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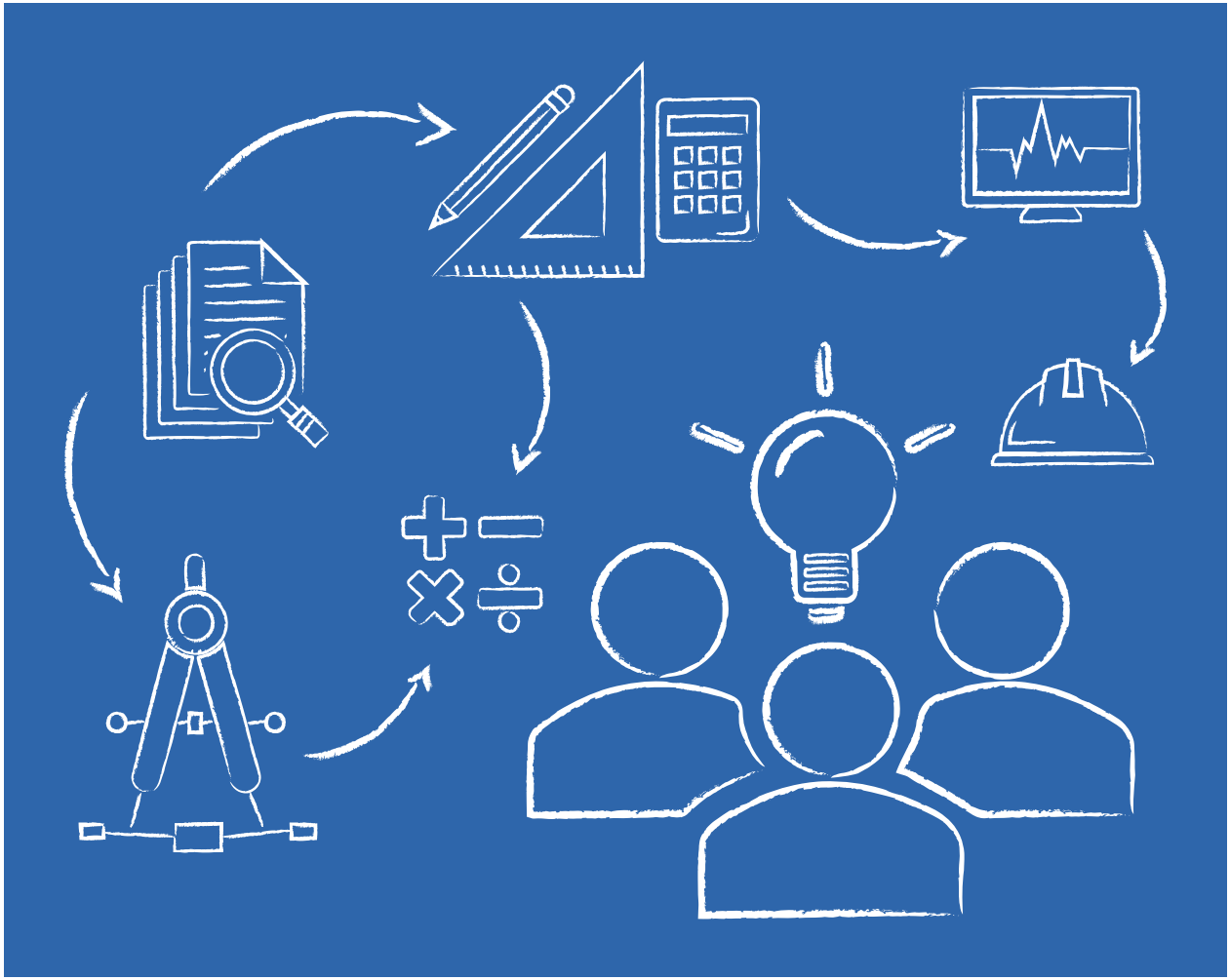

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Área de Innovación y Desarrollo, S.L.

C/Alzamora 17, Alcoy, Alicante (España)

Tel: 965030572

info@3ciencias.com _ www.3ciencias.com

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PROPUESTA METODOLÓGICA PARA DIBUJAR PROYECCIONES ISOMÉTRICAS

METHODOLOGICAL PROPOSAL TO DRAW ISOMETRIC PROJECTIONS

Manuel Morocho Amaguaya
Docente de la Facultad de Mecánica, Carrera de Ingeniería en Mantenimiento, Escuela Superior Politécnica de Chimborazo (ESPOCH), (Ecuador).
E-mail: mmorocho_a@espoch.edu.ec ORCID: https://orcid.org/0000-0002-3484-4661

Luis Danilo Flores Rivera
Docente Asociado, Dirección de Educación Continua a Distancia y Virtual, Universidad Técnica de Ambato (UTA), (Ecuador).
E-mail: ldaniflores77@gmail.com ORCID: https://orcid.org/0000-0003-1301-6880

Carlos Fernando Meléndez Tamayo
Profesor - Investigador, Director del Departamento de Educación Continua a Distancia y Virtual, Universidad Técnica de Ambato (UTA), (Ecuador).
E-mail: cmelendez77@uta.edu.ec ORCID: https://orcid.org/0000-0002-7990-4859

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RESUMEN

El presente artículo muestra una propuesta metodológica para dibujar proyecciones isométricas; su procedimiento se caracteriza por articular *el análisis, lo metódico y lo curioso* al proceso; siendo de gran beneficio para los estudiantes de la carrera de Ingeniería en Mantenimiento Industrial, Facultad de Mecánica, Escuela Superior Politécnica del Chimborazo (ESPOCH).

En el *análisis*, el método cumple con observar la disposición de la pieza mecánica y sus vistas; en lo *metódico*, se ejecuta una secuencia de pasos que facilitan la construcción de la pieza mecánica y sus vistas; y en lo *curioso*, es el interés por la visualización y resultado final de la pieza mecánica. Por tanto, la metodología y proceso empleado facilitan el aprendizaje y contribuyen a un pensamiento lógico indispensable para las carreras de ingeniería. Lo indicado, se justifica con resultados satisfactorios de estudiantes aprobados 88 % de la asignatura de dibujo técnico, en los últimos 10 años (2010 - 2019); así como información satisfactoria que se obtuvo de una encuesta practicada a los estudiantes de dibujo técnico semestre Octubre 2019 - Febrero 2020.

PALABRAS CLAVE

Dibujo técnico, Isometría, Metodología, Proyecciones, Perspectiva.

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ABSTRACT

This article shows a methodological proposal to draw isometric projections; its procedure is characterized by articulating the analysis, the methodical and the curious to the process; being of great benefit for the students of the Industrial Maintenance Engineering, Faculty of Mechanics, Polytechnic School of Chimborazo (ESPOCH).

In the analysis, the method complies with observing the arrangement of the mechanical part and its views; in the methodical, a sequence of steps that facilitate the construction of the mechanical part and its views is executed; and in the curious thing, it is the interest for the visualization and final result of the mechanical piece. Therefore, the methodology and process used facilitate learning and contribute to logical thinking essential for engineering careers. The above is justified with satisfactory results of approved students 88 % of the subject of technical drawing, in the last 10 years (2010 - 2019); as well as satisfactory information that was obtained from a survey conducted to students of technical drawing semester October 2019 - February 2020.

KEYWORDS

Technical drawing, Isometry, Methodology, Projections, Perspective.

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1. INTRODUCCIÓN

La importancia del dibujo técnico y específicamente el conocimiento de *proyecciones isométricas*, es significativo en componentes de aprendizaje de carreras de ingeniería o educación técnica. Por tal motivo, las Instituciones de Educación Superior (IES) en sus mallas curriculares (competencias básicas y competencias profesionales) acreditan el valor significativo del *dibujo técnico* en el proceso formativo de los estudiantes.

Considerando la premisa, el dibujo técnico es una de las asignaturas que fortalece y estimula la *inteligencia espacial* (capacidad mental de pensar en *tres dimensiones*, relación con la navegación y la rotación de objetos, visualización imaginaria desde distintos ángulos) concepto que se deriva de las *inteligencias múltiples* propuesta por el psicólogo Howard Gardner (Torres, 2016).

Definiendo al dibujo técnico, es *el lenguaje gráfico* que representa uno o más objetos existentes, con la finalidad de *comunicar información* útil para su análisis, diseño, construcción y mantenimiento; esto último vinculado a normas y convenciones preestablecidas por organismos reguladores que contribuyen a describir de modo preciso y claro *dimensiones, formas y características del objeto u objetos* (Raffino, 2019).

Otro factor fundamental del dibujo técnico es su relación con la geometría. Esto es evidente porque las gráficas dibujadas resultan de la composición de elementos geométricos como líneas rectas, líneas curvas, circunferencias, conos, prismas, polígonos, etc.; adicionalmente se tiene su relación teórica con conceptos de paralelismo, perpendicularidad, simetría, tangencia, etc.; conocimientos y procedimientos geométricos claves para la competencia de dibujar. En este sentido, la representación gráfica, se basa en la geometría descriptiva (rama de la matemática que se encarga de la representación de las figuras y cuerpos geométricos en el espacio) y utiliza las proyecciones ortogonales para dibujar las distintas vistas de un objeto (Estrada *et al.*, 2012; Sainz, 1990).

El estudio en cuestión, precisa una propuesta metodológica para la dibujar proyecciones isométricas. Las proyecciones isométricas promueven competencias para representar diversos objetos con su volumen

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en el plano. Además aportan con saberes específicos (conceptual, procedimental, actitudinal y valores) (Estrada *et al.*, 2012). Es conveniente que la propuesta metodológica, disponga de estrategias que facilitan la comunicación directa, simple y clara entre educador y educando para que el dibujo técnico sea una herramienta que facilite la solución de problemas teórico-prácticos inherentes a la ingeniería o profesión técnica a desempeñar (Trujillo, Sepulveda, y Parra, 2009).

2. FUNDAMENTO TEÓRICO

2.1. DIBUJO TÉCNICO

El dibujo técnico, es una representación gráfica de un objeto en forma real y precisa; parte de una idea para efectuar su construcción posterior (EcuRed, 2018); determina el cumplimiento de normas, específicamente la práctica del sistema diédrico (representación de la geometría descriptiva), que satisface la condición de reversibilidad, es decir, la figura del espacio se puede pasar al plano utilizando las proyecciones; y recíprocamente, dadas las proyecciones del plano, se puede obtener la representación de la figura en el espacio (Rojas-Sola *et al.*, 2011).

2.2. METODOLOGÍA

Metodología del origen griego *metà* (más allá), *odòs* (camino) y *logos* (estudio), hace referencia "al conjunto de procedimientos basados en principios lógicos, utilizados para alcanzar una gama de objetivos que rigen en una investigación científica o en una exposición doctrinal" (EcuRed, 2014).

En las proyecciones isométricas, la metodología mejora y facilita el proceso de aprendizaje de los estudiantes. La aplicación coherente proporciona eficacia a los métodos en los diversos campos del conocimiento; y la enseñanza resulta ser innovadora para el educando (Aguilera, 2013; EcuRed, 2014).

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2.3. PROCESO

Proceso del origen latino *processus*, este concepto describe "la acción de avanzar o ir para adelante, al paso del tiempo y al conjunto de etapas sucesivas advertidas en un fenómeno natural o necesario para concretar una operación artificial" (Real Academia Española, 2014).

De acuerdo a la propuesta, el proceso se considera como un conjunto de actividades que se realizan de manera ordenada para lograr un resultado determinado; y aplicado al dibujo técnico, se lo considera como la ejecución en secuencia de diversos pasos realizados de forma coherente para obtener una adecuada representación gráfica.

2.4. PROYECCIÓN

Proyección es la "línea o figura que resulta, en una superficie, de proyectar en ella todos los puntos de una línea, una figura o un sólido" (Real Academia Española, 2014).

En proyecciones de dibujo técnico, es la representación de un objeto (tres dimensiones) en un plano (dos dimensiones) (Rojas, 2015).

2.5. SISTEMAS DE PROYECCIÓN

Todos los sistemas, se fundamentan en la proyección de los objetos sobre un plano <<*plano de proyección*>>. En la Figura 1, se ilustra la proyección de los objetos en el sistema americano y europeo.

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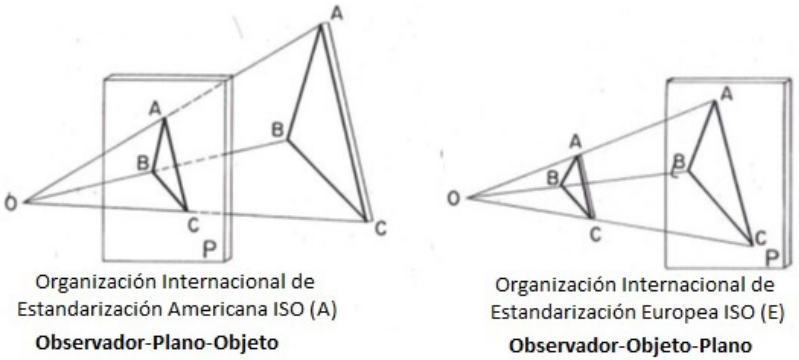

Figura 1. Proyección de los objetos en el sistema americano y europeo. **Fuente:** (Rojas, 2015).

Hay que considerar que las proyecciones relativas del observador y del objeto a representar, en el dibujo técnico, están reguladas bajo la Organización Internacional de Estandarización del inglés *International Standar Organization* (ISO), dividiéndose en dos sistemas (Rojas, 2015; Saab y Bielsa, 2004):

- Organización Internacional de Estandarización Americana ISO (A) *tercer cuadrante*.
- Organización Internacional de Estandarización Europea ISO (E) *primer cuadrante*.

2.6. CLASIFICACIÓN DE LAS PROYECCIONES

En forma general y observando el paralelismo de los rayos visuales (Figura 2), se clasifican en dos:

- ***Proyección cónica*** los rayos visuales parten del observador y se divergen hasta llegar al objeto.
- ***Proyección cilíndrica*** los rayos visuales son paralelos, el observador se encuentra en el infinito. Estos se subdividen en ortogonal y oblicua (Rojas, 2015).

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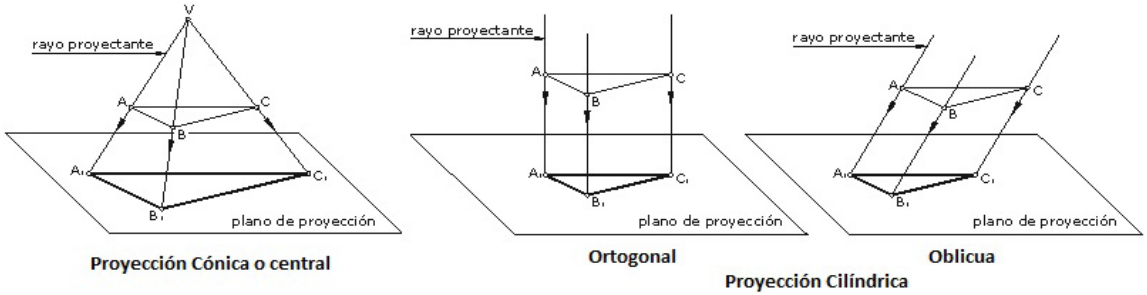

Figura 2. Diferentes Proyecciones. **Fuente:** (Rodríguez, 2014).

2.7. LA PERSPECTIVA

La perspectiva es un "sistema de representación que intenta reproducir en una superficie plana la profundidad del espacio y la imagen tridimensional con que aparecen las formas a la vista" (Real Academia Española, 2014). Para Pérez (1998), la perspectiva es la posibilidad de representar en un plano (dos dimensiones), objetos de tres dimensiones (largo, ancho y espesor). Así se produce el efecto psicológico de la tercera dimensión, es decir, la profundidad.

Los dibujos en perspectiva son métodos del dibujo técnico que representan proyecciones axonométricas (del griego *axon* <<eje>> y *metric* <<medida>>) cónicas u oblicuas (Pérez, 1998).

2.7.1. PERSPECTIVA CÓNICA

La perspectiva cónica, se proyecta en los planos como un haz de rectas; lo que se llama un *punto de fuga* y ello genera una secuencia lineal en forma de cono (Figura 3a).

2.7.2. PERSPECTIVAS CÓNICA DE UN CUBO

Las perspectivas de un cubo que tiene dos caras paralelas (plano del cuadro y las aristas de dichas caras), se proyecta paralela así misma y las otras caras al ser perpendiculares (plano del cuadro), se proyectan como un haz de rectas hasta juntarse en *punto fuga P* (Figura 3b).

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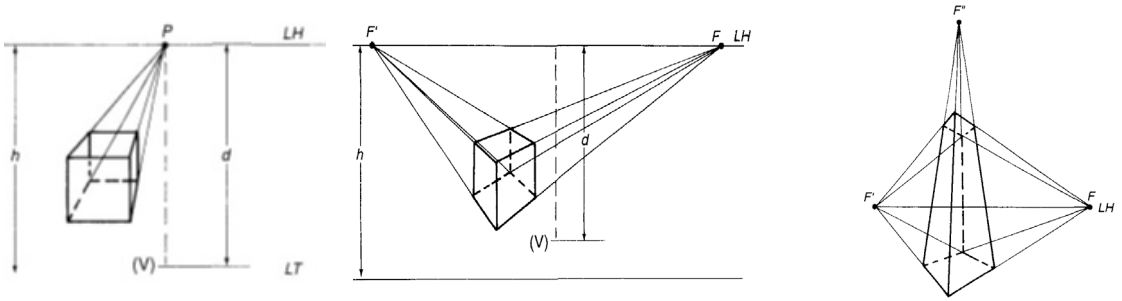
2.7.3. PERSPECTIVA OBLICUA O DE TRES PUNTOS DE FUGA

En la perspectiva oblicua o de tres puntos de fuga, es cuando las proyecciones de las aristas del cubo se juntan en tres puntos, lo cual se debe a que el cubo tiene todas las caras oblicuas al plano del cuadro y oblicuas serán las tres direcciones de haz de rectas en el espacio (Figura 3c) (Pérez, 1998).



a. Con un punto de fuga. **b. Con dos puntos de fuga.** **c. Oblicua con tres puntos de fuga.**

Figura 3. Perspectiva cónica. **Fuente:** (Pérez, 1998)

2.7.4. PERSPECTIVA OBLICUA CABALLERA

La perspectiva oblicua caballera (paralela), es donde la cara frontal del sólido se dibuja con su medida verdadera y las caras que muestran la profundidad, se dibujan con inclinaciones de 30 ° o 45 ° respecto a la horizontal y paralelas entre sí, ya sea con su medida real o a ¾ partes de la real para obtener un mejor efecto visual (Figura 4) (Trujillo *et al.*, 2009). Una característica adicional es considerar que uno de sus planos de referencia (formado por los ejes Y y Z) y los paralelos al mismo, se orientan al observador, con su verdadera forma y dimensiones, lo que facilita en gran medida el trazado (Figura 4) (IES Santa Teresa de Jesús, 2005).

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Figura 4. Perspectiva caballera. **Fuente:** (Pérez, 1998; IES Santa Teresa de Jesús, 2005).

2.7.5. PERSPECTIVAS AXONOMÉTRICAS OBLICUAS

Las perspectivas axonométricas, son oblicuas por la posición inclinada del modelo con respecto al plano de proyección, y tienen la siguiente clasificación:

Perspectiva dimétrica los ejes formados por dos ángulos iguales y uno diferente (Figura 5).

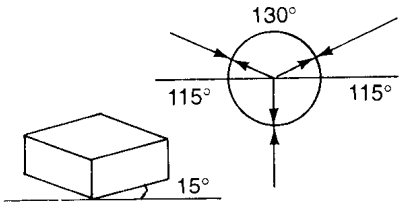

Figura 5. Perspectiva dimétrica. **Fuente:** (Pérez, 1998).

Perspectiva trimétrica está formada por ejes con los tres ángulos diferentes (Figura 6).

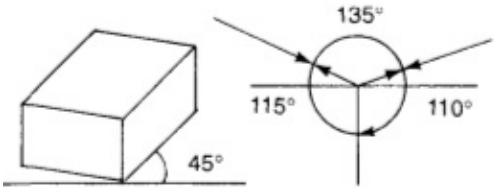

Figura 6. Perspectiva trimétrica. **Fuente:** (Pérez, 1998).

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Perspectiva isométrica del griego *iso* (igual) y métrica (medida), es aquella que mantiene las mismas medidas de largo, ancho y altura del objeto. Es la principal *perspectiva utilizada en el dibujo t*écnico; muestra a un objeto (dibujo) cualquiera con tres superficies básicas; lo que resulta con iguales inclinaciones con respecto al plano de proyección. Esta perspectiva se acerca a la realidad del sólido; siendo fácil de interpretar por personas que no tiene conocimientos especiales en dibujo. La construcción de la perspectiva requiere de tres ejes isométricos básicos, que forman entre sí ángulos de 120° (Figura 7) (SENATI, 2012).

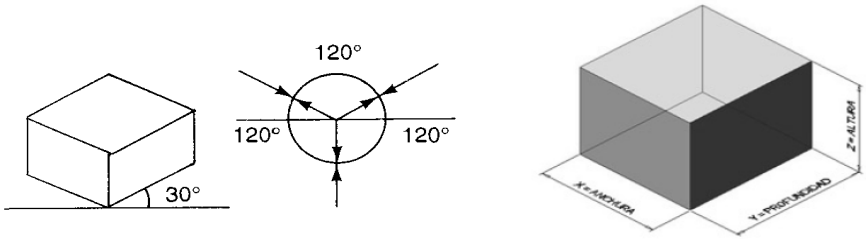

Figura 7. Perspectiva isométrica. **Fuente:** (Pérez, 1998; Trujillo *et al.*, 2009).

2.8. REPRESENTACIÓN DE VISTAS

Se tienen dos sistemas de representación de vistas:

- Primer Diedro - ISO E - Sistema Europeo de Proyección
- Tercer Diedro - ISO A - Sistema Americano de Proyección

Las vistas tienen las siguientes denominaciones:

Vista A: Vista de frente o alzado

Vista B: Vista superior o planta

Vista C: Vista derecha o lateral derecha

Vista D: Vista izquierda o lateral izquierda

Vista E: Vista inferior

Vista F: Vista posterior

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2.8.1. PRIMER DIEDRO - ISO E - SISTEMA EUROPEO DE PROYECCIÓN

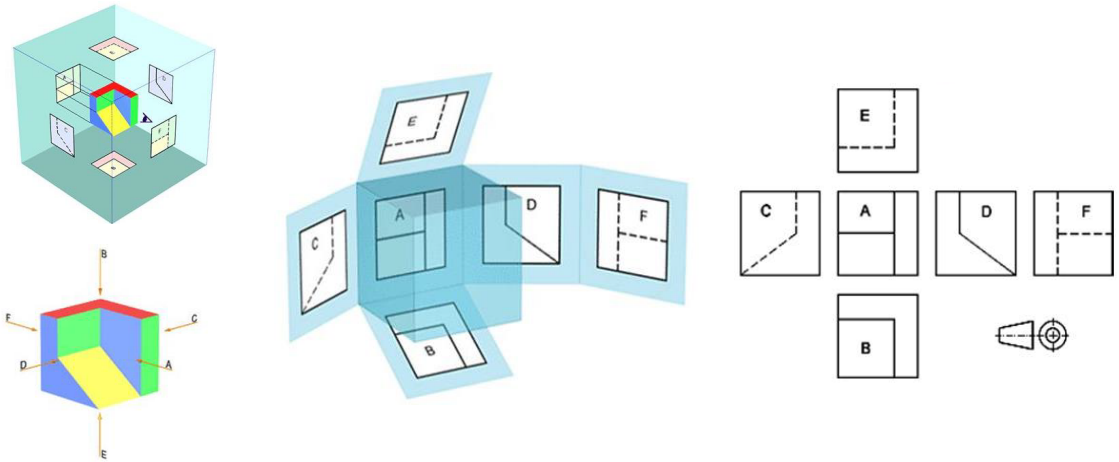

Figura 8. Primer Diedro - ISO E - Sistema Europeo de Proyección. **Fuente:** (Barry, 2015).

2.8.2. TERCER DIEDRO - ISO A - SISTEMA AMERICANO DE PROYECCIÓN

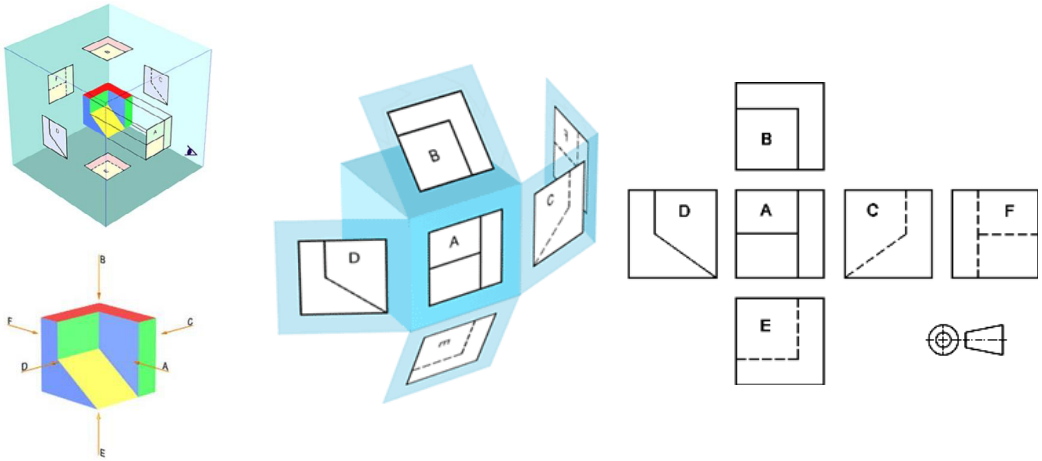

Figura 9. Tercer Diedro - ISO A - Sistema Americano de Proyección. **Fuente:** (Barry, 2015).

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Una pieza, se puede representar perfectamente *con solo tres vistas*, proyección frontal (vista de frente A), proyección horizontal (vista superior B) y una proyección lateral (vista izquierda o derecha C o D) (Barry, 2015).

3. METODOLOGÍA

Para la obtención de la perspectiva isométrica, previamente se realizan y emulan los siguientes pasos:

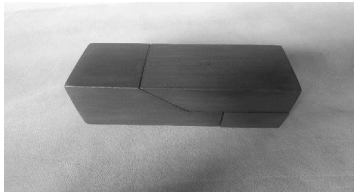
a) Se utiliza un *modelo o prototipo físico real a escala* (Figura 10 a).

b) Se prepara el *modelo de paralelepípedo* (Sólido limitado por seis paralelogramos, cuyas caras opuestas son iguales y paralelas" (Real Academia Española, 2014)) *de forma física real* (Figura 10 a).

c) Se realiza una *exploración espacial*, donde se quitan las partes sobrantes del plano frontal y el estudiante puede manipular y examinar el objeto (Figura 10 b).

d) Se realiza una *exploración espacial*, donde se quitan las partes sobrantes del plano superior y el estudiante puede manipular y examinar el objeto (Figura 10 c).

e) Finalmente, con los pasos efectuados y piezas reales, se demuestra cómo se obtiene la proyección isométrica de manera sencilla, rápida y concreta (Figura 10 d).



a) Paralelepípedo de forma física y real.

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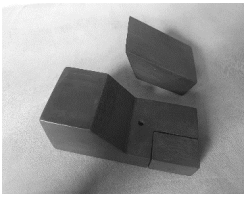
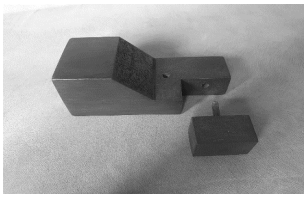
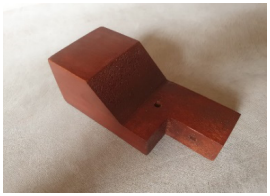


b) Exploración espacial, se quitan partes sobrantes del plano frontal.



c) Exploración espacial, se quitan partes sobrantes del plano superior.



d) Pieza real, proyección isométrica

Figura 10. Emulación física de la perspectiva isométrica. **Fuente:** elaboración propia.

Una vez explicado, los pasos previos del modelo a escala, se continúa con las actividades que corresponden a la *propuesta metodológica para dibujar proyecciones isométricas*.

a) Analizar las vistas que se encuentran dadas como datos y determinar cuál de ellas es la vista frontal (VF).

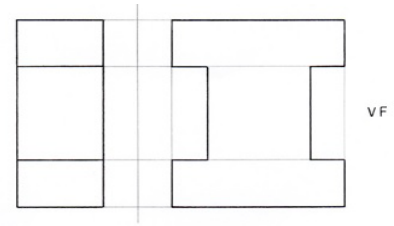


Figura 11. Análisis e identificación de la vista frontal. **Fuente:** elaboración propia.

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b) Dibujar un *paralelepípedo* isométrico de dimensiones iguales al largo, alto y ancho de las vistas dadas.

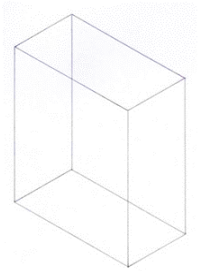

Figura 12. Elaboración del paralelepípedo isométrico de dimensiones iguales al largo, alto y ancho. **Fuente:** elaboración propia.

c) Trazar y formar las diferentes partes de la figura.

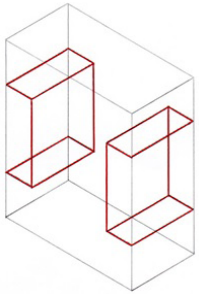

Figura 13. Ejecución de trazos para formar partes del dibujo. **Fuente:** elaboración propia.

d) Repasar la proyección isométrica obtenida con líneas continuas gruesas las aristas visibles y con líneas de segmentos las aristas ocultas.

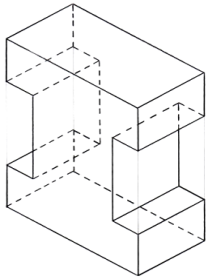

Figura 14. Ejecución de trazos con líneas gruesas (visibles) y segmentadas (ocultas) para formar el dibujo. **Fuente:** elaboración propia.

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e) Obtener la tercera vista, que en este caso se trata de la vista superior (VS).

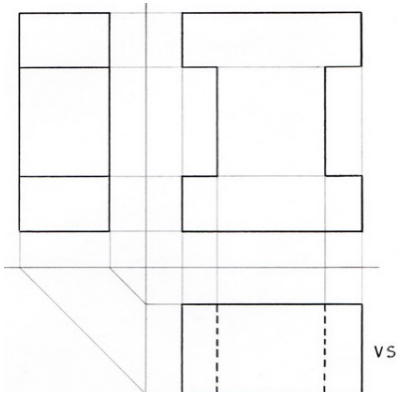

Figura 15. Proceso para obtener la vista superior. **Fuente:** elaboración propia.

7. APLICACIÓN PRÁCTICA

La práctica, se inicia con la *emulación del modelo físico a escala* que se explicó. Posteriormente, se continúa con el proceso para dibujar la proyección isométrica que para el caso, una matriz de doblado.

a) Analizar las vistas dadas como datos y determinar la vista frontal (VF).

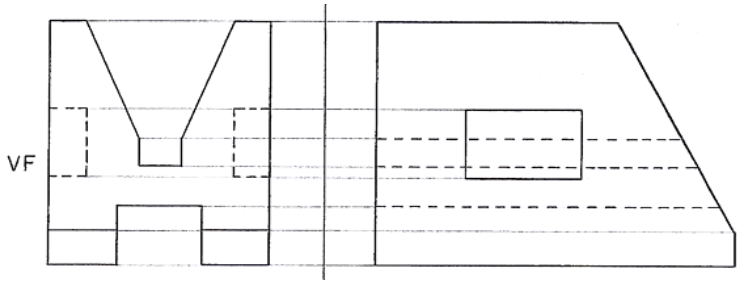

Figura 16. Análisis e identificación de la vista frontal. **Fuente:** elaboración propia.

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b) Dibujar un *paralelepípedo* isométrico de dimensiones iguales al largo, alto y ancho de las vistas dadas.

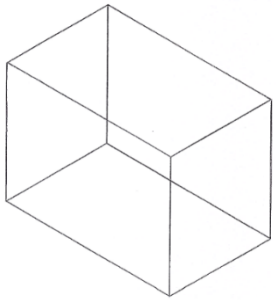

Figura 17. Elaboración del paralelepípedo isométrico de dimensiones iguales al largo, alto y ancho. **Fuente:** elaboración propia.

c) Quitar la parte inclinada que no existe en la vista lateral izquierda.

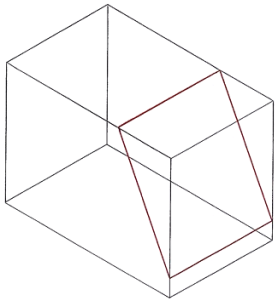

Figura 18. Ejecución de trazos para quitar la parte inclinada de la vista lateral izquierda. **Fuente:** elaboración propia.

d) Quitar la parte que no existe en la vista frontal y formar el ranurado central inferior.

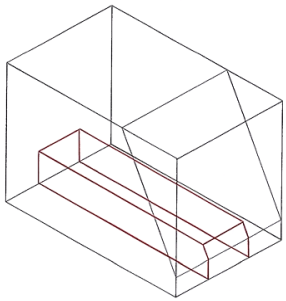

Figura 19. Ejecución de trazos para quitar parte que no existe en la vista frontal y formar el ranurado central inferior. **Fuente:** elaboración propia.

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e) Trazar las aristas que conforman el ranurado central superior inclinado de la matriz de doblado.

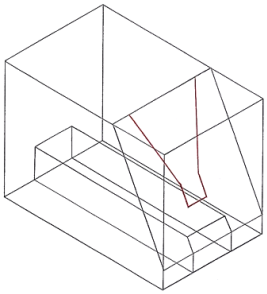

Figura 20. Ejecución de trazos para aristas que conforman el ranurado central superior inclinado de la matriz de doblado. **Fuente:** elaboración propia.

f) Quitar la parte que no existe y formar el ranurado central superior inclinado de la matriz de doblado.

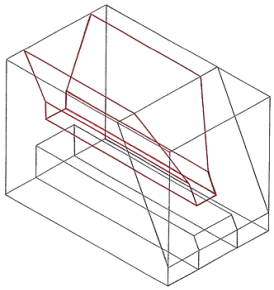

Figura 21. Ejecución de trazos para quitar la parte que no existe y formar el ranurado central superior inclinado de la matriz de doblado. **Fuente:** elaboración propia.

g) Dibujar el mecanizado rectangular ubicado en el plano lateral izquierdo.

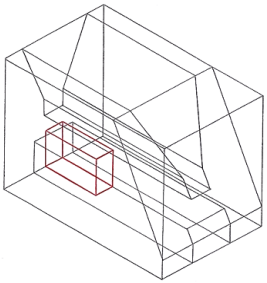

Figura 22. Ejecución de trazos para dibujar el mecanizado rectangular ubicado en el plano lateral izquierdo. **Fuente:** elaboración propia.

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h) Dibujar el mecanizado rectangular ubicado en el plano lateral derecho.

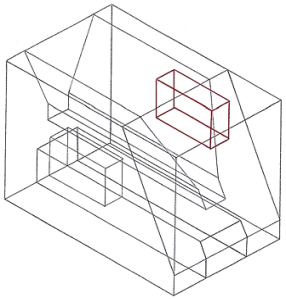

Figura 23. Ejecución de trazos para dibujar el mecanizado rectangular ubicado en el plano lateral derecho. **Fuente:** elaboración propia.

i) Repasar la proyección isométrica obtenida con líneas continuas gruesas las aristas visibles y con líneas de segmentos las aristas ocultas.

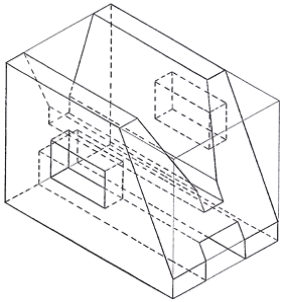

Figura 24. Ejecución de la proyección isométrica obtenida con líneas continuas gruesas las aristas visibles y con líneas de segmentos las aristas ocultas. **Fuente:** elaboración propia.

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j) Obtener la vista superior (VS) proyectando líneas de referencia verticales desde la vista frontal y líneas de referencia a 45° desde la vista lateral izquierda.

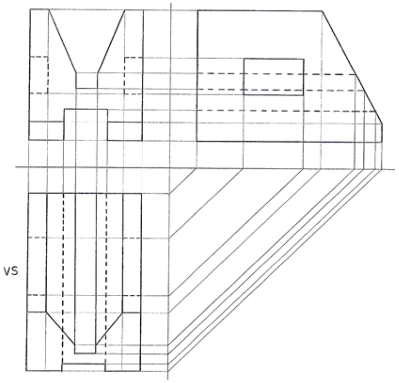

Figura 25. Proceso para obtener la vista superior (VS) proyectando líneas de referencia verticales desde la vista frontal y líneas de referencia a 45° desde la vista lateral izquierda. **Fuente:** elaboración propia.

8. RESULTADOS

El análisis de resultados, conto con la colaboración de 56 estudiantes de la carrera de Ingeniería en Mantenimiento Industrial, ESPOCH, semestre octubre 2019 - febrero 2020. A los cuales se aplicó una prueba diagnóstico al inicio de las clases y una encuesta final en la terminación del período académico, la cual determinó la importancia de la propuesta metodológica para dibujar proyecciones isométricas.

Prueba diagnóstico de la asignatura de dibujo técnico

Nivel de conocimiento	Porcentaje
Bajo (0% - 35%)	46%
Medio (36% - 70%)	36%
Alto (71% -100%)	18%

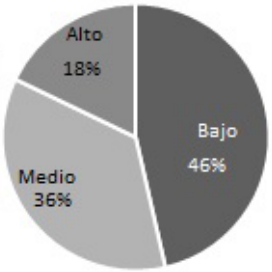

Figura 26. Prueba diagnóstico de conocimientos previos de la asignatura de dibujo técnico. **Fuente:** elaboración propia de acuerdo a la prueba diagnóstico de conocimientos previos de la asignatura de dibujo técnico de la Carrera de Ingeniería en Mantenimiento Industrial, ESPOCH, 2020.

http://doi.org/10.17993/3ctecno/2020.v9n2e34.17-47

En la encuesta final, se obtuvo resultados mayoritariamente favorables. A continuación se describe y visualiza los cuestionamientos más importantes.

El proceso empleado para la representación de proyecciones isométricas es claro, secuencial y facilita la ejecución del dibujo.

Tabla 1. El proceso empleado para la representación de proyecciones isométricas es claro, secuencial y facilita la ejecución del dibujo.

Opciones	Frecuencia	Porcentaje
Total desacuerdo	3	5%
Bastante desacuerdo	3	5%
Ni acuerdo ni desacuerdo	8	14%
Bastante de acuerdo	23	41%
Total de acuerdo	19	34%
Total	**56**	**100%**
Nota: Resultados de la encuesta diagnóstico a la Carrera de Ingeniería en Mantenimiento Industrial, ESPOCH.		

Figura 27. Resultados del proceso empleado. **Fuente:** elaboración propia de acuerdo a los datos de una encuesta diagnóstico a la Carrera de Ingeniería en Mantenimiento Industrial, ESPOCH, 2020.

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El proceso posee varios pasos para el desarrollo del dibujo.

Tabla 2. El proceso posee varios pasos para el desarrollo del dibujo.

Opciones	Frecuencia	Porcentaje
Total desacuerdo	4	7%
Bastante desacuerdo	2	4%
Ni acuerdo ni desacuerdo	6	11%
Bastante de acuerdo	24	43%
Total de acuerdo	20	36%
Total	**56**	**100%**
Nota: Resultados de la encuesta diagnóstico a la Carrera de Ingeniería en Mantenimiento Industrial, ESPOCH.		

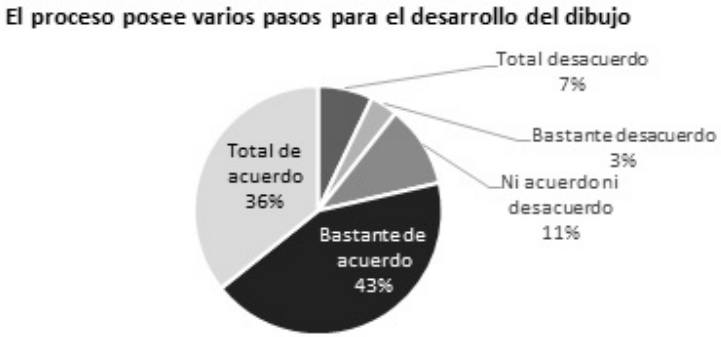

Figura 28. Resultados de los pasos para el desarrollo del dibujo. **Fuente:** elaboración propia de acuerdo a los datos de una encuesta diagnóstico a la Carrera de Ingeniería en Mantenimiento Industrial, ESPOCH, 2020.

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El proceso empleado disminuye el tiempo de ejecución de sus dibujos.

Tabla 3. El proceso empleado disminuye el tiempo de ejecución de sus dibujos.

Opciones	Frecuencia	Porcentaje
Total desacuerdo	7	13%
Bastante desacuerdo	5	9%
Ni acuerdo ni desacuerdo	14	25%
Bastante de acuerdo	21	38%
Total de acuerdo	9	16%
Total	**56**	**100%**
Nota: Resultados de la encuesta diagnóstico a la Carrera de Ingeniería en Mantenimiento Industrial, ESPOCH.		

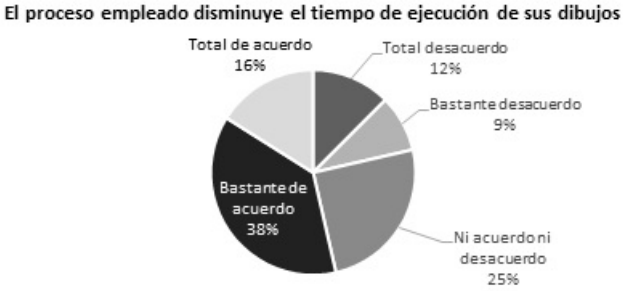

Figura 29. Resultados del tiempo de ejecución de sus dibujos. **Fuente:** elaboración propia de acuerdo a los datos de una encuesta diagnóstico a la Carrera de Ingeniería en Mantenimiento Industrial, ESPOCH, 2020.

En la Figura 30, se tiene un registro histórico de estudiantes (desde el año 2010 hasta el año 2019), que han cursado la asignatura de *dibujo técnico* en la *Carrera de Ingeniería de Mantenimiento, Facultad de Mecánica de la Escuela Superior Politécnica de Chimborazo*.

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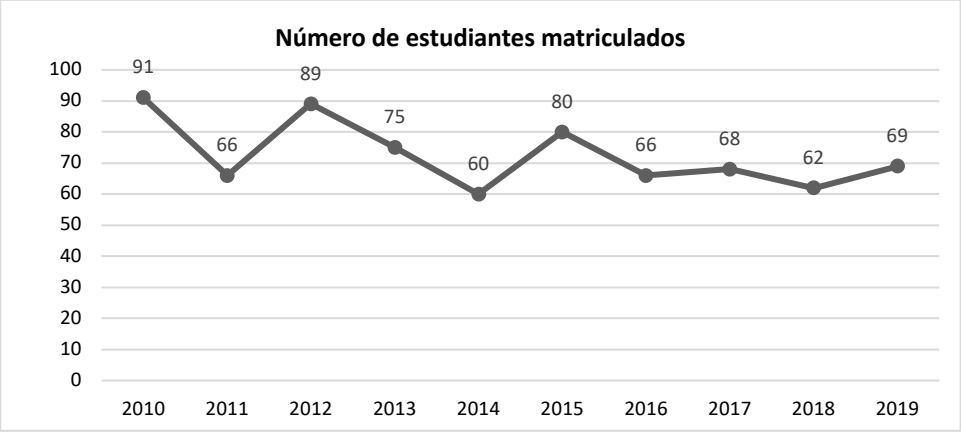

Figura 30. Número de estudiantes matriculados en la asignatura de dibujo técnico Carrera de Ingeniería en Mantenimiento Industrial ESPOCH. **Fuente:** elaboración propia con datos extraídos de la Secretaría de la Carrera de Ingeniería en Mantenimiento Industrial, ESPOCH.

La Tabla 4, muestra los totales de estudiantes aprobados y reprobados, en número y porcentaje. En la Figura 31, ilustra el significativo porcentaje de *estudiantes aprobados,* que se *han beneficiado de la propuesta metodológica para dibujar proyecciones isométricas*.

Tabla 4. Total de estudiantes matriculados año 2010 -2019.

Estudiantes	Número	Porcentajes
Aprobados	638	88%
Reprobados	88	12%
Total	**726**	**100%**
Promedio de estudiantes por año	**72,6**	
Nota: Tomado de la Secretaría de la Carrera de Ingeniería en Mantenimiento Industrial, ESPOCH.		

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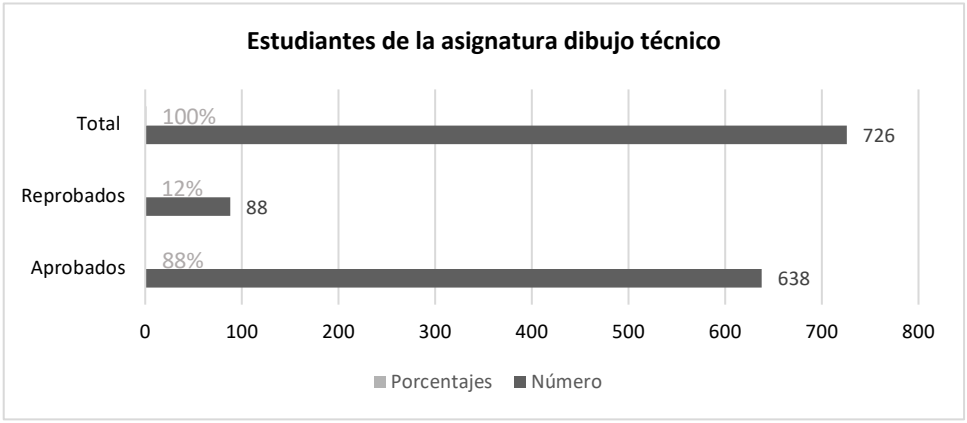

Figura 31. Estudiantes aprobados y reprobados de la asignatura de dibujo técnico Carrera de Ingeniería en Mantenimiento Industrial ESPOCH. **Fuente:** elaboración propia con datos extraídos de la Secretaría de la Carrera de Ingeniería en Mantenimiento Industrial, ESPOCH.

En la Figura 32, se tiene un registro histórico de estudiantes (desde el año 2010 hasta el año 2019), que han cursado la asignatura de *dibujo técnico* en otra carrera tecnológica.

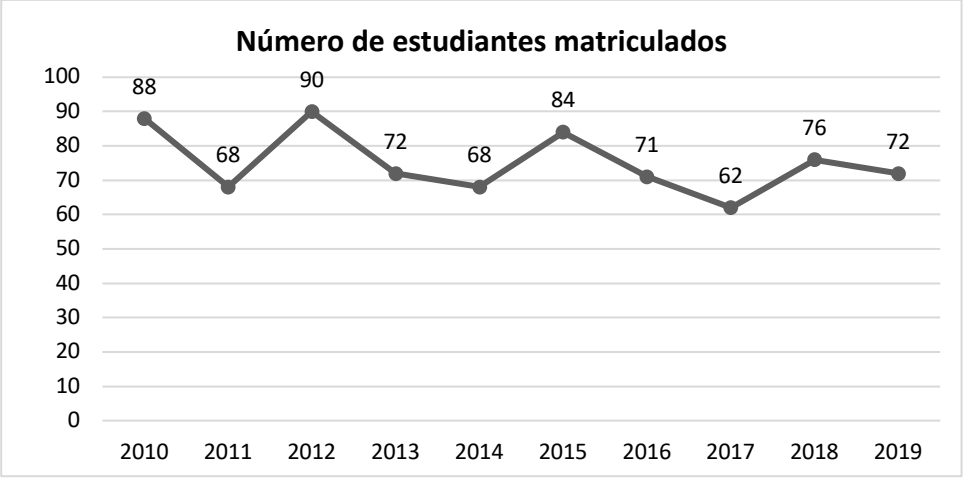

Figura 32. Número de estudiantes matriculados en la asignatura de dibujo técnico otra carrera tecnológica. **Fuente:** elaboración propia.

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La Tabla 5, muestra los totales de estudiantes aprobados y reprobados, en número y porcentaje. En la Figura 33, ilustra el porcentaje de *estudiantes aprobados y reprobados* de otra carrera, que *no aplican la propuesta metodológica*.

Tabla 5. Total de estudiantes matriculados año 2010 -2019.

Estudiantes	Número	Porcentajes
Aprobados	390	52%
Reprobados	361	48%
Total	**751**	**100%**
Promedio de estudiantes por año	**75,1**	
Nota: El porcentaje de estudiantes aprobados alcanza el 52%.		

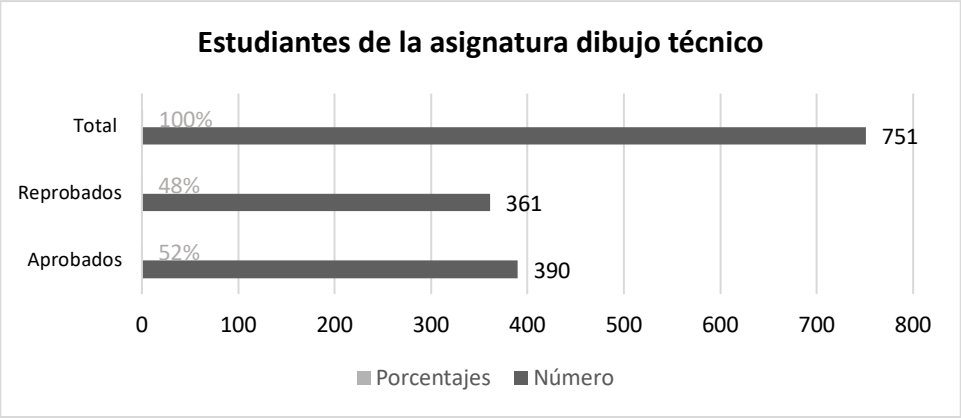

Figura 33. Estudiantes aprobados y reprobados de la asignatura de dibujo técnico en otra carrera tecnológica. **Fuente:** elaboración propia.

9. DISCUSIÓN

La información obtenida mediante la encuesta e interrogantes planteadas refleja lo siguiente:

- La *prueba diagnóstico de conocimientos previos* de la asignatura *dibujo técnico*, muestra que un ***46 %*** (calificaciones de 0 % al 35 %) ***de estudiantes tiene un nivel bajo de conocimientos***; ***36 %***

http://doi.org/10.17993/3ctecno/2020.v9n2e34.17-47

(calificaciones de 36 % al 70 %) ***de estudiantes tiene un nivel medio de conocimientos*** y un ***18 %*** (calificaciones de 71 % al 100 %) ***de estudiantes tiene un nivel alto de conocimientos de la asignatura***.

- El *proceso metodológico para la representación de proyecciones isométricas, estima ser claro, secuencial y de fácil ejecución*. Esto lo confirma el ***75 %*** (41 % bastante de acuerdo y 34 % total de acuerdo) ***de los estudiantes encuestados***, resultados observados en la Tabla 1 y Figura 27.
- El *dibujo isométrico en su construcción desarrolla varios pasos*. Un ***79 %*** (43 % bastante de acuerdo y 36 % total de acuerdo) ***de los estudiantes encuestados*** valida el criterio, resultados observados en la Tabla 2 y Figura 28.
- El *tiempo de ejecución empleado en el proceso de elaboración de dibujos, es menor al observado en otros procesos.* Esto lo consideran un ***54 %*** (38 % bastante de acuerdo y 16 % total de acuerdo) ***de los estudiantes encuestados***; esta apreciación se observa en la Tabla 3 y Figura 29, se justifica porque todo proceso de construcción de objetos o piezas mecánicas conlleva distintas dificultades y no todas las personas tienen el mismo enfoque espacial para la construcción de una perspectiva.
- La carrera de ingeniería de mantenimiento industrial, a lo largo de los últimos 10 años, registra un total aproximado de 726 estudiantes matriculados (Figura 30), un promedio aproximado de 73 estudiantes por año (Tabla 4), en la asignatura de dibujo técnico. Los datos en cuestión han permitido tener valores reales de estudiantes aprobados y reprobados. El índice de ***estudiantes aprobados es del 88 %*** (Figura 31), *evidencia que el proceso metodológico propuesto para dibujar las proyecciones isométricas* ***beneficia el desempeño académico de los estudiantes*** que cursan la asignatura de dibujo técnico.
- En otras carreras tecnológicas, a lo largo de los últimos 10 años, registra un total aproximado de 751 estudiantes matriculados (Figura 32), un promedio aproximado de 75 estudiantes por año (Tabla 5), en la asignatura de dibujo técnico. Los datos en cuestión han permitido tener valores

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reales de estudiantes aprobados y reprobados. El índice de ***estudiantes aprobados es del 52 %*** (Figura 33), *evidencia que el proceso metodológico utilizado para dibujar las proyecciones isométricas* ***no beneficia el desempeño académico de los estudiantes*** que cursan la asignatura de dibujo técnico.

- Los resultados obtenidos, muestran el ***grado de satisfacción de los estudiantes***; y *animan a que la propuesta metodológica para dibujar proyecciones isométricas pueda ir mejorando continuamente en favor de los educandos*.

10. CONCLUSIONES

Los estudiantes que ingresan a primer nivel de carrera, tienen bajo nivel de conocimientos y la asignatura *dibujo técnico*, no elude esta problemática. Los inconvenientes, se atribuyen a los componentes curriculares de las Unidades Educativas; así como una serie de cambios que se dieron en lo estructural y funcional del sistema educativo del país en los últimos años. La manera *sencilla, rápida y concreta del proceso metodológico para dibujar proyecciones* isométricas, ha nivelado los conocimientos y el grado de satisfacción en el aprendizaje de los estudiantes.

La metodología propuesta para dibujar proyecciones isométricas, agrega *la emulación con un modelo a escala del paralelepípedo*, que permite su *exploración espacial*; se quitan las partes sobrantes y se obtiene la perspectiva. Esta manipulación fortalece la *inteligencia espacial* del estudiante y facilita la propuesta metodológica en la construcción gráfica, siendo más ágil, por iniciar el proceso desde el *paralelepípedo* y luego llegar a la perspectiva. La diferencia con otras formas de representar perspectivas, es la secuencia de trazos redundantes.

La metodología permite que el proceso se facilite, debido a que cuando se forma la isometría, del objeto se vayan retirando las partes sobrantes, siendo más sencillo obtener la perspectiva.

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El dibujo técnico es un componente esencial en la formación profesional, puesto que ayuda a los estudiantes a tener un mejor *análisis y enfoque espacial* de objetos de investigación o estudio.

Existe una diferencia del 36 % en el índice *de aprobación*, entre los estudiantes de la carrera de Ingeniería en Mantenimiento Industrial y otras carreras tecnológicas; resultado significativo, que avala el proceso metodológico para dibujar proyecciones isométricas.

El proceso metodológico utilizado para dibujar proyecciones isométricas ha sido un *cúmulo de experiencias* desarrolladas en los diferentes cursos de la carrera de Ingeniería en Mantenimiento Industrial de la Escuela Superior Politécnica del Chimborazo.

La práctica del dibujo técnico estimula y fortalece la inteligencia espacial y de visión (enfoque o perspectiva), con transversalidad al conocimiento de ingenierías y ciencias aplicadas.

El aprendizaje de proyecciones isométricas, es una escenario que abre un sin número de posibilidades y se relaciona con varias asignaturas de la malla curricular, principalmente álgebra lineal, dibujo asistido por computador (CAD) y física vectorial; ciencias que fortalecen las competencias profesionales.

La metodología de aprendizaje para dibujar proyecciones isométricas, es un proceso que compromete *responsabilidad y disciplina* por parte del estudiante. Esto factores permitirá alcanzar los resultados programados.

La *precisión y autonomía* son otros de los factores que distingue al dibujo técnico; la *precisión*, se genera al realizar movimientos fijos (motricidad fina); y la *autonomía* por desarrollo de actividades propias, que inciden en una mayor actividad cerebral.

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ALGORITHMIC EFFICIENCY INDICATOR FOR THE OPTIMIZATION OF ROUTE SIZE

Ciro Rodríguez
National University Mayor de San Marcos. Lima, (Perú).
E-mail: crodriguezro@unmsm.edu.pe ORCID: https://orcid.org/0000-0003-2112-1349

Miguel Sifuentes
National University Mayor de San Marcos. Lima, (Perú).
E-mail: newangel2018@hotmail.com ORCID: https://orcid.org/0000-0002-0178-0059

Freddy Kaseng
National University Federico Villarreal. Lima, (Perú).
E-mail: fkaseng@unfv.edu.pe ORCID: https://orcid.org/0000-0002-2878-9053

Pedro Lezama
National University Federico Villarreal. Lima, (Perú).
E-mail: pedrolezamagonzales@gmail.com ORCID: https://orcid.org/0000-0001-9693-0138

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ABSTRACT

In software development, sometimes experienced programmers have difficulty determining before performing their tests, which algorithm will work best to solve a particular problem, and the answer to the question will always depend on the type of problem and nature of the data to be used, in this situation, it is necessary to identify which indicator is the most useful for a specific type of problem and especially in route optimization. Currently, there are techniques and algorithms used in Artificial Intelligence, which, however, cannot display their potential without a well-defined data set. The paper seeks to explain and propose an algorithm selection indicator to build a consistent data set, given the lack of availability of data that allows the best route size decision to be made.

KEYWORDS

Software development, Algorithm efficiency, Indicator, Route size.

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1. INTRODUCTION

The type of problem and nature of the data to be used is necessary to identify which indicator is the most useful for a specific kind of problem and especially in route optimization. As Microsoft (n.d.) explain are several ways to make the selection. In Machine Learning, cross-validation is one of the most commonly used. It was finding the best set of parameters like space, cross-validation, metric, accuracy. It is important to formulate, evaluate, and compare the values of the parameters, after the evaluation and comparison, it is possible to choose the best alternative as shown in Figure 1.

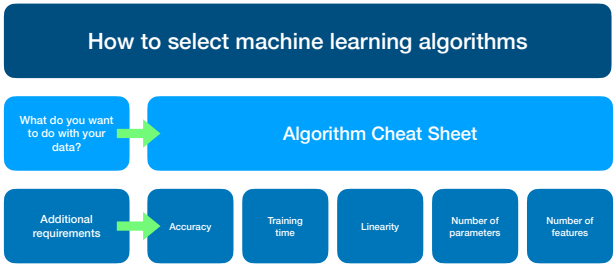

Figure 1. What are the requirements of your data science scenario? **Source:** (Microsoft, n.d.).

In the search for the most appropriate algorithm to implement in the route optimizer we will have three candidates for the best indicator: the algorithmic efficiency, the size (sum of weights of the edges) of the route obtained and the following relation, derived from the previous indicators. The witness search is expensive (Dibbelt, 2016), and therefore the witness search is usually aborted after a certain number of steps. If no witness was found, is assumed that none exists and add a shortcut, as shown in Figure 2.

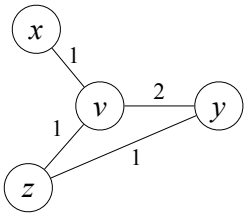

Figure 2. Contraction of v. **Source:** (Dibbelt, 2016).

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Figure 2 sows pair (x, y); if is considered first, a shortcut {x, y} with weight 3 is inserted. If the pair (x, z) is considered first, an edge {x, z} with weight 2 is inserted. This shortcut is part of a witness $x \rightarrow z \rightarrow y$ for the pair x, y. The shortcut {x, y} is thus not added if the pair x, z is considered first.

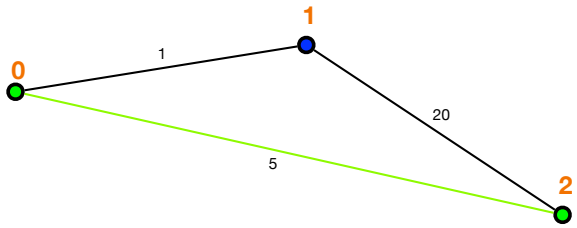

Figure 3. The minimum path from node 0 to node 2.

Figure 3 shows the result of using the Dijkstra algorithm in the graph, which presents the minimum sum of edges to get from node 0 to node 2, however, it is not the most efficient of the algorithms presented in this research paper.

2. CONCEPTUAL FRAMEWORK

2.1. ARTIFICIAL INTELLIGENCE AND DATASETS

Forecasts say that in the next decade, there will be approximately more than 150,000 million sensors connected to the network (more than 20 times the Earth's population). These data help AI devices to think as we think, accelerating their learning curve and automation of data analysis with all the processed information; considering as much data the system receives, more learning and accuracy becomes (PowerData, 2017).

Today, artificial intelligence can learn without human support. New cases are known daily, such as the example of a Google DeepMind algorithm, which recently learned on its own how to win 49 Atari games, without the need for any interaction from anyone.

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In the past, AI growth was minimal for two main reasons: limited data sets that used representative data samples, instead of using real-time data, and inability to analyze massive amounts of data in seconds (PowerData, 2017).

2.2. THE LACK OF DATASETS

The ability to manage large volumes and data sources is enabling the capabilities of AI (Artificial Intelligence) and machine learning . However, some organizations cannot yet exploit AI capabilities for various reasons:

- The lack of data availability.
- Limited sample sizes negatively affect their abilities.
- The lack of appropriate technologies to analyze massive data in milliseconds.

2.3. ALGORITHMICS

Knowing what problem is going to be solved is only half the job. In dealing with problems, they generally do not have a precise and straightforward specification of them. Problems such as creating a gourmet-worthy recipe or preserving world peace may be impossible to formulate in a way that supports a computer solution; Although it is believed that the problem can be solved on a computer, it is usual that the distance between several of its parameters is at least considerable (Aho, Hopcroft, & Jefrey, 1988).

Often only through experimentation, is it possible to find reasonable values for these parameters. If it is possible to express certain aspects of a problem with a formal model, it is generally beneficial to do so, because once the problem is formalized, solutions can be sought based on a precise model and determine if there is already a program that solves that problem. The algorithm has a remarkable importance in the development of software when considering various algorithms for a given problem.

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The algorithm is defined as the study of algorithms, which are a sequence of ordered and finite steps, each of which has a precise meaning and can be executed with a limited amount of effort in a finite time to solve a problem. By steps means the set of actions or operations that are performed on certain objects. For the solution of a problem, a collection of algorithms is taken into account, depending on the particular characteristics of the problem (selected algorithm) ("Complejidad algorítmica", n.d.).

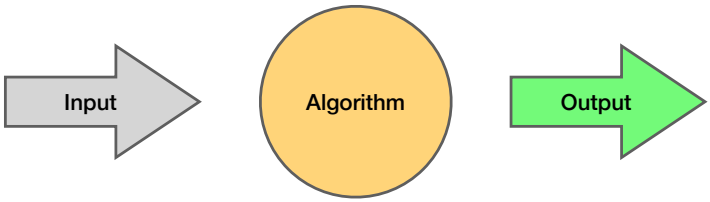

Figure 4. Determinism as a feature of the algorithms.

An algorithm as Figure 4 must have the following characteristics:

- Accuracy: An algorithm must be expressed without ambiguity.
- Determinism: Every algorithm must respond in the same way before the same conditions
- Finite: The description of an algorithm must be limited.

An algorithm must also achieve the following objectives, which are often contradicted:

- Simple: Make it easy to understand, code, and debug.
- Efficient: Efficient use of computer resources in time, space (memory) and processor, so that it runs as quickly as possible.

It is usually difficult to find an algorithm that meets both, so a compromise must be reached that best fits the requirements of the problem ("Complejidad algorítmica", n.d.).

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The algorithm allows evaluating the results of different external factors on the available algorithms in such a way that it will enable to select the one that best suits the particular conditions. It allows indicating how to design a new algorithm for a specific task.

It has been said that each instruction in an algorithm must have a "precise meaning" and must be executable with a "finite amount of effort"; But what is clear to one person may not be clear to another, and it is often challenging to demonstrate rigorously that an instruction can be done in a finite time. Sometimes, it is difficult to show the sequence of instructions ends with some input, even if the meaning of each instruction is very clear. However, an agreement is usually reached as to whether or not a sequence of instructions constitutes an algorithm (Aho *et al.*, 1988).

2.4. ALGORITHMIC COMPLEXITY

Algorithmic complexity represents the number of resources (temporary) that an algorithm needs to solve a problem and therefore allows to determine the efficiency of the said algorithm (Universidad de Valladolid Campus de Segovia). It is not referred to the difficulty in designing algorithms. The criteria that will be used to assess algorithmic complexity do not provide absolute measures but measures relative to the size of the problem. What is relevant, at first, is the measure of temporal complexity in terms of the input data.

When a problem is resolved, there is often a need to choose between several algorithms. How should you choose? Two objectives are often contradicted:

1. That the algorithm is easy to understand, code, and debug.
2. That the algorithm efficiently uses the computer resources and, in particular, that it be executed as quickly as possible ("Complejidad algorítmica", n.d.).

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When writing a program to be used once or a few times, the first objective is the most important. In this case, it is very likely that the cost of programming time dramatically exceeds the value of program execution, so that the price to be optimized is that of writing the program (Aho *et al.*, 1988).

On the other hand, when there is a problem whose solution is going to be used many times, the cost of executing the program can significantly exceed that of writing, especially if large entries are given in most executions. Then, it is more advantageous, from the economic point of view, to perform a complex algorithm provided that the execution time of the resulting program is significantly shorter than that of a more obvious program. And even in situations like that, it may be convenient first to implement a simple algorithm to determine the real benefit that would be obtained by writing a more complicated program. In the construction of a complex system, it is often desirable to implement a simple prototype in which simulations and measurements can be made before engaging in the final design. This concludes that a programmer must not only be aware of ways to get a program to run quickly but also know when to apply these techniques and when to ignore them (Aho *et al.*, 1988).

An algorithm will be more efficient compared to another, provided it consumes fewer resources, such as the time and memory space needed to execute it.

The evaluation of the algorithms for efficiency will be taken into account:

- The growth rate in time. Runtime: It has to do with the time it takes for a program to run (processing time).
- The growth rate in space.

Memory space: Study the amount of space that is necessary for operations during program execution (storage and processing space).

The efficiency of an algorithm can be quantified with the following complexity measures:

- Temporary Complexity or Execution Time: Computation time necessary to execute a program.

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- Spatial Complexity: Memory that an application uses for its execution. The memory efficiency of an algorithm indicates the amount of space required to execute the algorithm; that is to say, the area in memory that occupies all the own variables to the algorithm. To calculate the static memory of an algorithm, the memory occupied by the variables declared in the algorithm is added. In the case of dynamic memory, the calculation is not so simple since this depends on each execution of the algorithm ("Complejidad algorítmica", n.d.).

2.5. GRAPHS

A graph G is a set of points in space, some of which are linked by lines (Menendez, 1998), formally, a graph G consists of two finite sets N, and A. N is the set of elements of the graph, also called vertices or nodes. A is the set of arcs, which are the connections that are responsible for relating the nodes to form the graph. Arcs are also called edges or lines. Nodes are often used to represent objects and arcs to represent the relationship between them. For example, nodes can represent cities and arches the existence of roads that communicate them. Each arc is defined by a pair of elements n1, n2 ∈ N to which it connects. Although the parts are usually different, we will allow them to be the same node (n1 = n2).

Trees have been considered as a generalization of the list concept because they allow an element to have more than one successor. Graphs appear as an extension of the tree concept since, in this new type of structure, each element can have, in addition to more than one successor, several predecessor elements. This property makes graphs the most appropriate structures to represent situations where the relationship between the elements is completely arbitrary, such as road maps, telecommunications systems, printed circuits, or computer networks. Although there are more complex structures than graphs, we will not see them in this course. Graphs can be classified into different types depending on how the relationship between the elements is defined: we can find directed or non-directed and labeled or unlabeled graphs. We will use the tags when we work with the Dijkstra and Prim algorithms.

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The graph is not directed if the arcs are formed by pairs of unordered nodes, not pointed; A graph is directed, also called a digraph, if the pairs of nodes that form the arcs are ordered; they are represented with an arrow indicating the direction of the relation u → v, these being a pair of nodes (Joyanes & Zahonero, 2008).

In some instances it is necessary to associate information to the arcs of the graph. This can be achieved through a label containing any useful information related to the arc, such as the name, weight, cost or a value of any given data type. In this case we talk about labeled graphs. This label could mean the time it takes for the flight between two cities or indicates what the input and output parameters are in the call to a subprogram. An unlabeled graph is a graph where the arcs have no labels. In the case of the graph that represents the traffic direction, the arcs can be labeled.

3. METHODOLOGY

3.1. SHORTEST ROUTE

Researchers consider the Shortest Route Problem as a central problem within the area of networks due to the variety of practical applications, the existence of efficient solution methods, and the use of subroutines in the search for the right solution in complex problems. However, in the subjects in which these kinds of problems are addressed, they are usually presented in a simplified and unclear way, that is, the importance of studying these types of problems is often not recognized or stressed. Theoretical aspect and due to the great diversity of applications (Obregon, 2005), so this problem can be solved by, among others, the Dijkstra and Prim algorithms.

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3.2. MINIMUM PATH ALGORITHMS

A. Naive Algorithm

The naive algorithm for directed graphs has reasonably good efficiency; however, it cannot see beyond the node following the current one of the network.

It is an algorithm that starts from a source node and goes exploring the paths to the rest of the nodes. The following pseudocode shows its operation, using the priority queue as an auxiliary data structure (Jungnickel, 1999).

```
Naive (graph G, sourceN s)
  for u ∈ V[G] do
    distance[u] = INFINITY
    parentNode[u] = NULL
    seen[u] = false
  distance[s] = 0
  insert (queue, (s, distancie[s]))
  while ! isEmpty (queue) do
    u = extractMínimum (queue)
    seen[u] = true
    insert (queue, (v, distance[v]))
```

B. Dijkstra's algorithm

The Dijkstra algorithm, also called the minimum path algorithm, is a model that is classified within the search algorithms. Its objective is to determine the shortest route, from the origin node to any node in the network. Its methodology is based on iterations, so that, in practice, its development becomes difficult as the size of the network increases, leaving it at a clear disadvantage, compared to optimization methods based on mathematical programming (Jungnickel, 1999).

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```
Dijkstra (graph G, sourceNode s)
  for u ∈ V[G] do
    distance[u] = INFINITY
    parent_node[u] = NULL
    seen[u] = false
  distance[s] = 0
  insert (queue, (s, distance[s]))
  while ! istaEmpty (queue) do
    u = extract_mínimum(queue)
    sen[u] = true
    for each v ∈ adyjancency[u] do
        if ¡ seen[v]and distance[v] > distance[u] + length (u, v) do
        distance[v] = distance[u] + length (u, v)
        parent_node[v] = u
        insert (queue, (v, distance[v]))
```

C. Prim Algorithm

Prim's algorithm, given a related graph, not directed and weighted, finds a minimal expansion tree. That is, it can find a subset of the edges that form a tree that includes all the vertices of the initial graph, where the total weight of the edges of the tree is the minimum possible (Jungnickel, 1999).

Given a set of nodes N, a set of edges E, and a cost function p, our network (graph) G is defined. To apply the Prim algorithm and solve the problem of the minimum expansion tree, all costs associated with the edges mustn't be negative. It is an algorithm that continuously increases the size of a tree, starting with an initial node, chosen at random, to which nodes are added whose distance successively to the previous ones is minimal. In each step, we will consider the edges that contain nodes that already belong to the tree. The minimum cost expansion tree is entirely constructed when there are no more nodes left to add (Jungnickel, 1999).

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```
Prim (graph G (N, E, p))
  for every u in N do
    distance[u] = INFINITY
    parentNode[u] = NULL
    Insert (queue, < u, distance[u] >)
  distance[u] = 0
  while ! isEmpty (queue) do
    u = extractMínimum (queue)
    for each v adjacent to 'u' do
    if ((v ∈ queue) && (distance[v] > p (u, v)) then
      parentNode[v] = u
      distance[v] = p(u, v)
                              Update (queue, < v, distance[v] >) [10]
```

3.3. ROUTE SIZE INDICATOR

The size of the route is defined as the sum of the weights of all the edges of the graph that the algorithm has traveled.

For the graph in above Figure 2:

A. Routes that each algorithm has followed

- Naive Algorithm: $0 \rightarrow 1 \rightarrow 2$
- Dijkstra algorithm: $0 \rightarrow 2$
- Prim Algorithm: $0 \rightarrow 2$

B. Route size obtained with each algorithm

- Naive Algorithm: $1 + 20 = 21$
- Dijkstra Algorithm: 5
- Prim Algorithm: 5

Both the Dijkstra and Prim algorithms have obtained an optimal route size, with a value of 5.

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3.4. ALGORITHMIC EFFICIENCY COMPLEXITY INDICATOR

Big O notation is used to asymptotically limit the growth of a runtime that is within constant factors above and below. Sometimes we want to limit only above. It is convenient to have a form of asymptotic notation that means "the execution time grows at most by this much, but it can grow more slowly." We use the "big O" notation just for these occasions. If execution time is O (f (n)), then for a sufficiently large n, the execution time is at most k * f (n) for some constant k (Magzhan & Jani, 2013).

A. The efficiency of the naive algorithm (approximate)

   $0(log|V|)=(|log|V|)$

B. Dijkstra algorithm efficiency

   $0((|A|+|V|)log|V|)=0(|A|log|V|)$

C. Prim algorithm efficiency

   $0(n^2)$

To observe results quantitatively, the table 1 will show the data obtained from a previous study (Magzhan & Jani, 2013), regarding Dijkstra's algorithm and others; subsequently, the values will be extrapolated to the cases of the naive algorithm, of complexity O (| log | V |), and Prim, of complexity O (n^2), using the theoretical complexity of each of these algorithms.

Table 1. Results of performance time of the algorithms for different graphs (ms).

Nodes	Edges	Maximum edge cost	Dijkstra with d-heap O ($Alog_dN$) (ms)	Prim O (n^2) (ms)	Naive O (|log|V|) (ms)
100	100	10	0.14	0.12	0.0014
500	100	10	3.77	3.23	0.0377
1000	100	10	11.02	10.34	0.0110
3000	100	10	100.00	90.00	0.0100

Note: It is adapted from Magzhan and Jani (2013), the development of a library for minimum roads, applied to a data protection problem.

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Because the Naive algorithm does not consider the comparison to obtain the shortest distance with the adjacent nodes, unlike the others, it is the most efficient with a relative efficiency of O (| log | V |).

Initially, it was enough to analyze one of the indicators to choose the algorithm indicated for the minimum route problem, then there was an alleged contradiction between the results of algorithmic efficiency and route size, however, through the problem of backpack it was discovered that a relationship between these indicators could be established and we can also accommodate it to different scenarios through the parameters p and q.

4. INDICATOR OF ALGORITHMIC EFFICIENCY RATIO IN ROUTE SIZE OPTIMIZATION

When solving the problem of the selection of route optimizing algorithms, if the algorithmic efficiency indicator is the guide, we will obtain that the recommended algorithm is naive, but this algorithm is, in turn, one of the longest routes. Despite being the most efficient, it is not the right algorithm to solve these types of problems. And by following the criterion of the size of the route, we are not certain that we have the optimal algorithmic efficiency as Formula (1).

$$\frac{1}{(algorithmic\ efficiency)^p * (route\ size)^q} \qquad (1)$$

In the Knapsack problem, we saw how the apparent contradiction of indicators was solved; similarly, for the problem of selecting algorithms in route optimizers, it is proposed to establish a relationship between algorithmic efficiency and route size, thus generating a new criterion.

A third indicator is proposed through the relationship of the previous two (1), we have both indicators in the denominator because it seeks to minimize the size of the route and seeks to minimize complexity thus optimizing algorithmic efficiency. The parameters p and q serve us to graduate the level of importance that we will give to each indicator, for example, for a brute force algorithm it is advisable to assign at least

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a value of 2 to the parameter p and for our route optimizer the value of the parameter q, not It should be less than 3 due to the great importance of finding the minimum route in emergencies.

What this new indicator expresses to us is the relationship between efficiency and size of the route; however, it forces to decide to assign a level of importance to the two previous indicators.

Evaluating which algorithm to choose for the graph with the new indicator:

A. With p = 1 y q = 2, is possible get:

- Naive Algorithm: $1/(0(\log|3|) * 21^{2})=0.00475261513$
- Dijkstra Algorithm: $1/(0(|3|\log|3|) *5^{2})=0.02794537699$
- Prim Algorithm: $1/(0(3^{2}) * 5^{2})=0.00444444444$

The one that gets the highest score in the indicator is the Dijkstra algorithm, which is why it should be implemented in this specific graph and with these parameters.

B. With p = 5 y q = 1, is possible get:

- Naive Algorithm: $1/(0((\log|3|)^{5}) * 21)=1.92591398109$
- Dijkstra Algorithm: $1/(0/(|3|\log|3|)^{5} * 5)=0.03328740214341$
- Prim Algorithm: $1/(0((3^{2})^{5}) * 5)=0.00000338701$

The one that obtains the highest score in the indicator is the naive algorithm, due to the enormous priority given to efficiency (p = 5), recommended in embedded equipment with minimal processing capacity, it should be implemented in this specific graph and with these parameters.

C. With p = 1 y q = 4 (recommended for route optimizer in ambulances because $q \geq 3$), we get:

- Naive Algorithm: $1/(0(\log|3|) * 21^{4})=0.0000107769$
- Dijkstra Algorithm: $1/(0(|3|\log|3|) * 5^{4})=0.00111781507$

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- Prim Algorithm: $1/(0(3^2) * 5^4)=0.00017777777$

The one that gets the highest score in the indicator is the Dijkstra algorithm, followed by the Prim algorithm, so it should be implemented in this specific graph and with these parameters. These values of parameters p and q are recommended to optimize ambulance routes in an emergency.

It is essential to understand the power of the p and q parameters in the results since they affect the algorithmic efficiency and the size of the route in an exponential way.

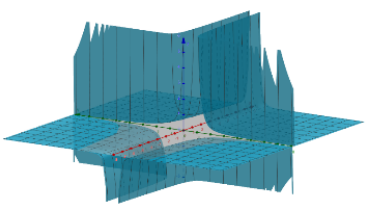

Figure 5. p =1; q = 2.

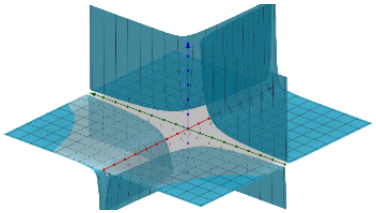

Figure 6. p =5 ; q = 1.

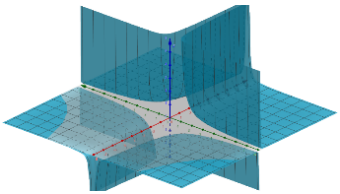

Figure 7. p =1 ; q = 4.

Figures 5, 6, and 7 show the behavior of the indicator with the different parameters assumed by p and q the X-axis, where the red axis represents the algorithmic efficiency and the green Y-axis the size of the route.

5. STORAGE OF RESULTS IN A DATASET

It is important to store the p and q values, preferably in tuples, for later analysis and to relates them to the results of the new indicator obtained and the order of the algorithms obtained to form a consistent dataset and subsequently worked with AI. With the use of the data sets built, various problems can be solved, such as the minimum path and data science through machine learning.

Machine learning is a technique to implement artificial intelligence (Mediaroom Solutions, 2019; Bustamante, Rodriguez, & Esenarro, 2019), without programming millions of rules and decision trees. Its objective is to allow machines to learn automatically and increasingly autonomously. It consists of

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learning algorithms that can be of 4 types: supervised, unsupervised, semi-supervised, and reinforced. A classic example is music recommendation systems based on preferences and songs that the user likes.

6. DISCUSSION ABOUT INDICATORS AND THE KNAPSACK PROBLEM

Apparent there are a contradiction of the indicators algorithmic efficiency and route size, differents criteria recommend different algorithms, which seems to show an apparent contradiction, a similar situation is presented in the Fractional Knapsack Problem where:

Given n elements e_1, e_2, ..., in with weights p_1, p_2, ..., p_n and benefits b_1, b_2, ..., b_n, , and given a Knapsack capable of holding elements up to a maximum of weight M ((Knapsack capacity), that is, we want to find the proportions of the n elements x_1, x_2, ..., $x_n (0 \leq x_i \leq 1)$ that we have to introduce in the Knapsack so that the sum of the benefits of the chosen elements be maximum. That is, we must find values (x_1, x_2, ..., x_n) so that the benefit is maximized, taking into account that the sum of weights cannot exceed M (the maximum capacity of the Knapsack) (Joyanes & Zahonero, 2008).

At the moment we have two options to achieve our goal, the first one would be to order our descending elements according to the benefit and select them when doing this we would be facing the problem in which we have an item with a great advantage, but with enormous weight.

As a second solution proposal, we have the order of ascending the elements and selecting them; however, the criterion does not work properly when finding an element with low weight, but with a small benefit.

Failing the criteria of maximum benefit and minimum weight gives the appearance that both requirements are in contradiction; however, this is not so because there is the alternative of expressing the third indicator through the relationship of the previous two: b_i/p_i. Here in the numerator, the criteria are to maximize and the denominator to minimize.

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A voracious algorithm that solves the problem orders the elements in a decreasing way concerning their ratio b_i/p_i and adds objects while they fit (Joyanes & Zahonero, 2008). The precondition for this algorithm is the vectors of weights and benefits are sorted in descending order according to the b_i/p_i ratio.

```
Knapsack (real benef, real weight, real cap, real sol)
  For i from 0 to n − 1 do
    sol[i] ← 0.0
  rest ← cap
  i ← 0
  While (i ≤ n − 1) and (weight[i] ≤ resto) do
    sol[i] ← 1
    resto ← resto − weight[i]
    i ← i + 1
  If i < n then
    sol[i] ← resto/weight[i] [12]
```

As we can see, the weight and benefits indicators were not confronted; it was only necessary to express the relationship between them and the connections used as a new indicator.

7. CONCLUSIONS

Initially, it was enough to analyze one of the indicators to choose the algorithm indicated for the minimum route problem, then there was an alleged contradiction between the results of algorithmic efficiency and route size, however, through the of Knapsack problem it was discovered that a relationship between these indicators could be established and we can also accommodate it to different scenarios through the parameters p and q.

In the search to contribute with the fruits of this study to the solution of various graph problems later with the results of the algorithms selected by the indicator (1), we can form consistent data sets that nourish current and future AI techniques.

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NUMERICAL DATA FOR WIND TURBINE MICROSITING INSPIRED BY HUMAN DYNASTIES BY USE OF THE DYNASTIC OPTIMIZATION ALGORITHM (DOA)

Shafiq-ur-Rehman Massan
QEC and Coordination
Mohammad Ali Jinnah University, Karachi and
Shaheed Zulfikar Ali Bhutto Institute of Science and Technology, Karachi, (Pakistan).
E-mail: srmassan@hotmail.com ORCID: https://orcid.org/0000-0001-6548-6513

Asim Imdad Wagan
Department of Engineering
Mohammad Ali Jinnah University, Karachi, (Pakistan).
E-mail: aiwagan@gmail.com ORCID: https://orcid.org/0000-0001-9765-5385

Muhammad Mujtaba Shaikh
Department of Basic Sciences and Related Studies
Mehran University of Engineering and Technology, Jamshoro, (Pakistan).
E-mail: mujtaba.shaikh@faculty.muet.edu.pk ORCID: https://orcid.org/0000-0002-1471-822X

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ABSTRACT

This work presents the newly formulated Dynastic Optimization Algorithm, DOA as applied to the wind turbine micrositing problem. The data is acquired by the use of the standard MATLAB software at a wind speed of 12 m/s. The values of the efficiency of the algorithm, cost per installation of per unit turbine, and total dissipated power at each number of turbines installed are discussed.

This algorithm is applied to two test functions and the results are described therein. It has been well-demonstrated that the proposed DOA exhibits superior performance over GA and DEA for test functions by hitting the minima very often and with higher precision. On the other hand DOA performance on WTM problem is also encouraging.

KEYWORDS

Dynastic Optimization Algorithm (DOA), Metaheuristic Algorithms, Genetic Algorithm (GA), Differential Evolution Algorithm (DEA), Wind Turbine Micrositing (WTM).

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1. INTRODUCTION

This work is inspired by the works of Grady, Hussaini, and Abdullah (2005), Mosetti, Poloni, and Diviacco (1994), Emami and Nougreh (2010) and Marmidis, Lazarou, and Pyrgioti (2008).

The data in this article has been compared with similar results of Mittal (2010), Rajper and Amin (2012) and Massan, Wagan, & Shaikh (2020). The nature-inspired algorithms use the best combination and evolution strategy in a given situation. In this work, a new metaheuristic algorithm is developed by using social behavior in human dynasties. The motivation, conceptual framework, mathematical model, pseudocode and working of the algorithm are described in this paper and the adjoining papers. The proposed dynastic optimization algorithm (DOA, which is the base paper supporting this data. Comparison was also made to similar studies (Massan, Wagan, & Shaikh, 2017; Massan *et al.*, 2015; Massan *et al.*, 2017a, 2017b).

The effect of wind speed on the resultant power output on an ascending number of turbines arranged by the metaheuristic method of the Dynastic Optimization Algorithm in a wind farm is evaluated. A new metaheuristic algorithm for wind form micrositing known as "Dynastic optimization algorithm" (DOA) was discussed in Massan, Wagan, and Shaikh (2020). The nature-inspired algorithms use the best combination and evolution strategy in a given situation. In this work, a new metaheuristic algorithm is developed by using social behavior in human dynasties. The motivation, conceptual framework, mathematical model, pseudocode and working of the algorithm are described in this paper and the adjoining papers. The proposed dynastic optimization algorithm (DOA, and the important data about the power produced, cost per unit turbine installation and efficiency of DOA are shared in this data article. The complete methodology of DOA can be found in Massan, Shaikh, & Wagan (2020). The data is summarized in Table 1 and Figures 1-3.

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2. OBJECTIVES

The work describes the data obtained for a novel algorithm that has been presented in Massan, Wagan and Shaikh (2020). The nature-inspired algorithms use the best combination and evolution strategy in a given situation. In this work, a new metaheuristic algorithm is developed by using social behavior in human dynasties. The motivation, conceptual framework, mathematical model, pseudocode and working of the algorithm are described in this paper and the adjoining papers. The proposed dynastic optimization algorithm (DOA and puts it forward for wider scientific use. It is evident that it shall prove to be useful while comparing with other algorithms as applied to this problem and other similar problems.

3. EXPERIMENTAL DESIGN, MATERIALS AND METHODS

The method is described in Massan, Shaikh, and Wagan (2020) and the following parameters have been used to carry out the simulations.

Using the below defined parameters from Massan, Wagan and Shaikh (2020). The nature-inspired algorithms use the best combination and evolution strategy in a given situation. In this work, a new metaheuristic algorithm is developed by using social behavior in human dynasties. The motivation, conceptual framework, mathematical model, pseudocode and working of the algorithm are described in this paper and the adjoining papers. The proposed dynastic optimization algorithm (DOA, and the methodology from Massan, Shaikh, and Wagan (2020), the numerical data concerning the power produced in (Kwh), cost per unit turbine installation (dimensionless), and the efficiency (per unit) of DOA application is shared in table 1 for the installation of 100 turbines.

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4. DATA ANALYSIS

The data was acquired by use of a Corei7 laptop (7th generation) and the runtime was less than 8 hours for Matlab 2017, student version. The data format is raw and analyzed. The parameter values are as per the given Table 1.

Table 1. Parameters used for DOA implementation.

α = 0.09437,	
a = 0.326795,	
C_T= 0.88,	
r_r= 40m,	
U_0= 12m/s, 10 m/s, 8 m/s and 6m/s,	
X = 200m	
Z_0= 0.3,	
Z = 60m,	
The configuration of DOA being,	
Niter, Number of iterations	10,000
Np, Number of population	100
r_r, Ratio of rulers	0.05
r_w, Ratio of workers	0.55
r_e, Ratio of explorers	0.4
rad_w, Radius of workers	0.4

The value of the data is that it depicts the actual implementation of a new algorithm for the computation of the WTM problem. It shall save the computation time for other researchers and shall be a viable source of comparison of other similar research and application of other algorithms.

This algorithm is competing with other algorithms such as the GA and DEA which are in wide use. The results are obtained by the use of the same code as used by Mittal (2010) and the data analysis methods utilized in Sultan, Shaikh, and Chowdhry (2020).

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The submission of results of a new algorithm in this domain opens new avenues for research and provides a base for comparison with standard benchmark algorithms. These results shall provide the basis of scientific testing of the DOA algorithm.

Table 2. Dynastic Optimization Algorithm, Results of power, cost, and efficiency per unit turbine.

# of Turbines	Power by DOA	Cost by DOA	Efficiency by DOA
1	518.4	0.001927894	1
2	1,036.80	0.001924553	1
3	1,555.20	0.001919021	1
4	2,073.60	0.001911358	1
5	2,592.00	0.001901641	1
6	3,110.40	0.00188997	1
7	3,628.80	0.001876462	1
8	4,147.20	0.00186125	1
9	4,665.60	0.001844484	1
10	5,184.00	0.001826323	1
11	5,702.40	0.001806936	1
12	6,220.80	0.0017865	1
13	6,739.20	0.001765195	1
14	7,257.60	0.001743204	1
15	7,776.00	0.001720706	1
16	8,294.40	0.00169788	1
17	8,812.80	0.001674896	1
18	9,328.22	0.001652447	0.999680735
19	9,845.28	0.00162982	0.999561186
20	10,359.23	0.001607955	0.999153779
21	10,880.17	0.001585428	0.999427594
22	11,394.89	0.001564361	0.999130908
23	11,909.58	0.001543903	0.998857632
24	12,429.13	0.001523553	0.998998052
25	12,805.65	0.00152085	0.988090649
26	13,453.78	0.00148705	0.998173546

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# of Turbines	Power by DOA	Cost by DOA	Efficiency by DOA
27	13,969.90	0.001469687	0.998078289
28	14,485.15	0.001453366	0.997929592
29	14,996.40	0.001438399	0.997525317
30	15,514.40	0.00142376	0.997582357
31	16,027.31	0.001410575	0.997318922
32	16,559.21	0.001396744	0.99821631
33	17,053.30	0.001387048	0.996849034
34	17,562.23	0.00137699	0.996404884
35	18,066.46	0.001368154	0.995726221
36	18,573.76	0.001359898	0.995250507
37	19,097.40	0.001351271	0.995652038
38	19,596.40	0.00134515	0.994781272
39	20,131.35	0.0013373	0.995733981
40	20,640.35	0.001331884	0.995387307
41	21,144.41	0.001327386	0.994825064
42	21,664.12	0.001322477	0.995008576
43	22,179.64	0.001318368	0.994995257
44	22,666.38	0.001316417	0.993721187
45	23,181.67	0.001313211	0.993727436
46	23,667.78	0.001312025	0.992509534
47	24,178.36	0.001309801	0.992348055
48	24,685.19	0.001308089	0.992042415
49	25,194.62	0.001306513	0.991851631
50	25,697.39	0.00130552	0.991411503
51	26,203.16	0.001304578	0.991102259
52	26,719.00	0.001303325	0.991178533
53	27,210.82	0.001303398	0.99037745
54	27,748.88	0.001301409	0.991258057
55	28,193.69	0.001303894	0.988835927
56	28,753.09	0.001301182	0.990447563
57	29,130.48	0.001306762	0.985843065

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# of Turbines	Power by DOA	Cost by DOA	Efficiency by DOA
58	29,687.59	0.001304321	0.987374528
59	30,242.16	0.001302135	0.988771037
60	30,741.34	0.001302418	0.988340485
61	31,278.57	0.001301147	0.989126935
62	31,640.64	0.00130715	0.984438589
63	32,200.11	0.001304997	0.985943057
64	32,642.62	0.00130761	0.98387515
65	33,123.50	0.001308655	0.983009914
66	33,632.55	0.001308591	0.982994074
67	34,173.13	0.001307335	0.983886443
68	34,195.85	0.001325909	0.970061967
69	35,102.20	0.001310625	0.981341563
70	35,651.06	0.001309114	0.982447598
71	36,224.84	0.001306755	0.984199447
72	36,637.20	0.001310223	0.981577858
73	37,072.03	0.001312822	0.979621874
74	37,613.83	0.001311622	0.980507256
75	38,080.59	0.001313042	0.979439083
76	38,671.75	0.001310201	0.981556231
77	39,084.93	0.001313401	0.979159875
78	39,661.54	0.00131111	0.98086661
79	39,516.82	0.001332779	0.964916909
80	40,750.09	0.0013088	0.982592726
81	41,107.04	0.001313651	0.97896282
82	41,465.55	0.001318369	0.975458058
83	42,185.95	0.001311657	0.980448512
84	42,506.64	0.001317444	0.976140856
85	43,123.26	0.001314065	0.978650658
86	43,316.21	0.001323602	0.971598857
87	43,863.89	0.001322274	0.972574453
88	44,328.75	0.001323446	0.971712521

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# of Turbines	Power by DOA	Cost by DOA	Efficiency by DOA
89	44,977.38	0.001319182	0.974852994
90	45,593.26	0.001315985	0.977221701
91	45,646.31	0.00132906	0.967607595
92	46,039.29	0.001332196	0.965330019
93	46,885.14	0.001322381	0.972494843
94	47,024.66	0.001332634	0.965012274
95	47,563.55	0.001331552	0.965796586
96	48,202.02	0.001327745	0.968565566
97	48,753.12	0.001326411	0.969539892
98	48,430.18	0.001349021	0.953290011
99	49,256.42	0.001339927	0.959759948
100	49,831.45	0.001337843	0.961254806

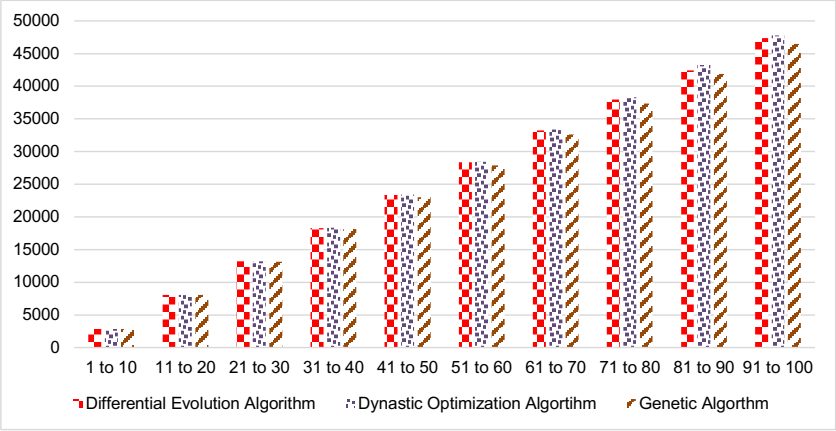

Figure 1. Comparison of mean power (kWh) produced by DEA (Massan *et al.*, 2017a, 2017b), DOA (Massan, Wagan, & Shaikh, 2020). The nature-inspired algorithms use the best combination and evolution strategy in a given situation. In this work, a new metaheuristic algorithm is developed by using social behavior in human dynasties. The motivation, conceptual framework, mathematical model, pseudocode and working of the algorithm are described in this paper and the adjoining papers. The proposed dynastic optimization algorithm (DOA and GA (Rajper & Amin, 2012) versus number of turbines.

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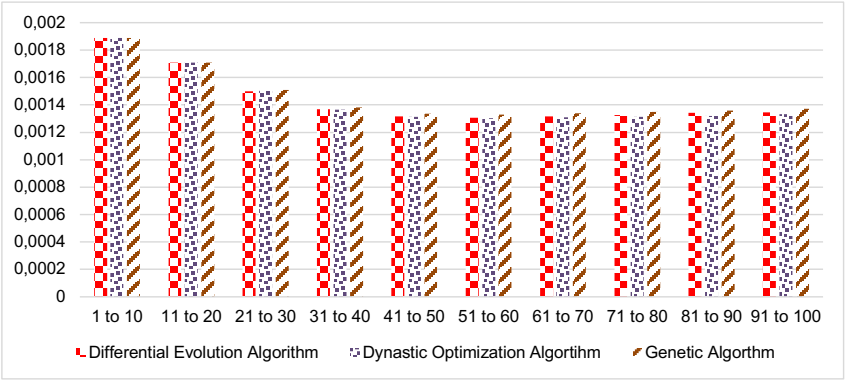

Figure 2. Comparison of mean cost per unit turbine (dimensionless) by DEA (Massan *et al.*, 2017a, 2017b), DOA (Massan, Wagan, & Shaikh, 2020). The nature-inspired algorithms use the best combination and evolution strategy in a given situation. In this work, a new metaheuristic algorithm is developed by using social behavior in human dynasties. The motivation, conceptual framework, mathematical model, pseudocode and working of the algorithm are described in this paper and the adjoining papers. The proposed dynastic optimization algorithm (DOA and GA (Rajper & Amin, 2012) versus number of turbines.

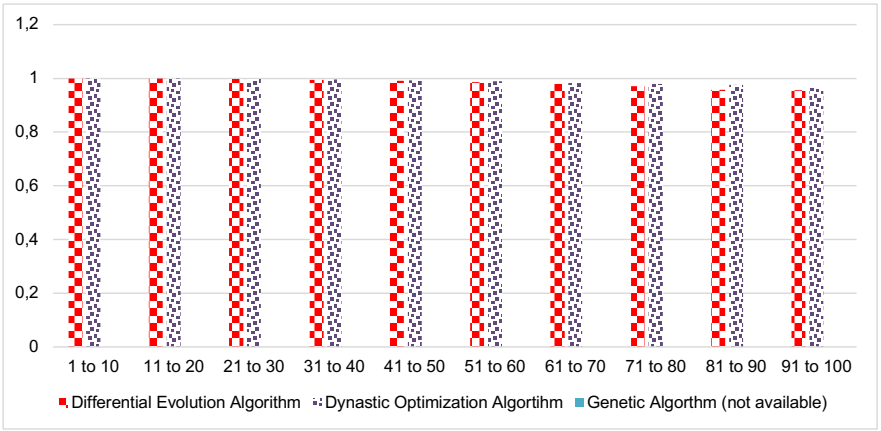

Figure 3. Comparison of efficiencies (per unit) by DEA (Massan *et al.*, 2017a, 2017b), DOA (Massan, Wagan, & Shaikh, 2020). The nature-inspired algorithms use the best combination and evolution strategy in a given situation. In this work, a new metaheuristic algorithm is developed by using social behavior in human dynasties. The motivation, conceptual framework, mathematical model, pseudocode and working of the algorithm are described in this paper and the adjoining papers. The proposed dynastic optimization algorithm (DOA and GA (Rajper & Amin, 2012) versus number of turbines.

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5. TEST FUNCTIONS

This algorithm was applied to the following two test functions and the comparative graphs are obtained herewith,

The DOA, DEA and GA were applied to the following test functions,

Booths's (f_1) and

$$f_1(x_1, x_2) = (x_1 + 2x_2 - 7)^2 + (2x_1 + x_2 - 5)^2$$

the Bohachevsky's (f2) functions

$$f_2(x_1, x_2) = -x_1^2 + 2x_2^2 - 0.3\cos(3\pi x_1) - 0.4\cos(4\pi x_2) + 0.7$$

The following figures were obtained,

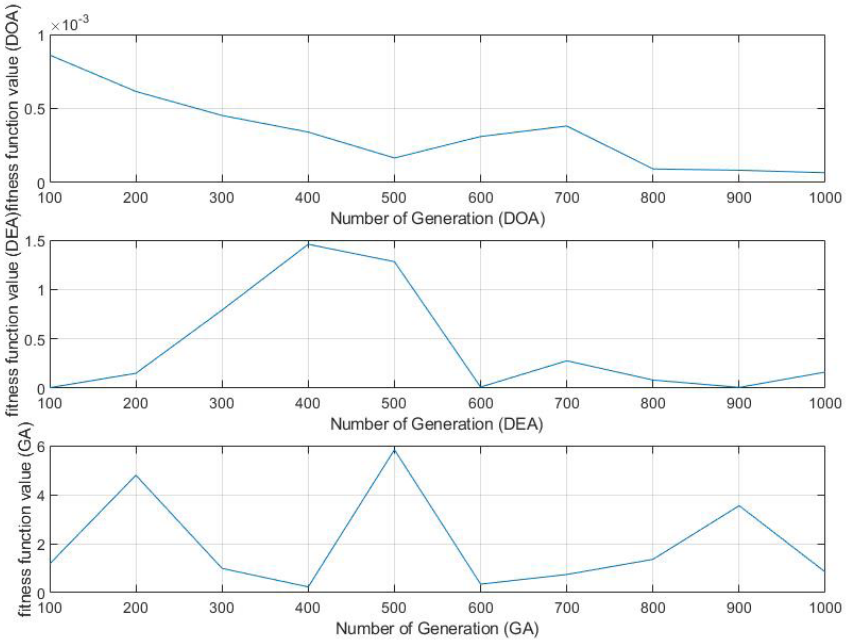

Figure 4. Comparison of minima attained versus number of generations by all methods for Booth's function.

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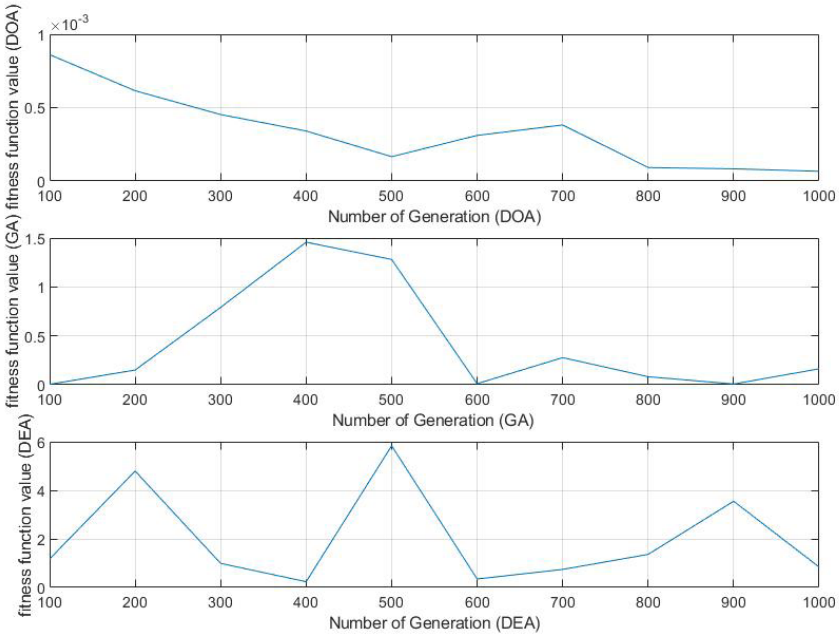

Figure 5. Comparison of minima attained versus number of generations by all methods for Bohachevsky's function.

The minimum value of the Booth's function is 0 at (1,3) and the minimum value of the Bohachevsky's function is 0 at (0,0).

The DOA approaches the minima of f1 and f2 more frequently and with comparatively much higher precision than GA and DEA as demonstrated through Figures 4 and 5 for a several values of generations.

6. RECOMMENDATIONS

In view of the encouraging results of the DOA algorithm it is now possible to depict that it is a viable algorithm that may be used in different fields of technology. The values of the test functions also depict encouraging results for this algorithm.

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7. CONCLUSION

The potential power saving, cost saving and efficiency benefits of proposed DOA (Massan, Wagan, and Shaikh, 2020). The nature-inspired algorithms use the best combination and evolution strategy in a given situation. In this work, a new metaheuristic algorithm is developed by using social behavior in human dynasties. The motivation, conceptual framework, mathematical model, pseudocode and working of the algorithm are described in this paper and the adjoining papers. The proposed dynastic optimization algorithm (DOA are shown in Figures 1-3, respectively against Differential Evolution Algorithm (Massan *et al.*, 2017a, 2017b) and genetic algorithm data (Rajper & Amin, 2012). The encouraging performance of DOA over GA and DEA is evident from the exhaustive comparison in Massan, Wagan, and Shaikh (2020). The nature-inspired algorithms use the best combination and evolution strategy in a given situation. In this work, a new metaheuristic algorithm is developed by using social behavior in human dynasties. The motivation, conceptual framework, mathematical model, pseudocode and working of the algorithm are described in this paper and the adjoining papers. The proposed dynastic optimization algorithm (DOA and the data shared in this article.

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AN OVERVIEW OF AI ENABLED M-IOT WEARABLE TECHNOLOGY AND ITS EFFECTS ON THE CONDUCT OF MEDICAL PROFESSIONALS IN PUBLIC HEALTHCARE IN PAKISTAN

Abdul Samad Dahri
Business Administration and Social Sciences
Mohammad Ali Jinnah University, Karachi, (Pakistan).
E-mail: dahriabdulsamad@gmail.com ORCID: https://orcid.org/0000-0003-4517-3493

Shafiq-ur-Rehman Massan
QEC and Co-ordination
Mohammad Ali Jinnah University, Karachi, (Pakistan).
E-mail: srmassan@hotmail.com ORCID: https://orcid.org/0000-0001-6548-6513

Liaquat Ali Thebo
Department of Computing,
Mohammad Ali Jinnah University, Karachi, (Pakistan).
E-mail: liaqaut.ali@jinnah.edu ORCID: https://orcid.org/0000-0001-7097-5610

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ABSTRACT

Interconnectivity of smart devices such as mobile technology adoption in healthcare holds humongous impacts. Yet, medical professionals are reluctant to reap potential benefits of technology and the reason behind this phenomenon is ambiguous. This study aims to highlight current critical conditions in public healthcare hospitals in Pakistan, and how IoT will add value in healthcare services effectiveness through mobile computing and also to indicate current concepts that may add value in over-all smart healthcare system. According to available information, study to on AI enabled M-IoT network-based healthcare system specially in developing countries to address healthcare problems are rarely known. This study empirically analyzed the factors that influence IoT based smart healthcare devices adoption in Pakistan. In understand the phenomenon, Partial Least Square Equation Model (PLS SEM) was used to understand the relational influence of performance expectance, effort expectance, and social influence over behavior to use through intention to use the technology supported by Unified Theory of Acceptance Technology (UTAUT) assumptions. The results show that clinicians are reluctant to use technology though the results also reveal that same clinicians have positive influence of performance and effort expectations on their intention to use technology that leads the actual behavior of using the technology. Though, this research is among few to beacon upon urgent focus of public healthcare management in developing countries. Yet, new research is lacking far behind to facilitate methods to opt for M-IoT healthcare devices powered by AI.

KEYWORDS

Artificial Intelligence (AI), Internet of Things (IoT), Technology proliferation, Unified Theory of Acceptance Technology (UTAUT), Coronavirus (COVID-19), Healthcare.

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1. INTRODUCTION

The ongoing pandemic of corona virus has become one of the biggest threats to global economy and especially healthcare. Healthcare is backbone to any nations' development and growth (Samad, Memon, & Kumar, 2020). It is always the healthcare facilities that serves when the state is faced with critical public healthcare risk. Whether it be the eradication of Smallpox globally, Polio from USA, Cholera in Asia claiming 100,000 deaths, Bubonic plague in China claiming 12 million deaths and Coronavirus also known as "COVID-19"outbreak in Wuhan district of China, which has become a global public healthcare risk. According to Centers for Disease Control and Prevention, the Coronavirus (COVID-19) was reported on 30th January 2020 in USA as well. With reference to ongoing spread of COVID-19 besides its exponential negative impact ranging from service, manufacturing, stock market and oil prices to Gross Domestic Product of countries globally (see Figure 1) as well as it has become global health risk by sickening more than 482,800 people and claimed 21,896 deaths in more than 171 countries globally.

Though, before COVID-19, healthcare was in chronic crises mainly of doctor and nurse's shortage, burnout of physicians and high demand for enduring care (Meskó, Hetényi, & Győrffy, 2018). But global healthcare systems were never in such a desperate condition ever before. In china for instance, hospitals were maxed out and basic medical supplies such as gloves were empty and lead to shutdown of public life at all levels (Wallace-Wells, 2020).

Therefore, for an effective healthcare system needs the availability, accessibility, acceptability and quality of its healthcare workforce (World Health Organization, 2013). World Health Organization (WHO) (2013) estimated problem of aged workforce with need-based healthcare workforce shortage globally by 17.4 million? Whereas, high frequency of patients and shortage of medical staff overloads physicians while increasing burnout experience (Meskó *et al.*, 2018).

As a result, lack of access to healthcare by masses and compromised quality in healthcare facilities is common globally. According to Meara *et al.* (2015), 400 million people lack to one or more essential

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health services and 5 billion people do not have access to safe and affordable surgical and anesthesia care when needed. According to Bernaert and Dimitrova (2017), at World economic, 9 billion people will need healthcare services by 2050. While, staggering $ 142.6 billion were invested for developing countries' healthcare targets which no government could achieve. Moreover, global healthcare is $ 300 billion healthcare question that needs accurate spending. Since, 20% of healthcare spend is wasted globally and top 15 countries waste $ 1100 to $ 1700 on an average. Which is above the average ($120/ person) spent on healthcare of more than 50 bottom countries (Bernaert & Akpakwu, 2018). According to Malkani (2016) in this context, reported healthcare sector being ignored by the government and policies and practices lack efficient implementation and virtually absent in case of Pakistan. Thus, new approaches and eloquent work to ventilate vital healthcare services is the need of the hour.

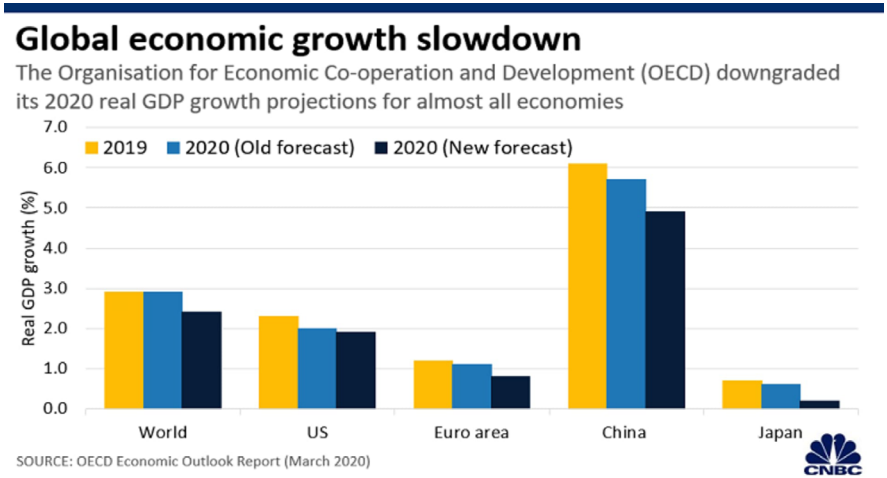

Figure 1. Global Economic Growth Slowdown.

According to UN (2018) report, 90% of the global population lives in the rural areas, and this number will reach to its peak by 2020. Where, life expectancy is worse, limited access to healthcare facilities, lack of trained healthcare workers, transport difficulty and so on, contribute to low quality of healthcare among rural population (Strasser, Kam, & Regaldo, 2016). Besides, that skyrocketing costs, high priced

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drugs, hospital-acquired infections, and failure of to deliver healthcare boost adverse healthcare events. Specially in developing countries like Pakistan where doctor to patient ratio is 1: 1300, doctor to nurse is 1: 2.7 (Khan, 2019) nurse to patient ratio is 1:12411 patients (Zaidi, 2012), and only 22% of patients are served through public hospitals (Solangi *et al.*, 2017b)

Since, now a days, production, application and utilization of information technology demarks difference between developed and developing countries (Ajami, Ketabi, & Torabiyan, 2015). The workflow of hospital may vary from patient to patient, population problem, poor healthcare services and scarcity of healthcare resources, where working conditions are exceptionally uncertain, unscheduled, and care decentralized for instance COVID-19 pandemic, craves for the utilization of information technology (Nazir *et al.*, 2019).

The healthcare information technology (HIT) development holds potential to improve healthcare quality and accuracy in emergency, safety, medical errors, efficiency, and patient care (Rothenhaus *et al.*, 2009).Therefore, the immediate innovative intervention is needed in rural areas of developing countries (Samad, Al-Athwari, & Hussain, 2019). Where, managers could use medical equipment and new technological tools to improve patient safety and satisfaction (Birgani & Asadpoor, 2011).

Similarly, the development of hospital information systems accompanied with gradual advancement of software, hardwires, and new methods in order to enhance agility and quality of healthcare services is growing (Siamian *et al.*, 2005). The increased population and scarcity of healthcare resources necessitates the adoption of IoT serves the best solution in terms of cost and efficiency (Tyagi, Agarwal, & Maheshwari, 2016).

Post 80s and 90s, Kevin Ashton in 1999 initiated term Internet of Things (IoT), referring as uniquely identifiable connected objects with radio-frequency identification (RFID) technology. IoT basically observes interconnectivity of devices as data sources through existing internet infrastructure (Shaikh, 2019). IoT and technological advances in healthcare services to patients not only reduce errors, increase

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agility and accuracy in healthcare quality, but also, lowers costs through information integration (Malliarou & Zyga, 2009). Therefore, it is worth acknowledging the role of every healthcare department in hospital, recognize the importance of IoT integration in healthcare and to improve quality and reduce cost of emergency department and related provisional units in hospitals (Mirhoseinie *et al.*, 2014).

Recent developments in IoT unleashed unprecedented potential in business world (see Figure 1). According to Global Forecast, IoT healthcare market is expected to grow from US $55.5 billion to US $ 188.0 billion by 2024 at an annual compound growth rate of 27.6%. This is due to active patient healthcare monitoring, patient centric management and high speed network technologies for IoT connectivity (Singh, n.d.).

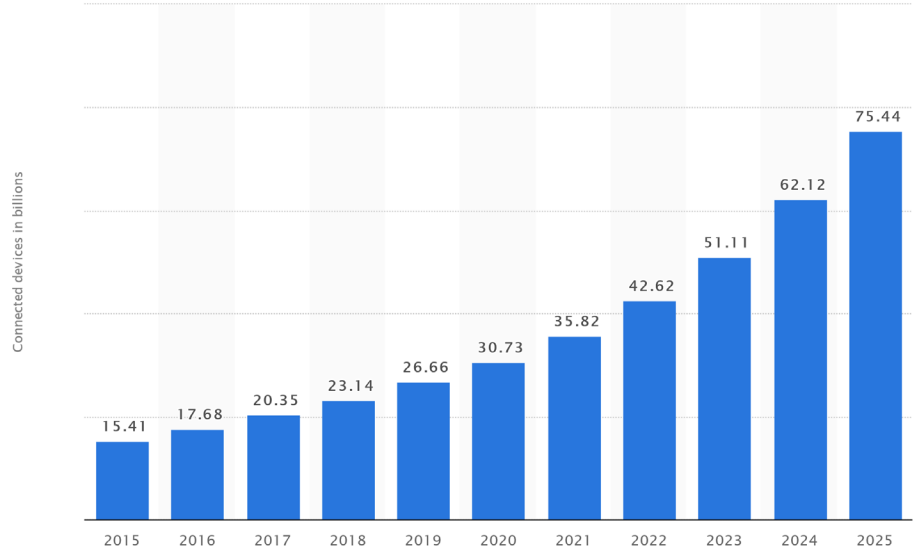

Figure 2. Source - Statista Research Department, Nov 14, 2019.

At present various tools and methods are used to quantify the healthcare performance. Accordingly Van der Meulen (2017) reported a forecast that the IoT will connect 26 billion units till 2020. IoT brings rich user experience, connectivity, reliability and smart healthcare services to patients (Islam *et al.*, 2015),

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which leads to smart healthcare system (see Figure 2) composed of smart functionality, remote server, and the network to remotely monitor patients (Yuehong *et al.*, 2016). On a recent note, 76% healthcare organizations believe that IoT will transform healthcare industry (Anurina, 2019).

Similarly, to address this problem, mobile technology provides grounds for IoT by using mobile phones, IP connectivity, lower power consumption, security, apps, or through m-health care system (Nazir *et al.*, 2019). Mobile computing is new trend involved in many areas including healthcare providing quality processing, storage, information and query to the users at remote geographical areas. Where, IoT serves as an intelligent sensing technology that supports vitally in sending and receiving mobile medical data (Ma *et al.*, 2018).

Currently, most of the mobile-health applications are used by healthcare professionals for various tasks (Elazhary, 2019). For instance, m-health and m-learning. Where, m-health apps are used for diagnosis of diseases, drug references, and medical computations. Therefore, using M-IoT devices in healthcare will reduce cost and improve effectiveness of healthcare system.

One of the most important use of m-health app is in PHS-personalized health system, where various sensors in mobile such as gyroscope, accelerometer, altimeter, general packet radio service (GPRS), 4G systems, global positioning system (GPS) and blue-tooth technology integrated with IoT environment will collectively help monitor, diagnose, or even forecast health risks at a distance (Qi *et al.*, 2017). Or these sensors separately may be attached to body of patient (ankle, wrist, and chest) and collect data through mobile app and sent it to respective department or doctor (Subasi *et al.*, 2018).

The technological adoption in the healthcare paced the information flow between doctor and patient pilling up twice every three years for which an estimated reading time for physician to remain up to date is 29 hours straight which is impossible (Curioni-Fontecedro, 2017). This adds critical call for more advanced computational power to smart devices used in healthcare system such as Artificial Intelligence

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(AI) agents to enhance the predictiveness in healthcare workflow (Bui, 2000), improve quality and lower costs for patient care.

An AI enabled system uses sophisticated algorithm to 'learn' and extract useful information from a large patient population to assist in making real-time inferences for healthcare outcomes. Moreover, there are more than 97000 AI enables mobile healthcare (mHa) available on google play store and Apple store and these would be downloaded by 500 million people globally till 2015 (Jahns & Houck, n.d.), while, 50% of these apps will be downloaded in smart phones by 2017 (Siltala, 2013). This phenomenon progressively has turned smartphones into medical kits for real-time healthcare monitoring for patient activities, early predictability, disease screening, improved medication adherence (Alemdar & Ersoy, 2010) by medical professional and minimized medical errors that are inevitable in human clinical practices (Pearson, 2011).

Moreover, healthcare data is broadly classified into non-AI and AI systems. Though, non-AI data uses less complex computational process, is gradually replaced by AI enabled systems due their in-efficiencies. AI based platforms (applications) which are mostly hybrid in nature and involve AI Neural Networks (ANNs), Fuzzy theory, and evolutionary algorithms (Sannino *et al.*, 2019). For example, Dargazany, Stegagno, and Mankodiya (2018) introduced the concept of wearable deep learning (WearDL) which is unifying conceptual architecture inspired by human nervous system that offered inclusion of deep learning, IoT, and wearable technologies. Where, brain was conceptualized as deep learning for cloud computing and big data processing, the spinal cord as IoT for fog computing and big data transfer, and the peripheral sensory and motor nerves as wearable technologies as edge devices for big data collection (Sannino *et al.*, 2019). Although, these techniques are theoretically sound yet lack potential practical explorations.

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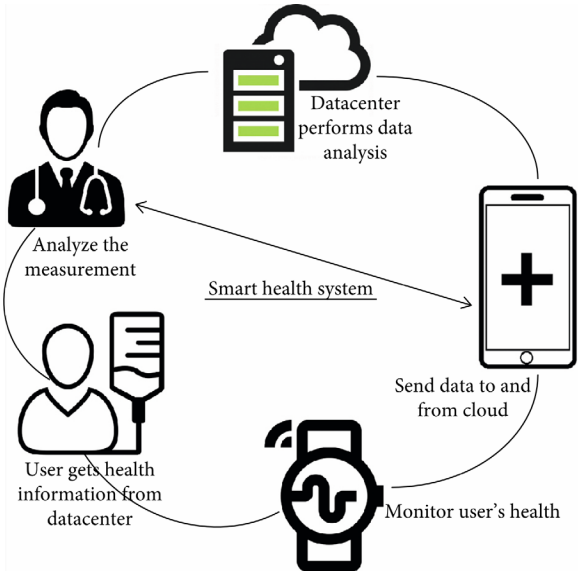

Figure 3. M-IoT Warble Smart Healthcare System.

Advantageously, over 85% of global population is under wireless signal (World Health Organization, 2013), 80% of them hold smartphones (Chaffey, 2019), and in developing countries like Pakistan over 90% users have 2G internet (PTA annual report 2014-2015). These smartphones with m-health apps enable patients to use healthcare applications to monitor their health indicators and diseases (Karaca *et al.*, 2019) and categorized into single condition apps which are developed for specialized diseases and cluster condition applications which treat certain disease together. Based on literature, few of these applications are discussed below:

Single condition Applications:

Glucose Level Sensing: This app is helpful for Diabetes patients whose glucose level sustains at higher levels than normal. Through blood glucose monitoring system suggests best meal, exercise and medicine time to the patient. Doctors may propose a noninvasive glucose measuring m-IoT method on actual basis. In this method, sensor attached to patient body serves as IoT device and transmits real time

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information to respective department or doctor. This device is equipped with blood glucose collector, smartphone, and a processor.

Blood Pressure Monitoring System: Blood pressure (PB) is force by heart to circulate blood in body. An IoT medical device can assure monitoring of Bp, glucose level in blood, and any irregularity can also be transmitted supported by IoT network.

Body Temperature Monitoring System: monitoring and maintaining body temperature is an important element of healthcare. From m-IoT perspective, temperature varies from body to body yet gives accurate readings and assists in infrared detection and RFID module.

Oxygen Saturation Monitoring System: device named pulse oximeter measures oxygen saturation level in the blood. The use of IoT with pulse oximeter benefits technology-based healthcare applications on wrist. This is a low power, low cost, Bluetooth enabled device that connects with IoT network which enables doctor or respective department to monitor patient remotely.

Electrocardiogram (ECG) Monitoring system: This device can display the ECG waves on the user. This device generates specific ECG bio-signal reports of the patient and link this information to respective user by integrating with IoT network. IOIO-OTG is micro controller that converts ECG analog signals into digital data in binary numbers which can be monitored on IoT network. This device can be very helpful for hospitals/ ED as it helps in detecting any anomalies in the patient health condition in advance and reduces wait time at hospitals.

Cluster Condition Application:

Wheelchair Management System: keeping in view of elderly and disabled patients, smart wheelchairs are recommended by health experts. These wheelchairs are enabling location, movement and status of the user and links it with IoT network, helping respective users in monitoring patients.

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Rehabilitation System: IoT can help rehabilitation system regarding population growth and lack of health expertise. Body sensor network can improve the abilities of the disabled person through IoT networks that would enhance rehabilitation system. Number of rehabilitation system for example smart city rehabilitation and integrated application system for prisoners (Islam *et al.*, 2015).

Healthcare Solutions Using Smartphones: Currently, smartphones are equipped with sensors and electronic control applications. In the healthcare field smartphones provided real-support and monitoring and communication between patient and respective department or physician. Few of smartphone m-healthcare apps include; blood pressure watches which is smart wrist band connected with smartphone and gathers blood pressure data. Another one is, heart rate monitors that measures and records heart related data. Health assist is also m-health app that keeps record of bloom-health app that keeps record of blood pressure, heart rate, body temperature and other designated physical activities.

Regrettably, in general, it is observed in the healthcare sector that usage of technology by doctors across the nation for various medical and investigative techniques, is not best fitted with technological healthcare framework globally (Solangi *et al.*, 2017a). Moreover, negative attitude towards technology adoption is also observed among healthcare professional which directs significant concerns towards acceptance and efficient use of technology (Mitzner *et al.*, 2010). Followed by Safi, Thiessen, and Schmailzl (2018) who reported medical professionals avoided using technologic fearing mass control by management. Since, negative attitude of medical professionals using technological devices in healthcare may delay fruits of m-IoT in healthcare system.

Similarly, various problems are linked with future structure of healthcare for embracing m-IoT innovations, specially getting doctors and healthcare services on standby for global uncertain calamities such as COVID-19. Indirect Emergency Healthcare (IEH) for instance, keeping these conditions on hand, a dedicated service called indirect emergency healthcare offers varying solutions to these situations including information availability, alter information, post-accident action, and record keeping. These problems require novel investigation to establish m-IoT smart healthcare system for remote patient

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assistance, monitoring, early diagnosis, and early treatment, especially in less privileged areas of developing nations.

Therefore, this research leads to utilize standard constructs of technology acceptance model (TAM) to understand the relevance and attainability of m-IoT based smart healthcare system. The technological acceptance model (TAM) is grounded on the idea of social psychology use as a gage to illustrate and asses the behavior of users to utilize innovation. TAM is used for best quality level (Bagozzi, 2007). The refined version of TAM is Unified theory of acceptance and use of Technology (UTAUT) which has been quite effective to measure the factors that determine use behavior of technology in the healthcare consumers (Venkatesh *et al.*, 2003). The UTAUT theory is inclusion of Innovation Diffusion Theory (IDF), Theory of Planned Behavior (TPB), Social Cognitive Theory (SCT), Motivation Model (MM), Theory of Reasoned Action (TRA), Model of Personal Computer Utilization (MPCU), and TAM itself to better understand the acceptance and usage of new technology.

Since, UTAUT model proved valuable framework to understand behavioral aspect of technological acceptance and utilization in different cultures over short period of time. The UTAUT model measures the behavior (BU) of technology through behavioral intention (BI) of technology use influenced by four determinants namely, performance expectancy (is the degree of worth performing a task to achieve set goals), effort expectancy (is the ease associated with use), social influence (social importance linked with new system utilization), and facilitating conditions (one's believe of technological and organizational infrastructure exists for support) (Venkatesh, Thong, & Xu, 2016). Specially, Pakistan has under-developed technical and infrastructure support system (Kurji, Premani, & Mithani, 2016). Based on UTAUT theory to examine its relevance and practicability in the field of M-IoT healthcare system. Since, in healthcare technological adoption behavior is at individual level, therefor, performance expectancy, effort expectancy, and social influence determinants are used based on UTAUT to understand behavioral intention towards utilization of M-IoT in public and private healthcare sector.

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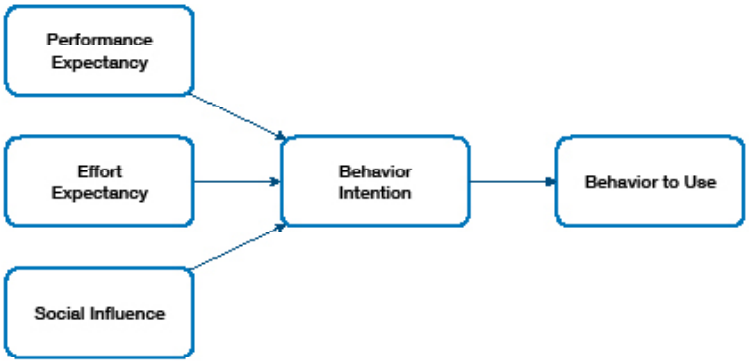

2. MATERIAL AND METHODS

Population for this study comprised of over 479 (Bureau of statistics planning & development department government of Sindh, 2016), including dentists, physicians, and gynecologist and surgeons in Sindh public hospitals, out of which 9 medical professionals were unclear on using wearables M-IoT healthcare devices. Remaining population (who understood m-health applications and IoT wearable devices) of 470 healthcare professionals following Krejcie and Morgan (1970) model for a minimum sample of 214 was selected for data collection on random bases. The study uses questionnaire of acceptance of technology adapted from previously validated instrument by Cimperman, Makovec, and Trkman (2016) as this scale specifically addresses home telehealth devices, to focus on M-IoT applications on determinants of behavioral intention to use M-IoT technology. It comprises of one part for participants' demographics and second part including 15 items for UTAUT determinants for performance expectancy (PE), effort expectancy (EE), and social influence (SI) on behavioral of use (BU) of using new technology, through behavioral intention (BI), where the answers were recorded on 7-point frequency Liker scale. Since, incomplete responses were screened, the final sample for analysis was of 185 responses that belonged to age group of 20 to 40 years mainly female (74%) and male (36%). They were graduates (68%) and undergraduates (42%), with work experience ranging from 2 years to 40 years in field of Sindh province of Pakistan.

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3. RESEARCH FINDINGS

3.1. RESULTS OF MEASUREMENT MODEL

For measurement model, convergent validity and discriminant validity values were evaluated.

Convergent validity

Convergent validity is the degree of latent variables correlated with other variables items (Hair *et al.*, 2016). Following Henseler *et al.* (2014) factor loadings, average variance extracted (AVE) and composite reliability (CR) were assessed. Further, factor loading threshold of 0.6 was achieved (see Figure 1 outer loadings and t-values), for AVE values were above 0.5, and CR values were also above 0.7 on recommended threshold by Chin (1998); Nunnally and Bernstein (1994); and Hair *et al.*, (2011) (see Table 1).

Discriminant Validity

Discriminant validity is simply the distinctiveness among the constructs. Following Henseler, Ringle, Sarstedt (2015) Hetero-Trait-Mono-Trait (HTMT) ratio of correlation was evaluated. For HTMT threshold values should be below 0.9 recommended by Gold and Arvind Malhotra (2001) along with confidence interval for better significance assessment which should be less than 1 (Henseler *et al.*, 2015). Table 1 reveals achievement of all suggested criterion for discriminant validity.

Table 1. Hetero-trait-mono-trait (HTMT), CR, AVE (N=185).

Variable	PE	EE	SI	BI	BU	CR	AVE
PE	1					0.821	0.641
EE	0.042	1				0.844	0.66
SI	0.057	0.047	1			0.798	0.611
BI	0.012	0.048	0.055	1		0.804	0.638
BU	0.081	0.078	0.057	0.039	1	0.884	0.617

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Note: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Behavioral intention (BI), and Behavioral of Use (BU).

4. MEASURES AND METHODS

Hair *et al.* (2016) recommended R2, standard beta, t-values via bootstrapping procedure on 5000 samples for predictive relevance Q2 and the effect size f2. Moreover, confidence interval values were also taken into consideration which ensures the confidence of same response from same sample of target population as revealed in Table 2 below.

Table 2. Results of Structural model Assessment.

Path	Beta	St. Dev	T Stats	P Values	R2	f2	Q2
PE -> BI	0.459	0.112	4.098	0.000	0.524	0.267	0.139
EE -> BI	0.126	0.023	5.478	0.001	0.494	0.248	0.238
SI -> BI	-0.013	0.068	0.195	0.849		0.152	
BI-UB	0.326	0.07	4.639	0.000		0.251	
PE-BI-UB	0.096	0.029	3.288	0.001			
EE-BI-UB	0.121	0.034	3.567	0.002			
SI-BI-BU	0.035	0.016	2.187	0.001			

Table 2 above, reveals that PE is significantly related to BI (b=0.459, t=4.098, p=0.000), EE is significantly related to BI (b=0.126, t=5.478, p=0.001), SI is significantly related to BI (b=-0.013, t=0.195, p=0.849), BI is significantly related to UB (b=0.326, t=4.639, p=0.195). BI mediated between PE and UB (b=0.096, t=3.288, p=0.000), BI mediated between EE and UB (b=0.096, t=3.288, p=0.001), and BI mediated between SI and BU (b=0.035, t=2.187, p=0.001).

Moreover, PE had effect size of 0.267on BI, EE had effect size of 0.248on BI, SI had effect size of 0.152 on BI, and BI had effect size of 0.251 on BU.

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In addition to that, Stone-Geisser (Stone, 1974; Geisser, 1974) test for predictive relevance by blindfolding procedure for goodness-of-fit was followed as shown in Table 2. These values were found above zero (0.139) for BI and (0.238) for BU. which according to Henseler, Ringle, and Sinkovics (2009) shows model had good predictiveness as bearing value above 0 "Zero".

5. DISCUSSION

Aim of this study was to address the phenomenon of technology adaptability in the light of AI enabled IoT warble devices effectiveness for adoptability behavior through UTAUT assumptions particularly in context of developing countries. And the overall model was found to have 52% variance explained by acceptance determinants and 42% of variance explained intentional use on actual use of technology which is 10% reduced due to social influence that affected negatively over behavior to use the technology. Moreover, the study reveals the mediating effect of intention to use the technology between determinants and behavior to use the AI enabled m-health applications for wearable IoT devices technology in healthcare.

The behavior to use technology was positively influenced by the performance expectancy and effort efficiency. Whereas, the social influence negatively affects the behavioral intention of technology adoption. These effects were further carried by the behavioral intention to actual behavior of using the technology. It was noticed that social influence in developing countries was not supportive and that also reduced the actual behavior to use the technology by 10% in local context of Pakistan. This highlights the fact that in social structure of Pakistan, technology is either less trusted and still rely on physical method of getting treatment for diseases or diagnoses.

6. CONCLUSION

The aim of this study was to elaborate technological advancement to enable efficiency of existing healthcare services specially in developing countries. This study also reviews the potential areas that are

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enhanced in terms of technology adoption. Since, the technology holds the future of any organization, healthcare practitioners were reluctant towards technology adoption. Thus, this study focuses on important elements that might hinder clinician's technology adoption behavior.

Findings of this study beacon the direct effect of UTAUT determinants on behavioral intention of medical professionals to use new technology in healthcare system. Findings also revealed the usefulness of UTAUT model to test the behavioral intention towards M-IoT use and provides additional contribution in the literature in the role of experience and significance behavioral role in new technological adoptions.

There are certain limitations that may attract new research as this study gather viewpoint of only clinicians and focusses only public healthcare sector which might less likely to adopt technology. Further, social and cultural dimensions must be included to better asses behavior of patients and medical professionals towards technology adoption.

Typically, in developing countries like Pakistan, hospital-acquired infections are themselves a big killer. Thus, hospital management could deploy devices that monitor medical professional within hospital and patients out of hospital vicinities. Such as M-IoT based hygiene monitoring system could save million patients, time of doctors, and efficiently manage the resources. This can be reflected in current COVID-19 pandemic, where global system in all respects has collapsed, specifically the healthcare sector. And failure of healthcare is currently approximated to failure of the state machinery.

Therefore, the future of healthcare, even in emergency department, performance typically relies on connectivity of smart devices over the internet, and the transfer of information is crucial for any developed as well as developing countries like Pakistan. This research beacons the AI enabled M-IoT adoption in healthcare to benefit masses with high accuracy, effectiveness and efficiency.

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ENERGY HARVESTING USING KINETIC ENERGY OF VEHICLES

Mirsad Hyder Shah
Ex-Fellow, Department of Electrical Engineering, DHA Suffa University. Karachi, (Pakistan).
E-mail: itsmirsadhyder@yahoo.com ORCID: https://orcid.org/0000-0003-2476-5887

Gasim Othman Alandjani
Associate Professor, Computer Science and Engineering Department. Yanbu University College, Yanbu Industrial City, (Kingdom of Saudi Arabia).
E-mail: alandjanig@rcyi.edu.sa ORCID: https://orcid.org/0000-0003-0321-7013

Maryam Asghar
Ex-Fellow, Department of Electrical Engineering, DHA Suffa University. Karachi, (Pakistan).
E-mail: maryamasghar1998@gmail.com ORCID: https://orcid.org/0000-0001-5356-7818

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ABSTRACT

With the increasing global energy demand, clean and affordable sources of energy are being adopted over time. Road Power Generation (RPG) is thus an alternate to conventional electricity generation. RPG technologies generate electrical power from vehicles by harnessing their kinetic energy. The most common RPG technology is RPG by speed breaker mechanism. However, this paper will discuss the construction of a novel Electro-Mechanical system which can be employed on the surface of a road and thus can produce electricity of up to six kilowatts per day. A vehicle induces reciprocating linear motion into the RPG flip plates which is then converted to rotary motion via rack and pinion. This angular motion is converted to electricity via a PMDC generator which can be used to power streetlights. This method of generating electricity is called RPG by flip plate mechanism or RPG by reciprocating linear motion.

KEYWORDS

Flip plate mechanism, Road power generation, Energy harvesting, Rack and Pinion, Reciprocating Linear Motion, Kinetic Energy of Vehicles.

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1. INTRODUCTION

The need of alternate energy sources is not a debate but a necessity in this modern era. The demand of clean and affordable energy sources led to the breakthrough of renewable energy sources. RPG is a similar advancement which can be argued to be a green source of energy. With the increasing number of cars on roads, RPG should be the base of smart cities.

Previous RPG methods have not been successful because of the following reasons:

- They require the vehicles to slow down their movement because they have the characteristics of a speed breaker.
- The wear and tear of the RPG unit requires substantial maintenance; specifically the springs.
- The safety of the vehicles to step on these units is a major challenge.

RPG by flip plate mechanism addresses the above issues significantly. This foot unit utilizes the hortizontal stroke of the vehicle and as a result; the vehicles do not have to slow down anymore. The maintenance of the RPG unit is very easy, and any malfunction does not endanger the vehicle above.

1.1. LITERATURE REVIEW

1.1.1. RPG BY PIEZOELECTRIC MATERIAL

The piezoelectric material as discussed above is a handy way to generate electricity but has several drawbacks when applied to the concept of RPG (Lee *et al.*, 2010).

- Sound waves bend the piezoelectric material, creating a changing voltage.
- Crystal is prone to crack if overstressed.
- It may get affected by long use at high temperatures.

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1.1.2. RPG BY SPEED BREAKERS

Road Power generation by speed breakers is the most common RPG method as of now, but it also has several drawbacks (Rao, Kumar, & Suresh, 2014):

- Cannot be installed on main roads or highways since it requires the car to stop.
- If too much pressure is applied the spring can deform.
- If too less pressure is applied, the unit may not produce any electricity.

1.1.3. RPG BY HARNESSING THE WASTED HEAT ENERGY

This type of road power generation is a prediction made in the domain of RPG. It can be set up by employing heat absorbing material to capture the wasted heat energy of tires. It is predicted to have the following pitfalls:

- Very high setup cost.
- Material quality is very rare.
- High maintenance cost.

2. METHODOLOGY AND RESEARCH

The RPG unit is 4 foot wide, 3 foot long and 3 foot high in structural dimension. The frame which holds everything in place is made up of high tensile steel or can be made of any material with high stress tolerance. It has the following parts:

2.1. FLIP PLATES

First, let us discuss the dimensions of the flip plates. A foot, checkered, mild steel sheet with a gauge of 10 mm was cut to achieve a special design as shown in Figure 1. As a result, the rectangular sheet was

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transformed into two female (Flip plate A and Flip plate C) and one male flip plate (Flip plate B). The two female flip plates with dimensions of inches were welded at the corners of the frame. The male flip plate or the moving plate was inches in dimension. The female flip plates had teeth of inches while the male flip plate's teeth dimensions were inches.

Second, four springs at positions A1-A2, B1-B2, C1-C2 and D1-D2 hold the flip plate B and flip plate C together. As a result, a distance of 5 cm is achieved between the flip plate A and flip plate B under normal circumstances.

Third, to minimize the friction employed and to smoothen the male flip plate's movement; small wheeled cars were tightened with the male flip plate at positions E,F,G and H through nuts and bolts. These small wheeled cars were placed inside a rack and tightened at the top of the frame.

With this arrangement, when we drag the male flip plate towards the female flip plate, it would roll over the frame and this movement will be stored as elastic potential energy in the spring. Finally when we let go of the male flip plate, it would come back to its original position.

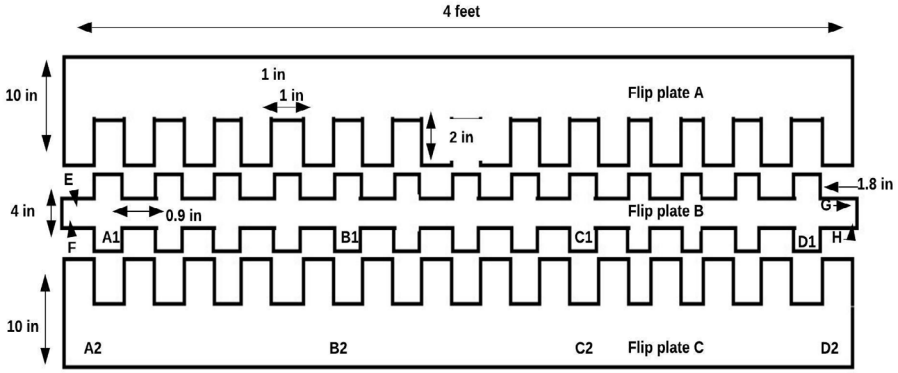

Figure 1. Detailed dimensions of flip plates.

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2.2. UPPER SHAFT

The purpose of this shaft is to produce rotary motion from the linear motion of the flip plate. To interconnect the flip plate system with the upper shaft, three racks were placed directly upon three pinions which were mounted on the shaft. These racks were welded under Flip plate B at equi-distant positions and placed directly upon the upper shaft. Each of these racks had 64 teeth, were 12 inches in diameter and had a gauge of 3 inches.

The upper shaft had a 20 mm gauge and had 3 circular pinions mounted on it. Each pinion had 64 teeth, a diameter of 5 inches and thickness same as that of the rack. Each pinion had a clutch bearing fitted at the center and then passed through the 20mm shaft. The shaft also has a type A sprocket mounted on it with 66 teeth. The shaft was placed just below the rack arrangements by the means of pillow blocks and fitted in the RPG unit.

Figure 2. Picture of racks.

Figure 3. Picture of Pinion.

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2.3. LOWER SHAFT

The purpose of this shaft is to couple the RPG unit with the Generator. To interconnect the upper and the lower shaft, a type B sprocket is mounted on the lower shaft and connected via a chain drive with the type A sprocket with 22 teeth.

The lower shaft is 20mm in gauge and consists of a 10kg flywheel having a diameter of 10 inches. Furthermore, to transfer the energy of this shaft to the DC generator, one spur gear is also mounted on the lower shaft. This shaft was also held using pillow blocks and fitted in the RPG unit.

2.4. POWER GENERATION AND STORAGE

The other spur gear was fitted on the shaft of a 24V, 1050 rpm, 1.1 kW PMDC generator. After the generator does some useful work, the voltage produced was fed to a buck/boost converter. This buck-boost converter steps up or down the input voltage to a constant 13V DC output. This voltage was then fed to a charge controller which cuts off the supply once the battery is fully charged.

An Arduino Uno was connected to a voltage sensor module and a current sensor module to monitor the average energy production per vehicle.

Table 1. Comparison of Generator characteristics.

GENERATORS	SPEED REGULATION	STARTING TORQUE	OTHER FACTORS.
DC SHUNT	Good	Poor	Field winding can be separately excited or same as Armature. Expensive
DC SERIES	Good	Depends upon armature Resistance	Cannot be used when constant speed is required.
DC COMPOUND	Good	Good	Very expensive
PMDC	Good	High	Smaller in size
AC GENERATORS	None in Synchronous	High	Requires VFD or inverters. Cost is high. Weighs more

Source: (Edvard, 2015).

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3. WORKING OF THE RPG UNIT

The RPG unit is placed on the same level as the road surface. When a moving car runs over the RPG unit, the male flip plate is displaced 5 cm to the female flip plate. This displacement causes potential energy to be stored in the springs. When the spring releases that stored energy (by bringing the male flip plate back to its original position), the racks rotate the pinions by a circumference of 5 cm. This rotation induces a unidirectional rotation in the upper shaft, since the pinions have clutch bearings at their centers. As a result, a uniform, unidirectional, rotation is produced (Chandwani, Patel, & Kothari, 2017).

This rotation in the upper shaft is transferred to the lower shaft by means of a chain drive sprocket. Since torque and angular velocity are inversely proportional, the upper shaft will have high torque and low angular velocity compared to the lower shaft which will have lower torque and a higher angular velocity.

The flywheel in the lower shaft helps to resist the change in the rotational speed of the lower shaft due to its high moment of inertia. As a result, energy is stored in the flywheel and released to the generator which converts the energy stored into electrical energy (Fatima & Mustafa, 2011).

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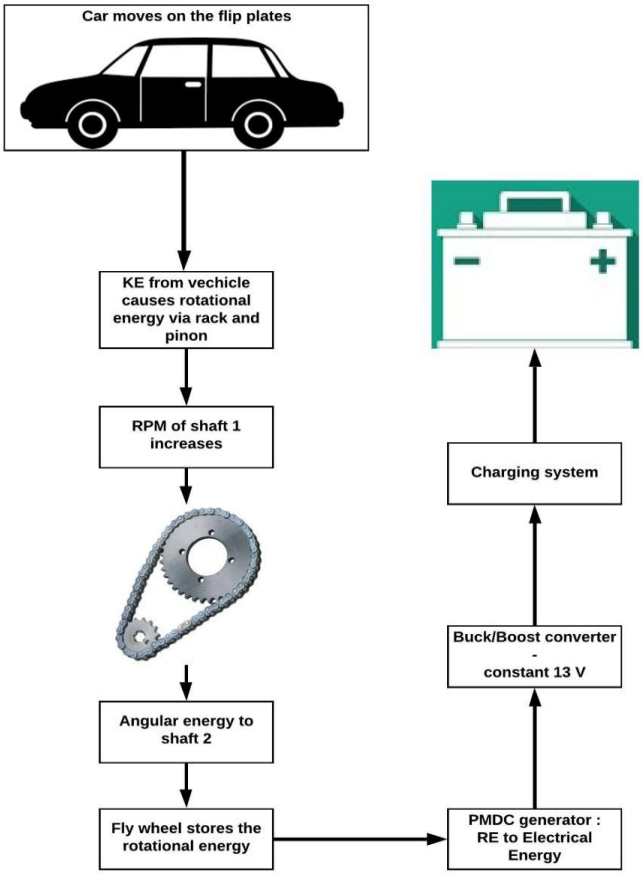

Figure 4. Block of diagram of RPG Working. **Source:** (Gowri *et al.*, 2018).

4. CALCULATIONS

If we suspend a block of mass 1 kg vertically, we can find out the spring constant (k) by simply measuring the displacement (x).

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According to Hooke's law,

$$F = kx \qquad (i)$$

Since the vertical force acting upon the block will simply be the weight,

$$(W = mg) \text{ of the block.} F = \omega \qquad (ii)$$

Equating (i) & (ii), we get:

$$kx = mg$$

Where m is the recorded mass of the object, and x is the extension of the string.

Where $= 10\,kg\,, g = 9.8\,m/s\text{^}2\,, x = 8.64\,cm$,

$$k = \frac{80 * 9.8}{0.0864}$$

$$k = 1133\,N/m$$

The force on each rack is given below with distance between the racks is 5 cm:

$$F = kx$$

$$F = 1133 * \frac{5cm}{100}$$

$$F = 56.69\,N$$

Since there are three racks employed:

$$F_t = F_1 + F_2 + F_3 \qquad (iii)$$

$$\tau_t = \sum_{i=1}^{3} \tau_i \qquad (iv)$$

$$\tau_t = \tau_1 + \tau_2 + \tau_3 \qquad (v)$$

$$\tau_t = r_1F_1 + r_2F_2 + r_3F_3 \qquad (vi)$$

Since r_1, r_2 & r_3 are the radii of each of the pinions, $r_1 = r_2 = r_3 = r$ = 12,7 cm

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$$\tau_t = r(F_1 + F_2 + F_3) \qquad (vii)$$

Substituting Equ. (iii)

$$\tau_t = F_t \qquad (viii)$$

$$\tau_t = \frac{12.7}{100} * (56.69 * 3)$$

$$\tau_t = 21.59\ N.m$$

From Newton's second law:

$$\tau_t = I * \alpha \qquad (ix)$$

$$\tau_t = I * \frac{\omega_L}{f} \qquad (x)$$

Where, is angular velocity of shaft and is the inertia

$$I = \frac{1}{2} * m * r^2 * 3 \qquad (xi)$$

$$I = \frac{1}{2} * \frac{320}{1000} * (\frac{12.7}{100})^2 * 3$$

$$I = 0.007774192\ kg * m^2$$

From equation (x):

$$\omega_L = \frac{\tau_t * t}{I} \qquad (xii)$$

$$\omega_L = \frac{21.59 * t}{0.007774192}$$

Assuming that the car on the RPG unit is driving at a speed of 50 km/hr which translates as 13.88 m/s

$$13.88\ meters \longrightarrow 1\ second$$

That means

$$1\ meter \longrightarrow \frac{1}{13.88}\ seconds$$

Since the distance between the plates is 5 cm

$$0.05\ meters \longrightarrow \frac{0.05}{13.88}\ seconds$$

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$$\omega_L = \frac{21.59}{0.007774192} \times \frac{0.05}{13.88}$$

$$\omega_L = 10.05\ rad/sec$$

Converting to RPM

$$\omega_L = 95.48\ rpm$$

From chain drive we know

$$\frac{\omega_2}{\omega_1} = \frac{Teeth\ of\ large\ sprocket}{Teeth\ of\ small\ sprocket} \quad (xiii)$$

Where is the angular velocity on shaft 2.

Teeth of large sprocket = 66 and teeth of small sprocket = 22

$$\omega_2 = 95.48 * \frac{66}{22}$$

$$\omega_2 = 286.44\ rpm$$

The shaft transfers this angular velocity to the sprocket of the generator with a gear ratio of 85/17

$$\frac{\omega_3}{\omega_2} = \frac{Teeth\ of\ large\ sprocket}{Teeth\ of\ small\ sprocket} \quad (xiv)$$

Teeth of large sprocket = 85 and teeth of small sprocket = 17

$$\omega_3 = 286.4417 * \frac{85}{17}$$

$$\omega_3 = 1432.20\ rpm$$

The EMF produced by the generator is represented by the equation below:

$$E_g = K * \varphi * \omega \quad (xv)$$

Where K is a constant, φ is the flux and w is the angular velocity.

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5. RESULTS AND CONCLUSION

In this paper an Electro-mechanical system was designed and implemented. It is clear that the factors affecting the power production is the spring's constant 'k' and the distance between the plates. Since it was not possible for us to continuously change the distance between the flip plate A and B, we decided to change the spring constant. Upon experimentation, following results were obtained.

Table 2. Results.

	Spring Constant	Power produced per-car	Expected Power produced per day
1.	1133 N/m	3 Watts	6 kilo Watts
2.	1278 N/m	3.6 Watts	7.2 kilo Watts

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