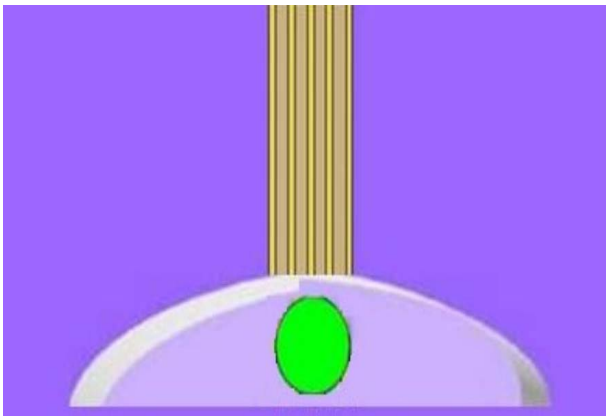


Figure 1a: Inside the lens we can see a brightness circle

This is in fact our phenomena, and it that can be used in many applications, principally in determined the polarized light positions. Using photo sensors placed to 90^0 from each other, for example, when its value been the same, the polarized light will be at 45^0 between the *extremes positions*.

a) Concept

Return to the photo sensors, which are showing in Fig.1a, the difference between the light intensity of each one, will be equivalent to the position of the beam polarized plane

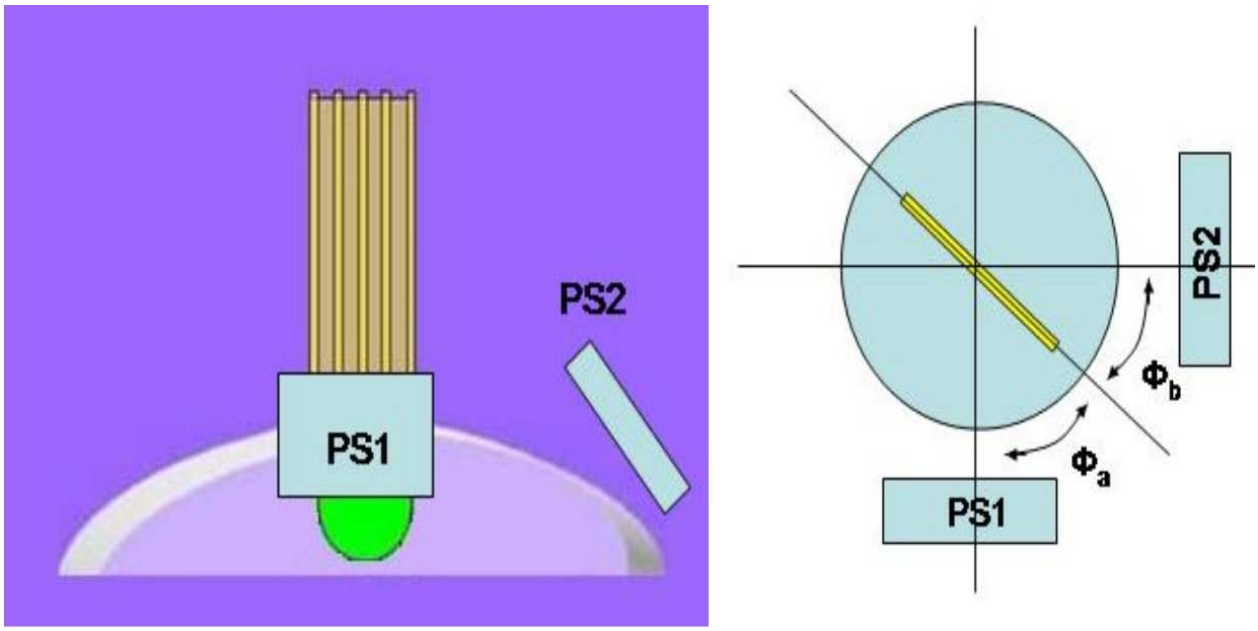


Figure 1b: Photo sensors PS1 and PS2

In the PS1:

(1) $I_a = I_0 Sin((\pi - \Phi_a)/1$

In the PS2:

(2) $I_b = I_0 Sin((\pi - \Phi_b)/180)$, $\Phi_b = 90^0 - \Phi_a$

I_0 is the incident light intensity and the difference I_a-I_b is equivalent to the rotation of the polarize plane Φ, and can be calculated:

(3) $\Phi = (0.5)*90^0 *(I_a-I_b)$

Ahead will see another concept, *coplanar lenses* and these equations will be not the same in that case, this is when only one lens has been used.

There is a way in which no matter if the light intensity has variation or not. These are an optical trigonometric system and follow trigonometric rules. The angle Φ can go between 0^0 and 90^0 how we can see in Fig. 1b, if we divided 90^0 between 3.1416, the value result is 28.64 when Φa is CERO, them Ia is equal to 3.1416, but Io in this conditions will be equal to Ia divided between Sin (90^0/180^0) is equal to 2(3.1416), which value is 6.28. Now can make the substitution of Io by 6.28 in the equations 1 and 2 and no matter if Io has variation or not, the result will be constant, because of the values Φa and Φb have variations, how they are subtracted, the variation will be annulated. In this way the effect of the absorption can be controlled.

Lets go used the EXCEL software, but first we will see the equations that we will use in it:

A2=K, A3=A2, A4=A3,…….
B2=Io, B3=B2, B4=B3,…….
C2=Q (Perturbación que se introduce a Φa1 y Φb1)
D2=Φa, D3=D2+1, D4=D3+1,…..
G2= Φb, G3=G2+1, G4=G3+1,……
Ia= (2,085852*3,1416/A2)*(A2*B2/B2)*SIN((90-D2)/(180))
Ib=(2,085852*3,1416/A2)*(A2*B2/B2)*SIN((90-G2)/(180))
Φ= (GRADOS((F2-I2)/180))
Φ=0.5*90*(Ia-Ib)=45*K2
Φa1=D2-C2
Φb1=G2-C2
Ia1=(2,085852*3,1416/A2)*(A2*B2/B2)*SIN((90-E2)/(180))
Ia2=(2,085852*3,1416/A2)*(A2*B2/B2)*SIN((90-H2)/(180))
Φ1=(GRADOS((O2-P2)/180))
Φ1=0.5*90*(Ia1-Ib1) =45*Q2

In the appendix is the Figure 1.1 which is Excel app.

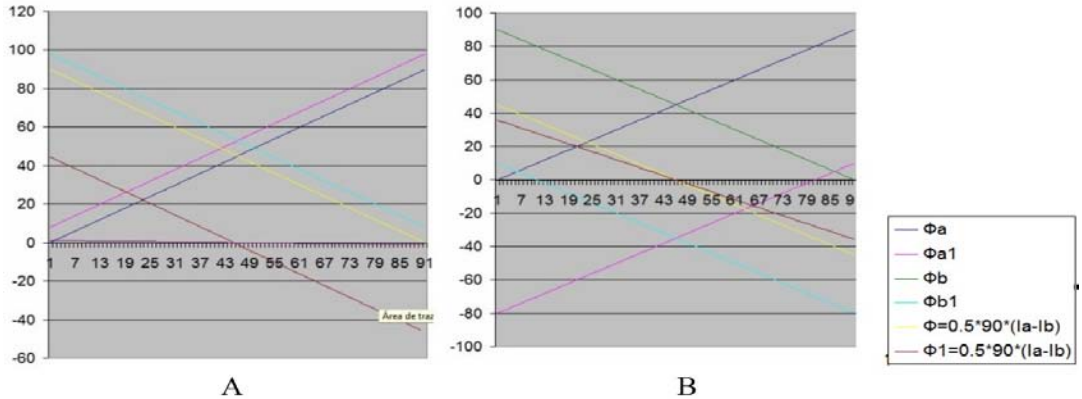


Figure 1.2: In A, Q = - 8; in B, Q= 80

When the perturbation Q is lowest than CERO, the line Φ1 is over the line Φ, that is not have perturbation. This is due to negative values are equivalent to increase the light intensity.

When the perturbation Q is upper than CERO, is equivalent to an absorption of light and pendent of Φ1 decrease respect pendent of Φ.

With these properties is possible avoid that perturbations could affect the measurements, only using an additional source or light (Q<0) nearest the lens, or the lenses in the case of coplanar lenses. The lector one can probe all this himself if build the excel table (Fig. 1.1) and change the values in columns A, B y C; but the values Φ and Φ1 remain approaches to each other.

If we desire construct an instrument to determine the value of the rotation of the plane of polarization of light using this phenomenon, it is necessary use two light sensors placed parallel to the optical axis and 90^0 spaced from each other and on the sides of the lens

This has been possible because of the physical properties when linearly polarized light impinging on a lens, the light beam is reflected and refracted following the lines curves resulting from the interception of a plane of polarization with a lens spherical surface maintaining the orientation of refraction and reflection inner the plane of polarization.

This is the physical concept obtained with our research and it permitted us understand better the phenomena and the procedure to follow in order give it a correct application.

The extension in the application of the phenomena gives us the possibility to find out the concept of *coplanar lenses* that do better than the precision of the measurements, with out loss the simplicity of the optical system used, and understood the difference between use one or two lenses and when we must use one lens or use two lenses.

If we used only one lens, when the polarized plane is rotated, there is a space between the photo sensors where the light not insides over the photo sensors areas, whereas in the system with two lenses always the light is over the photo sensors surfaces.

In conclusion we have given hear important concepts that abstract the more important things that most be remembered for a better understanding of the following matter.

II. Researching

I in Figure 1 let go place two observers, one on the right and another one on the left of the diametric line of the lens, the observer at the right sees the left side of the light source image, the rays that reach him are the result of the refraction and reflection within of the lens from the left side of the light source. The left observer sees from his position the right side of the light source image.

When the plane of polarization is orthogonal to the plane of the paper, that means it is parallel to the two observers, both observers observed that the light intensity of the image decry completely.

In that way the lens gives information about the orientation of the plane of polarization and the lens behaviour is like an analyzer of polarized light, which, shows this effect in Figure 2.

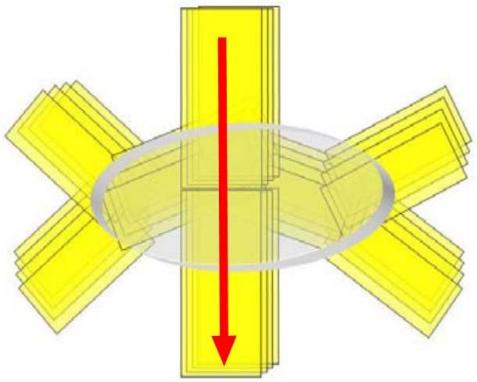


Figure 2: Inner reflection and refraction in a convex lens

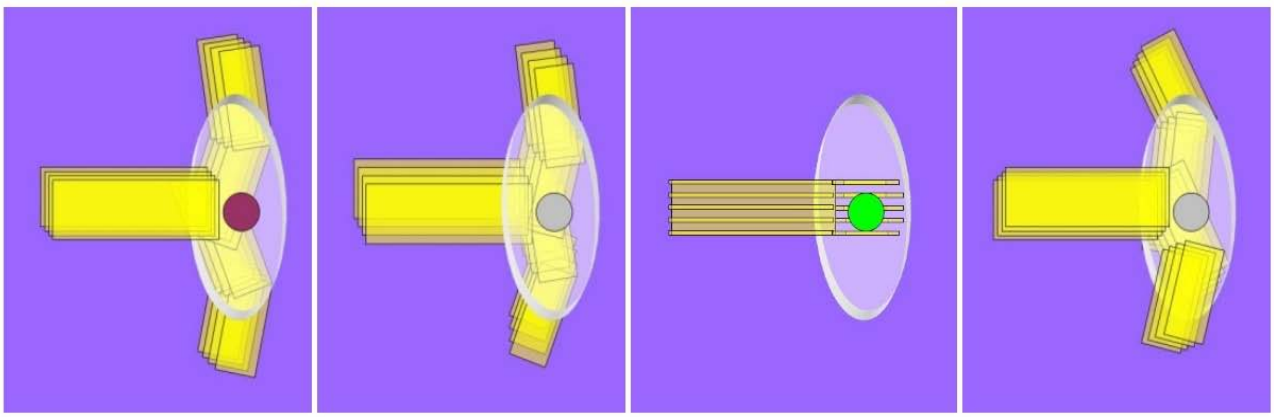


Figure 3: Sequence of the polarize plane rotation

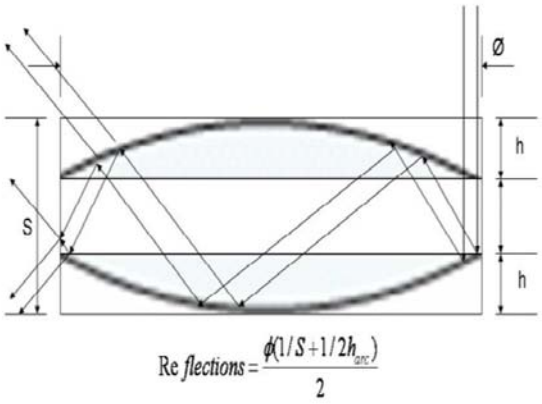
Over the lens spherical surface can be placed perfectly **n** circles of radius **r**, the number **n** is inversely proportional to the radius **r,** whereas, while the radius will be shortest, the numbers of insert lens will be biggest. Each circle is an independent lens.

When the linearly polarized light incident chining on the lens edge, will occurred all explained before, but in the incidence region. The light travel along the lens diametric line and will exit the edge of the lens diametrically opposed to the incident beam and only at that point the image can be seen and not in any other region of the lens.

What has been explained here can be seen in Figure 4, where is including an equation in order to determine the number of reflections and selecting the appropriate lens according the lens geometry.

The entire lens and the beam of polarized light are showing in Figure 2. The biggest light intensity of refraction and reflection occurred where the geometric central plane of the beam radiating on the diametric line of the circumference defined by the plane polarization of the light beam on the lens surface.

A sequence of rotation of plane polarized light beam is showing in Figure. A light spot is observed in the centre of the lens, and the light intensity varies according on the plane of polarization spatial position, in relation to the observer position. An observer, who turns around the lens at the same speed that the plane of polarization is rotated, always will see the same intensity.



$$\text{Re flections} = \frac{\phi(1/S + 1/2h_{arc})}{2}$$

Figure 4: Reflections on the lens to make an impact on its edge beam perimeter

Where:
Φ: light incident angle
h: arc lens wide
S: lens wide

Let's do the beam of polarized light shinning in the lens edge, and after that the plane of polarization is rotated, when the lens diametrical line coinciding with the orientation of the polarization plane, the image of the light source, in the lens diametric opposite side, will be very bright. That bright will decrease when the polarization plane will be moved from that point.

We can be seen how change the outgoing light when the polarizing plane is rotated in the sequence shower in Figure 5.

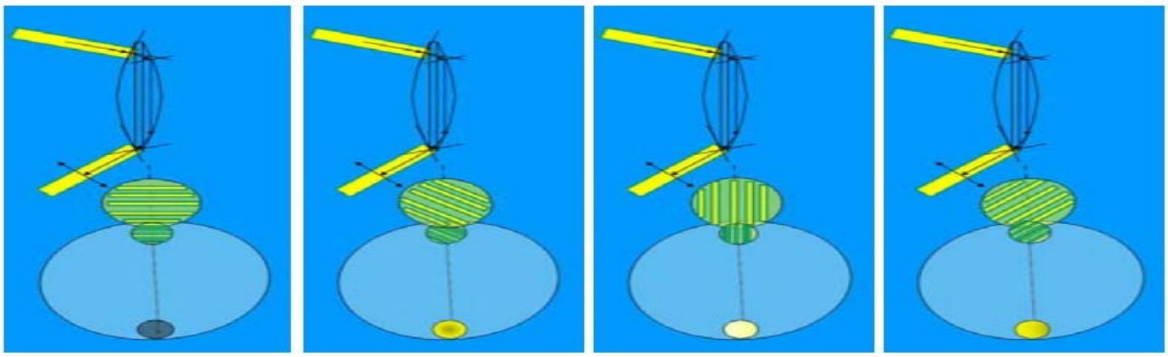


Figure 5: Sequences that shows how changes the out coming light lens

III. Coplanar Lens Systems

Placing two identical lenses in a same plane, where they join the edges lets traced between touching edges an extending line, so the intercept between this line, with another line tangent to the upper edges of the two lenses and perpendicular to the first line, will have the centre of the polarized light beam, and the light emerging in each of the lenses will be 90° to each other in two points diametrically opposite in each lens. The geometric representation of this phenomenon is represented in Figure 6.

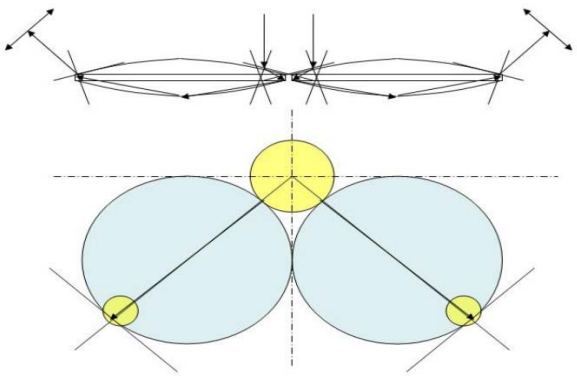


Figure 6: Coplanar lenses

If the light beam linearly polarized is rotated, when the diametrical path of one of the lens coincides with the polarization plane orientation, an image so bright of light source will be obtained in the opposite diametric position in that lens, while there be not light in the diametrically opposite position in the other lens. Rotating the plane of polarization in towards the lens with a less than intensity of light, the intensity of light in this point will grow in intensity, whereas in the other lend will decrease. The difference between the booths points is 90°.

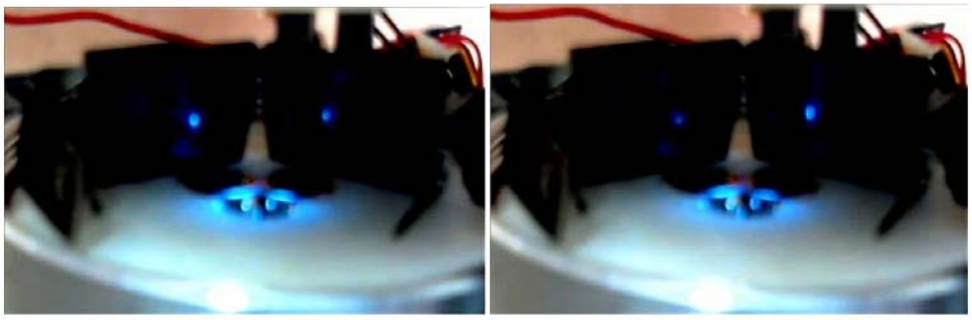


Figure 7: Scream shoots an experiment media film

The scream shoot of two still pictures taken from a media conducted in the laboratory is showing in Figure 7. In the lower part (the floor) there is a hole through which passes the polarized light beam, two lenses are positioned downwards for the back and sides of this orifice, and the bottom are projects the light emerging from the lens which are the white-bluish halos over two black screens. In the left picture the projected halo over the left black screen is brightness than the halo over the right black screen. In the left picture the spot of light of greater intensity is over the right black screen as a consequence of the polarization plane rotation.

IV. Applications

There are various applications in which this phenomenon can be used.

1. Data transmission using polarized light in which, for example 0^0 represent zeros and 90^0 represent ones in function of the variation of the polarization plane position and can be detected using a polarizer electric effect, This have the advantage in avoid the loss of information because we are only interested in the angles of the plane of polarization and it does not matter the levels of light intensity does not remain constant, and only take the information corresponding to ones and zeros and them depends of the light plane polarized position, not of the intensity.
2. Sea and air signalling guidance.
3. Rotation of the polarization plane would be proportional to body weight.
4. In polarimetry instruments.
5. In determining if a beam of light is polarized or not (astronomic).

a) One application

Stimulating a light emitter diode (LED) or a semiconductor laser with electric pulses and make passing the pulsing beam of polarize light obtained thru an optical system and the end of this system place two photodiodes spatially arranged at 90^0 to each other and their detection surfaces parallel to the transmission axis of polarized light, and its polarization plane axis oriented at 45^0 of the vertices of the edges where the photodiodes join, at output of two operational amplifiers, there will be two pulse train signals one in each one with the same shape in time, but when the polarization plane will be rotated, the radiance of the light projected onto the photodiodes change, and signals being out of phase to the outputs of the amplifiers, the difference between the fronts of the pulses in booths signals is proportional to the rotation of the plane of polarization light angle.

With a phase discriminator digital circuit, is obtained a pulse equal to the difference in time between two sides of the rise time in the output of booths amplifiers.

The value of rotation of the plane of polarization of light is directly proportional to the width of this deference, that is, the greater the rotation, the greater the pulse width.

The composition that will be used is:

1) A very simple optic system.
2) Luminous source to light emitting diode (LED).
3) Two Optic-Electronic Amplifiers sensor associated to front wave differentiating digital circuits.

This system will can be possible determined the polarized light plane rotation in form very comfortable and precise, without the necessity to use analyzers, rotational modulators, neither magnetic coil that are those more commonly employees for the polarized light plane measure. Give there that the outlined method has the advantage the mobile mechanical parts total lack and not having to use big currents densities in induction coils, its precision depending of the pulses modulation electric sign stability and the optic system alignment precision, including the photodiodes spaced to 90^0 degrees among them incidence faces.

If linearly polarized light affect in a lens, the polarized light will be reflected and refracted along the curves lines between the interceptions of a plane with a sphere, i.e. the polarized light plane on the surface of the lens, and following the orientation of the of polarization plane. Only looking at the lens side this effect is significant. Then the lens behavior is like a side analyzer when the polarization plane of polarized light that falls on it is rotated.

With this principle and adding that over the spherical surface lens we can put n circle of radius r, been n is inversely proportional to r, and each circle is a lens it self, so if we shine a beam of light in one of these areas the phenomenon of polarization is expressed lateral side and diametrically opposite to where the linearly polarized light incident.

b) *System with only one lens*

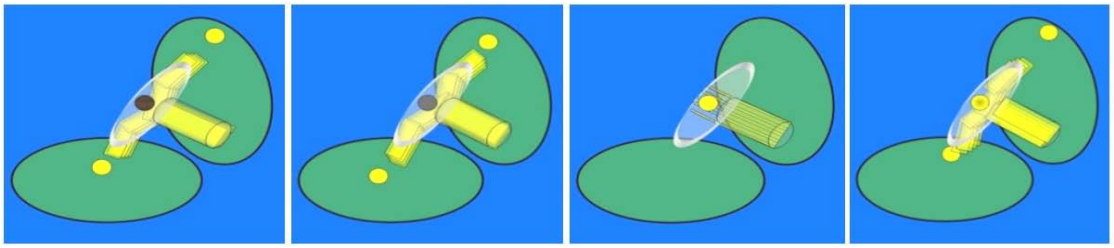


Figure 8: How two photodiodes spatially to 90 degree are illuminated when the polarize plane change

If we desire construct an instrument to determine the value of the rotation of the plane of polarization of light using this phenomenon, it is necessary use two light sensors placed parallel to the optical axis and 90^0 spaced from each other and on the sides of the lens. In Figure 8, the green color circles are the photodiodes and when the plane of polarization of light rotated, the light over photodiodes detection surface change. But this has two disadvantages, one is the light intensity is low and the other is the absorption effect of distorting information because there is a lighted space between the sensors would not touch the surface of both.

c) *System with only two lens*

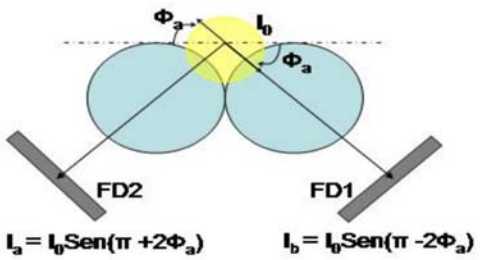


Figure 8.1: Lenses coplanar system

In this case:

(4) $I_a = I_0 Sin((\pi + 2\Phi_a)/180)$
(5) $I_b = I_0 Sin((\pi - 2\Phi_b)/180)$
(6) $\Phi = (I_a - I_b)*(0.5)*90^0$

The Eq. (6) is the same to Eq. (3) when used only one lens is; the difference is between Eq. (1) and Eq. (4) and between Eq. (2) and Eq. (5).

The problems of low light intensity and the absorption effect of distorting information because there is a lighted space between the sensors would not touch the surface of both, was fixed with a geometric study of the lenses where were find out the solution. Over the lens spherical surface can be placed perfectly **n** circles of radius **r**, the number **n** is inversely proportional to the radius **r,** whereas, while the radius will be shortest, the numbers of insert lens will be biggest. Each circle is an independent lens.

When the linearly polarized light incident chining on the lens edge, will occurred all explained before, but in the incidence region. The light travel along the lens diametric line and will exit the edge of the lens diametrically opposed to the incident beam and only at that point the image can be seen and not in any other region of the lens. In this way we will not have a cone-shaped beam on the side of the lens, but a point where we will get the whole picture and therefore with greater intensity.

In Figure 5 the sequence is showing, where the intensity of out coming light is a function of position of the polarize plane incident over the border lens surface.

But we still have a problem and we have to use two sensors to polarized light to come on as a light source. When the polarized plane is rotated, there is a space between the photo sensors where the light not insides over the photo sensors areas. The solution to this problem is to use a system of two identical lenses placed in the same plane and positioned so that they cross a line where you play two of its edges with another drawn from the edges that touch the two lenses and orthogonal to the first, is the center of the beam. This ensures that the two points of light coming out diametrically opposed in each of the lenses are at 90^0 from each other. Figure 6 is the geometric representation

By rotating the linearly polarized light beam, the lens diameter path coincides with the orientation of the polarization plane will have a very bright image of the light source, while the diametrically opposite position of the other lens will have not light. If we continue to rotate the plane of polarization in the direction of the lens with less intensity than light, it will grow in intensity and decreasing the other, when both intensities are equal will be in the place where the instrument has its zero. There will be a gap of 90^0 between the points.

Now the light sensors are always under the light field (see Figure 9), recording exactly light variations that are proportional to the rotation of the polarization plane of light. So that by modulating the polarized light with a train of pulses of light and use as sensors photodiodes, electric current is generated in them will be directly proportional to the amount of light reaching them, there is a gap between rising fronts amplified signal pulses obtained in photodiodes if they do not receive the same amount of light and that is the value of rotation of the polarization plane.

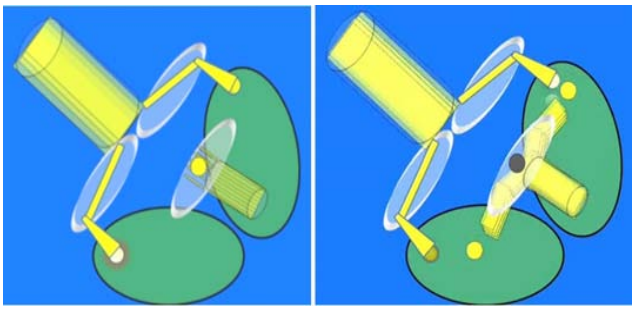


Figure 9: With two lenses the light sensors are always under the light field

d) A know methode

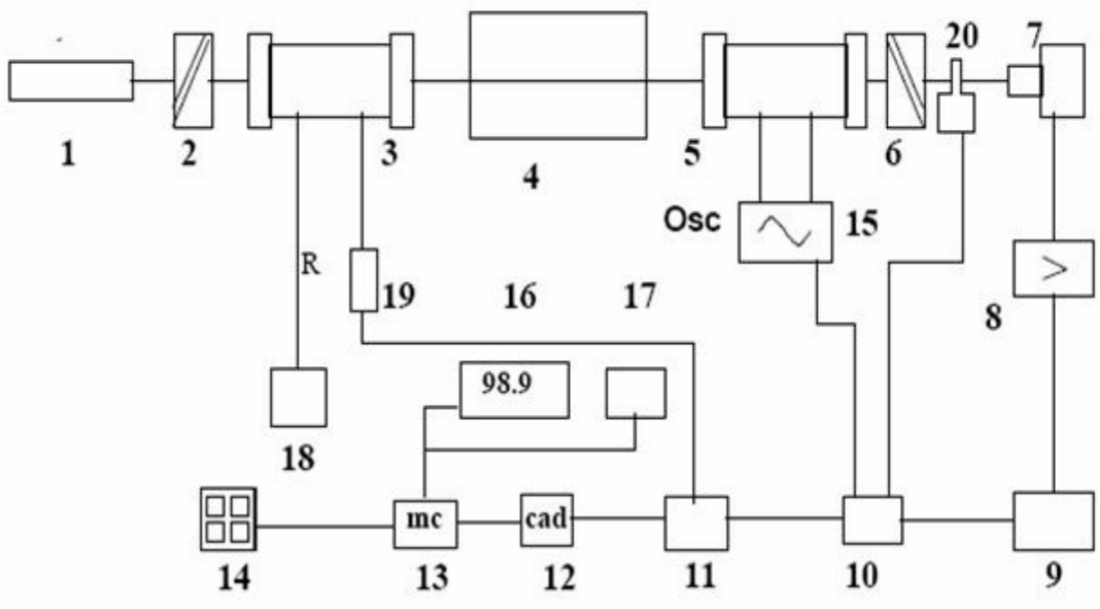


Figure 9.1: Laserpol 4

In the Fig. 9.1 we have a block diagram of the equipment LASERROL 4 [4], where:

1) He-Ne 2mW laser
2) Polarized film
3) Compensetion cell (inside de coil)
4) Sampel chamber
5) Faraday cell (modulator, inside the coil)
6) Analized film
7) Photo sensor
8) Electronic amplifier
9) Filters
10) Fase detector
11) Sampel circuit

In this case is necessary the use of two coil (3 and 5) in order compensated and modulate with a ramp electric signal the laser beam and detect the moment in which the compensation occur, and that time interval is the value of the polarized plane rotation, in our case only need a little electronic amplifier, without compensation coil nether modulation coil, ramp electric signal or scale extension mechanics because only can measurement little amount of rotation angles with this equipment.

The coils 3 and 5 are so big and its electric energy consumption is so big too and introduces errors in the measurement value.

Our method no has these problems and beside is simpler than this. See the Fig. 13 and made a comparison with Fig. 9.1.

The fundamental advantage with other methods is that the method that we are defendant hear is optic fully and uses the lens like ayes, no need process extra in order obtain the desire objective, this property reduce the errors in the measurement values, is more precision and simple than any other. It works like Laurent polarimetry [5] Fig. 9.2, in which the sensor is the human aye.

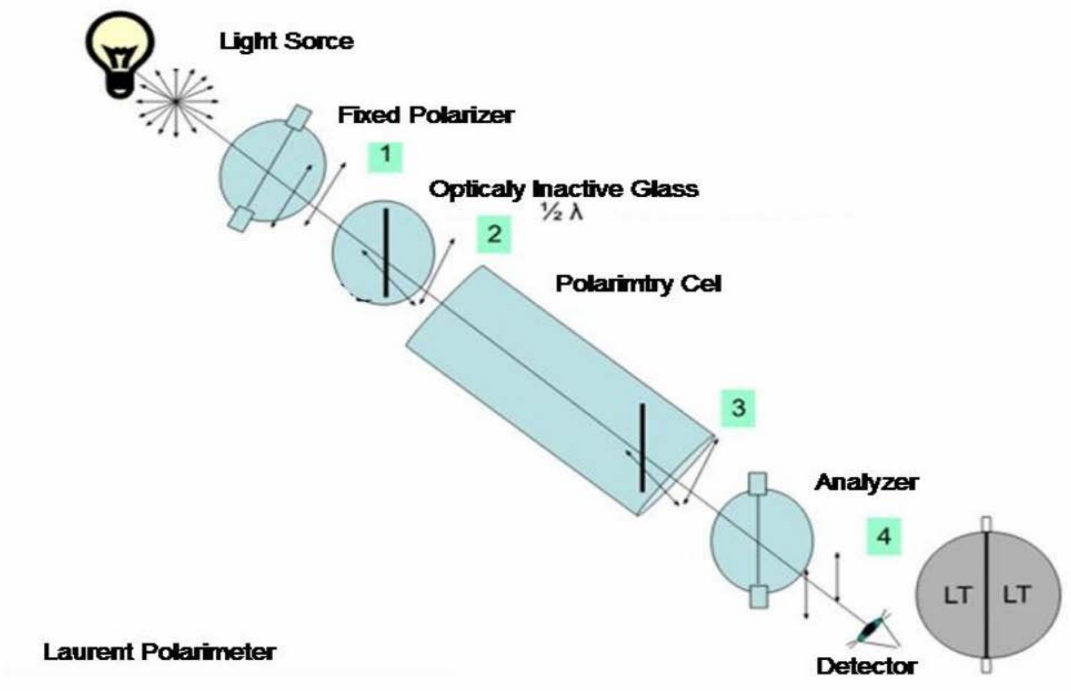


Figure 9.2: Laurent polarimetry

V. Malus`s Low Behavior. [1, 2]

If between a pulsating light source and a radiometer we place two polarizing sheets, with their polarization axes at 90^0, the radiometer will measure zero or minimal candle power, then as broken the polarizing sheet, will go increasing the light intensity reading in the measuring instrument, until a maximum that will correspond when we have rotated it 90^0 (Malus`s low).

If now the polarizing sheet utilized as analyzer is retired and used instead of the radiometer and our amplifier is placed, its exit, view in an oscilloscope, a pulse will appear which width will go increasing until a maximum valor when going rotating the polarizing sheet in the same sense, and starting from there it will begin to diminish until a minimum and a phase shift will take place, increasing the width until a maximum, but now in opposed sense (Figure 10).

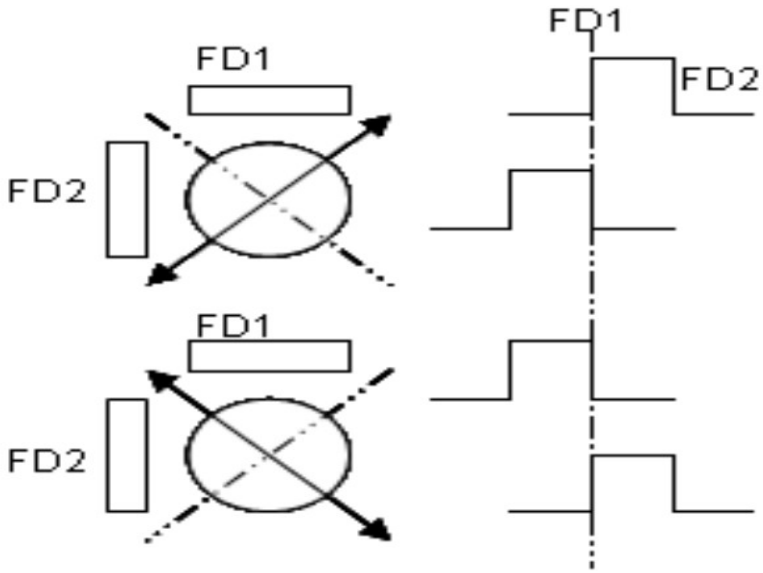


Figure 10: Operational amplifier output following the rise time of the pulse signal in each output amplifier, according to the Malus`s Low

Comparing both methods has obtained more information with our amplifier than with the radiometer. When in the oscilloscope appear a minimum, the polarized light plane will be exactly at 45^0 or – 45^0 regarding the horizontal one give the paper plane and like the line with double arrow represent, that is to say that already know in the fact that the sense the polarization plane is oriented of and to identify this in the polarizing sheet.

Now then, if we place an active optic substance in that trajectory, being the plane of polarization placed at 45^0, superior image gives the drawing in Figure 10, we will have a pulse that will increase its width toward the right if the substance is levorotary, and counter-clockwise if it is not levorotary, being its magnitude in agreement with the angular quantity that the substance has rotated the plane of polarization.

If initially the plane of polarization is to – 45^0, inferior image gives the drawing in Figure 8, a pulse will increase its width counter-clockwise if the substance is levorotary, and toward the right if it is not levorotary. FD1 and FD2 in the Figure 10 represent the photodiodes space disposition utilized.

The Fig. 10.1 represents how the system works.

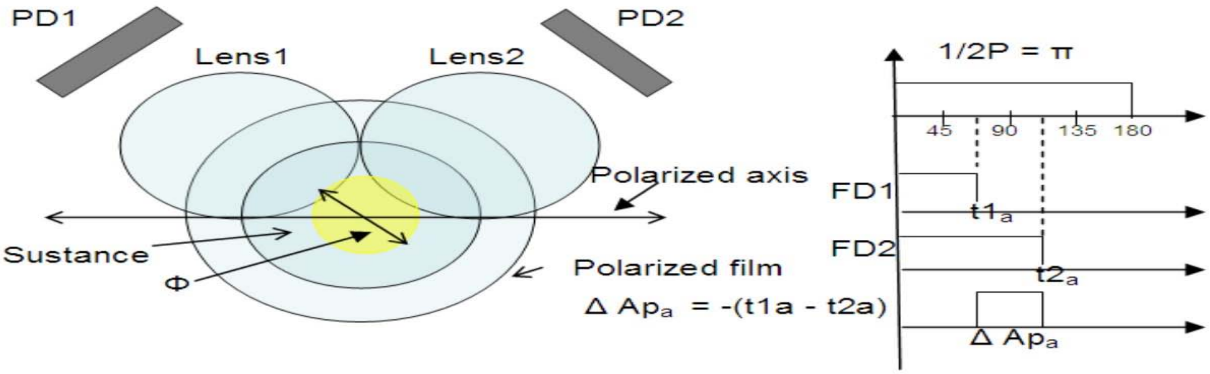


Figure 10.1: How it works

When an optical substance is put in inner measurement chamber, the polarized plane will be rotated and in one of the lents the light will be increasing and in the other the light will be decreasing, them the pulse wide in witch lents where the light increased will less than the wide where the light decreased. This deference between booths pulses will be the polarized plane rotation. If the difference is more than CERO, it means that the substance is LEVOGIRA and the wild of the pulse in FD1 will be greater than the wild pulse in FD2. Whereas, is the deference is less than CERO, it means that the substance is DEXTROGIRA and the wild of the pulse in FD1 will be less than the wild pulse in FD2.

With these is demonstrated that the system has optical behavior, no need uses others applications in order obtained the results of measurement of the polarized plane rotation.

VI. Wave Form at the Output Electronic Amplifier

In the Figure 11 the signs time letters, where we only use the rise time between the pulse signals in each output of both operational amplifiers. That difference is equivalent to the rotation of the polarize axis, this value is equal to signal pulse in the last one line.

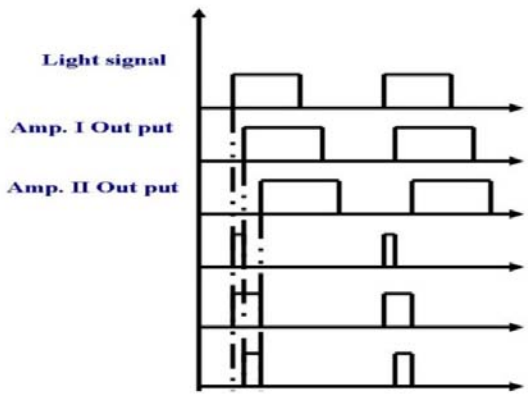


Figure 11: Letters time

In Fig.12 is represented the Equipment block diagram [3]; the first block on the left is the Electronic Light Modulator who chining the Optical System, which is represented in Fig.13. The light that thru out from the Optical System is sensed by the photodiodes FD1 y FD2 that are coupling to separately to the amplifiers I y II respectively. Each output of both amplifiers are cleaned in the Electronic Cleaner I y II by the modulator signal, and after that, that signals are compared in theirs front up, like is showed in Fig.11; and in the last block we can see the Rotation Value of the polarized light.

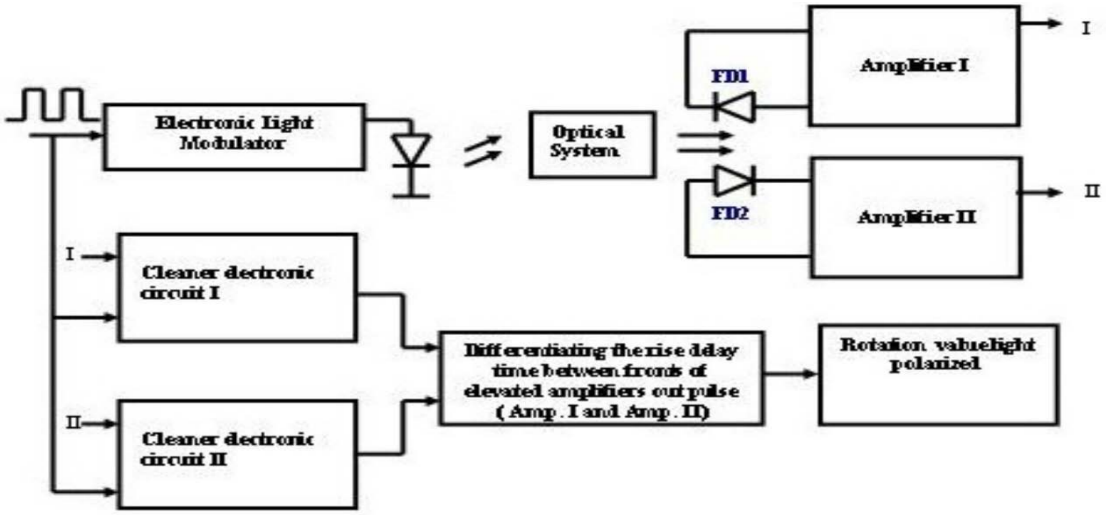


Figure 12: Equipment block diagram

The Figure 13 is the optic system utilized

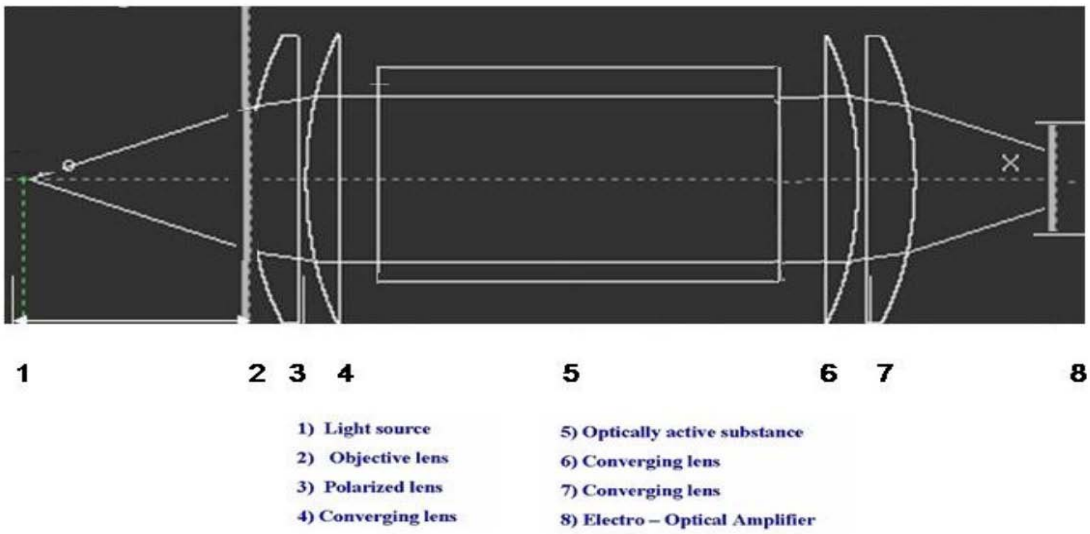


Figure 13: Optic system

VII. Conclusions

The optical system and the phenomenon which occurs therein can be used as a new polary metric detection method, in which the accuracy of alignment of the optical system is essential for accuracy of detection. It's a new polari metric detection method, based, first, the new principle of refraction and reflection of light polarized in lenses and the first time use of coplanar optical lens systems that significantly improve the use of the phenomenon analyzed.

When a bean of polarized light incident in the lens geometrical centre, with the polarized plane oriented vertically to us, we can see a brightness circle inside the lens, which is light; light get out laterally from the lens. And it is so brightness if we are front of the polarized plane of the bean. With the polarized plane oriented parallel to us, the circle disappears, because there are two bean of light get out of the lens 90^0 from us to booths lens sides and parallel to our position, then we cannot see the light. Let's consider that these two positions are *extremes positions* and between those positions, the circle change in intensity, decreasing while the polarized plane of bean is rotated up to be parallel to us.

All this has be possible because when linearly polarized light impinging on a lens, it will reflect and refract along the lines curves resulting from the interception of a plane (plane of polarization) with a sphere (lens surface) maintaining the orientation of refraction and reflection within the plane of polarization.

This is the physical concept obtained with our research and it permitted us understand better the phenomena and the procedure to follow in order give it a correct application.

Concept: The reflection and refraction when linearly polarized light impinging on a lens, it will be maintaining within the plane of polarization.

The extension in the application of the phenomena gives us the possibility to find out the concept of *coplanar lenses* that do better than the precision of the measurements, without loss the simplicity of the optical system used, and understood the difference between use one or two lenses and when we must use one lens or used two lenses.

By first time have been used a parallel lens systems and this is a new optical method for polarymetric measurement, with this, extremely simple, sure and precise measurements equipments can be built.

If we used only one lens, when the polarized plane is rotated, there is a space between the photo sensors where the light not insides over the photo sensors areas, whereas in the system with two lenses always the light is over the photo sensors surfaces.

The Constant Height and Variable Phase Electro-Optic Amplifier allow determine the beam of light polarization plane orientation. It also allows to determine the magnitude that has been rotated when introducing an active optic substance and to also know if the same one is levorotary or not.

The fundamental advantage with other methods is that the method that we are defendant hear is optic fully and uses the lens like ayes, no need process extra in order obtain the desire objective, this property reduce the errors in the measurement values, is more precision and simple than any other.

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Note References have been mentioned rather to indicate the field belonging the subject matter thereof, as the phenomenon is not reflected in the literature.

Appendix

	A	B	C	D	E	F	G	H	I	K	M	O	P	Q	R
1	K	Io	Q	Φa	Φa1	Ia	Φb	Φb1	Ib	Φ	Φ=0.5*90*(Ia-Ib)	Ia1	Ia2	Φ1	Φ1=0.5*90*(Ia-Ib)
2	6,28	1	8	0	-8	3,141633673	90	82	0	1,00001306	45,00058757	3,39403484	0,29114469	0,98768061	44,44562746
3	6,28	1	8	1	-7	3,109636901	89	81	0,03640488	0,97824013	44,02080603	3,36284117	0,32750913	0,9661762	43,47792886
4	6,28	1	8	2	-6	3,077544153	88	80	0,07280864	0,95643702	43,03966582	3,33154372	0,36386346	0,94464196	42,50888836
5	6,28	1	8	3	-5	3,045356418	87	79	0,10921015	0,93460438	42,05719724	3,30014343	0,40020656	0,92307857	41,53853586
6	6,28	1	8	4	-4	3,013074692	86	78	0,1456083	0,9127429	41,07343059	3,26864129	0,43653731	0,9014867	40,56690131
7	6,28	1	8	5	-3	2,980699969	85	77	0,18200194	0,89085325	40,08839625	3,23703827	0,47285459	0,87986699	39,59401469
8	6,28	1	8	6	-2	2,94823325	84	76	0,21838997	0,8689361	39,10212462	3,20533534	0,50915727	0,85822013	38,61990605
9	6,28	1	8	7	-1	2,915675537	83	75	0,25477126	0,84699214	38,11464614	3,17353348	0,54544424	0,83654679	37,64460543
10	6,28	1	8	8	0	2,883027833	82	74	0,29114469	0,82502203	37,12599128	3,14163367	0,58171437	0,81484762	36,66814294
11	6,28	1	8	9	1	2,850291148	81	73	0,32750913	0,80302646	36,13619056	3,1096369	0,61796655	0,79312331	35,69054873
12	6,28	1	8	10	2	2,817466491	80	72	0,36386346	0,7810061	35,14527453	3,07754415	0,65419966	0,77137451	34,71185296
13	6,28	1	8	11	3	2,784554875	79	71	0,40020656	0,75896164	34,15327377	3,04535642	0,69041257	0,74960191	33,73208584
14	6,28	1	8	12	4	2,751557316	78	70	0,43653731	0,73689375	33,1602189	3,01307469	0,72660418	0,72780617	32,7512776
15	6,28	1	8	13	5	2,718474833	77	69	0,47285459	0,71480312	32,16614057	2,98069997	0,76277336	0,70598797	31,76945853
16	6,28	1	8	14	6	2,685308447	76	68	0,50915727	0,69269043	31,17106946	2,94823325	0,798919	0,68414798	30,78665892
17	6,28	1	8	15	7	2,65205918	75	67	0,54544424	0,67055636	30,17503628	2,91567554	0,83503997	0,66228687	29,80290911
18	6,28	1	8	16	8	2,618728061	74	66	0,58171437	0,64840159	29,17807177	2,88302783	0,87113518	0,64040532	28,81823945
19	6,28	1	8	17	9	2,585316117	73	65	0,61796655	0,62622682	28,18020672	2,85029115	0,9072035	0,61850401	27,83268035
20	6,28	1	8	18	10	2,551824379	72	64	0,65419966	0,60403271	27,1814719	2,81746649	0,94324382	0,5965836	26,84626222
21	6,28	1	8	19	11	2,518253881	71	63	0,69041257	0,58181996	26,18189815	2,78455487	0,97925503	0,57464479	25,8590155
22	6,28	1	8	20	12	2,48460566	70	62	0,72660418	0,55958925	25,18151632	2,75155732	1,01523601	0,55268824	24,87097066
23	6,28	1	8	21	13	2,450880753	69	61	0,76277336	0,53734127	24,18035728	2,71847483	1,05118566	0,53071463	23,88215821
24	6,28	1	8	22	14	2,417080203	68	60	0,798919	0,51507671	23,17845194	2,68530845	1,08710287	0,50872464	22,89260865
25	6,28	1	8	23	15	2,383205051	67	59	0,83503997	0,49279625	22,17583122	2,65205918	1,12298652	0,48671895	21,90235253
26	6,28	1	8	24	16	2,349256344	66	58	0,87113518	0,47050058	21,17252606	2,61872806	1,15883551	0,46469823	20,91142042
27	6,28	1	8	25	17	2,315235129	65	57	0,9072035	0,44819039	20,16856743	2,58531612	1,19464874	0,44266318	19,91984289
28	6,28	1	8	26	18	2,281142456	64	56	0,94324382	0,42586636	19,16398631	2,55182438	1,23042509	0,42061446	18,92765055
29	6,28	1	8	27	19	2,246979378	63	55	0,97925503	0,40352919	18,15881371	2,51825388	1,26616347	0,39855276	17,93487403
30	6,28	1	8	28	20	2,212746949	62	54	1,01523601	0,38117957	17,15308066	2,48460566	1,30186277	0,37647875	16,94154397
31	6,28	1	8	29	21	2,178446225	61	53	1,05118566	0,35881818	16,14681819	2,45088075	1,33752189	0,35439313	15,94769102

Figure 1.1: Excel

32	6,28	1	8	30	22	2,144078265	60	52	1,08710287	0,33644572	15,14005737	2,4170802	1,37313973	0,33229657	14,95334585
33	6,28	1	8	31	23	2,109644131	59	51	1,12298652	0,31406287	14,13282926	2,38320505	1,40871518	0,31018976	13,95853917
34	6,28	1	8	32	24	2,075144884	58	50	1,15883551	0,29167033	13,12516495	2,34925634	1,44424716	0,28807337	12,96330167
35	6,28	1	8	33	25	2,04058159	57	49	1,19464874	0,26926879	12,11709555	2,31523513	1,47973456	0,26594809	11,96766406
36	6,28	1	8	34	26	2,005955314	56	48	1,23042509	0,24685894	11,10865216	2,28114246	1,51517629	0,2438146	10,97165709
37	6,28	1	8	35	27	1,971267127	55	47	1,26616347	0,22444146	10,09986592	2,24697938	1,55057126	0,22167359	9,975311484
38	6,28	1	8	36	28	1,936518099	54	46	1,30186277	0,20201707	9,090767949	2,21274695	1,58591837	0,19952573	8,978658
39	6,28	1	8	37	29	1,901709301	53	45	1,33752189	0,17958643	8,081389402	2,17844622	1,62121653	0,17737172	7,981727398
40	6,28	1	8	38	30	1,866841809	52	44	1,37313973	0,15715025	7,071761429	2,14407827	1,65646466	0,15521223	6,984550446
41	6,28	1	8	39	31	1,831916698	51	43	1,40871518	0,13470923	6,061915194	2,10964413	1,69166166	0,13304795	5,987157923
42	6,28	1	8	40	32	1,796935047	50	42	1,44424716	0,11226404	5,051881862	2,07514488	1,72680644	0,11087957	4,989580611
43	6,28	1	8	41	33	1,761897935	49	41	1,47973456	0,08981539	4,041692609	2,04058159	1,76189794	0,08870776	3,9918493
44	6,28	1	8	42	34	1,726806444	48	40	1,51517629	0,06736397	3,031378612	2,00595531	1,79693505	0,06653322	2,993994784
45	6,28	1	8	43	35	1,691661656	47	39	1,55057126	0,04491047	2,020971054	1,97126713	1,8319167	0,04435662	1,996047862
46	6,28	1	8	44	36	1,656464657	46	38	1,58591837	0,02245558	1,010501121	1,9365181	1,86684181	0,02217865	0,998039333
47	6,28	1	8	45	37	1,621216533	45	37	1,62121653	0	0	1,9017093	1,9017093	0	0
48	6,28	1	8	46	38	1,585918371	44	36	1,65646466	-0,02245558	-1,010501121	1,86684181	1,9365181	-0,02217865	-0,998039333
49	6,28	1	8	47	39	1,550571261	43	35	1,69166166	-0,04491047	-2,020971054	1,8319167	1,97126713	-0,04435662	-1,996047862
50	6,28	1	8	48	40	1,515176294	42	34	1,72680644	-0,06736397	-3,031378612	1,79693505	2,00595531	-0,06653322	-2,993994784
51	6,28	1	8	49	41	1,479734562	41	33	1,76189794	-0,08981539	-4,041692609	1,76189794	2,04058159	-0,08870776	-3,9918493
52	6,28	1	8	50	42	1,44424716	40	32	1,79693505	-0,11226404	-5,051881862	1,72680644	2,07514488	-0,11087957	-4,989580611
53	6,28	1	8	51	43	1,408715182	39	31	1,8319167	-0,13470923	-6,061915194	1,69166166	2,10964413	-0,13304795	-5,987157923
54	6,28	1	8	52	44	1,373139725	38	30	1,86684181	-0,15715025	-7,071761429	1,65646466	2,14407827	0,15521223	-6,984550446
55	6,28	1	8	53	45	1,337521888	37	29	1,9017093	-0,17958643	-8,081389402	1,62121653	2,17844622	-0,17737172	-7,981727398
56	6,28	1	8	54	46	1,30186277	36	28	1,9365181	-0,20201707	-9,090767949	1,58591837	2,21274695	-0,19952573	-8,978658
57	6,28	1	8	55	47	1,26616347	35	27	1,97126713	-0,22444146	-10,09986592	1,55057126	2,24697938	-0,22167359	-9,975311484
58	6,28	1	8	56	48	1,230425092	34	26	2,00595531	- 0,24685894	-11,10865216	1,51517629	2,28114246	-0,2438146	-10,97165709
59	6,28	1	8	57	49	1,194648737	33	25	2,04058159	- 0,26926879	-12,11709555	1,47973456	2,31523513	-0,26594809	-11,96766406
60	6,28	1	8	58	50	1,158835511	32	24	2,07514488	- 0,29167033	-13,12516495	1,44424716	2,34925634	-0,28807337	-12,96330167
61	6,28	1	8	59	51	1,122986518	31	23	2,10964413	- 0,31406287	-14,13282926	1,40871518	2,38320505	-0,31018976	-13,95853917
62	6,28	1	8	60	52	1,087102865	30	22	2,14407827	- 0,33644572	-15,14005737	1,37313973	2,4170802	-0,33229657	-14,95334585
63	6,28	1	8	61	53	1,05118566	29	21	2,17844622	- 0,35881818	-16,14681819	1,33752189	2,45088075	-0,35439313	-15,94769102
64	6,28	1	8	62	54	1,015236011	28	20	2,21274695	-0,38117957	-17,15308066	1,30186277	2,48460566	-0,37647875	-16,94154397
65	6,28	1	8	63	55	0,979255028	27	19	2,24697938	-0,40352919	-18,15881371	1,26616347	2,51825388	-0,39855276	-17,93487403
66	6,28	1	8	64	56	0,94324382	26	18	2,28114246	-0,42586636	-19,16398631	1,23042509	2,55182438	-0,42061446	-18,92765055
67	6,28	1	8	65	57	0,907203501	25	17	2,31523513	-0,44819039	-20,16856743	1,19464874	2,58531612	-0,44266318	-19,91984289
68	6,28	1	8	66	58	0,871135181	24	16	2,34925634	-0,47050058	-21,17252606	1,15883551	2,61872806	-0,46469823	-20,91142042
69	6,28	1	8	67	59	0,835039974	23	15	2,38320505	- 0,49279625	-22,17583122	1,12298652	2,65205918	-0,48671895	-21,90235253
70	6,28	1	8	68	60	0,798918995	22	14	2,4170802	-0,51507671	-23,17845194	1,08710287	2,68530845	-0,50872464	-22,89260865
71	6,28	1	8	69	61	0,762773358	21	13	2,45088075	-0,53734127	-24,18035728	1,05118566	2,71847483	-0,53071463	-23,88215821
72	6,28	1	8	70	62	0,726604178	20	12	2,48460566	-0,55958925	-25,18151632	1,01523601	2,75155732	-0,55268824	-24,87097066
73	6,28	1	8	71	63	0,690412573	19	11	2,51825388	-0,58181996	-26,18189815	0,97925503	2,78455487	-0,57464479	-25,8590155
74	6,28	1	8	72	64	0,654199658	18	10	2,55182438	-0,60403271	-27,1814719	0,94324382	2,81746649	-0,5965836	-26,84626222
75	6,28	1	8	73	65	0,617966552	17	9	2,58531612	-0,62622682	-28,18020672	0,9072035	2,85029115	-0,61850401	-27,83268035
76	6,28	1	8	74	66	0,581714373	16	8	2,61872806	-0,64840159	-29,17807177	0,87113518	2,88302783	-0,64040532	-28,81823945
77	6,28	1	8	75	67	0,545444241	15	7	2,65205918	-0,67055636	-30,17503628	0,83503997	2,91567554	-0,66228687	-29,80290911
78	6,28	1	8	76	68	0,509157273	14	6	2,68530845	-0,69269043	-31,17106946	0,798919	2,94823325	-0,68414798	-30,78665892
79	6,28	1	8	77	69	0,472854591	13	5	2,71847483	-0,71480312	-32,16614057	0,76277336	2,98069997	-0,70598797	-31,76945853
80	6,28	1	8	78	70	0,436537314	12	4	2,75155732	-0,73689375	-33,1602189	0,72660418	3,01307469	-0,72780617	-32,7512776
81	6,28	1	8	79	71	0,400206564	11	3	2,78455487	-0,75896164	-34,15327377	0,69041257	3,04535642	-0,74960191	-33,73208584

82	6,28	1	8	80	72	0,363863462	10	2	2,81746649	-0,7810061	-35,14527453	0,65419966	3,07754415	-0,77137451	-34,71185296
83	6,28	1	8	81	73	0,32750913	9	1	2,85029115	-0,80302646	-36,13619056	0,61796655	3,1096369	-0,79312331	-35,69054873
84	6,28	1	8	82	74	0,29114469	8	0	2,88302783	-0,82502203	-37,12599128	0,58171437	3,14163367	-0,81484762	-36,66814294
85	6,28	1	8	83	75	0,254771263	7	-1	2,91567554	-0,84699214	-38,11464614	0,54544424	3,17353348	-0,83654679	-37,64460543
86	6,28	1	8	84	76	0,218389974	6	-2	2,94823325	-0,8689361	-39,10212462	0,50915727	3,20533534	-0,85822013	-38,61990605
87	6,28	1	8	85	77	0,182001943	5	-3	2,98069997	0,89085325	-40,08839625	0,47285459	3,23703827	-0,87986699	-39,59401469
88	6,28	1	8	86	78	0,145608296	4	-4	3,01307469	-0,9127429	-41,07343059	0,43653731	3,26864129	-0,9014867	-40,56690131
89	6,28	1	8	87	79	0,109210155	3	-5	3,04535642	-0,93460438	-42,05719724	0,40020656	3,30014343	-0,92307857	-41,53853586
90	6,28	1	8	88	80	0,072808642	2	-6	3,07754415	-0,95643702	-43,03966582	0,36386346	3,33154372	-0,94464196	-42,50888836
91	6,28	1	8	89	81	0,036404883	1	-7	3,1096369	-0,97824013	-44,02080603	0,32750913	3,36284117	-0,9661762	-43,47792886
92	6,28	1	8	90	82	0	0	-8	3,14163367	-1,00001306	-45,00058757	0,29114469	3,39403484	-0,98768061	-44,44562746

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The Impact of Urban form Attributes, Vehicle Cost, and Gas Price on Household Vehicle Ownership and Usage in Metro Manila

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Abstract- Sustained economic growth coupled with inadequate public transport service are the main factors that contribute to increasing private vehicle dependency in Metro Manila. These issues exacerbate traffic congestion and spur higher energy demand resulting in more greenhouse gas (GHG) production. This paper developed a multinomial logit (MNL)-based household vehicle ownership model and a linear regression-based household energy demand model taking account of urban form attributes, gas price, and vehicle cost. The mentioned factors are hypothesized to have negative impactson household vehicle ownership and usage. The models utilized the primary dataset gathered from2,300 households surveyed from various areas within Metro Manila.

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Monorom Rith [α], Raymund P. Abad [σ], Alexis Fillone [ρ], Kenji Doi [ω], HirotoInoi [¥] & Jose Bienvenido M. Biona[§]

Abstract- Sustained economic growth coupled with inadequate public transport service are the main factors that contribute to increasing private vehicle dependency in Metro Manila. These issues exacerbate traffic congestion and spur higher energy demand resulting in more greenhouse gas (GHG) production. This paper developed a multinomial logit (MNL)-based household vehicle ownership model and a linear regression-based household energy demand model taking account of urban form attributes, gas price, and vehicle cost. The mentioned factors are hypothesized to have negative impactson household vehicle ownership and usage. The models utilized the primary dataset gathered from2,300 households surveyed from various areas within Metro Manila. The developed models were the napplied for the "what-if" scenario analysis that assumes a 25% gas price increase, a 25% vehicle cost increase, improvement of residential area accessibility to key destinations and services, and improvement of public transport line density. Had all the mentioned scenarios beencombined, the vehicle fleet and total energy demand would have been reduced by 78.95% and 84.92%among the households surveyed, respectively. Another finding highlights that a1% gas price increase would reduceCO_2emission by0.172% per household .The improvement of key destination accessibility and public transport line density are the most effective options to address private vehicle dependency toward sustainable urban transportation, rather than increasing gas and vehicle prices and road density.

Keywords: urban form, gas price, vehicle cost, household vehicle ownership and usage, metro manila.

I. Introduction

The Philippines has become one of Asia's fast-growing economies with an average gross domestic product (GDP) growth of 6.8% per annum in the last three years [1]. Unhampered economic growth is an influential factor expected to fuel private passenger vehicle sales and usage, which triggers traffic congestion exacerbation, higher energy demand, air quality degradation, and greenhouse gas (GHG) production in the metropolitan area. Average travel time of one person trip in Metro Manila, the national capital region of the Philippines, was expected to increase from 1.17 hours at present up to 1.33 hours in 2030 [2]. The CO_2 emission from road passenger transport sector in the metropolis was 13.78 million tons in 2015, and it would double up to 27.9 million tons in 2040 in case of no strategic intervention from the government [3].

Metro Manila leads all the regions in the vehicle fleet with a total of 1.698 million units registered in 2016 with an average annual uptake of 204,404 new passenger vehicles from 2015 to 2016 [4]. Private vehicles were responsible for 71.3% of vehicle trips in 2012 with an average annual growth of 3.3% from 1996 to 2012 [2]. In line with this, about 50% of the metropolitan roads have already operated at a volume/capacity (V/C) ratio of 0.80 [2], and the up-trend projected private vehicle dependency is expected to saturate the roads further. An increasing private vehicle dependency over the years has rapidly degraded the effectiveness of the vehicular volume reduction schemes implemented [5, 6]. Furthermore, an increase in vehicle dependency is associated with higher road energy demand and emissions. Some literature has looked at some alternative solutions to mitigate energy demand and GHG productions through increasing accessibility of residential areas to railway stations, improvement of fuel quality, implementation of Euro 4 emission standard, expansion of the metropolitan railway network, and reduction of private vehicle kilometers traveled [3, 7, 8]. Regidor and Javier [9] and the Asian Development Bank [10] emphasized the significance of managing private vehicle ownership, usage, and energy intensity to combat GHG emissions. Moreover, Mijares et al. [11] speculated that the improvement of mass public transport service might be inefficient if car ownership cost is not increased. Recently, the government launched the Tax Reform for Acceleration and Inclusion (TRAIN) law or RA No. 10963 to raise gas

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and vehicle price [12]. However, a reduction in energy demand for private passenger vehicles through increasing gas and vehicle prices and improving the urban form has yet to be explored in Metro Manila. A better understanding of the quantitative impact of changes in gas and vehicle prices and urban form attributes is indispensable to crafting consistent, appropriate strategic approaches toward a sustainable urban transportation system by reducing private vehicular volume and energy demand.

Evidence from the existing literature in developed countries suggests that a number of household vehicles and vehicle type choice are significantly influenced by vehicle cost [13–15]; these are considered to be more significant than increases on gas taxes [15]. Penalty taxes on older SUVs could reduce emissions by inducing people to hold on to their existing sedans or purchase new SUVs in lieu of second-hand units [13]. Lower-income households are more responsive to gas prices than higher-income households [15]. As to urban form attributes, households living in higher density area are less likely to own more vehicles and put on miles [16, 17] and more inclined to use smaller vehicles [14, 18]. A similar finding reported that building compact cities or encouraging urban densification contributes to a reduction in mobile CO_2 emissions [19, 20]. One explanation could be that the access to or use of parking lots is prohibitive [14] and expensive in urban high-density areas [21]. Vehicle users that originated from central business districts (CBDs) are willing to own small and luxury vehicles, presumably on account of ease in parking, and in addition to that those living in CBDs have high income [22]. Japanese households residing in high-density areas in the vicinity of railway stations have lower propensity to own more vehicles as the railway system in Japan is systematic, convenient, and sufficient to use [21]. A similar finding in Dublin, Ireland, also showed that households located close to more bus stops are less likely to own more vehicles [23]. Households living in a neighborhood with high bike lane density have a lesser likelihood to acquire vehicles, while those located in a high street block density community are more inclined toward holding smaller vehicle types [14].

However, the state of the public transport system in Metro Manila is apparently different from that of developed countries. The Public Utility Jeepney (PUJ), whose features are like a minibus, is the dominant mass transit mode in Metro Manila. PUJ stops are practically non-existent because passengers are loaded and unloaded anywhere along the roads. There are bus stops along the roads, but the buses (standard buses) also operate the same way as the PUJs. Correspondingly, the impact of bus stop density in the metropolis is hypothesized to have no impact on household vehicle ownership and usage, unlike in developed countries. The empirical finding in Ho Chi Minh City was reported that the bus stop density had no impact on vehicle type choice and usage [24]. In this context, we should consider the road public transport line density rather than the bus stop density. Additionally, on-street parking is rampant in Metro Manila. Higher block density or road density is associated with more on-street parking space, which in turn probably encourages private vehicle ownership. The proximity of residential areas to critical destinations (i.e., hospitals, schools, markets, and recreational centers) and the accessibility to CBDs have not been known how these factors affect household energy consumption for private vehicle usage. The impact of an increase in one percent of gas price on household vehicle ownership and usage in developing countries is not known to be higher or lower to some extent, compared with that of developed countries, because for developing countries the per-capita GDP is relatively even lower, but the public transport service is relatively much inefficient and inadequate.

This paper intends to identify the impact of vehicle and gas price and urban form attributes on household vehicle ownership and energy demand within Metro Manila, using the sample data of 2,300 households gathered from various traffic analysis zones (TAZs) in the metropolis in April and May 2017, based on a simple random sampling technique. For the urban form characteristics, a multi-criteria accessibility index of communities to essential destinations, road public transport line density, road density, and accessibility of residential areas to CBDs took into account important peculiarities and measures. The multinomial logit (MNL) regression and linear regression were applied to develop the models. Also, the developed models were used in a sensitivity analysis by varying the significant variables captured by the models. The findings of this study provide insights on effective solutions on how to lower private passenger vehicles and energy demand in Metro Manila toward a sustainable urban transportation system.

II. Methodology

This section provides a brief description of the model formulation followed by the sample data, the mathematical framework, the scenario formulation, and the elasticity of energy demand and CO_2 emission with respect to the gas price increase.

a) *Model Formulation*

We classified household vehicle holdings (vehicles and types owned by households) into five different bundles (alternatives). The description of the

dependent and independent variables is provided in Table 1. Car refers to a small vehicle (i.e., hatchback, sedan, and multipurpose vehicle (MPV)), whereas UV (utility vehicle) refers to a large vehicle (i.e., SUV, minivan, van, pickup, and Asian utility vehicle (AUV)). Correspondingly, the UV has a larger seating and luggage capacity than the Car. Households owning two UVs or more than two vehicles are very few (less than 0.1%) in our data sample, and we thus removed those households to avoid problems arising during the model estimation. The likelihood value of the model estimation cannot be maximized if an alternative has very few observations in the data sample, specifically the household energy demand model.

A multi-criteria gravity-based accessibility function was taken into account to approximate the accessibility of household residential areas to key destinations or facilities (see Equation (1)). The center point of a TAZ was used as the coordinate of a residential area, and the TAZs are based from [25].

$$Multi-criteria\ accessibility = \sum_j w_j \sum_i \frac{1}{e^{d_{j,i}}} \quad (1)$$

The key destinations are categorized as Educational Institutions, Hospitals and Medical Care Centers, Public Markets, and Recreational and Shopping Areas. Distance $d_{j,i}$ represents kilometer travel required to reach a point of interest i of a destination category j, while weight W_j refers to the importance of a destination category j. The weights W_j were adopted from [26] and are provided in Table 2.

Soltani [27] identified the impact of distance from home to CBD on household vehicle holding using the cut-off approach. The impact of distance to CBD is changed if the distance cut-off is varied. Using the gravity-based accessibility approach (see Equation (2)) is likely to be more reliable to understand the impact of distance from a residential area to CBD on household vehicle holding and energy demand. If the distance linearly increases, the accessibility to CBD exponentially decreases.

$$CBD\ Accessibility = \sum_i \frac{1}{e^{d_i}} \quad (2)$$

where distance d_i represents kilometer travel required to reach CBD point i.

Table 1: Description of the model formulation and the explanatory variables

Variable	Description
	Dependent variable
Household vehicle holdings: Alternative 1 Alternative 2 Alternative 3 Alternative 4 Alternative 5	 Zero-vehicle owned by a household One car owned by a household One UV owned by a household Two cars owned by a household One car and one UV owned by a household
Energy demand: Energy 2 Energy 3 Energy 4 Energy 5	 Energy demand by a one-car household Energy demand by a one-UV household Energy demand by a two-car household Energy demand by a car-UV household
	Independent variable
Household size	Continuous variable (the total number of family members)
Age of household head	Dummy variable (1 = if the household head is 40 years old or above; 0 = otherwise)
Multi-criteria accessibility[a]	Continuous variable (TAZ-based accessibility to key destinations)
Line density	Continuous variable (road public transport line density at TAZ level taking into account Jeepneys (minibusses), public utility vans, and buses)
Road density	Continuous variable (road density at TAZ level)
Population density	Continuous variable (population density at TAZ level)
CBD accessibility [a]	Continuous variable (TAZ-based accessibility to CBD)
Vehicle cost/ income [b]	Continuous variable (an average purchasing cost of one vehicle divided by annual household income)
10 x Gas expenditure/ income[b]	Continuous variable (an average monthly expenditure on gas for one vehicle divided by monthly household income)
	TAZ : Traffic analysis zone; CBD: Central business district [a] See Equations (1) and (2) [b] Based from [14]

Table 2: Destination importance weights

Facility	Weight
Hospital and medical care center	20.9%
Educational institution	32.9%
Public market and supermarket	10.7%
Social, eating and recreational facility	35.5%
adopted from [26]	

b) Data Source

A total number of 2,300 households were selected through various TAZs in Metro Manila to participate in the face-to-face interview from April to May 2017, using a simple random sampling technique. The status of each randomly selected household had not been known. Such a technique is the ease of assembling the sample, and every household gets an equal probability of being selected. Furthermore, Metro Manila has no baseline statistical data of household vehicles and types owned by households. After cleaning the data, only 2,140 observations were used for data modeling. Based on the Cochran formula, the size of 2,140 samples provided a confidence level of 99% with a margin of error of 2.79%. Table 3 presents the distribution of households vehicle holdings and the descriptive statistics of energy demand by household vehicle holdings. The household energy demand is converted from the monthly household expenditure on gasoline and diesel. The data sample shows that 47.29% of households have no vehicle, and this figure corresponds to a report of Nielsen Global Survey of Automotive Demand that about 47% of Philippine households have no four-wheeler [28].

Table 3: Distribution of household vehicle holdings and descriptive statistics of energy demand

Alternatives	Household vehicle holdings	Energy demand (GJ/month)			
	Frequency (%)	Min	Mean	Max	SD
No vehicle	1,012 (47.29)	–	–	–	–
One car	711 (33.22)	0.312	2.968	9.899	1.184
One UV	288 (13.46)	0.593	4.731	14.848	2.640
Two cars	69 (3.22)	3.119	6.917	15.593	2.117
Car & UV	60 (2.81)	3.119	8.246	16.136	2.738

Table 4 shows the descriptive statistics of the independent variables. All the independent variables have 2,140 observations, except vehicle cost and monthly expenditure on gas having 344 observations. As mentioned earlier, we use the average vehicle cost and monthly gas expenditure to capture the impact of gas price and vehicle cost on household vehicle holdings and energy demand, and any vehicle purchased before the year 2012 was removed to avoid data inconsistency. To explain, for instance, some vehicles purchased in the year 2000 or 2005 cost much cheaper than those of the current year and using the actual vehicle cost in the former year relative to the household income in the survey year might not make sense. Specifically, vehicle average lifespans for car and UV in Metro Manila are 14.225 and 13.929 years, respectively [29]. Additionally, vehicle cost and gas expenditure are considerably varied from household to another (see the last two rows of Table 4).

Table 4: Descriptive statistics of the explanatory variables

Variables	Frequency	Min	Mean	Max	SD
Household size	2140	1	3.322	11	1.230
Age of household head	2140	0	0.679	1	0.467
Multi-criteria accessibility	2140	1.126	8.743	13.129	2.507
Line density (km/km^2) [a]	2140	0	28.18	154.22	31.210
Road density (km/km^2) [a]	2140	0.419	9.456	28.201	4.167
Population density (10^3	2140	1.524	41.257	147.848	17.976

perons/ km^2) [a]					
CBD accessibility (10)	2140	0	0.835	8.601	1.312
Monthly household income	2140	0.412	6.891	41.343	5.968
(10^4 PHP)					
Vehicle cost for one vehicle	344	200,000	819,287	3,615,000	349,643
(PHP)					
Monthly expenditure on gas for one vehicle (PHP)	344	716	4,086	12,857	1,321
[a] Based from [25]					

c) Mathematical Framework

The existing literature has applied various joint discrete-continuous choice algorithms to develop the household vehicle ownership and usage model to capture the dependency between the discrete choice and the continuous choice; however, the estimated percentage shares of the discrete choice component and the estimated output variables of the continuous choice component were inaccurate [16, 17, 30–34]. If we apply the developed model using those algorithms to simulate the total vehicle fleet and vehicle usage of each alternative as numerical values in response to variation of the input variables, those algorithms cannot perform well. Accordingly, all the existing literature simulate the percentage changes of the output variables in place of numerical values under changes in the input variables for the sensitivity analysis. Therefore, this study developed the household vehicle ownership model and energy demand model separately but estimate the two models simultaneously.

The household vehicle ownership model was developed using the MNL regression, on account of its simple form and ease in interpretation. The probability of an alternative *T* chosen by a household *n* is expressed as Equation (3) below [35]:

$$Pr(T) = \frac{\exp(\beta_T' x_{nT})}{\sum_{t=1}^{M} \exp(\beta_t' x_{nt})} \quad (3)$$

Let *n* (*n = 1, 2 . . . N*) and *t* (*t = 1, 2 . . . M*) be the indices representing households and household vehicle holdings, respectively, T∈t. x_{nt} is a column vector of explanatory variables including a constant, and $\boldsymbol{\beta}_t$ is a column vector of the corresponding coefficients.

The parameters of the utility functions can be estimated using the maximum likelihood function (*LL*), as seen in Equation (4):

$$LL_{discrete} = \sum_{n=1}^{N} \sum_{t=1}^{M} R_{nt} \left[\log(Pr(t))\right] \quad (4)$$

where R_{nt} defines the dummy variable of choice indicator, taking the value 1 if an alternative *t* is made by a household *n* and 0 otherwise.

We assumed the energy demand for the bundle *T* chosen by a household *n* is a linear function, as seen in Equation (5).

$$E_{nt}' = \alpha_t' y_{nt} + \eta_{nt} \quad (5)$$

The column vector of the coefficients are estimated by maximizing the term "$-\sum_{n=1}^{N} \sum_{t=1}^{M} R_{nt} [\eta_{nt}^2]$" ,based from [13], using the maximum likelihood function, as seen in Equations (6), (7), and (8):

$$\eta_{nt} = E_{nt} - \alpha_t' y_{nt} \quad (6)$$

$$-\sum_{n=1}^{N} \sum_{t=1}^{M} R_{nt} [\eta_{nt}^2] = -\sum_{n=1}^{N} \sum_{t=1}^{M} R_{nt} [(E_{nt} - \alpha_t' y_{nt})^2] \quad (7)$$

$$LL_{continuous} = -\sum_{n=1}^{N} \sum_{t=1}^{M} R_{nt} [(E_{nt} - \alpha_t' y_{nt})^2] \quad (8)$$

where y_{nt} is a column vector of explanatory variables including a constant, $\boldsymbol{\alpha}_t$ is a column vector of the corresponding coefficients for an alternative t, and an error term $\boldsymbol{\eta}_{nt}$ is the unobserved part.

d) Scenario Formulation

Five different scenarios were formulated to simulate the percentage changes in household vehicle holdings and energy demand based on the "what if" concept rather than the intrinsic forecast method for the sensitivity analysis as follows:

- Scenario 1: High accessibility to key destinations (all TAZs = maximum multi-criteria accessibility);
- Scenario 2: High public line density (all TAZs = maximum line density);
- Scenario 3: a 25% vehicle price increase;
- Scenario 4: a 25% gas price increase;
- Scenario 5: Integration of scenarios 1 through 4.

The percentage changes of the total energy demand of all the above scenarios relative to the actual total energy demand are expressed as follows (Equations (9), (10), and (11)):

$$Total\ energy_{t,scenario} = \sum_{n=1}^{2140} R_{nt}[\alpha_t' y_{nt}] \quad (9)$$

$$Total\ energy_{scenario} = \sum_{t=2}^{5} \left(\frac{\%\ share_{t,scenario}}{\%\ share_{t,actual}}\right) \times total\ energy_{t,scenario} \quad (10)$$

$$\%\ Energy\ change = 100 \times \left(\frac{Total\ energy_{scenario} - Total\ energy_{actual}}{Total\ energy_{actual}}\right) \quad (11)$$

For the gas price scenario analysis, the retail gas prices in April 2017 in Metro Manila were used as the reference values because the survey was carried out during the mentioned period. The retail pump prices were 47Php/liter (for gasoline RON97) and 30Php/liter (for diesel) during that period [36].

e) Elasticity

Once we obtain the energy demand model by household vehicle holdings, we calculate the elasticity of energy demand (GJ/household-month) with respect to a 1% gas price increase to capture the marginal effect of gas price, as seen in Equation (12). The elasticity of CO_2 emissions (Tons/household-month) with respect to 1% gas price increase is calculated using Equation (13):

$$Energy\ elasticity_t = \frac{Total\ energy_{t,1\%\ gas} - Total\ energy_{t,actual}}{Total\ households_t} \quad (12)$$

$$CO_2\ elasticity = Emission\ Factor_{CO_2} \times Energy\ elasticity_t \quad (13)$$

where $Total\ energy_{t,\ 1\%\ gas}$ defines the total energy demand of 1% gas price increase for bundle *t* and $Total\ households_t$ is the total number of households for bundle *t*. The CO_2 emission factor is 74.10 tons/TJ [37].

III. Results and Discussion

This section discusses the model estimation results, scenario analysis, and elasticity of energy demand and CO_2 emissions with respect to a 1% gas price increase.

a) Model Estimation Results

The estimation results of the household vehicle holding model and the energy demand model are listed in Table 5.

i. *Household vehicle holdings*

For the household vehicle ownership model, the parameter estimates are shown from rows 2 through 11, and the zero-vehicle bundle was used as the reference category. The McFadden R^2 was 0.396 that is higher than the critical value of 0.3 [38]. The intercept coefficients of the MNL model have no interpretable meaning, but they are included to capture the average unobserved effect [35]. The household size coefficients are negative for all the alternatives, which indicate that households with more family members are less likely to hold vehicles, unlike previous studies. One explanation may be that large-sized families have low income, relative to small-sized families in Metro Manila, and therefore large size families have a lower vehicle purchasing power. The coefficients of the age of household head demonstrate that older households (household head aged 40 years old and above) have a higher propensity to hold more and large-sized vehicles (UVs), compared with younger households (household head aged below 40 years old). That household heads reach the mid-age (40 years and older) is just about the time their children become adults; therefore, the older households need vehicles with large seating and luggage capacity (i.e., UVs). For wealthy households, it is the stage when the kids are provided with their own vehicles.

The high accessibility of residential areas to the key facilities and the high road public transport line density have negative impacts on household vehicle holdings, and the impact of the multi-criteria accessibility was at a higher degree relative to the road public transport line density. As hypothesized, the high road density encourages household vehicle holdings for all the bundles, on account of larger on-street parking space and generally no law reinforcement related to on-street parking in residential areas in Metro Manila. Unlike the findings in other countries [16–18, 21, 34], the population density has no effect on household vehicle holdings. This could be explained that the multi-criteria accessibility has a stronger impact on household vehicle holdings than the population density, and all the studies in the existing literature have never considered the factor of multi-criteria accessibility to the key facilities. Households with high accessibility to CBDs are more likely to hold more vehicles. It is intuitive that those located close to CBDs have higher income, which means higher purchasing power for more vehicles. A similar finding in China was also reported by Jiang et al. [22].

The coefficients of vehicle cost-to-annual household income ratio factor are negative for all the alternatives, which indicates that high-income households are likely to hold more and large vehicles. Inversely, households are more prone to hold fewer and small-sized vehicles, if the vehicle cost is increased.

ii. *Energy Demand*

The parameter estimates of the energy demand model for all the bundles are demonstrated in the last ten rows of Table 5. As explained previously, zero-vehicle households have no energy demand. The positive intercept coefficients indicate that household holding vehicles are more likely to consume energy. Larger household size is associated with higher energy consumption for one-UV households and one-car households but has no statistically significant effect on households owning two cars. Generally speaking, households with more members are associated with more trips, which in turn requires more energy demand. It is surprising to see that car-UV households with more family members are likely to consume less energy. Age of household head has an effect on bundle 5 (i.e., car-UV households) only, and older households for this bundle are associated with less energy consumption, relative to younger households intuitively having more small child-related trips.

The multi-criteria accessibility has a negative impact on energy demand for one-car households but has a positive effect on energy demand for two-car households. Such a factor has no effect on energy demand for the one-UV and car-UV households. The road public transport line density has a negative impact on energy demand for one-car households, but a positive effect on energy demand for one-UV households. The line density has no effect on two-vehicle households. One-car households located in high road density area are more likely to consume more energy, probably owing to the fact that high road density is associated with more moving vehicles and narrow road space wherein traffic flow is slower. Additionally, an average fuel economy of a private vehicle in Metro Manila was 8.97km/l at 39.79km/h speed and 5.26km/l at 16.25km/h speed [39]. Contrary to one-car households, the other households are likely to consume less energy, and this could be explained that households holding larger and more vehicles might put on fewer miles, probably because a higher road density area has more convenience stores, supermarkets, and other facilities resulting in fewer private vehicle trip activities. It is not surprising to see that households of all the bundles having higher accessibility to CBDs require lower energy demand since the CBD area is the proximity of land-mixed use, pedestrian-friendly street, and better public transport accessibility.

The negative coefficients of expenditure on gas-to-income ratio factor were found for all the bundles, and most significant for one-UV households. Generally speaking, households with higher income are more like to consume more energy; and inversely, an increase in gas price has a negative impact on energy consumption.

Furthermore, the developed models for household vehicle holdings and energy demand are applied to estimate the output variables and then compared with the actual output variables as discussed below.

Table 6 presents the estimated output variables and the actual output variables. As seen in columns 2 and 3, the predicted percentage shares exactly matched the actual percentage shares for all the bundles. As apparent from columns 4 and 5, the predicted total energy demands are equal to the actual ones for all the bundles. The root mean square errors (RMSEs) of the estimated energy demand (the last column of Table 6) are very small for all the bundles (except bundle 2), as compared to the corresponding mean energy demands (see column 4 of Table 3). The RMSEs of bundles 3 and 5 were higher than those of bundles 2 and 4, on account of the relatively higher standard deviations of bundles 3 and 5 (see column 6 of Table 3).

Table 5: Estimation results of the MNL regression and linear regression – parameters (t-value)

Variables	One car	One UV	Two cars	Car & UV
Household vehicle holdings				
Intercept	5.442	5.521	5.039	4.720
	(12.62)**	(10.71)**	(5.64)**	(4.82)**
Household size	-0.443	-0.279	-0.346	-0.147
	(-6.47)**	(-3.35)**	(-2.29)*	(-0.96)
Age of household head	0.049	0.239	1.038	1.576
	(0.30)	(1.15)	(2.47)*	(2.80)**
Multi-criteria accessibility	-0.513	-0.554	-0.524	-0.707
	(-11.56)**	(-10.69)**	(-6.30)**	(-8.01)**
Line density (km/km2)	-0.019	-0.016	-0.008	-0.015

	(-4.69)**	(-3.74)**	(-1.50)	(-2.69)**
Road density (km/km2)	0.260	0.226	0.230	0.287
	(8.87)**	(6.79)**	(5.14)**	(6.34)**
Population density (10^3/km2)	0.002	-0.003	-0.004	-0.004
	(0.41)	(-0.45)	(-0.37)	(-0.40)
CBD accessibility (10^{-1})	0.999	0.974	1.093	1.245
	(10.12)**	(8.89)**	(7.96)**	(9.25)**
Vehicle cost/annual income	-1.590	-2.478	-5.699	-5.977
	(-13.98)**	(-13.04)**	(-10.53)**	(-10.01)**
Energy demand				
Intercept	3.059	4.996	8.116	15.923
	(21.12)**	(24.42)**	(13.29)**	(25.66)**
Household size	0.074	0.425	0.147	-0.335
	(2.71)**	(11.05)**	(1.26)	(-3.57)**
Age of household head	0.038	0.149	0.467	-2.613
	(0.65)	(1.50)	(1.66)	(-6.89)**
Multi-criteria accessibility	-0.035	-0.039	0.414	-0.067
	(-2.54)*	(-1.69)	(5.87)**	(-1.11)
Line density (km/km2)	-0.007	0.011	-0.005	-0.002
	(-7.90)**	(6.65)**	(-1.85)	(-0.63)
Road density (km/km2)	0.035	-0.069	-0.099	-0.07
	(4.83)**	(-5.54)**	(-3.60)**	(-2.80)**
Population density (10^3 people/km2)	-0.001	0.004	-0.055	-0.013
	(-0.67)	(1.56)	(-7.88)**	(-1.69)
CBD accessibility (10)	0.052	-0.044	-0.276	-0.171
	(2.21)*	(-1.18)	(-2.82)**	(-3.40)**
10 x Gas expenditure/income	-0.342	-2.509	-5.293	-6.493
	(-3.90)**	(-16.46)**	(-8.90)**	(-8.77)**

No vehicle alternative was used as the reference category for the discrete choice model.
Discrete choice component: LL = -1553.1; McFadden R^2 = 0.396
Continuous choice component: LL = -3203.7

Table 6: Comparison of the estimated and actual output variables

Bundles	% Shares		Total Energy Demand (GJ/month)		RMSE
	Actual	Estimated	Actual	Estimated	
Zero vehicle	47.29%	47.29%	–	–	–
One car	33.22%	33.22%	2110.19	2110.19	1.15
One UV	13.46%	13.46%	1362.52	1362.52	2.44
Two cars	3.22%	3.22%	477.27	477.27	1.77
One car & one UV	2.80%	2.80%	494.77	494.77	2.34
RMSE: Root mean square error					

As can be seen in Table 6, the separate estimations of the discrete choice model and the continuous choice model using the maximum likelihood function performed well in terms of accuracy of the estimated output variables, as compared with other algorithms. Those algorithms include the two-step approach proposed by Dubin and McFadden [40], the multiple discrete-continuous extreme value (MDCEV)

model proposed by Bhat [41], the Bayesian Multivariate Ordered Probit & Tobit (BMOPT) model proposed by Fang [34], the copula-based MNL-linear regression model proposed by Bhat and Eluru [33], and the integrated multinomial logit-multinomial probit-linear regression model proposed by Liu et al. [16].

In summary, improvement of accessibility of residential areas to the key destinations, improvement of road public transport line density, and increases in gas and vehicle prices have negative impacts on household vehicle holdings and energy demand. These factors are considered for scenario analysis in the subsection below, whereas a 1% gas price increase is taken into account of investigating the elasticity of energy demand and CO_2 emissions.

b) Scenario Analysis

The simulated percentage changes in household vehicle holdings are illustrated in Figure 1. The positive sign means an increase, and the negative sign means a decrease. Scenario 1 shows the percent changes in household vehicle holdings if all the TAZs have the same highest accessibility to the integral destinations and services. The percentage share of the zero-vehicle households would have increased by 26.43% that could be traced to a decrease in the households owning vehicles had all the TAZs been maximized. The percentage share of the zero-vehicle households would have increased by 21.09% shall all the TAZs have been introduced with the same highest road public transport line density (see scenario 2). A marginal increase in percentage change in two-car households could be traced from a decrease in percentage changes in one-UV households and car-UV households. It is also evident from scenario 3 that a 25% increase in vehicle cost would have reduced the vehicle-owning households by 4.88% only.

As assumed earlier for scenario 4, gas price changes have no impact on household vehicle holdings. Had all the scenarios been integrated, the percentage share of zero-vehicle households would have increased from 47.29% up to 89.78% (a 42.49% increase), which translates to a 78.95% decrease (55.42% of car and 23.53% of UV) in the vehicle fleet.

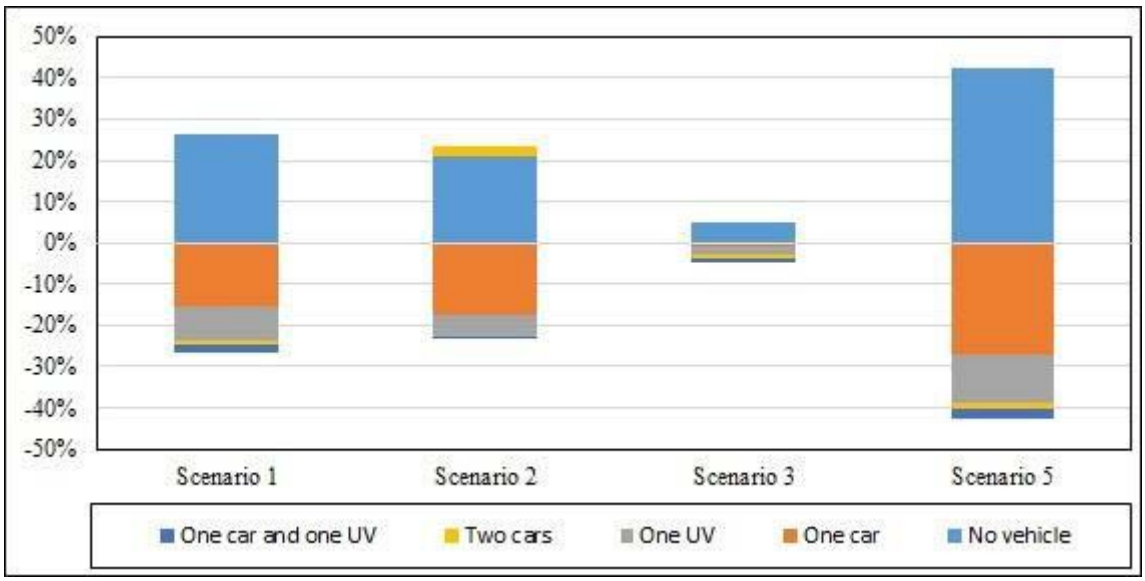

Figure 1: What-if scenario analysis of percentage changes in household vehicle holdings

The simulated percentage changes in energy demand based on the various scenarios are shown in Figure 2. If the key facility accessibility and the road-based public transport line density for all the TAZs had been improved, the energy demand would have decreased by 37.45% and 50.43%, respectively (see scenarios 1 and 2). An increase in vehicle and gas prices would cut down the energy demand by 12.81% and 4.30%, respectively, and the impact of vehicle and gas prices is much smaller than that of the improvement of the urban form attributes. An increase in vehicle price is more effective than an increase in gas price by 2.97 times, which is slightly smaller than a finding in the USA wherein an increase in vehicle price is more effective than an increase in gas price by 3.19 times [13]. Had the four scenarios been coupled, the energy demand would have lowered by 84.92%. Based on the "what if" scenarios analysis, the improvement of accessibility to the key facilities and public line density could be the chosen solutions for the adoption of strategic options to suppress household vehicle ownership and usage,

rather than controlling household vehicle ownership via an increase in gas and vehicle prices.

For a 25% gas price increase, the energy demand in Metro Manila would have been reduced by 4.30%, which is smaller than the vehicle usage decrease of 9.91% in the USA [16]. Generally speaking, households living in developing countries are less sensitive to a gas price increase, presumably owing to "forced vehicle usage" compared to those living in developed countries, as a result of inadequate public transport service in the former even though the households residing in developing countries have a relatively lower income. Thus, an increase in gas price to reduce vehicle usage, vehicular energy demand, and CO_2 emissions is more effective in a developed country relative to a developing country. For more clarification, the elasticity of CO_2 emission with respect to a 1% gas price increase is shown in the subsection below.

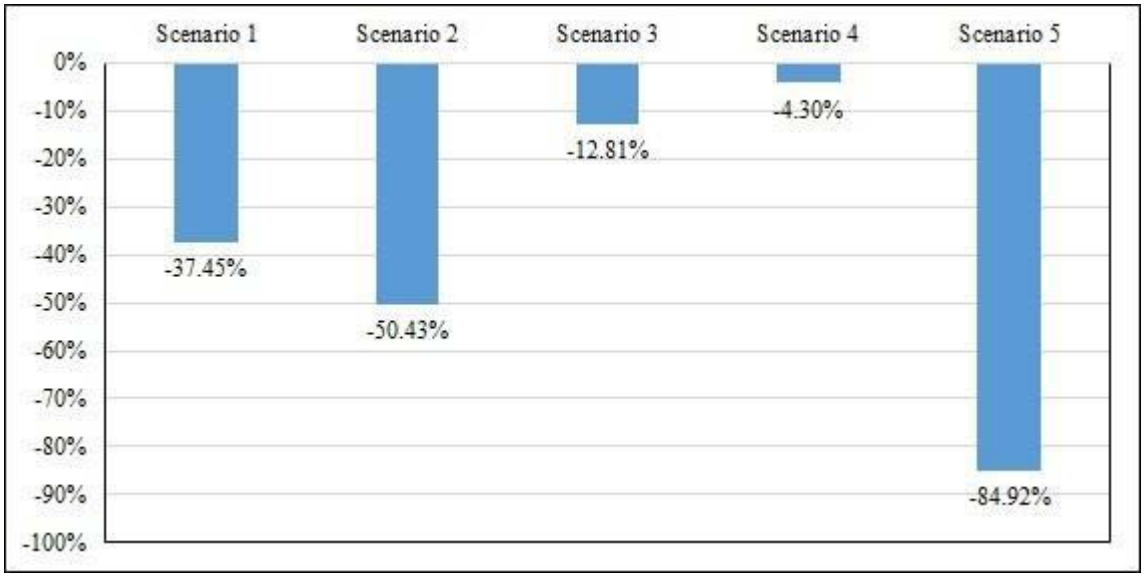

Figure 2: What-if scenario analysis of percentage changes in energy demand

c) *The elasticity of Energy Demand and CO_2 Emissions in terms of Gas Price*

The elasticity of energy demand and CO_2 emission with respect to a 1% gas price increase are listed in Table 7. As apparent in the last column of the table, one-UV households are most responsive to the gas price increase, followed by two-car households, car-UV households, and one-car households. The energy demand and CO_2 emission would decrease by 3.57 x 10^{-3}GJ/ household-month and 0.27 x 10^{-3}tons/ household - month, respectively, among vehicle-owning households in response to a 1% gas price increase (see the last row of Table 7). A 1% gas price increase would reduce the energy demand and CO_2 emission by 0.172%, this value is marginally lower than a 0.211% emission reduction in the USA [13].

Table 7: The impact of 1% gas price increase in energy demand and CO_2 emission

Household vehicle holdings	Energy (GJ/household-month)	CO_2 emission (tons/household-month)	% changes
One car	-2.19×10^{-3}	-0.16×10^{-3}	-0.074%
One UV	-12.99×10^{-3}	-0.96×10^{-3}	-0.274%
Two cars	-16.96×10^{-3}	-1.26×10^{-3}	-0.245%
Car & UV	-19.69×10^{-3}	-1.46×10^{-3}	-0.238%
Overall	-3.57×10^{-3}	-0.27×10^{-3}	-0.172%

IV. Conclusions and Recommendations

This study develops the MNL-based household vehicle ownership model and the linear regression-based energy demand model using the sample data of 2,300 households gathered from various areas within Metro Manila. Unlike findings in other countries, households in Metro Manila with more members are most likely not to own vehicles because most large-sized families have lower income associated with lower

purchasing power. However, vehicle-owning families with more members consume more energy conceivably as a result of more trip activities. Households with older family heads are more likely to own more and large vehicles but less likely to consume energy. Households with high income have a higher propensity to hold more and large vehicles and require more energy demand. An increase in gas price and vehicle cost have a negative impact on household vehicle ownership and usage. In terms of urban form factors, population density has no statistically significant effect on household vehicle holdings, while an increase in road density would encourage households to own vehicles as a result of the availability of more on-street parking spaces. Households located in an area with high accessibility to CBDs are more induced toward holding more small vehicles but consume less energy. Households located in an area with high accessibility to the key destinations and high public transport line density are most likely not to own vehicles.

A 1% increase in gas price would reduce energy demand and CO_2 emission by 0.174%. The elasticity of CO_2 and energy demand reduction from private vehicles in term of the gas price increase was lower for Metro Manila relative to the USA. The developed models were also applied using the "what if" scenario analysis as explained earlier. Results showed that if the accessibility to the key facilities and the road-based public transport line density for all the TAZs had been maximized, the energy demand would have been reduced by 37.45% and 50.43%, respectively, while a 25% vehicle price increase and a 25% gas price increase would have cut down the energy demand by 12.81% and 4.30%, respectively. Therefore, improvement of both the key facility accessibility and the public transport line density are the most effective solutions toward a sustainable urban transportation system rather than increasing gas and vehicle prices. Shall all the mentioned scenarios have been combined, the vehicle fleet and energy demand would have decreased by 78.95% (55.42% of car and 23.52% of UV) and 84.92%, respectively.

It is evident from the empirical findings that transportation planners and policymakers should consider the improvement of accessibility to the core facilities and public transport line density rather than increasing gas and vehicle taxes in order to mitigate traffic congestion, energy consumption, worsening urban air quality, and GHG emissions in metropolitan areas of developing countries.

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We shall provide you intimation regarding launching of e-version of journal of your stream time to time.This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The MARSE member can apply for approval, grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A.

Once you are designated as MARSE, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria.

It is mandatory to read all terms and conditions carefully.

AUXILIARY MEMBERSHIPS

Institutional Fellow of Open Association of Research Society (USA)-OARS (USA)

Global Journals Incorporation (USA) is accredited by Open Association of Research Society, U.S.A (OARS) and in turn, affiliates research institutions as "Institutional Fellow of Open Association of Research Society" (IFOARS).

The "FARSC" is a dignified title which is accorded to a person's name viz. Dr. John E. Hall, Ph.D., FARSC or William Walldroff, M.S., FARSC.

The IFOARS institution is entitled to form a Board comprised of one Chairperson and three to five board members preferably from different streams. The Board will be recognized as "Institutional Board of Open Association of Research Society"-(IBOARS).

The Institute will be entitled to following benefits:

The IBOARS can initially review research papers of their institute and recommend them to publish with respective journal of Global Journals. It can also review the papers of other institutions after obtaining our consent. The second review will be done by peer reviewer of Global Journals Incorporation (USA) The Board is at liberty to appoint a peer reviewer with the approval of chairperson after consulting us.

The author fees of such paper may be waived off up to 40%.

The Global Journals Incorporation (USA) at its discretion can also refer double blind peer reviewed paper at their end to the board for the verification and to get recommendation for final stage of acceptance of publication.

The IBOARS can organize symposium/seminar/conference in their country on behalf of Global Journals Incorporation (USA)-OARS (USA). The terms and conditions can be discussed separately.

The Board can also play vital role by exploring and giving valuable suggestions regarding the Standards of "Open Association of Research Society, U.S.A (OARS)" so that proper amendment can take place for the benefit of entire research community. We shall provide details of particular standard only on receipt of request from the Board.

The board members can also join us as Individual Fellow with 40% discount on total fees applicable to Individual Fellow. They will be entitled to avail all the benefits as declared. Please visit Individual Fellow-sub menu of GlobalJournals.org to have more relevant details.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time. This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

After nomination of your institution as "Institutional Fellow" and constantly functioning successfully for one year, we can consider giving recognition to your institute to function as Regional/Zonal office on our behalf.
The board can also take up the additional allied activities for betterment after our consultation.

The following entitlements are applicable to individual Fellows:

Open Association of Research Society, U.S.A (OARS) By-laws states that an individual Fellow may use the designations as applicable, or the corresponding initials. The Credentials of individual Fellow and Associate designations signify that the individual has gained knowledge of the fundamental concepts. One is magnanimous and proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice.

Open Association of Research Society (US)/ Global Journals Incorporation (USA), as described in Corporate Statements, are educational, research publishing and professional membership organizations. Achieving our individual Fellow or Associate status is based mainly on meeting stated educational research requirements.

Disbursement of 40% Royalty earned through Global Journals : Researcher = 50%, Peer Reviewer = 37.50%, Institution = 12.50% E.g. Out of 40%, the 20% benefit should be passed on to researcher, 15 % benefit towards remuneration should be given to a reviewer and remaining 5% is to be retained by the institution.

We shall provide print version of 12 issues of any three journals [as per your requirement] out of our 38 journals worth $ 2376 USD.

Other:

The individual Fellow and Associate designations accredited by Open Association of Research Society (US) credentials signify guarantees following achievements:

- The professional accredited with Fellow honor, is entitled to various benefits viz. name, fame, honor, regular flow of income, secured bright future, social status etc.

- In addition to above, if one is single author, then entitled to 40% discount on publishing research paper and can get 10%discount if one is co-author or main author among group of authors.
- The Fellow can organize symposium/seminar/conference on behalf of Global Journals Incorporation (USA) and he/she can also attend the same organized by other institutes on behalf of Global Journals.
- The Fellow can become member of Editorial Board Member after completing 3yrs.
- The Fellow can earn 60% of sales proceeds from the sale of reference/review books/literature/publishing of research paper.
- Fellow can also join as paid peer reviewer and earn 15% remuneration of author charges and can also get an opportunity to join as member of the Editorial Board of Global Journals Incorporation (USA)
- • This individual has learned the basic methods of applying those concepts and techniques to common challenging situations. This individual has further demonstrated an in–depth understanding of the application of suitable techniques to a particular area of research practice.

Note :

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- In future, if the board feels the necessity to change any board member, the same can be done with the consent of the chairperson along with anyone board member without our approval.
- In case, the chairperson needs to be replaced then consent of 2/3rd board members are required and they are also required to jointly pass the resolution copy of which should be sent to us. In such case, it will be compulsory to obtain our approval before replacement.
- In case of "Difference of Opinion [if any]" among the Board members, our decision will be final and binding to everyone.

"

We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

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Authors should submit their complete paper/article, including text illustrations, graphics, conclusions, artwork, and tables. Authors who are not able to submit manuscript using the form above can email the manuscript department at submit@globaljournals.org or get in touch with chiefeditor@globaljournals.org if they wish to send the abstract before submission.

Before and during Submission

Authors must ensure the information provided during the submission of a paper is authentic. Please go through the following checklist before submitting:

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2. Authors must accept the privacy policy, terms, and conditions of Global Journals.
3. Ensure corresponding author's email address and postal address are accurate and reachable.
4. Manuscript to be submitted must include keywords, an abstract, a paper title, co-author(s') names and details (email address, name, phone number, and institution), figures and illustrations in vector format including appropriate captions, tables, including titles and footnotes, a conclusion, results, acknowledgments and references.
5. Authors should submit paper in a ZIP archive if any supplementary files are required along with the paper.
6. Proper permissions must be acquired for the use of any copyrighted material.
7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

Declaration of Conflicts of Interest

It is required for authors to declare all financial, institutional, and personal relationships with other individuals and organizations that could influence (bias) their research.

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Plagiarism is not acceptable in Global Journals submissions at all.

Plagiarized content will not be considered for publication. We reserve the right to inform authors' institutions about plagiarism detected either before or after publication. If plagiarism is identified, we will follow COPE guidelines:

Authors are solely responsible for all the plagiarism that is found. The author must not fabricate, falsify or plagiarize existing research data. The following, if copied, will be considered plagiarism:

- Words (language)
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- Findings
- Writings
- Diagrams
- Graphs
- Illustrations
- Lectures

- Printed material
- Graphic representations
- Computer programs
- Electronic material
- Any other original work

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1. Substantial contributions to the conception and acquisition of data, analysis, and interpretation of findings.
2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

Changes in Authorship

The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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Appealing Decisions

Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

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Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

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Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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