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# Defining the Contextuality around Heritage Site to Maintain Cultural Sustainability

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## Abstract

Addressing pressing contextual issues related to settlements near world heritage sites is imperative. Preserving a settlement's unique identity and maintaining a sense of place and cultural sustainability in the area is crucial. This paper aims to explore the contextuality of Borobudur Temple and examine how the existing conditions support its contextuality. Our research focuses on the roof styles and motifs of the area, and we interpret contextuality through relief readings. To assess the contextual factors of the existing buildings along the Balaputeradewa corridor, we used matrix analysis and concluded how the context of recent buildings affects the area. Our findings indicate that variations in roof styles and motifs are crucial considerations for cultural sustainability. While some existing buildings reflect these findings, others are out of context. Moreover, some contexts in relief are outside the research area. These findings can be utilized to develop strategies for cultural sustainability in both rural and urban areas, especially in maintaining the area's sense of place.

**Keywords:** Contextuality, Relief of Borobudur Temple, Roof Style and Motifs, Cultural Sustainability

## 1. Introduction

### *1.1 Cultural Sustainability in Sustainable Development*

UNESCO identifies four critical dimensions of sustainable development: society, environment, culture, and economy. Cultural considerations must be taken into account. Cultural offerings such as tourism, food, and handicrafts have the potential to contribute significantly to economic growth. Moreover, cultural sustainability is an essential component of sustainable development, as it enables the preservation and enhancement of important values and attitudes in the face of external pressures.

Cultural sustainability is intricately linked to the concept of a "sense of place". This term refers to the unique life experiences that are associated with a particular location (Graham et al, 2009). A sense of place is defined by the specific characteristics of a space that give it an identity, and it can be recognized through these qualities. These qualities are influenced by three main factors: the physical form of the space, the activities that take place there, and the meanings that are associated with it (Lynch, 1960). While everyone may have a different sense of place

for a given location, all of these meanings are rooted in the physical elements of the space and the individual's experiences there (Hasbullah, 2021).

Academic literature employs the sense of place in two distinct ways. Firstly, it is utilized as a *genius loci*, exploring the various elements that contribute to the local character, such as topography, cosmology, the built environment, and the emotional and psychological connections that people have with the place. Secondly, the sense of place is used in life experiences to comprehend how a particular place influences one's identity (Shamai, 1992). The significance of physical elements and related concepts in the definition of place cannot be overstated. While physical features exist as an objective reality of space, they are only one of three known components of place: physical context, activity, and meaning (Carmona, 2013).

The spirit of place holds both physical and non-physical strengths that can leave a lasting impression on a city (Mutfiandi & Soemardiono, 2009). The interdependence of past traditions, identities, and perceptions of time travel is reflected in the contextual nature of buildings and urban landscapes. Attention to contextuality is crucial in historical sites to avoid a disconnect between old and new identities and to preserve the value of the spirit of place (Ostanevics, 2017). The root of the word "context" comes from the Latin verb *contexere*, meaning "weave together, weave, join, write" (Hufford, 2003). Context refers to the state that sets the stage for an event, statement, or idea in a fully comprehensible sense (Oxford, 2021). Additionally, context can be defined as a combination of phenomena, circumstances, facts, events, and settings that form a broader whole, background, environment, or framework (Cizgen, 2012).

City development is important in terms of time adjustment, but by directing, it is expected to provide the best results for the whole connected city. This is because contextualism in architectural design aims to create unifying relationships and dialogues, an idea that aspires to move coherently in its entirety while carving out a niche for itself. The starting point for designing in context is the evaluation of the existing structure and the conclusion that the existing structure is considered important for urban urbanism (Ostanevics, 2017). And or the purpose of contextual architecture is to preserve the natural beauty of the site through careful design that relates to the surrounding Wolford in (Zhou & Zhang, 2015).

Context cannot be understood as standard or inviolable but must be interpreted, manipulated, changed, or rediscovered during the architectural design process (Dağlıoğlu, 2015). Respect for context and contextual design always tries to connect new architecture with that already exists, thus encompassing it in overall sustainable progress (Feisal, 2019). Contextualism is considered to achieve aesthetic fitness for the preservation of historical areas (Sotoudeh & Abdullah, 2012), such as the importance of an interdisciplinary approach in an interactive framework involving architecture, urbanism, and restoration in a case study of development in a historical context in the Tabriz Bazaar Complex, Iran (Gharebaglou et al, 2019).

The role of urban development in adapting to changing times cannot be overstated. By strategically directing development efforts, the best possible outcomes can be achieved for the entire interconnected city. Contextualism in architectural design is key to achieving this goal. Its focus is on fostering cohesive relationships and dialogues that enable the city to move forward as a whole, while also creating distinct spaces that are unique in their own right. To begin designing within a specific context, it is crucial to assess the current structures in place. These structures hold great significance in urban planning, and contextual architecture strives to maintain their inherent charm through thoughtful design that complements the surrounding landscape. Nonetheless, it is essential to understand that context is not necessarily fixed and may require interpretation, manipulation, alteration, or rediscovery throughout the design phase. Valuing context and contextual design involves integrating new architecture with existing structures to promote sustainable progress. This approach is especially crucial for preserving historical areas. A multidisciplinary approach that incorporates architecture, urbanism, and restoration is essential, as demonstrated by a case study of development in the historical context of Tabriz Bazaar Complex in Iran.

Contextuality can be divided into four categories (Cizgen, 2012; Mirhallaj, 2016): 1) visual/physical context, 2) formal/climatic context, 3) human/historical context, and 4) sociocultural and economic context. Among these categories, the visual/physical context offers a comprehensive overview of an area's unique contextual identity.

In this case, the design interprets and applies elements such as size, scale, rhythm, mass, and the use of colors and materials in a compatible manner with surrounding buildings. The types of contexts are time, space, and people. The context of time consists of technology and the economy. The context of space consists of geophysical and climate. Meanwhile, from the geophysical context, it consists of buildings, monuments, and landscapes. Furthermore, in the context of people, it consists of perception, needs, and tradition. Sanghvi provides several criteria that need to be considered to build in context, namely: order, scale and proportion, color, materials and texture, symmetry, rhythm, and details (Sanghvi, 2017).

To ensure a harmonious integration of new designs into historic environments, a set of guidelines has been established. These guidelines emphasize the importance of ensuring compatibility with various aspects of the environment such as height, street line, facade composition, rhythm, and pedestrian experience. Additionally, attention should be paid to the correlation between the facade and the context with regards to massing, sitting, height, setback, orientation, rhythm, material, color, and scale. Designers must also consider the character, scale, form, sitting, materials, color, and detailing of the historical environment. Finally, there are five building conditions and their contexts, which include homogeneous, similar, different, contradictory, and diametrically opposed.

## 2. Method

The research conducted in this study utilized a qualitative descriptive methodology. A narrative review of past research on relief in the Borobudur temple was used to establish the context of the research area. The study collected and analyzed various interpretations of the relief in the temple, particularly those related to the roof style and its motifs. These interpretations were based on leading theories about contextuality (Alliance, 2007; Ostanec, 2017; Beamer, & Pidcock, 2005). The roof was chosen as a focus because it is an important element of a building that affects its physical shape, such as its height, street line, facade composition, scale, and massing. The researchers then used contextuality variables to assess the extent to which the existing research area was contextualized. The corridor of Balaputeradewa was chosen because it had undergone significant changes and was located near the Borobudur temple. Additionally, many building developments in this area were driven by the financial background of residents. The researchers analyzed 137 buildings using contextuality variables in different groups of research findings. The study focused solely on analyzing the roof style and motif on relief, comparing it to the existing conditions collected through visual corridor survey techniques. Matrix analysis was used to assess the contextuality of the research area along the corridor. Analyzing roof style and motif on relief and comparing it to existing conditions collected by visual corridor survey techniques. Matrix analysis was used to assess the contextuality of the research area along the corridor.

## 3. Results and Discussion

### 3.1 Existing condition in Balaputeradewa corridor around Borobudur Temple

There were 137 buildings to assess to get how the context of existing condition, along corridor of Balaputeradewa, both on south and north side of corridor.

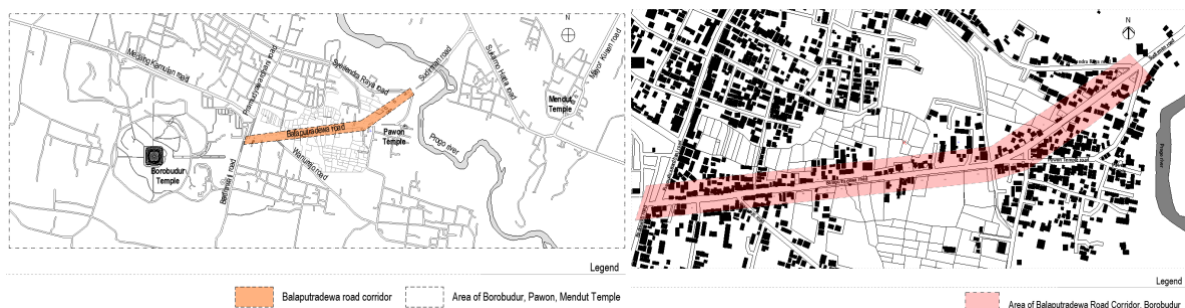


Figure 1: The context of research area and Borobudur temple (left) and research area (right)

Source: Rahmat, 2022

The existing condition, the corridor consists of a rice field area, a commercial area, a public garden, and private houses (figure 1). Most of the buildings have been changing from their original shape to the recently needed shape, i.e., commercial facade. Less than 50% of the total building looked like to consider the context of Borobudur temple. Some of the empty lands have a big potential to develop a new building, and the chance to refer to the context is pessimistic so far.

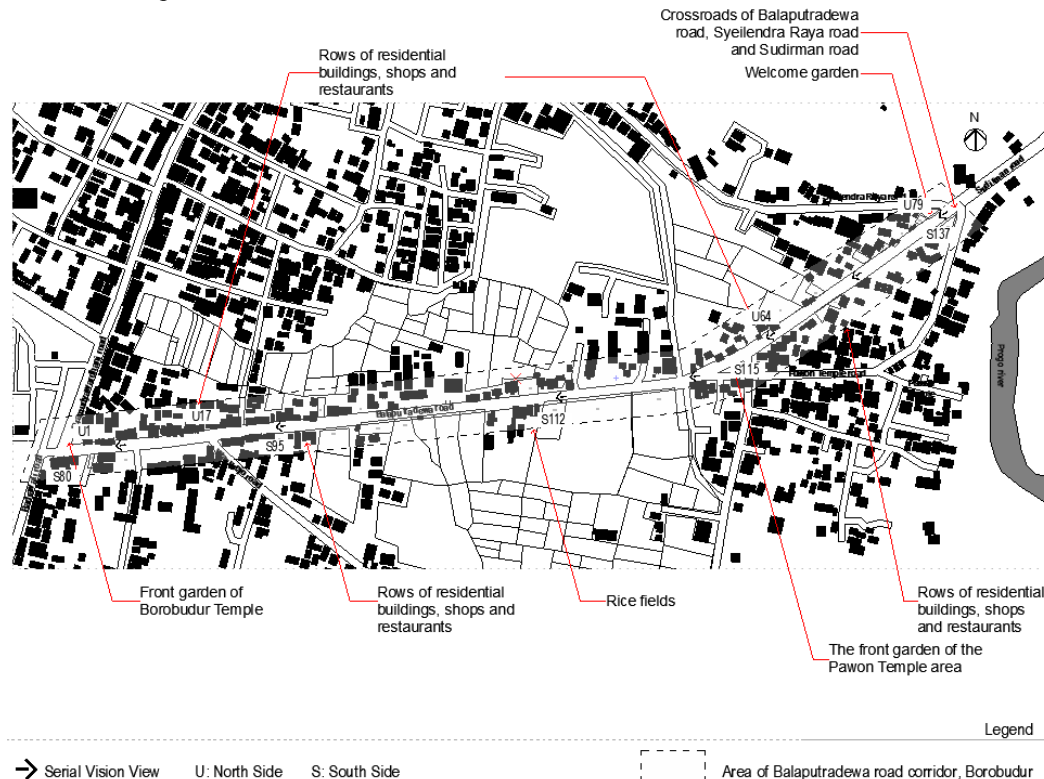





Figure 2: Spatial zone along Balaputeradewa corridor

Redraw by Rahmat, 2022








### 3.2 Findings of architectural style, motifs, and themes in relief of Borobudur temple

In the discussion of Javanese vernacular architecture depicted on The *Karmawibhangga* relief panels, various forms of roofs, walls, foundations, building functions, and materials are identified. Notably, the shape of the roof stands out as the most prominent feature from an architectural perspective. Hardiati and Priatmodjo grouped the identified roof shapes into three categories: shield, saddle, flat, bell, curved, and danted roofs, often made with leaves or grass. The shape of the wall follows the function of the building, with residential houses being closed and meeting places, palaces, and courts being open to the public. The relief panels also reveal two main types of buildings: temples and residential houses, with stone pedestals and wooden poles commonly used for foundation elevation (Hardiati & Priatmodjo, 2008). Table 1 showcases recent research on the Borobudur temple relief panels, contextualizing the surrounding area and illustrating the diversity of roof styles and building functions.

Table 1: Relief in Borobudur Temple which draw the Contextuality of Building

No	Roof style	Relief
1	The O30 panel scene identifies the building with a shield roof shape (front) and a gable roof (back). The function of the building as a temple.	
2	Panel scene O158 identified a building with a perisan roof, functioning as a sanctuary (sanctuary)	
3	Panel scene O47 identifies a residential house with a shield roof (in the middle) and a gable roof (on the side).	



4	Panel scene O65 identifies a residential house with a gable roof for a person (left), the house on the right is identified with a slightly curved gable roof (bell), an open wall with the function of a semi-public building for many people (right).	
5	The panel scene O128 identifies a building with a flat roof that functions as a public building where important people meet, the walls are open	
6	The panel scene O129 identifies a building with a roof shape (Bell), which functions as a place for the royal palace, the walls are open.	
7	The O76 panel scene identifies a building with a bell roof with a function as a place to try guilty people, the walls are open.	
8	The O88 panel scene identifies a building with a curved roof shape like a stupa with the function of a building in hell.	
9	One of the panel scenes identified the shape of a curved roof with the function of meeting people (perhaps the royal court), the walls are open	
10	The relief panel scene identified a building with a sunken roof with a stupa crown, functioning as a temple.	

Roof style that drew in Borobudur temple can conclude in table 3 as the group of roof style that open the possibility to analyze the context around Borobudur.

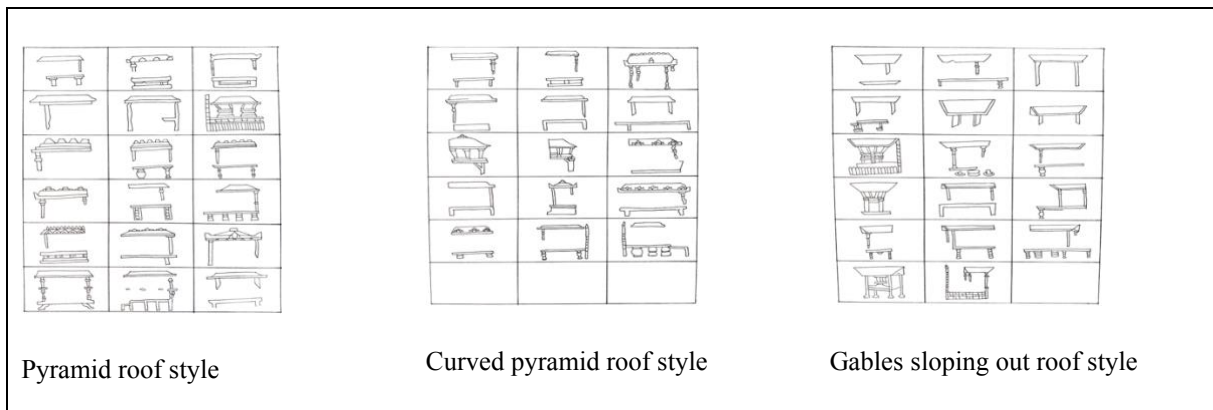


Figure 3: Roof style interpretation from relief

The research assessed the existing roof style to the roof style in relief. Some of roof style used saddle type and shield type.

Table 2: Roof assessment refers to the roof types in relief of Borobudur.

Roof style	Qty.	Code of building									
		1	2	3	4	5	6	7	8	9	10
Shield style.	10					U1	U2	U2	U3	U4	U5
		U1	U5	U6	U9	8	2	3	9	6	2
				U5		U6	U7	U7			
		U53	U54	8	U60	2	2	3	S80	S86	S90
		S1		S1	S1	S12	S13	S12	S12		
		S92	S95	03	S109	17	27	8	6	4	3

		S82	S132								
Saddle style.	64	U2	U3	U4	U7	U8	U1	U1	U1	U1	U1
				U1		U2	U2	U2	U2	U3	U3
		U15	U16	7	U21	4	5	6	8	0	1
				U3		U4	U4	U4	U4	U4	U5
		U32	U33	5	U38	1	2	3	8	9	0
				U5		U7	U7	U7			
		U51	U57	9	U70	1	4	5	S81	S83	S85
				S9		S9	S9	S10	S10	S10	S10
		S87	S93	4	S97	8	9	0	1	7	8
				S1		S1	S1	S12	S12		S13
	S111	S118	19	S120	21	26	9	5	S91	1	
			U4								
		S134	S110	0	S135						
Plat style	2	U19	U36								
Bell style	0										
Curved style	0										
Dented style	0										
<i>Panggang Pe</i> style	9	U27	U56	U6	U63	U6	U6	U7	S13	U4	
Shield and saddle combination	5	U64	U65	U4	U55	S8	9				
Shield and flat combination	1	S116									
Unidentified	2	U20	U29								
Landscape (no building)	22	U34	U37	U4	U66	U6	U7	U7	U7	S84	S88
				S1	S105	S1	S1	S11	S11	S11	S12
		S96	S102	04	06	12	3	4	5	2	
		S137	S133								
<b>Total</b>	<b>137</b>	<b>S: South side of corridor; U: North side of corridor</b>									

Table 4 summarizes the function of each roof type. The prevalent roof styles for houses are shield and saddle roofs. However, for public buildings such as palaces, courts, stupas, and temples, there is a variety of roof styles including flat, bell, curved, danted, and *Panggang Pe* styles. This discovery suggests that public buildings in the vicinity of Borobudur have many different roof variations, which contribute to the sense of place in that area during ancient times. Only two simple roof types, shield and saddle, are used for houses. This is likely because as private properties, houses do not play as significant a role in defining the sense of place for the area.

Table 3: The building function of each roof style

Roof Styles	The Building Functions
Shield roof style	House, religious activity
Saddle roof style	House
Flat roof style	Public building with open wall
Bell roof style	Palace, court, <i>stupa</i>
Curve roof style	Public building (palace)
Danted roof style	Public (palace/ temple)
<i>Panggang Pe</i> roof style	Public

For the motif on each roof style, stated in table 4

Table 4: Variation of roof motifs in Relief

No	Variation of roof motif
1	Plain motifs
2	Vertical block motifs
3	Wreath and tassel ornament motifs

### 3.3 Analysis of the contextuality in existing building

This segment will evaluate the contextual nature of the research zone. Among the 137 structures lining the path of Balaputeradewa, 116 are tangible edifices while 21 constitute landscape garden fences, sculptures, gates, gardens, rice fields, and farm areas. The tabulated data below pertains to the examination of roof styles, which directly correlates to the discoveries made in Borobudur relief.

Table 5: Analysis of recent roof style in Balaputeradewa

Roof Styles	Total buildings
Shield roof style	32 buildings
Saddle roof style	66 buildings
Flat roof style	2 building
Bell roof style	0
Curve roof style	4 buildings
Dented roof style	0
<i>Panggang Pe</i> roof style	9 buildings
Combination of shield and saddle style	4 buildings
Combination of shield and flat	1 building
Not identified	2 buildings

Two buildings remain unidentified due to the recent addition of a facade obscuring their original roof structure or form. Regrettably, current research cannot identify roofs with distinct bell, curve, or dented styles within the existing building typology. In terms of roof motifs, plain motifs were used in 90 buildings, vertical block motifs (antefix) in 26 buildings, while garland and tassel motifs were not used in any buildings. The inclusion of unique roof types in a building's design can present challenges when developing a contextual strategy for its new function. In today's world of franchised businesses, specific building designs, motifs, and interior decor are often pushed forward. However, without proper regulation, this phenomenon could make it difficult to achieve cultural sustainability around heritage sites. To maintain the sense of place around the Borobudur temple in Balaputeradewa, corridor development strategies must be considered in governmental public policy. This includes regulations for building design, such as roof styles and motifs, and building improvements that align with the context of Borobudur itself. As such, the study of roof styles and motifs is one of many ways to understand the context of the Balaputeradewa corridor.

Borobudur's relief was utilized in the analysis due to gaps in regulations concerning the architectural style of buildings around the area, such as the UDGL of Borobudur and the Government law about National Tourism Strategic Area (*Kawasan Strategis Pariwisata Nasional – KSPN*). While there are buildings around the

Borobudur complex (*Kompleks Taman Wisata Candi Borobudur*) that can serve as a precedent for assessing contextuality, the challenge lies in the Balaputeradewa corridor and other corridors outside the temple complex, which are privately owned. Unfortunately, private property presents a higher gap between maintaining a sense of place and economic issues. Preserving cultural sustainability around heritage sites is crucial for maintaining the sense of place in the area. To achieve this, guidelines for roof styles and motifs are often recommended. By leveraging data from relief in places like the Borobudur temple, creating a precedent for improvement becomes possible. By adapting these styles to fit both new and old building guidelines within their context, cultural sustainability can be effectively maintained within heritage sites. The impact of such preservation efforts can be significant and long-lasting.

#### 4. Conclusion

The Borobudur temple boasts ten unique roof styles that are categorized into pyramid, curved pyramid, and gables sloping out styles. These styles are further enhanced by three roof motifs, including plain, vertical block, wreath, and tassel motifs. Unfortunately, two of the roof styles remain unidentified due to the recent building cladding that obscures the original roof structure. The lack of information on these two roof styles and two roof motifs presents a challenge for maintaining the heritage and cultural sustainability of the Borobudur area. New regulations will need to be implemented to ensure that the sense of place is preserved.

The research findings suggest that the roof style and motifs can serve as physical form indicators for maintaining a sense of place and cultural sustainability in heritage areas. By using the Borobudur temple as a contextuality indicator, we can develop strategies to maintain cultural sustainability beyond the building's form, style, material, and color.

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# The Effect of Supply Chain Disruptions on Business Post COVID-19

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## Abstract

There are many reasons for experiencing supply chain disruptions. The reasons could be miscommunication between the factory and the warehouse, miscommunication between the warehouse and the stores, or miscommunication between the stores and the customers. We investigated these possible disruptions throughout this paper with the help of a questionnaire. We further investigated the effect of various problems that may occur with the company stock which resulted in supply chain disruptions. There have been many papers written about the effect of the disruptions regarding these problems. With the goal of finding out the tactical approach from the company affects the value of the stock, we investigated this further. Additionally, this paper examined the nature of the tactical standings of the company and the effects on supply chain disruptions and the position of the company stock. Based on the responses to the questionnaire, we found how the tactical elements affect the supply chain disruptions. We also showed the effect of the supply chain disruptions on the company stock.

**Keywords:** Supply Chain Management, Supply Chain Disruptions, Disruptions due to Inventory, Disruptions due to Miscommunication between Factory and Warehouse, Disruptions due to Miscommunication between Warehouse and Store, Disruptions due to Miscommunication between Store and Customer

## 1. Introduction

This paper looks at the effects of how disruptions affect the firm and their position in the stock market. We will also discuss how the tactical elements of supply chain affects the wellbeing of the company in terms of their position in the stock market. "A Supply Chain Disruption is an unplanned and unanticipated event that disrupts the normal flow of goods and materials within an entire supply chain" (WGA Consulting, 2017). Because supply chain disruptions are occurring more frequently and with greater intensity, supply chain disruptions are on a continual increase. A supply chain disruption begins with one simple mistake or issue that continues to affect the product, its assembly, testing the product, and shipping the product (Gurman, M., Wu, D., & Bloomberg, 2020). In this part of the paper, we show how supply chain processes effect the cost, procurement, logistics, managing returns and risks, and creating an effective supply chain (Stevenson, 2017).

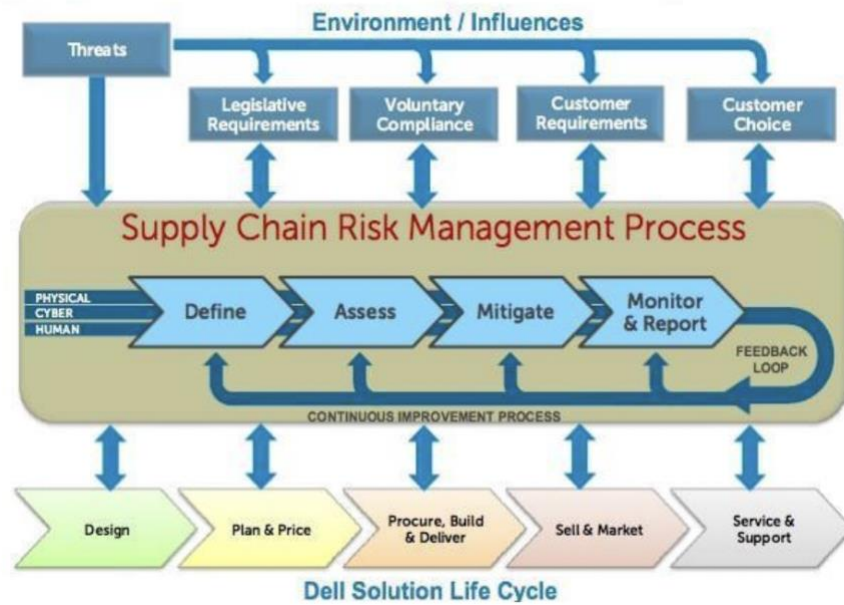


Figure 1: The map of Supply Chain Risk Management Program

There are many factors that weigh into how supply chain disruptions occur. Supply chain risk is shown above in figure 1. Some of these factors include timing, cost, product type, possible risk of a supply chain disruption because of excess inventory or lack of inventory (Luthy, J., 2018). Supply chain risk management is when trying to control risks by being able to legislate the proper requirements to comply voluntarily with the environmental risks while satisfying customers’ requirements and choices.

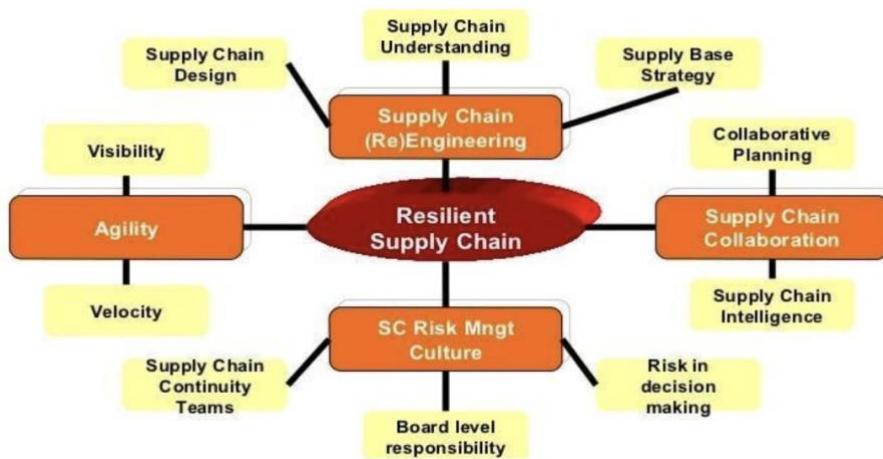


Figure 2: Supply Chain Risk Management Framework.

In figure 2, many aspects of supply chain are shown from understanding the supply chain to collaborative planning. Supply chain risk is shown toward the bottom of the figure. This figure shows how supply chains can be reengineered in an agile environment. We tried to show how supply chains can be planned collaboratively, with the help of a team. Supply chain can be further demonstrated with the team in the context of managing risk.

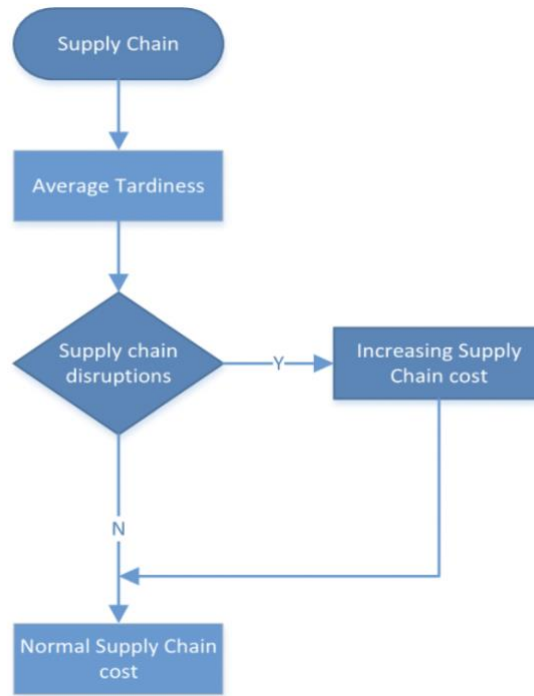


Figure 3: Effect of Average Tardiness on Supply Chain Disruptions and Cost.

In this paper, we also try to control how disruptions affect the position of the firm with respect to inventory. We will try to show how disruptions affect the position of the company with respect to the stock market. We also try to show how average tardiness affects the supply chain disruptions with respect to the cost of the supply chain. As shown in figure 3, we illustrate how average tardiness affects the supply chain disruptions and cost. For example, as illustrated in figure 3, if there is an increased cost the outcome of the supply chain may be affected by increasing the amount of time before the cost returns to normal for the supply chain. The average tardiness affects the supply chain cost due to shifting it from the normal supply chain cost, as shown in the example below.

A machine shop produces customized machinery for the aerospace industry. A particular machine has the following six jobs waiting to be processed.

Table 1: Original Machine Processing Time with Due Dates.

Job	Due Date	Processing Time (Days)
A	28	5
B	15	7
C	19	3
D	10	8
E	20	6
F	25	4

We should create a table according to the earliest due date sequence. This sequence is shown in the table below.



Table 2: Original Machine Processing Time with Due Dates according to earliest due date.

Job	Due Date	Processing Time (Days)
D	10	8
B	15	7
C	19	3
E	20	6
F	25	4
A	28	5

Table 3: Calculation of Lateness and Tardiness.

Job (EDD)	Flow Time	Due Date	Lateness	Tardiness
D	8	10	8-10=-2	0
B	8+7=15	15	15-15=0	0
C	15+3=18	19	18-19=-1	0
E	18+6=24	20	24-20=4	4
F	24+4=28	25	28-25=3	3
A	28+5=33	28	33-28=5	5
Total			-2+0+-1+4+3+5=9	4+3+5=12
Average			9/6=1.5	12/6=2

Lateness = flow time – due date

Tardiness = lateness if positive. Negative and zero values = zero

Table 1-3 elaborate of the Original Machine Processing Time with consideration of the Due Dates which include the earliest due date and the calculation of lateness and tardiness. If you look at table 3 it starts with 8 days. So, 8 days in addition to 7 days is 15 days of flow time. The Due date is in 15 days therefore for job B there is no tardiness. Tardiness measures how late the arrival will be in days. Tardiness is 0 if the items arrive early. For example, considering job E in table 3, we have a situation where item E comes after item C. Looking at the table and the due dates, we can see that a supply chain disruption occurs with item E because the flow time takes longer than the due date which results in a four-day tardiness of the job. The flow time for item E is 24 days. However, item E was due on day 20, which makes item E tardy by 4 days. Disruption occurs because item E is tardy by 4 days. This flow time situation lingers into the following items tardiness status. The disruption in item E affected the following items F and A.

Table 4: Medical Equipment used in Supply Chain

Number of Disruptions Occurring due to	Shortage/Surplus of Supplies (effect of number of units short)
Vaccines	44.4 Million Doses (USA)
N95 Face Masks	160 Million per month
Nitrate Gloves	800 Million per year
Hand Sanitizer	400 Million per year
Syringes	Low dead weight needles reported to become a shortage if demand exceeds supply. They account for 14% of syringes

**Vaccines:** 10x the effect of the shortage makes the vaccine more valuable due to the fact that there is such a limited supply of vaccines at the moment with an ever-increasing demand.

**N95 Face Masks:** Universal facemask wearing policy would put an enormous burden on the facemask supply.

**Nitrate Gloves:** The overall shortage in gloves is more valuable than the surplus. The world needs hundreds of billions of new pairs of gloves. Part of the reason for the glove shortage has to do with the inherent manufacturing limitations that deal with a decreased availability of labor for these gloves and materials.

**Hand Sanitizer:** There are 400 million units of hand sanitizer produced per year. Due to Covid-19 the demand of hand sanitizer increased substantially over a short period of time, therefore resulting in a shortage of hand sanitizers.

**Syringes:** A low dead space needle is a type of syringe that holds the maximum amount of fluid in the needle. The plunger pushes up against the needle and allows for even more vaccine doses to be given from the tiny glass bottles. These needles were never as important because we haven't had a product like this that has been so valuable and in such a small quantity.

**Of the 286,000,000 syringes made by the largest manufacturer, Becton Dickinson. The federal government asked for this company to make 40M are low dead space syringes.**

Table 5: Vaccine Types Available

Vaccine Brand	Capacity per Year	Dose Required per Patient	Efficacy	Dose per Vial
Moderna	20 million	2	94.5%	8-10
Johnson-Johnson	100 million	1	66.1%	15
Pfizer	20 million	2	95%	6

In this Covid environment there are various vaccines that have been developed the vaccines are summarized in the following table.

Table 6: Population's vs COVID-19 Cases and Deaths

Country	Population	# of Cases	# of Deaths	% of cases to Population	% of deaths to Population
United States	329,731,224	27,882,557	496,112	8.46%	0.150%
Mexico	126,577,691	2,041,380	180,107	1.61%	0.142%
Canada	38,037,578	845,652	21,674	2.22%	0.057%
Turkey	84,338,067	2,646,526	28,138	3.14%	0.033%
Australia	25,499,884	28,930	909	0.11%	0.004%
Italy	60,461,826	2,818,863	95,992	4.66%	0.159%
Argentina	45,195,774	2,064,334	51,198	4.57%	0.113%
Netherlands	17,134,872	1,060,801	15,249	6.19%	0.089%
United Kingdom	67,886,011	4,126,150	120,757	6.08%	0.178%
New Zealand	4,822,233	2,357	26	0.05%	0.001%
Brazil	212,559,417	10,168,174	246,560	4.78%	0.116%

Upon examination of table 5, it is easy to see that the most populated countries, United States, Brazil and Mexico also share the highest number of cases. With this noted, these three countries also share the highest number of deaths. In the table, the dark red and dark green represent the largest population and highest number of cases and deaths. Green specifically represents population. For example, the United Kingdom although their population is smaller than the USA, the United Kingdom has a higher death rate per population. New Zealand and Australia, with consideration that they do have active cases (not many when compared the rest of the countries) the death rate is very low for these two countries. Italy, (death rate .159%) having a population of over 60 million which is roughly 18% of the USA's overall population has a higher death rate than the USA (death rate .150%).

## 2. Methodology

Questionnaire

What is the current management structure?

- A. Top down
- B. Bottom up
- C. Left right
- D. Middle right

The nature of supply chain:

- 1. Warehouse to retail
- 2. Store to store
- 3. Factory to store
- 4. Warehouse to factory
- 5. Retail to store
- 6. Store to customer
- 7. Retail to customer

Possible supply chain disruptions due to problems between different parts of the business:

- A. Problem with the shipment from warehouse to factory
- B. Problem with shipment from factory to store
- C. Problem with shipment from warehouse to customer
- D. Problem with shipment from store to customer

Possible supply chain disruptions due to transportation:

- A. Problems with transportation to customer
- B. Problems with transportation to the warehouse
- C. Problems with transportation to the store
- D. Problems with transportation from the factory

Possible supply chain disruptions due to problems with communications among:

- A. Factory and store
- B. Factory and warehouse
- C. Warehouse and customer
- D. Warehouse and store

Possible supply chain disruption with inventory:

- 1. Too much inventory in the factory
- 2. Too little inventory in the factory
- 3. Communication problems between the factory and the warehouse
- 4. Communication problems between the warehouse and the stores
- 5. Communication problems between the stores and the customers
- 6. Too little inventory in the warehouse
- 7. Too much inventory in the warehouse

Scheduling:

- 1. Low volume systems effect on supply chain disruptions
- 2. Services effect on supply chain disruptions
- 3. Strategies effect on supply chain disruptions
- 4. Minimize average tardiness (Average tardiness = total tardy days/number of jobs)
- 5. Average lateness is always less than or equal to the
- 6. average tardiness

Management of waiting lines:

- A. Managerial implications of waiting lines
- B. Goal and strategy of how waiting lines are managed
- C. The impact of waiting lines on supply chain disruptions
- D. The impact of characteristics of waiting line on supply chain disruptions

In the future we want to run a survey comparing the supply chain disruptions per country using these questions. The questionnaire would explore the basic knowledge that business officials would have in regards to supply chain. For which we can then use to evaluate why certain countries/ business are having supply chain problems. For example, knowledge on possible disruptions involving inventory can allude to knowledge that is not acquired by potential inventory managers which can affect the supply chain and create a distribution. Therefore, there will be a shortage versus having an excess inventory of additional product. The questionnaire can also give valuable insights about the management of waiting lines. Waiting in line can cause a disruption in a supply chain so understanding how to effectively manage them is crucial to a successful supply chain. This ties into the idea of scheduling. Accurate and time-based deliveries of equipment result in less waiting time for the receiver of the equipment.

### 3. Discussions

In this paper we will discuss how disruptions affect the tactical nature or position of the company with respect to performance in the stock market. We will also discuss how a decline or increase in the inventory will affect the supply chain disruptions and ultimately how it will affect the position of the company on the stock market. We will try to show how average tardiness affects the supply chain disruptions, as shown in figure 2.

We can mitigate the effect of supply chain disruptions with the risk of understanding it (Gray, S., 2019). There is additional pressure put on the company when the supply chain disruption changes. When discussing possible risks for supply chain disruptions, having unreliable transportation and possibility of delays is a significant risk. To help avoid this risk, companies must have proper communication between each factory, warehouse, and stores transportation methods (Gray, S., 2019). We also learned that due to the COVID-19 pandemic, demands for a product or service can swing tremendously depending on what is happening in the world. For example, at the beginning of the pandemic the demand for air travel dropped tremendously due to the fact that everyone was in a lockdown. The lockdown then also caused the demand of supplies such as toilet paper and paper towels to skyrocket, leaving thousands of potential buyers emptyhanded when it came to supplies such as those (Montgomery, O., 2020).

The COVID-19 pandemic has shifted the business environment for organizations across the world. It has placed an emphasis on the importance of being able to react, adapt and set up crisis management mechanisms in order to weather situations of uncertainty. As restrictions and lockdowns began to create many dire situations that required immediate attention in the early stages of the pandemic, many companies are now beginning to move into "recovery mode" and began to plan for the long term. As companies seek to strengthen operations, the importance of supply chain resilience and risk management is more apparent than ever (Hedwall, M., 2020).

There are many negative effects of this pandemic that have affected many companies' supply chain such as airlines, shipping industries, food industries, the health care industry and so forth. However, one aspect that many people have looked over is the emergence of communication-based technology and sharing based technology. Applications such as Zoom and Microsoft teams were always around but were never as big as they are today due to COVID-19. The lockdown required people to go out and find new methods to see each other and communicate face-to-face and applications such as Zoom and Teams were able to do just that (Flynn, B., Cantor, D., Pagell, M., Dooley, K., Azadegan, A., 2021). However, we still have many supply chain disruptions related to this pandemic such as the shortages of healthcare supplies and food that must not be overlooked by the emergence of communication and sharing technologies.

How due supply chain disruptions effect the performance of the stock market? A company's ability to get product to the consumer efficiently displays a healthy well ran business. Therefore, if the business is not getting

the product to the consumer, it is because of a supply chain disrupting that has hindered efficient movement of the product. Therefore, customer satisfaction decreases.

From the supplier's perspective, issues that arise within the supply chain are usually those caused by outside issues. For example, Covid-19. Covid's impact on logistical services directly impacted the supplier's ability to continue to function as a healthy service.

Supply chain disruption affect each company differently. For example, shortages of inventory versus surplus of inventory have different impact on the company. Shortages of inventory result in various problems for the manufacturer for that when the customer demand is high for the product, shortages can arise. In an attempt to avoid supply chain disruptions that deal with shortages of inventory, many companies are creating alternative routes to distribution centers and also evaluating new sources for supplies. These alternative outbound routes will positively affect the company's ability to get products distributed to the customers. (Butt, A., 2021).

#### 4. Introduction of the References for Each Article Cited:

Authors Saurabh Ambulkar, Jennifer Blackhurst, and Scott Grawe wrote an empirical examination of the resilience of the firm on the supply chain disruptions: Scale development and empirical examination *Journal of Operations Management* (Ambulkar S., Blackhurst J., Grawe S., 2015).

Authors Chia -Hsien Tang, Chih-Yu Chin, Yen-Hsien Lee wrote an empirical analysis titled *Coronavirus disease outbreak and supply chain disruption: Evidence from Taiwanese firms in China, Research in International Business and Finance*. The research shows a link between the COVID-19 outbreak and the disruption of logistics along with negative returns this had within Taiwanese firms (Chia -Hsien Tang, Chih-Yu Chin, Yen-Hsien Lee, 2021).

Authors Ceyhun Ozgur, Sanjay Kumar and Yiming Shen are responsible for writing the working paper titled the effect of supply chain disruption on average lateness and tardiness and lateness and how that affect can influence the supply chain disruption and also effect the firm. This paper explores how different tactical elements such as 'make to order' or 'make to stock firms' or 'level or chase' strategy of the firm affect the supply chain (Ozgur C., Kumar S., Shen Y., 2018).

Author Ceyhun Ozgur wrote the article titled Coronavirus supply chain disruption will affect those outside China: Sourcing CEO, elaborates on the many reasons for experiencing supply chain disruptions. Miscommunication between the factory and the warehouse or the warehouse and the stores, or the stores and the customers (Ozgur C., 2020).

Author Sinha Deepankar who wrote The Supply Chain Disruption Framework Post COVID-19: A System Dynamics Model. The authors capture the mathematical and operational relationships amongst the relevant factors and propose a System Dynamics model to carry out the simulations. The approach considers the impact of the force majeure condition, that is, COVID period on individuals' income, prices and demand of goods, cost of input and supply of finished goods (Deepankar S., 2020).

Authors M. A. C. Ekanayake, Geoffrey Q. P. Shen, Mohan M. Kumaraswamy responsible for writing Identifying supply chain capabilities of construction firms in industrialized construction. *Production Planning & Control*, elaborate on industrialized construction. This study examines how supply chain resilience can be boosted using clear focus of the relevant and appropriate supply chain capabilities ( Ekanayake M. A. C., Shen G. Q. P., Kumaraswamy M. M. 2021).

Author Frederico F. Guilherme who wrote the article titled "Towards a Supply Chain 4.0 on the Post-COVID-19 Pandemic: a Conceptual and Strategic Discussion for More Resilient Supply Chains." This article basically goes into details about how supply chain disruptions and failures in supply chain management often result in lost sales or financial losses and have a negative impact on shareholder and operating performance. Supply chain

management has been paid to improving the process of managing a disruption from its discovery through to complete recovery process (Guilherme F., 2021).

Authors Derek Friday, David Savage and Steven Melnyk, et.al. wrote the article titled, “A Collaborative Approach to Maintaining Optimal Inventory and Mitigating Stockout Risks during a Pandemic: Capabilities for Enabling Health-Care Supply Chain Resilience.” the article goes into detail about how the COVID-19 pandemic presented unanticipated demand shocks due to stockpiling of medical supplies caused stockouts, and the stockouts triggered systematic supply chain disruptions. This created a risk for customers and put the managers working individually mitigating circumstances they had limited information about (Friday, D., Sqavage D., Melnyk S., 2021).

Authors Jiangxia Liu Sourish Sarkar Sanjay Kumar Zhenhu Jin, responsible for writing the analysis titles, *An Analysis of Stock Market Impact from Supply Chain Disruptions in Japan*, *International Journal of Productivity and Performance Management* elaborates on how supply chain disruptions effect the stock market (Liu J., Sarkar S., Kumar S., Jin Z., 2009).

Authors Harri Lorentz and Olli-Pekka Hilmola, responsible for writing the paper *titled Confidence and supply chain disruptions*, *Journal of Modelling in Management* speak about how managerial behavior is important to consider when supply chain disruptions are affecting the business performance. (Lorentz, H., Hilmola, O., 2012) Authors Elena Revilla and Maria Saenz are the authors of the article *The Impact Of Risk Management On The Frequency Of Supply Chain Disruptions A Configurational Approach*, *International Journal Of Operations & Production Management*, speak about the frequency of supply change disruptions and how they affect the performance of the business. The paper also goes into detail about supply-chain / inter-organizational partners (Revilla, E., Saenz, MJ., 2017).

Authors Dmitry Ivanov, Alexandre Dolgui, Boris Sokolov & Marina Ivanova who wrote the *Literature Review on Disruption Recovery in the Supply Chain*, published in the *International Journal of Production Research* elaborate on recent research underlines the crucial role of disruption events and recovery policies in supply chains. The literature on supply chain design with disruption considerations, there is no survey on supply chain with disruptions and recovery considerations (Ivanov, D., Dolgui, A., Sokolov, B., Ivanova, M., 2017).

Authors Joseph B. Skipper, Joe B. Hanna. Who wrote, *minimizing supply chain disruption risk through enhanced flexibility* talks about how the use of a strategic approach will limit the risk of a supply chain disruptions. Their study show that flexibility has been shown to enhance the ability to minimize risk exposure (Skipper J. B., Hanna J. B., 2009).

Authors Konstantinos Nikolopoulos, Sushil Punia, Andreas Schäfers, Christos Tsinopoulos, Chrysovalantis Vasilakis who wrote the article *Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions*, published in the *European f Operational Research* speak about how policymakers during COVID-19 operate in uncharted territory. This type of research plays a vital role in selling the supply chain distributions related to Covid-19 (Nikolopoulos, K., Punia, S., Schäfers, A., Tsinopoulos, C., Vasilakis, C., 2021).

Authors Kouvelis and Panos are in the *Handbook of Integrated Risk Management in Global Supply Chains*, *John Wiley & Sons, Incorporated* speak about the five key operational strategies, namely stockpile inventory, diversifying supply, backup supply, how to manage demand and strengthen supply chain. In addition, the value of deploying multiple strategies, and identifies some directions for future research to advance the knowledge and practice of supply chain disruption management (Kouvelis, P., 2011).

Author Maxamilian Kunovjanek and Christian Wankmüller wrote the article titled, “An Analysis of the Global Additive Manufacturing Response to the COVID-19 Pandemic.” Published in the *Journal of Manufacturing Technology Management*. This paper elaborates on how the production of medical items, such as personal protective equipment during the pandemic was short of supply when in consideration for the demand. This

shortage caused global supply chain disruption and resulted in countries battling over these products that were desperately needed (Kunovjanek M., Wankmüller C., 2020).

Authors Rachel A. Dowty and William A. Wallace responsible for writing the article titled *Implications of organizational culture for supply chain disruption and restoration*, *International Journal of Production Economics* which is about how to manage supply chain disruptions while teamed up with diverse organizational cultures to work together in order to restore resiliency (Dowty, R., Wallace, W., 2010).

Authors Brian Tomlin wrote the article titled *On the Value of Mitigation and Contingency Strategies for Managing Supply Chain Disruption Risks*. The paper speaks about how suppliers are capacity-constrained, and reliable supplier may possess volume flexibility. The paper shows that in the special case in which the reliable supplier has no flexibility and the unreliable supplier has infinite capacity, a risk-neutral firm. (Tomlin, B., 2006) Authors Sanjay Kumar, Jiangxia Liu, Jess Scutella responsible for writing the paper titled *The impact of supply chain disruptions on stockholder wealth in India*, *International Journal of Physical Distribution & Logistics Management*. The paper speaks about supply chain structure, characteristics, and applicable policies differ between developing and developed countries. Supply chain management research is aimed at supply chains in developed countries, the authors of this paper look at the disruptions of supply chain and the financial impact the disruptions have in India and Turkey (Kumar. S., Jiangxia. L., Scutella, J., 2015).

Author Sanjay Kumar is responsible for writing the paper titled *Advance Warning of Supply Chain Disruption: A Behavioral Experiment*, *11th Annual Behavioral Operations Management Conference, At University of Wisconsin-Madison, Madison* goes on to speak about how improving supply chain performance using predictive tools such as forecast accuracy and inventory management can help disruptions within a supply chain be avoided (Kumar, S., 2016).

Authors Sunil Chopra and Man Mohan S. Sodhi the authors of *Reducing the Risk of Supply Chain Disruptions*, *MIT Sloan Management Review* elaborates on how managers discuss solutions to reduce supply chain disruptions and if those solutions aren't implemented the disruption continues (Chopra S., Mohan, M., Sodhi, S., 2014).

Authors Shahed, K.S., Azeem, A., Ali, S.M. *et al.* who wrote "A supply chain disruption risk mitigation model to manage COVID-19 pandemic risk" speak about how the optimization model focuses on managing supply chain disruptions for a pandemic where disruptions can occur to both the supplier/ retailer. The idea of the inventory-policy using the Renewal Reward theory for maximizing profit for the manufacturer (Shahed K.S., Azeem A., Ali S.M., 2021).

Authors Katrin Schmitt, Ravi Kumar, Kathryn Stecke, Fred Glover, and M. Ehlen who wrote the paper titled *Mitigating Disruptions in a Multi-echelon Supply Chain Using Adaptive Ordering*, *Omega*. Go on to speak about impact of disruption based on facility location and the benefits of expediting the orders (Schmitt, T., Kumar, S., Stecke, F., Glover, F., Ehlen, M., 2017).

Author Tadeusz Sawik, titled *Stochastic Mixed Integer Programming* speaks about practical uses of stochastic approaches and how these approaches can deflect supply chain disruptions. The paper also elaborates on mixed (Sawik T., 2020).

Authors T. Wu, J. Blackhurst & P. O'grady wrote the article titled *Methodology for supply chain disruption analysis*, *International Journal of Production Research* speak about how the complexity of many supply chains, in order to understand the impact of disruptions on the operation of the system. network-based modelling methodology is used to determine how changes or disruptions propagate in supply chains and how those changes or disruptions affect the supply chain system (Wu T., Blackhurst J., O'grady P. 2007).

Author s Nick Wildgoose, Patrick Brennan, and Simon Thompson wrote the article *Understanding your supply chain to reduce the risk of supply chain disruption*. *Journal of Business Continuity & Emergency Planning*, elaborate on how the frequency of supply chain disruptions is high. Understanding this gives practical advice to

help reduce the cost associated. Understanding the frequency will help with the understanding of how to identify critical suppliers (Wildgoose N., Brennan P., Thompson S., 2012).

Author L. Veselovská has published the paper titled *Supply chain disruptions in the context of early stages of the global COVID-19 outbreak* which talks about how central European countries distributed food and supplies during the early stages of the pandemic to assess the long-term effects of it. This study found that nearly 20% of Slovak companies and 30% of Czech companies made little to no changes at all in their operations during the early stages of the pandemic. The study found that those companies were actually able to survive the supply chain disruptions brought among them during the pandemic and this had no effect on the businesses or the supply chain (Veselovská, L., 2020).

Author Atif Saleem Butt looked into the steps/countermeasures taken by buying and distributing firms to address supply chain disruptions caused by the COVID-19 pandemic. He found that buying firms are moving to supply production, focusing on the most important supplier risks, enhancing inbound material visibility and temporarily shutting down production facilities to answer to the challenges caused by COVID-19. He also found that distribution centers are changing their inventory policies, assessing substitute outbound routes and sources of supply to control the disruptions that have been caused to their businesses by COVID-19 pandemic (Butt, A., 2021).

## 5. Post-COVID-19 Implications for Supply Chains

COVID-19 has affected supply chains for businesses. Because of COVID-19 businesses experienced many supply chain disruptions. Some of these disruptions could include lack of inventory or lack of vaccine availability. These disruptions cause many difficulties for businesses including national lockdowns that slow or temporarily stop the flow of goods coming into and going out of the business, this can lead to a disruption in manufacturing. These disruptions can also lead to a lack of workers due to not being vaccinated, this can lead to the greater use of technologies such as robotics or artificial intelligence.

## 6. Conclusion

Supply Chain disruptions are higher in advanced countries like the United States and United Kingdom. But they are low in countries like New Zealand and Australia. When you consider the supply chains in general the first thing we should look at is the availability and efficacy of vaccines. Considering the population of the world we need to consider the supply chain disruptions that can affect the entire world. For example, when we consider the vaccines we should look at the availability of syringes as well. We should also consider how effective the vaccines are. When you look at the number of deaths, we should consider how effective the vaccines are for different populations of people. For that different populations from different countries may not have the same type of health care that a country with a lower death rate has. Turkey has a death rate of .033% while the USA has a much more effective health care system but still has a higher death rate (.150%). Italy has a death rate of (.159%) while the USA has a death rate of (.150%) with Italy having a higher death rate than the USA. Another example shows us supply chain disruptions in the syringe manufacturing, production and distribution field are suspected to run low if worldly supply chains are prepared for the global demand of syringes.

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# Enhancing Data Visualization Accessibility: A Case for Equity and Inclusion

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## Abstract

Over the decades, information and the transferring of information between parties have led to the evolution of human civilization from the pre-stone age to the AI era. Science, Technology, Engineering, and Mathematics have relied on data visualization to communicate and convey complex information to diverse audiences. However, traditional approaches to data visualization often rely heavily on color variations that have left a specific population with color vision deficiencies to walk the extra mile to decode the information provided in most data visualization boards due to their color selections. The importance of accommodating all forms of color blindness in data visualization to ensure inclusivity and accessibility dispersion of information can't be understated. This paper explores strategies for enhancing data visualization accessibility to accommodate all. Addressing the needs of individuals with diverse color vision deficiencies requires a proactive approach to designing inclusive visualizations. One approach involves adopting color palettes that maintain adequate contrast and employ hues distinguishable by individuals with various color vision deficiencies. Utilizing patterns, textures, and varying line styles alongside color can provide redundant cues for conveying information effectively.

**Keywords:** Data Visualization, Color Theory, Color Perception, Visualization Quotient

## 1. Introduction

Communication involves nonverbal, written, and verbal cues. Every conversation on a macro stage has a sender/producer and a recipient/consumer. In data visualization, the sender 'encodes' complex information into graphs, charts, maps, logos, and colors in a mixture to tell a story that provides affordance to the consumer (Norman, 1988). Information visualization systematically examines (interactive) visual depictions of data to enhance cognition. This data encompasses numerical and non-numerical information, such as textual and geographic data. A key element frequently employed in this practice is color, utilized as a medium to encode and convey meaning. However, it is evident through empirical observation that the selection of colors in visualization creation often lacks proper attention. It is imperative to ensure that the chosen colors not only prevent the creation of cluttered visuals but also facilitate comprehension for all individuals, including a

significant portion of the population who experience color vision deficiency. The communication channel between the producer of information and the consumer of communication can be broken down in Figure 1.

What drives the preference for conveying information through visual mediums? Of humans' five senses, vision stands out for its unparalleled capacity to process information swiftly and efficiently. This superiority stems from the human brain's intricate pattern recognition and matching capabilities. Indeed, it's commonplace for individuals to engage in mental visualization, whether consciously or subconsciously, while structuring thoughts and reasoning. Visual thinking is ingrained in our cognitive processes. Humans, alongside many other species, can discern light in various dimensions: spatially, by intensity, and by frequency. Variations in intensity manifest as distinctions between light and darkness, while differences in frequency translate into the perception of color. However, it's essential to acknowledge that all visual interpretations are inherently subjective. Whether it's geometric patterns, contrasts between light and dark, or the spectrum of colors, our perception is influenced by the brain's interpretation of electrical signals received through the eyes (Ferreira, 2017).

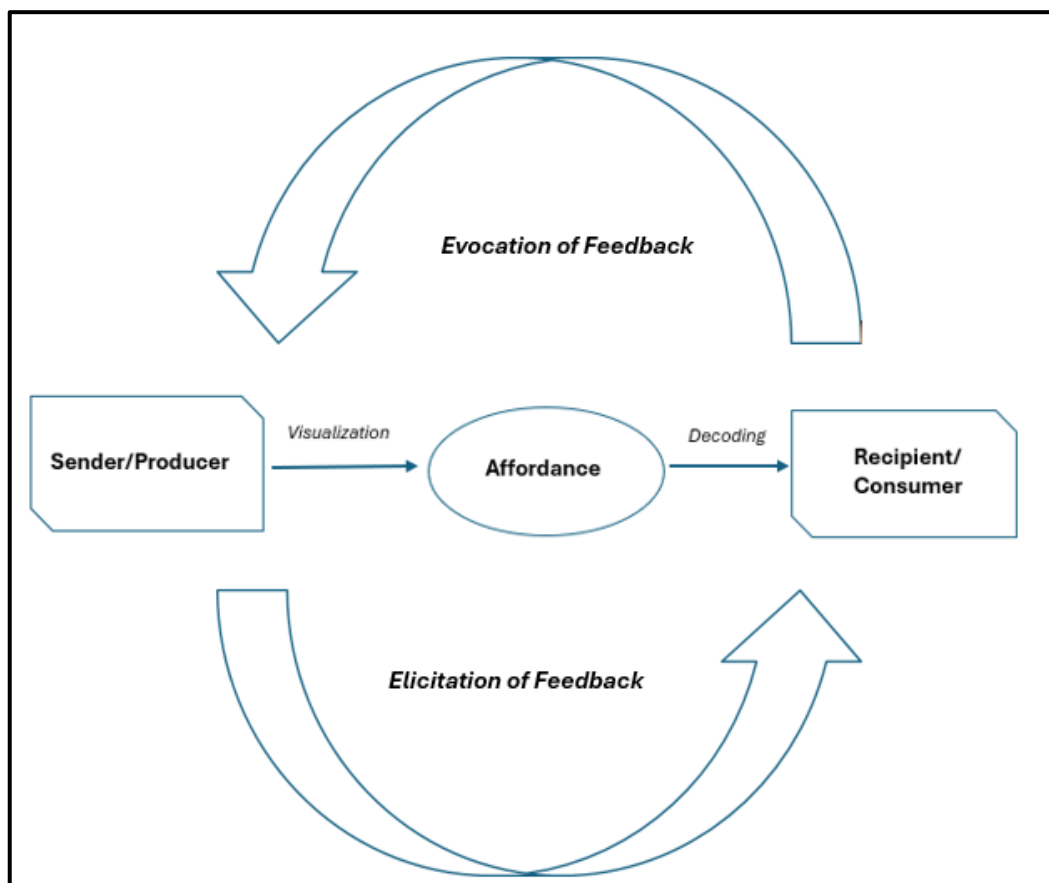


Figure 1: Communication Process Via Visualization

Source: Authors' Creation

Information visualization encompasses the exploration of visual representations, both interactive and static, to enhance human cognition when processing abstract data. These data types span numerical figures, textual information, and geographic data, facilitating a comprehensive understanding of complex datasets. The frequency between the sender of information, affordance, and the recipient of the information in data visualization has to be at equilibrium, with both parties constantly evocating and eliciting feedback from each other. The primary aim of this paper is to highlight how data visualization can accommodate people with monochromatism, dichromatism, and anomalous trichromatism, where dichromatism and anomalous trichromatism are further into tritanopia (deficiency to see blue light) protanopia (deficiency to see red light) and deuteranopia (deficiency to see green light) (Woods, 2021).

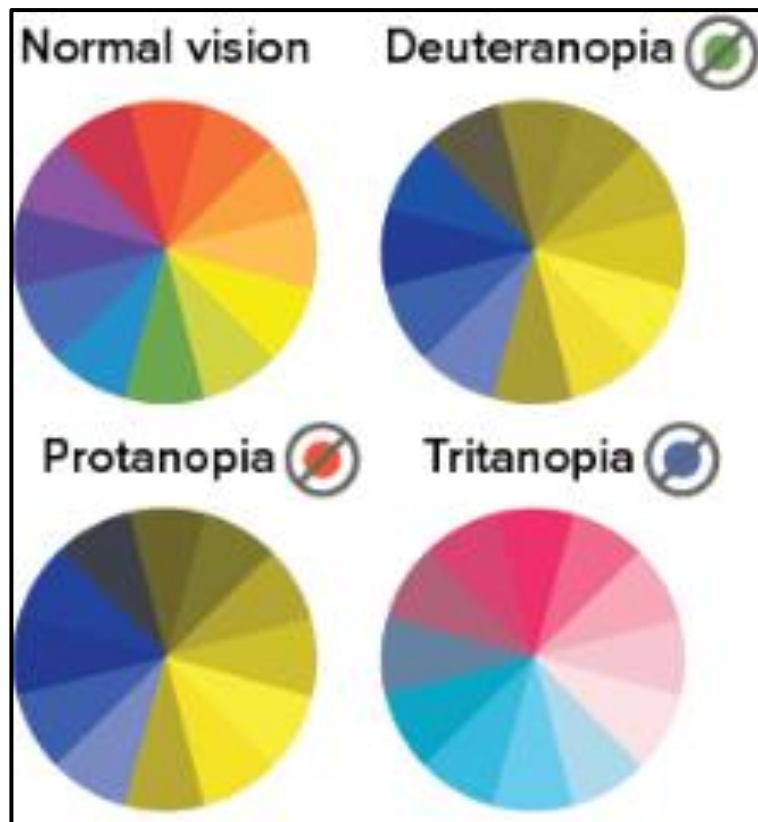


Figure 2: Anomalous Trichromatism Spectrum  
(Woods, 2021)

The challenge arises from the subjectivity inherent in our perceptual systems, posing a significant hurdle for achieving accurate and objective data interpretation, a primary aim of information visualization. This hurdle stems from not all individuals possessing identical visual capabilities; a substantial portion of the population experiences color blindness, known as color vision deficiency. Color blindness entails a diminished capacity to perceive colors or distinctions between them. It's crucial to note that most individuals with color blindness still retain some degree of color perception, contrary to the misconception that they perceive images solely in grayscale, a condition referred to as monochromatism (Ferreira, 2017).

In the colorblind population, deuteranomalous (or green-weak) vision is the most prevalent. The official breakdown is as follows: protanopes 12.5%, protanomalous 12.5%, deuteranopes 12.5%, and deuteranomalous 62.5% (Woods, 2021). Typically, colorblind individuals maintain the ability to discern between blue and yellow hues, and many fall under the category of anomalous trichromats rather than complete dichromats. While they may exhibit a diminished ability to distinguish colors along the red-green axis of the color space, they still retain some discrimination, albeit limited (see Fig. 1). Regrettably, there is currently no known cure for this form of vision deficiency.

## 2. How to be more Mindful?

When working with a visual board, a data analyst should ask the following questions to exhibit a high Visualization Quotient (VQ). This study defines VQ as the ability to present complex information using data visualization tools while creating a conceptual and visual affordance environment. Does the information perceived by individuals differ for those with color blindness? Is it imperative to complement images, graphs, or charts with captions, contrary to the adage "a picture is worth a thousand words"? Is there a predetermined necessity to meticulously select colors for information visualization to prevent conflicts in interpretation? To what extent can individuals with color blindness adapt to interpret visual artifacts? Should we meticulously analyze each case of color blindness to establish an ideal color model, thereby precluding the existence of a

"universal artifact" suitable for all? Will these considerations overly constrain creators of visual information, or can they flexibly adapt their visual display and aesthetic ideals?

Understanding the essence and prevalence of color deficiencies proves instrumental in devising displays catering to a broad spectrum of users, encompassing a substantial portion of color deficiency in data visualization. An elemental directive in crafting displays accessible to color-deficient individuals resides in implementing redundant luminance cues to underscore pivotal distinctions within the image (see Figure 3).

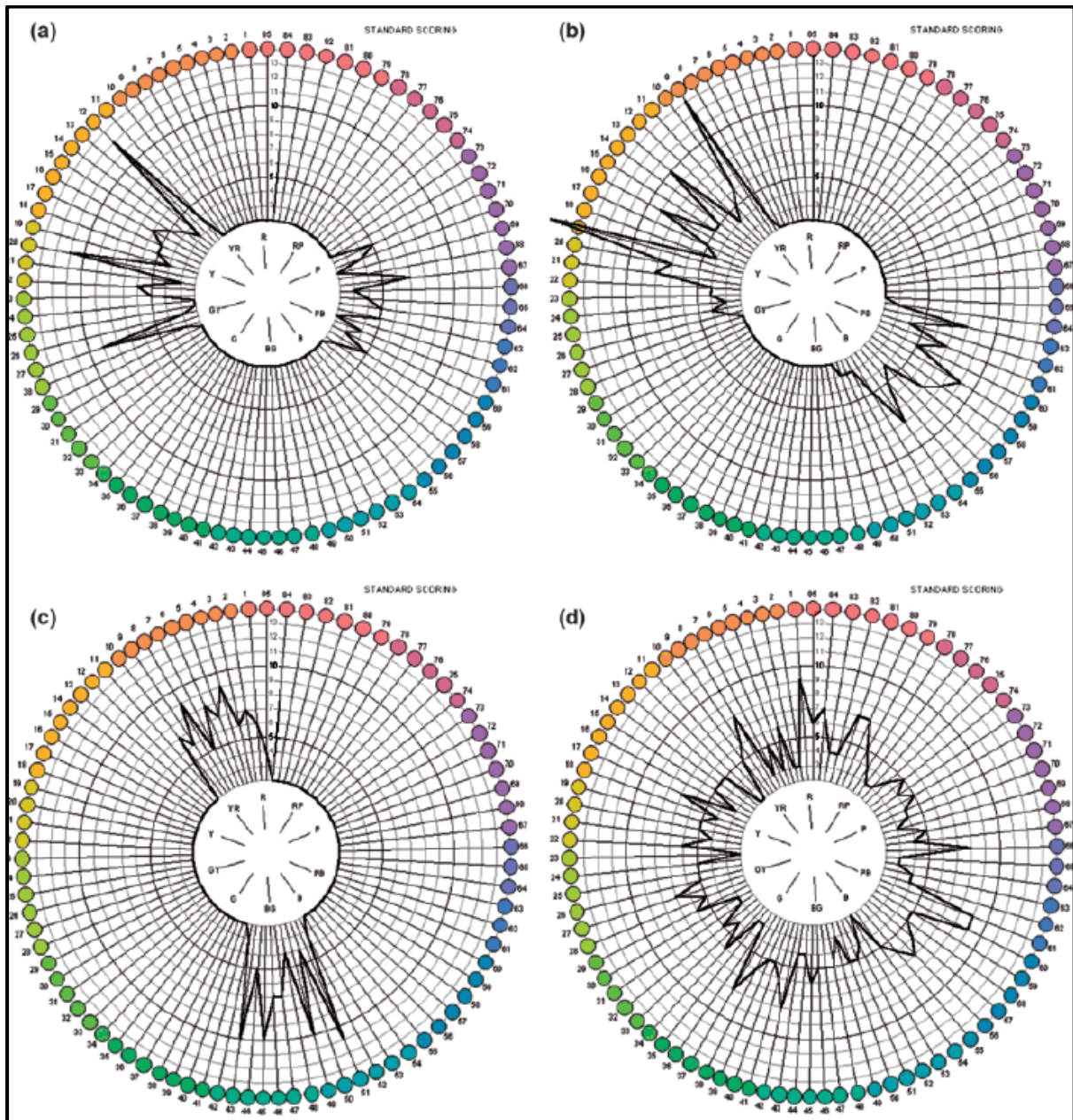


Figure 3: Farnsworth-Munsell 100 Hue's Online Color Test  
(Ferreira, 2017)

This principle mandates the incorporation of differential coloration alongside distinct variations in brightness. For instance, optimizing user experience necessitates highlighting discovered terms within the browser by juxtaposing dissimilar hues and luminosity levels in the context of a World-Wide Web search tool (Ferreira, 2017). In tandem with leveraging redundant luminance cues, it is imperative to abstain from utilizing colors along prominent opponent-processes chromatic channels, notably the red-green axis, given the prevalence of

red-green color deficiency. Instead, strategic color coding must be directed along an axis that amalgamates red-green and yellow-blue channels, enhancing perceptual differentiation (Ferreira, 2017). Other mindfulness steps one can take in displaying a high VQ include but are not limited to:

2.1. Integration of mindful color palettes

One of the simplest ways to improve your data visualizations for colorblind users is to choose colors that are easy to differentiate for most types of color blindness. For example, avoid using red and green together, as people with protanopia or deuteranopia often confuse them. Instead, use contrasting colors like blue and orange or purple and yellow. You can also use tools like ColorBrewer or Color Oracle to test and select color palettes suitable for different vision impairments (Nichols, 2024).



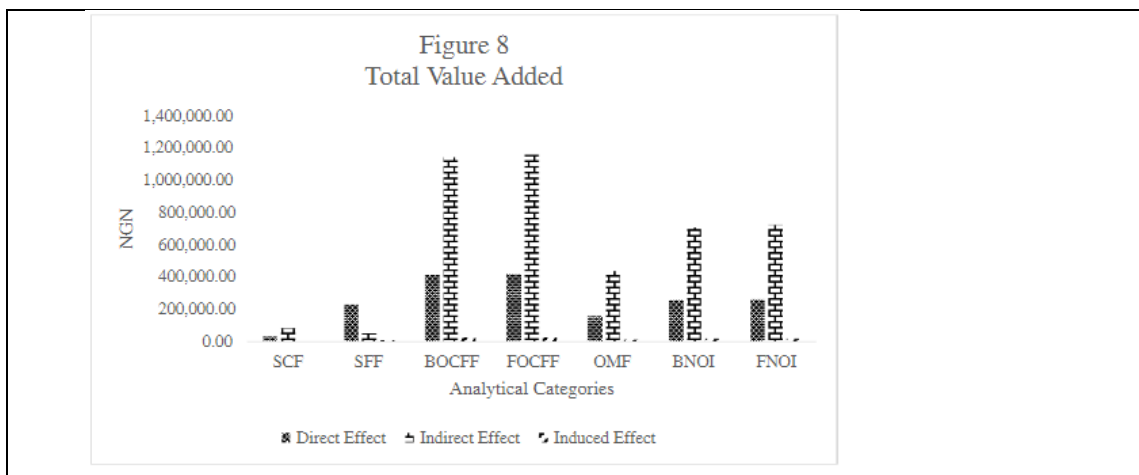
Figure 4: Color Palette Visual Differentiation (Nichols, 2024)

Where:

- True: Actual color visualization
- Prof: Protanopia
- Deut: Deuteranopia
- Trit: Tritanopia

2.2. Integration of patterns, textures, or symbols

Another way to enhance your data visualizations for colorblind users is to add patterns, textures, or symbols to your data points, bars, or areas. This way, you can create more visual cues that help users distinguish between different categories or values, regardless of the color. For example, you can use dots, stripes, or checks to fill your bar chart bars or use circles, squares, or triangles to mark your points in a scatter plot. You can also use tools like Plotly or Matplotlib to customize your ML models' patterns, textures, or symbols.





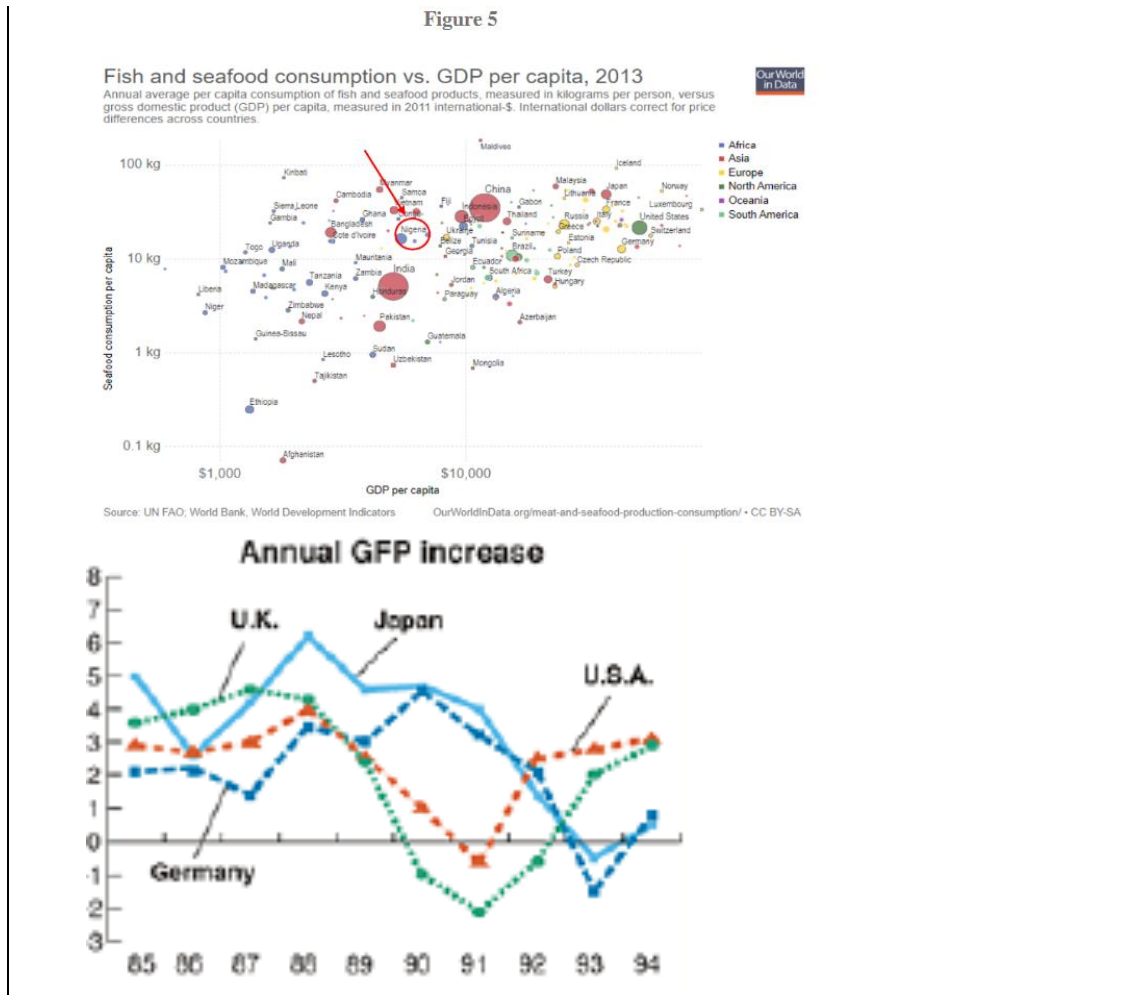
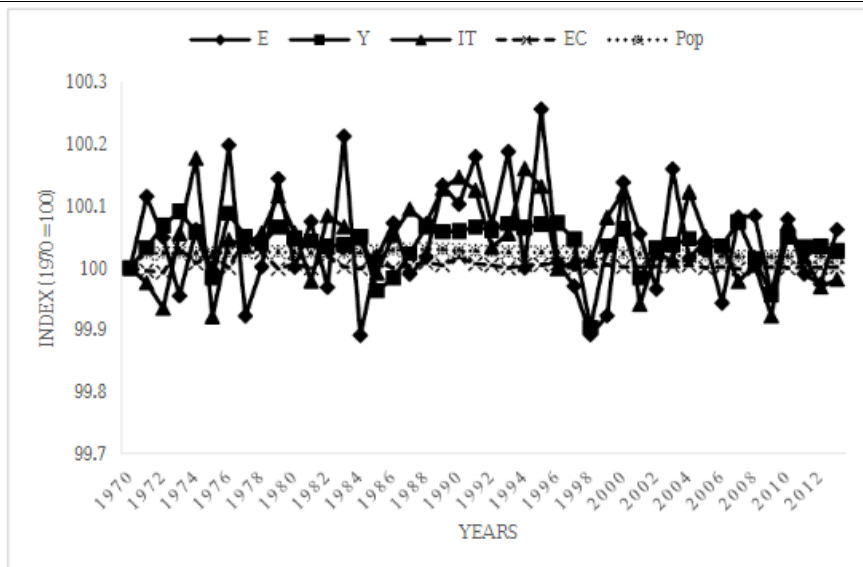
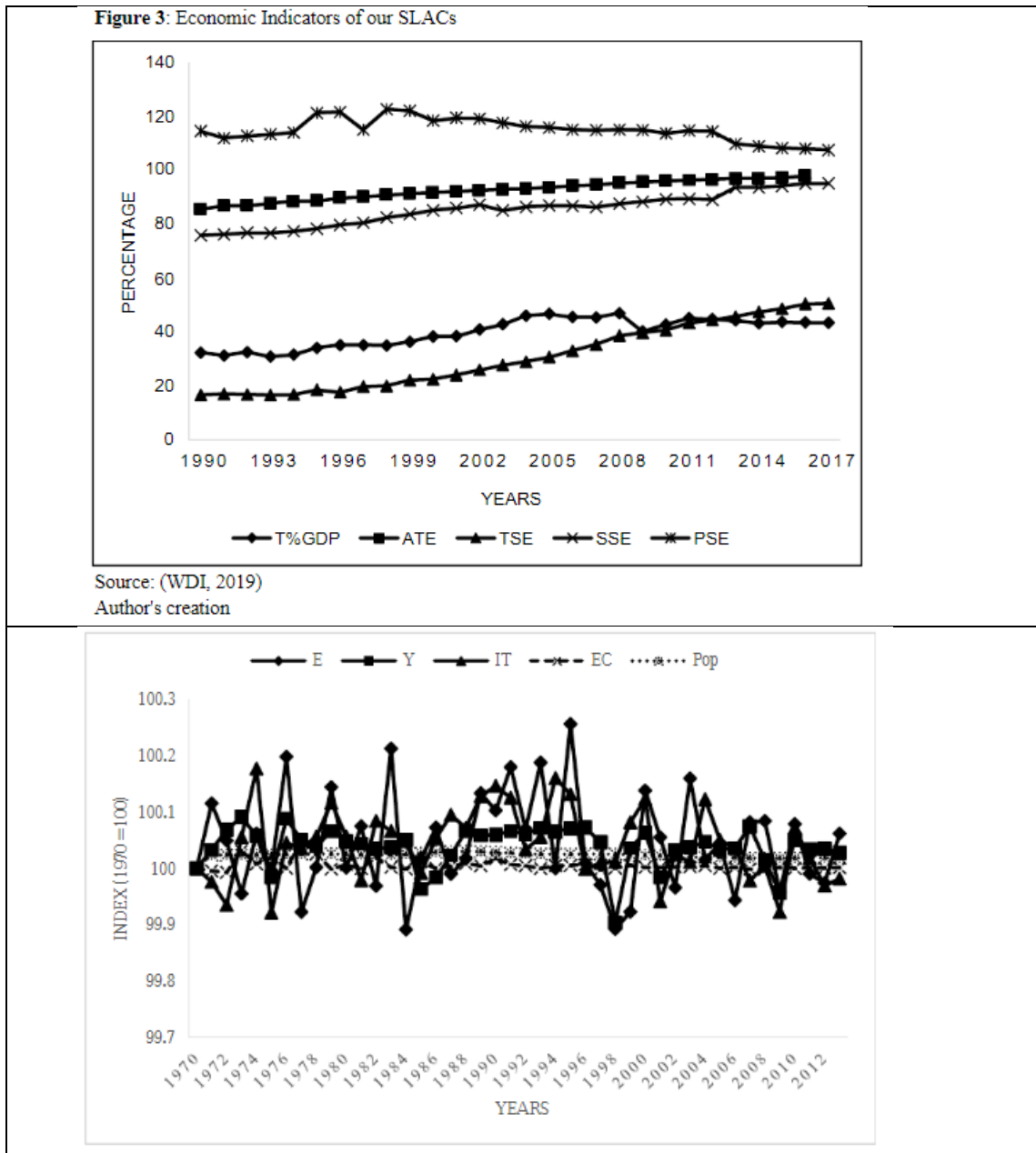


Figure 5: Integration of Patterns, Textures, or Symbols in Bar Charts & Line Graphs (Ferreira, 2017) & (Osiobe, 2018)

### 2.3. Integration of labels, legends, and annotations

A third way to improve your data visualizations for colorblind users is to use labels, legends, and annotations to provide more information and context to your charts and graphs. Labels are text identifying your visualization's axes, titles, or data points. Legends are boxes that explain the meaning of the colors, patterns, textures, or symbols used in your visualization. Annotations are notes that highlight or illustrate specific features or trends in your visualization. By using labels, legends, and annotations, you can make your data visualizations clearer and more understandable for colorblind users.



2.4. A method of color, text, and shapes

A fourth way to improve your data visualizations for colorblind users is to avoid using color alone to convey meaning or importance in your charts and graphs. Color can help emphasize or differentiate data, but it should not be the only way. If you rely solely on color to convey meaning, you risk losing or confusing your colorblind users. Instead, use other visual elements, such as size, shape, position, or text, to reinforce or supplement color's message. For example, you can use larger or smaller circles to show the magnitude of data points in a scatter plot or arrows or labels to show the direction or significance of data trends in a line chart.

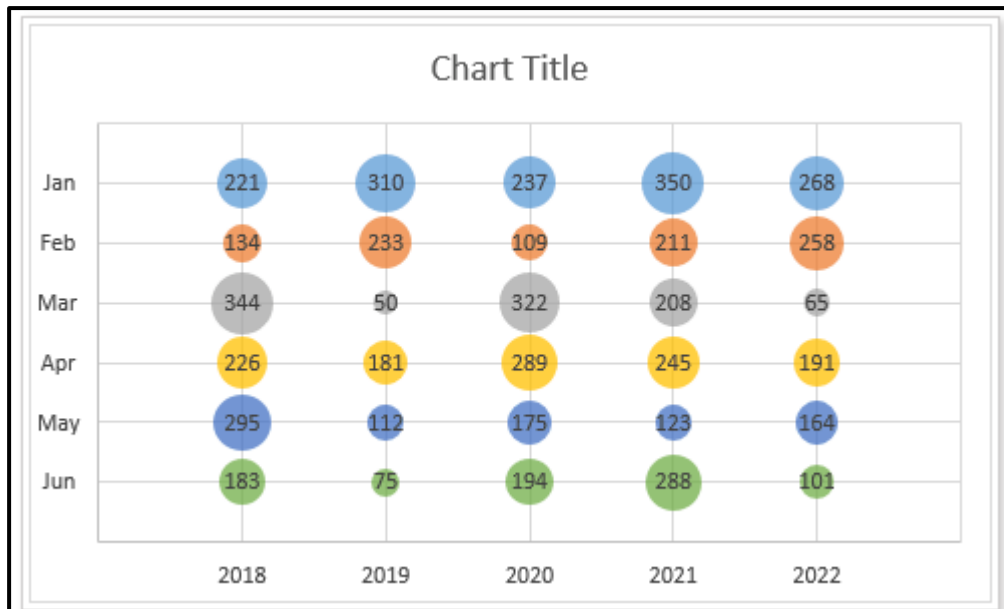


Figure 7: Matrix Bubble Chart  
(Extend Office, 2020)

### 3. Recommendation and Conclusion

More education on data visualization for students, academics, practitioners, and designers about how to increase their VQ and be mindful of their visual boards and the impact of color blindness on visual perception will lead to more accommodating guidelines for creating inclusive visualizations in academia and mainstream economy are essential steps toward fostering accessibility and inclusivity in data communication. Testing one's charts and graphs with colorblind users or simulations can help you get feedback and suggestions on making your charts and graphs more accessible and practical. Simulating their vision with tools or apps can help you check and improve your data visualizations' color contrast, clarity, and readability. Some examples of tools or apps that can help you test or simulate color blindness are the Color Blindness Simulator, Color Blind Check, or Sim Daltonism.

Following data visualization best practices that apply to all users, regardless of their vision, and adopting them as the new visualization standard are best practices for a more engaging presentation; these include but are not limited to choosing the right type of chart for your data, using clear and consistent labels and legends, avoiding clutter and distortion, and telling a story with your data. By following data visualization best practices, you can ensure that your data visualizations are not only accessible for colorblind users but also practical for all users. Addressing the needs of individuals with color vision deficiencies in data visualization is imperative for promoting inclusivity and ensuring equitable access to information. By employing thoughtful design principles, utilizing alternative visual cues, and embracing user-centric approaches, data visualization can effectively accommodate all forms of color blindness, enhancing accessibility and fostering universal understanding and engagement with data-driven insights.

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# Effect of Different Doses of Animal Manure on Growth and Yield of Common Bean

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## Abstract

This research (the effect of different doses of animal manure on growth and yield of common bean) carried out based on (RCBD) in Yakawlang district. This experiment conducted in three replications and eighteen treatments (each replication contains six treatments). Land preparation was first done, all extra materials removed from field and the field was furrowed by traditional tools. All other operation for preparing land to cultivate was done in a traditional manner. Descriptions of treatments are as follow: T1 (control) T2 (2 ton ha<sup>-1</sup>) T3 (4 ton ha<sup>-1</sup>) T4 (6 ton ha<sup>-1</sup>) T5 (8 ton ha<sup>-1</sup>) T6 (10 ton ha<sup>-1</sup>). This study was conducted in Yakawlang district during 2023. For achieving of this research, agricultural lands was selected and prepared for common bean cultivation through using traditional tools, shovel, and other essential tools.

**Keywords:** Animal Manure, Bean, Growth, Yakawlang, Yield

## 1. Introduction

Common bean is one of the food supply resources for human, so I decided to work on organic fertilizer on bean in Yakawlang district. Common bean (*Phaseolus vulgaris* L.) is an annual leguminous, self-pollinated plant having non-endospermic seeds which mostly differ in size and color from wild type small black to mottled large red, black, brown or white seeds 7-16mm long (coble and steele, 1976). Nitrogen is the main component of cellular compounds, including amino acids and nucleic acids. Nitrogen deficiency greatly reduces plant growth (Hauggaard et al., 2009). Animal manure guaranty higher levels of comparatively obtainable nutritional elements, especially N, which is basically, desired for plant growth (Amanullah et al., 2007). Bean (*Phaseolus vulgaris* L.) is an important legume, a rich protein source for humans and animals, in the developing countries. Grains of beans contain 18% to 32% protein, which considerably have more validity than animal protein in the diet of low-income people. Drought and lack of nutrients, particularly nitrogen (N), are the most important environmental stresses threatening bean yields (Majnoon Hosseini, 2008). Organic manure in the soil is as store

house for nitrogen supply to plant. There is very little inorganic nitrogen in soil and much of it obtained by the conversion of organic forms. Organic manure not only increases the yield but also improve physical, chemical and biological properties of soil that improve the productivity of crop (Blane, *et al.*, 1998).

To provide enough N for the bean plant and increase its product or yield organic and inorganic fertilizers have to apply. By this way the yield of agricultural products may increase. N availability influences the distribution of assimilates between vegetative and reproductive organs, while N deficiency leads to a delay in growth and development. (Ali and Lal, 1992).

Generally, application of NPK fertilizer increased yield and yield components of common bean, this result is in agree with other results of the same crop (Arf *et al.*, 2011). Other researchers found that organic fertilizer increased growth, yield pods in cluster bean followed by chemical fertilizer as compared with the control (Balbhim *et al.*, 2015). Organic fertilizer (cow manure) increased pod weight, pod dry weight, and total yield of bean (Olfati *et al.*, 2012). Positive response of common bean to chicken manure application could be due to the reduction of soil pH by the manure that makes the nutrient such as phosphorus more available to the plants. Using of poultry manure combined with NPK increased yield and yield component of maize plant (Izuchukwu *et al.*, 2007). Also another study showed that cow manure combined with chemical fertilizer increased yield and yield component of sweet maize (Anonymous, 2007). Nitrogen is the main component of cellular compounds, including amino acids and nucleic acids. Nitrogen deficiency greatly reduces plant growth (Hauggaard-Nielsen, *et al.*, 2009). Compost and vermicompost are soil conditioners, which provide nutrients and organic matter within the soil and also ameliorate the water holding capacity, firmness and structure of soil (Vogtmann *et al.*, 1993). The application of 5 and 10 ton<sup>1</sup> of cow manure increased yield of green bean (Mudji Santosa *et al.*, 2017).

## 2. Materials and methods

This research (the effect of animal manure on growth and yield of common bean) carried out based on (RCBD) in 2023 in Yakawlang district. One local variety seed namely *Lobia Negrabi* was used in this research. Other equipment including Raja, shovel, Kidman, ruler, paper pockets, were used for research's various purposes. Soil samples were taken randomly before preparing the land and sowing from the experimental field from 0 to to 30 cm in depth to check its pH and other properties such as texture and electrical conductivity. The pH of the soil that was taken from the experimental area was checked in laboratory of ministry of agriculture, irrigation and husbandry showed 8.95. after land prepared the heaps created and then seeds in specific rate, distance between two plant was 20cm and the distance between two heaps were 40cm, the depth of cultivation was 4cm. 22 seeds were put on each heaps (11seeds on one side and 11seeds on other sides of heaps were placed). It was a problem or a challenge that I couldn't find an improved seed to cultivate that and get a result. So, one variety of local common bean (*Lobia Negrabi*) was provided from market (Mandawi) and cultivated in the farm and the effect of animal manure was considered in different ways on growth, and yield of local bean variety. Irrigation was conducted according to the necessity of the plant under Yakawlang climatic conditions, weed control was another fact that was done in a traditional manner, no chemicals were applied. Several time weeds were controlled by hand, pulled from the root and put away from the field. All data was statistically analyzed by SAS. Checking differences among the means of all parameters were calculated by using Duncan.

## 3. Result

For evaluation of different doses of animal manure effects on the growth and yield of common bean, this research conducted in Yakawlang district. Various plant parameters including plant height, No. of branches, No. of leaves per plant, Dry weight per plant, No. of seeds per pod, No. of pods per plant and yield per plant was evaluated to explore the effects of applied fertilizer doses. So, this study described the results of those recorded parameters in details. For better interpretation of results, results will be explained under two portions (growth parameters & yield parameters). According to (Table 1) The effect of different doses of animal manure on growth attribute studied and showed different effects and results. Plant height, number of branches per plant and number of leaves per plant was significantly affected throw application of 10-ton animal manure<sup>1</sup> in compare with control. Application of

10-ton animal manure per hectare recorded the highest effect on height of plant, number of branches per plant and number of leaves per plant respectively (51 cm, 23.5 branches per plant and 58.6 leaves per plant).

Table 1: Plant height, no of branches and no of leaves.

Treatments	height of plant/cm	no of branches/plant	no of leaves / plant
T1 (Control)	30.6 c	10.7 c	35 d
T 2 (2 ton)	32.8 bc	11 c	37.9 c
T3(4 ton)	33.3 bc	13 bc	34.6 c
T4(6 ton)	34.6 b	13.4 bc	48.13 b
T5 (8 ton)	36 b	15 b	53 a
T6 (10 ton)	51 a	21.5 a	54 a
Cv	24.5	12.9	24

The effect of animal manure on yield components of common bean are showed on (Table 2), more number of pods per plant are produced in T6 where 10-ton animal manure has been applied (24.9 pods per plant).it was a significant effect on producing of number of pods per plant. lengths of pods are also significantly affected by applying 10-ton animal manure per hectare (8.6 cm). Number of seed per plant also significantly affected over control throw applying 10-ton animal manure per hectare (66 seed per plant.) 10-ton animal manure put significant effect on dry weight and yield of common bean respectively (95 and 112.8 g/plant).

Table 2: No of pod, length of pod, no of seed, dry weight and yield / plant (g).

Treatments	no of pod/plant	length of pods /plant	no of seeds/plant
(Control)	13.5 c	5 c	40.9 d
(2 ton)	12 c	5.2 bc	52 c
(4 ton)	16.9 b	6.5 b	52.7 cd
(6 ton)	17 b	7 b	54.5 c
(8 ton)	23.4 a	8 ab	62.3 b
(10 ton)	24.9 a	8.6 a	66 a
CV	28.4	26	20.7

### 3. Conclusion

In this research I focused to evaluate the effect of different doses of organic fertilizer (animal manure) on growth and yield attributes of common bean. As I result from the application of different doses of animal manure, it was found that treatment T1 (10-ton animal manure per hectare) put significant effect on most of the growth and yield attributes of common bean exactly on height of plant, number of branch per plant, number leaves per plant, number and length of pods per plant, number of seed per plant, dry weight and yield of common bean.

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# Simple House Construction Innovations Made from PVC Pipes and GRC Boards in Indonesia

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## Abstract

This innovation aims to provide a Simple House (SH) Type 24 m<sup>2</sup> (T-24) floor area made from PVC pipes and Glass-Fiber Reinforced Cement (GRC) boards. The simple house-building structure in this invention consists of PVC pipes and GRC boards which are arranged based on simple building designs in Indonesia. PVC pipes as components of the building space frame and roof are reinforced with reinforced concrete mixed and PVC pipe connections. The potential for users of simple houses for low-income people (MBR) is very large in Indonesia. With a shortage of one million houses per year, the PUPR Ministry is only able to meet 30% or around 400,000 units per year of people's housing needs. The benefit and advantage of innovation is that space frame building construction consisting of floor beams, columns, and ring beams made from PVC pipes is easy to do using relatively simple craftsman equipment. The T-24 simple house innovation is a building that is easy to work on because this building uses materials that can be easily found in various regions in Indonesia, namely PVC pipe materials and GRC boards. In summary, the T-24 simple house prototype has the following innovations: 1) cement brick foundation, 2) construction of floor beams, columns, and ring blocks using PVC pipes and concrete mix without splitting, 3) main roof material structure (rafters and battens) made from PVC pipes, 4) SH T-24 roof covers and walls made from GRC boards, 5) Building features such as doors and windows use a combination GRC boards and glass materials.

**Keywords:** Innovation, Construction, Simple House, PVC Pipes, GRC Boards

## 1. Introduction

The global population is increasing by 45 million every year, there is an increase in demand for food, water, and material and importantly housing. The need current level for new housing is forcing the housing industry to encourage construction innovation to use prefabricated materials to accelerate the new housing supply in various parts of the world and various regions of the country (Ramadhiani & Alexander, 2018). The Population growth in Indonesia is increasing day by day. This causes the need for housing to increase over time. The Ministry of Public

Works and Public Housing (PUPR) said that in 2023 it will strive to overcome the housing shortage and encourage the availability of decent housing for the community. Around IDR 11.27 trillion was allocated for residential construction for the community. This is proof of the government's efforts to provide adequate housing for people in need (Kementrian PUPR, 2023). Currently, in the conditions of limitations and poverty that have not yet been resolved 100%, the economic problem is still the only thing that absolutely must be overcome. Meanwhile, the price of building materials is getting more expensive day by day, affecting house prices. This is what causes problems to arise, such as these obstacles to realizing the desire to have a livable house.

One step to answer this challenge is to improve the Indonesian nation's output quality (Okrah, James, Nepp, Alexander, & Agbozo, 2018). Policies to strengthen the community's economy need to be supported by the government, so that they develop over time, cause a country's progress depends on how they increase economic activity (Ram, M., Deakins, 1996). Stable economic conditions help people to realize their dream of having a simple house. Here construction efforts are necessary. Community involvement in encouraging the construction of livable houses through policies that are pro-welfare of the Indonesian people. The need for adequate housing then invites industry construction to innovate to overcome these obstacles. Some of them have innovations or initiatives toward a building house.

Then an idea arose about initiating the construction of a simple house made from PVC pipes and GRC boards, which is an alternative for obtaining a house construction model for low-income communities because of the ease of obtaining materials and the use of relatively easy technology or appropriate technology. This requires cooperation between certain institutions to encourage innovation. The presence of Higher Education (PT) is very much needed to develop innovative works that have use value and benefit the wider community through the educational process (Syahza, 2019). So, the effort to make prototypes through the laboratory's active roles in HEIs involving lecturers, assistants, laboratory assistants, and students becomes very important and very strategic.

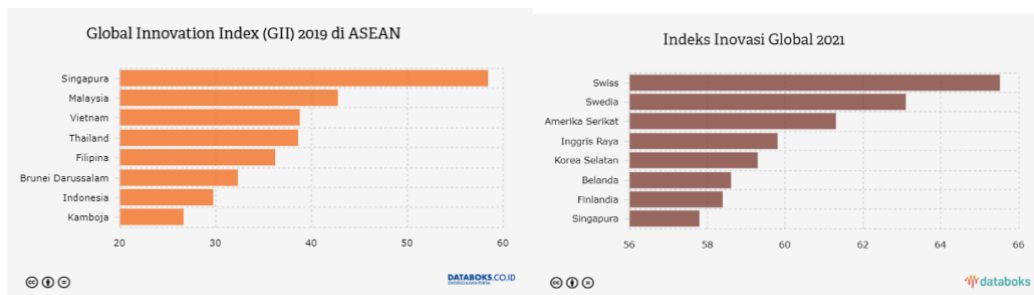


Figure 1: Innovation Global Index and Asean

Source: (Jayani, 2019)

Through this image, we can find out what position Indonesia is currently in. Through this image, Figure 1 shows Indonesia's innovation index position, which is ranked 7th in Asia and not in the top 10 at the global level. This condition is both a challenge and a motivation for PT in Indonesia to continue to increase innovation and transformation so that the benefits value, it can be felt by the wider community over time (Jayani, 2019).

The prototype design for housing construction is the result of scientific developments. This shows the relevance of careful planning to create innovation which must go through the results of trials and research from experts to find out how effectively the design is realized and has implications for achieving satisfaction as expected, namely safe and comfortable development. It cannot be denied that the facts on the ground show that renewable scientific developments are influencing the interest and design of modernist houses, influencing all aspects of life. In its implementation, obstacles often arise such as housing designs that are less affordable for Low Income Communities (MBR). One of the efforts is to create a prototype design as a form of residential construction planning that can be afforded by MBR and is affordable and reliable (Howedi & Jwaid, 2017). The use of fabricated materials can be an alternative for successful construction that is easier to carry out. Moreover, the use of materials that are environmentally friendly or easy to recycle, such as PVC pipe, allows for a fast construction process (Almed et al., 2016).

This research was carried out to present the findings by making the simple prototype that T24, T30, and T36 houses made from PVC pipes and GRC boards, to analyze building construction innovations in the components: 1) Foundation construction; 2) Space frame construction (i.e. tie foundation beams, column, and ring beam construction connections); 3) Construction of truss roofs and roof coverings; 4) Wall construction; and 5) Window door construction. This research was different from previous conventional simple housing studies conducted by (Hadimoeljono, 2016; Kementrian PUPR, 2021; Debnath, 2016) (Hafid, 2011; Cairns, 2021) based on the material and technology used by. Therefore, this current research on building construction and practices can be greatly improved by embracing the industrialization materials of construction. By utilizing local and industrial materials readily available in different regions of Indonesia, such as PVC pipe, GRC sheets, and concrete brick, we will able to revolutionize the innovative construction and potential low-cost housing industry in Indonesia.

## 2. Literature Review

### 2.1 *State of the Art and Novelty*

A popular simple house building is a house building that has sections (Hadimoeljono, 2016), including 1) The foot is a river stone foundation with reinforced concrete tie foundation beams ties; 2) The body consists of walls reinforced by columns and reinforced concrete ring beams and has door and window opening facilities made of wood and glass; with a wooden or light steel frame roof equipped with a clay/ceramic tile roof or concrete tile roof. These simple houses usually have ceramic floors, tiles, or plaster floors. Other construction models such as wooden houses (Kementrian PUPR, 2021; Debnath, 2016) and bamboo houses (Hafid, 2011) (Cairns, 2021) or both combinations. This paper presents a different approach to using materials, technologies, and performances. Materials used in this simple house are 1) cement brick for foundations, 2) PVC pipes and concrete for the building frame, 3) PVC pipes and GRC sheets for the roof construction; and 4) fully GRC boards for the wall construction. This use of materials and technology presents a new innovative potential low-cost housing in Indonesia

### 2.2 *Literature Review*

Many Indonesian people want private homes. Even though their income is not much, they are still trying to build their own house. A simple, healthy and pleasant home is the dream of most people. Residences with medium size, affordable prices, and inhabited by people with middle to lower economic conditions. The characteristics of a simple house usually have an ideal plot area or meet the minimum land area requirements. Simple houses strive to support the health of their residents, despite economic limitations, but they have the right to a decent environment, safety and comfort, or simple and healthy. To fulfill the need for decent and affordable housing, there are several considerations that prospective owners must know, such as the surrounding environment, physical building, land conditions, materials, space, and various other related material elements, for the construction of a habitable house. The building in question (simple) is clearly far from having a modern impression or using a luxurious interior. Before building a residence, a person should consider various related things such as the level of security, comfort and support for personal health, strategic location and ease of access (Akmal, 2005). All of this can be realized if house construction is carried out with advance planning, or in the form of a simple house prototype design.

Regarding simple houses, there is a research study from Vincentius Totok Noerwasito which states that each type of building has different energy, and this needs to be taken into account. Especially in the use of materials, if you use materials that have low energy levels, it will affect the energy levels in the building (Noerwasito, 2017). This study emphasizes the need to consider construction materials that are safe and environmentally friendly and have low heat energy.

On the other hand, Dwi Kurniati<sup>1</sup> and Restu Faizah in their study found that house construction that meets technical requirements or complies with development rules is said to be habitable. The construction of houses in the Bantul area of Yogyakarta is carried out by considering the quality of implementation and by the design and having related elements, both structural and non-structural elements (Kurniati & Faizah, 2021). Thus, prototype design or construction design is an urgent matter, especially by related scientific principles. Not far from the study carried out, regarding innovations in simple house construction made from PVC pipes and GRC boards.

Researchers seek to innovate through the results of construction tests carried out with prototype designs as an initial step before construction is carried out.

The approach to solving the problem of the T-30 and T-36 simple house prototypes made from PVC pipes, light steel, and GRC boards with building reliability tests at relatively affordable prices for low-income people can be determined from a review of simple house building elements which include 1) Foundation or feet, 2) Building body or container; and the head or roof of the building (see Figure 2) (Hadimoeljono, 2016).

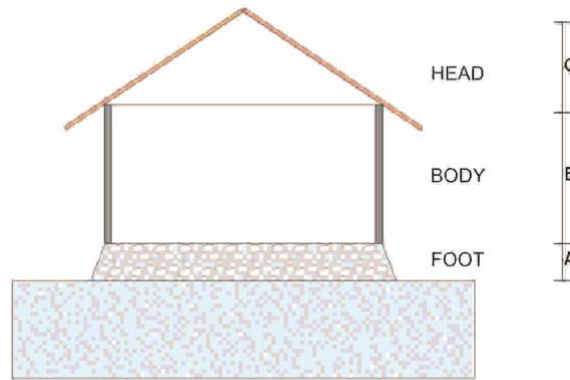


Figure 2: simple building element  
 Source: (Hadimoeljono, 2016)

Table 1: Elements and Components of a Simple House

RS Element (RS)	RS Building Component
	<p>a. Foot Elements (Foundation):</p> <ol style="list-style-type: none"> <li>1) Foundation: river stone, padas/white stone</li> <li>2) Bottom bond tie foundation beams beam; reinforced concrete, wood, etc.</li> <li>3) Floor: tiles, ceramics, plaster, etc.</li> </ol>
	<p>a. Body elements that include</p> <ol style="list-style-type: none"> <li>1) Column: wood, concrete, glugu, bamboo</li> <li>2) Upper bond ring beam; wood, concrete, bamboo</li> <li>3) Wall; brick masonry, woven bamboo, triplex, zinc, etc.</li> <li>4) Door and window openings: wood, concrete, aluminum, etc.</li> </ol>
	<p>c. Head Element (Roof):</p> <ol style="list-style-type: none"> <li>1) Ceiling or ceiling: cemet fiber, asbestos</li> <li>2) Roof frame: Wood, light steel</li> <li>3) Roof covering: concrete tiles, clay, zinc, fiber cement</li> </ol>

Source: (Hadimoeljono, 2016)

The structure and construction of conventional Houses or SNI-compliant Houses (Firmanti, 2021) (Debnath, 2016), include several things, including a) River stone foundation elements; b) Elements of the body/living space which are limited by walls that are usually made of plastered brick or light brick with openings such as doors, windows made of wood or aluminum, etc.; c) Roof elements supported by construction trusses made of wood or

light steel or bamboo and others with roof coverings made of tile, zinc, asbestos cement, thatch, and others. (see Figure 3).

### *2.3 Simple House Construction to Improve Quality of Life*

The construction of a simple house is understood as a comfortable place to live, synonymous with a house that is far from modern interior design. The house is made from construction materials at a very affordable cost. Building construction researchers have taken the initiative to build simple houses with attractive designs and low costs. Even though it is low cost, the simple house design still contains a touch of modern design. This construction complies with or meets standard requirements, including stability, strength, resistance to moisture and water, as well as durability, and comfort that is not harmful to humans. In 2017, the World Bank provided approximately \$450 million specifically for the National Affordable Housing Program (NAHP). This project is used to support the construction of affordable housing realization throughout Indonesia. This project is a collaboration with the government and the Ministry of PUPR.

Building a simple house made from PVC pipes is one alternative. This material can be said to be quite light, strong enough, resistant to fire, leaks, and corrosion, and more flexible. These properties are ideal for carrying out its function as a house-building material. House building construction as time goes by, is increasing along with the latest technological developments. In its essence, the house has a significant role in every society, both low-income, middle, and high-class. However, the problem is, that people from middle to lower economic groups, have difficulty building houses because of cost constraints. The increasing rate of structural poverty causes social inequality. In conditions like these, the right alternative is innovation in building livable houses that are affordable for people to live in safely and comfortably and are made from materials that have good durability.

Responding to this, Doxiadis has the view that housing has five elements that constitute an integrated system, including Nature, humans, society, containers, and networks (Doxiadis, 1972). Everything is an interrelated unit and if fulfilled it will run well. A simple livable house can be interpreted in several aspects, namely: philosophical, sociological, health, legal, and physical, as well as energy aspects. At least it fulfills human needs to live comfortably and more humanely. Referring to the Regulation of the State-Minister for Public Housing Number 22 of 2008 concerning Minimum Service Standards in the Housing Sector in Article 2 (1), it states that the Government provides services in the field of public housing so that people can live in livable and affordable houses in a healthy and safe environment. supported by infrastructure and public utilities (PSU).

The concept of sustainable residential development is a development principle that creates building construction that is safe to use and does not have negative implications for the environment, let alone causing detrimental global warming effects. Construction with a green construction theme is an alternative contribution to environmental preservation and improvement. Residential construction efforts made from PVC pipes. The characteristics of this material are non-conductors of electricity or immune to electrochemistry caused by acids, bases, and salts. PVC pipes are made lightweight, are water resistant, have long and short dimensions, have excellent durability, are watertight can handle various leaks, and are sustainable products that do not produce waste and can be recycled. PVC pipes have a long lifespan and do not rot easily, so they are one of the right alternatives as residential construction materials (Pramono et al., 2019).

## **3. PRO-G House Construction Innovation Methods**

### *3.1 Research Method*

This research uses a qualitative approach. The focus is to collect information regarding 'Simple House Construction Innovations Made from PVC Pipes and GRC Boards.' Policy on making simple house prototypes made from PVC and GRC using an architectural approach to strengthen the UII Green Matrix. This research seeks to find effectiveness through efforts to create innovation as an alternative. A simple residential prototype design made with detail. To find the results of the study, researchers used several data collection techniques, namely interviews, observation and documentation. The research informants were subjects who were part of the team in

the simple house construction project. Observations were made by looking at the field and the construction process, documentation by reading several literatures related to this study, and related data.

Different from other research, this study follows previous research conducted by Howedi, & Jwaid regarding the design and implementation of low-cost and multifunctional smart system home prototypes (Howedi & Jwaid, 2017). Then other research by Loss, C., M. Piazza, and R. Zandonini, regarding construction system innovation for sustainable development (Loss et al., 2015). This research identifies the importance of building simple houses designed through the design of habitable house prototypes for middle to lower-economic communities to improve their welfare and have comfortable, low-cost cost, and environmentally friendly housing made from PVC and GRC boards.

### 3.2 Building and Construction Innovation Methods

This invention aims to provide a house-building structure made from PVC pipes. The house building structure by this invention consists of PVC pipes arranged according to the desired construction design; (The wall and roof elements of the building use GRC (Glass Reinforce Concrete) fabrication materials which are environmentally friendly and easily available on the market or in the community. The process of making a house structure made from PVC pipes consists of the following steps: 1) Installation of brick foundations, 2) Installation construction of tie foundation beams, columns and ring blocks using PVC material and concrete mixture, 3) Installation of the main roof structure (horses and battens) made of PVC material, 4) Installation of roofs and walls made of GRC.

#### 3.2.1 Prototype Design Innovation Method

The prototype design plan that will be carried out is the T-24 Simple House prototype made from PVC pipes and GRC boards (SH T-24 Pro-G) which can be seen in Figure 6. This building prototype uses a brick foundation with space frame walls made from PVC pipes. with reinforced concrete fill without gravel. The walls are constructed using 9 mm GRC board material which is attached to the beam tied to the foundation, columns, and ring beams. The triangular truss frame is made from PVC pipe and battens are made from PVC pipe. The legs of the PVC trusses are filled with reinforced concrete without gravel and the PVC pipe battens are filled with a sand-cement mixture. The roof tiles use 6 mm thick GRC material. "Prototypes provide an overview, to provide specific answers so that product creation can be repeated and improved before it becomes the final product" (Aji, 2018; Planningnotepad.com, 2012).

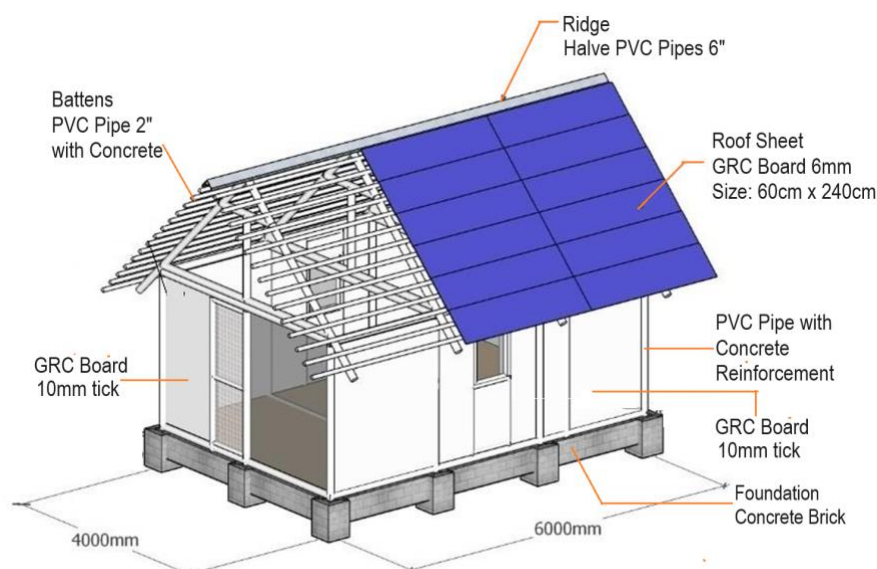


Figure 3: The SH T-24 Pro-G prototype is made from PVC and GRC

The study of making a simple building prototype at the SH T-24 Pro-G will be the basic product for developing a simple house that is environmentally friendly and refers to the SNI for Earthquake Resistant Residential Houses

(Ministry of Public Works, n.d.; Minister of Public Works and Housing, 2016 (Kementerian PUPR, 2017). The SH T-24 Pro-G prototype design will refer to the House, Buildings a Prosperous Home (Ministry of Public Works, n.d.), and the Indonesian National Standard (SNI) for Building Simple Houses - Surabaya Panel Houses. The house area of a simple house according to the State Housing Company (PERUMNAS) is between 12m<sup>2</sup> to 70 m<sup>2</sup> with adjustments to the modular system.

### 3.3 Method for Implementing Pro-G House Innovation Development

The construction stages of the SH T-24 Pro-G are as follows: 1) Preparation, 2) Management, assistance, quality control, monitoring funds, 3) Construction of the SH T-24 Pro-G as a management process for implementing the construction of a simple grow house project. The construction stages of the SH T-24 Pro-G include the following steps: 1) Making the frame, 2) Installing the roof, 3) Installing walls and floors, 4) Installing doors and windows (Suryadi & Cattleya, 2018) which is a technical strategy for the stages of building a simple house. So, these steps will be used for the construction implementation stages of the T-24 Pro-G RS Prototype.



Figure 4: simple house pavilion building

Based on Figure 4 above, researchers are attempting to study prototype products for the pavilion building (see Figure 4). The picture on the bag is an example of the RS T-36 which is made from light steel and GRC board. Then it was developed again with innovations. Starting with the steps to design a simple T-24 house prototype made from PVC pipes and GRC boards. The efforts made by researchers, namely making simple building constructions made from PVC pipes and GRC boards, aim to increase the variety of alternative simple house constructions with a quality that is not much different from residential buildings in general. Several strategies were carried out in the construction of the Pro-G House for construction innovation, including: 1) Preparation of technical drawings for the SH T-24 Pro-G building: Pre-Plan Drawings, Plan Drawings, Detailed Drawings, and Engineering Design (DED), Budget Plans Costs (RAB) and 2) Implementation of Development and Construction of the Pro-G T-24 House.

The next stage carried out was the process of building the RS Pro-G T24 prototype. The initial prototype specifications were developed with the following specifications: 1) Implementation of the Main Structure, including Foundations, tie foundation beams, columns; perimeter beam/ring; and roof structure. The construction process of the main structure must pay attention to dimensional accuracy and use the correct methods; 2) Implementation of roof and wall covering construction, including work: Installation of roof coverings, installation of walls, doors, and windows. Before the implementation stage was carried out, construction design was carried out through a simple house prototype design made from PVC pipes and GRC boards.

## 4. Data, Analysis, and Discussion

### 4.1. Location of RS Pro-G Building Site

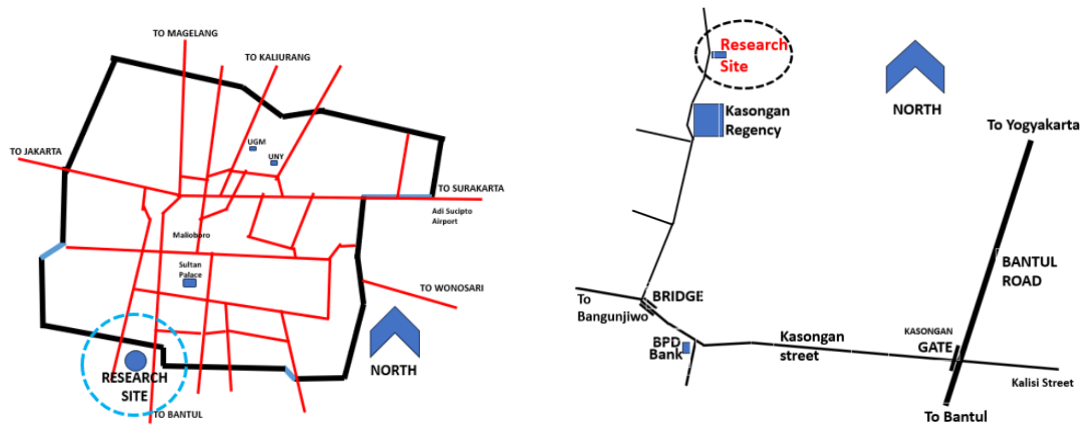


Figure 5: Prototype Location of SH T-24 Pro-G

The picture above is the location for making a prototype of a simple house for testing earthquake-friendly and environmentally-friendly house construction, precisely in the Gang Romowijoyo area, RT:- RW:06 Dukuh Tirto, Bangunjiwo, Kasongan, Kasihan, Bantul, Yogyakarta. More detailed pictures of the construction of the RS Pro-G T24 prototype can be seen in the following stages of development.

#### 4.2. Data on Development and Innovation Implementation of Pro-G T24 House

##### 4.2.1. Construction Implementation

##### 4.2.1.1. Foundation Work

##### 4.2.1.1.1. Making Uitzet Bouwplank



Figure 6: Uitzet Bouwplank Construction

The construction of the bow plank utility refers to the SH T24 Pro-G prototype with a floor area of 24 m<sup>2</sup>, namely a building width is 4m and a building length is 6m. The location of the building is 3 meters from the east fence and 1 m from the north fence of the land or land boundary.

##### 4.2.1.1.2. Excavation of land





Figure 7: Excavation of Land

#### 4.2.1.1.3. Foundation Construction



Figure 8: Foundation Construction

The foundation material is a mixture of cement sand and brick. The choice of material is adjusted to the load on the roof, walls and main structure.



Figure 9: Foundation Installation

Installation of the foundation in the form of a pair of 10x20x40 bricks glued with a cement-sand mixture with a ratio of 1:4.

#### 4.2.1.2. Tie foundation beams, Column and Ring Beam Work

##### 4.2.1.2.1. Tie foundation beams Works



Figure 10: Tie foundation beams Process

1. The tie foundation beam material is 1) PVC pipe (PVC) with a diameter of 4 inches, 2) a cement-sand mixture with a ratio of 1:3 and 3) iron reinforcement with a diameter of 10 mm.
2. Installation of the tie foundation beams is done by cutting and installing PVC pipes connected to the fitting. Next, the PVC pipe is filled with 10mm iron reinforcement and after the steel reinforcement enters the PVC pipe, it is tied to each other in the pipe. After bonding the reinforcement in the PVC pipe, cement sand casting is carried out.

#### 4.2.1.2.2. Column Works

1. Column materials are 1) PVC pipe (PVC) with a diameter of 4 inches, 2) a mixture of sand cement ratio 1:3, fitting 4 inches, and 3) iron reinforcement with a diameter of 10 mm.
2. Column installation is done by cutting and installing PVC pipes connected to the fitting. Next, the PVC pipe is filled with 10mm iron reinforcement and after the steel reinforcement enters the PVC pipe, the reinforcement is tied to each other in the pipe. After bonding the reinforcement in the PVC pipe, cement sand casting is carried out.



Figure 11: Column Works

#### 4.2.1.2.3. Ring Beam Job



Figure 12: Ring Beam Job Results

- i. The ring beam material is 1) PVC pipe (PVC) with a diameter of 4 inches, 2) a mixture of sand cement ratio 1:3, fitting 4 inches, and 3) iron reinforcement with a diameter of 10 mm.
- ii. Installation of ring beams is done by cutting and installing PVC pipes connected to fitting. Next, the PVC pipe is filled with 10mm iron reinforcement and after the steel reinforcement enters the PVC pipe, the reinforcement is tied to each other in the pipe. After bonding the reinforcement in the PVC pipe, cement sand casting is carried out.

#### 4.2.1.3. Roof Truss Job

##### 4.2.1.3.1 Truss Frame Job



Figure 13: horse frames process



Figure 14: truss frames installations

##### 4.2.1.3.2. Batten Work Process

1. Manufacture of battens



The batten material uses 1.25-inch PVC pipes and is filled with a sand cement mixture with a 1:3 ratio

## 2. Batten Installation



The battens are installed on the pralon trusses leg by bolts means. The distance between the battens is 50 cm taking into account that the roof covering (tile) uses GRC board material with 6 mm thickness.

### 4.2.1.4. Tile Job

#### 4.2.1.4.1. Roof tile material



The tile material used is a 6 mm thick GRC board with a size of 60 x 240 m<sup>2</sup> and using the original GRC board module measuring 120 x 240 cm<sup>2</sup> by dividing it by 2 with 60 cm width. Next, the GRC board tiles are painted (tile paint) blue.

#### 4.2.1.4.2. Roof tile Installation



Roof tile material (60x240) is installed on PVC pipe battens (containing hardened sand cement) at a distance of 50 cm by bolting. Its overlap between roof tiles is 10cm to prevent water from entering. Meanwhile, for tile boards longitudinal joint, aluminum profile H 6 mm, 5 cm wide, and 55cm long is used.

#### 4.2.1.5. Wall Works

##### 4.2.1.5.1. Materials



The wall material is used on the GRC board which functions for the wall area and wall frame.

##### 4.2.1.5.2. Installation



The wall installation uses GRC boards combined with GRC board frames to produce walls that also function as shelves or even cupboards. GRC frames can be used with GRC thicknesses of 8mm, 9mm, or 10mm. Meanwhile, GRC frame width can be used at 10 cm or 15 cm according to the thickness of the wall/shelf being designed.

#### 4.2.1.6. The door and window job

##### 4.2.1.6.1. Material



The door and window materials use the GRC board which functions for the door leaf and door or window frames/frames. The thickness of GRC boards for doors and windows varies between 8mm, 9mm, or 10mm according to the needs and construction or design appearances.

##### 4.2.1.6.2. Installation



From the photo next to it, it can be seen that the GRC board material is very flexible in its use for doors and windows. In the RS T24 Pro-G building, door frames were installed in a minimalist style, and wide glass windows were installed with frames that had a 60cm<sup>2</sup> frame module. The door leaf will be made using GRC boards, while the wide windows with GRC frames will be installed with the GRC 6mm thick.

#### 4.2.1.7. Kitchen Job Process

##### 4.2.1.7.1. Material



The kitchen spelling material uses GRC board which functions for the table area and table frame. The thickness of GRC boards for doors and windows varies between 8mm, 9mm, or 10mm according to the needs and appearance of the construction or design.

##### 4.2.1.7.2. Installation



The GRC board is made in doubles to function as a vertical table frame and a kitchen table surface which is installed in doubles horizontally.



The use of GRC boards for walls is very flexible. The side image shows the outer kitchen wall button that uses GRC boards for plant shelves, which means it is a green wall based on GRC shelves and plants.

#### 4.2.1.8. The floor Job Process

#### 4.2.1.8.1. Material



Materials for the floor are cement sand mixture for the plaster floor and 6mm GRC board for the floor covering. As a finish, the GRC floor covering boards are painted with waterproof paint. GRC boards for floor coverings are given a 60x60 pattern before painting the floor.

#### 4.2.1.8.2. Installation



The GRC board installation for floor covering. The GRC board has been given a 60x60 floor pattern. The next floor job is finishing the floor paint.

### 4.3. Analysis and Discussion of RS Pro-G T24 Innovation

Residential construction with a 'simple' or low-cost theme is starting to become a concern for some people. They realize that this construction innovation has a positive impact on economic growth, such as stimulating demand for energy-saving services and business opportunities or start-up, then implication is to create new Works in the construction sector (Nallathiga et al., 2022). Environmentally friendly home has received attention from foreign countries, one of which is the United States. House building construction is directed at cost savings thereby contributing to economic growth. With this alternative, various groups of society, including the lower middle class, can access construction financing. Meanwhile, based on study result by the University of California, Berkeley found that certified buildings actually have very high sales compared to non-environmentally friendly certified buildings (Eichholtz et al., 2010). Construction at affordable costs plus environmentally friendly material use is very profitable. The simple house construction with environmentally friendly concept using PVC pipes and GRC boards as basic materials has gone through trial results. A prototype design is made first to see whether the results of this innovation are suitable or not. The construction implementation went through several job stages using appropriate technology.

In this research, there are several construction findings or innovations by looking at the details of the development process. There are structural innovation number found from this construction, including several things: a) Roof. With a gable roof shape, the pralon PVC pipe material and GRC boards are easy to support this shape. Even the roof covering is very easy to form with GRC boards in wider and lighter sheets. So installation is easier and faster than traditional roof tiles or concrete roof tiles. A material that is similar in area to GRC board is zinc type material. b) On walls, doors and windows. 1. Wall. From the construction aspect, the RS T24 wall is very special, because the wall uses GRC board material and a GRC board frame where the results of this construction not only produce walls but also produce shelves or cupboards. Even on the facade (outer face) the wall produces shelves that can be

used to place plants so that the wall supports green building construction. 2. Door. Doors are generally made of wood iron or zinc, and other materials. However, on the RS T24 Pro-G, the door is made from GRC board which is the construction of the door leaf and door frame. 3. Window. In general, windows wood made or aluminum. However, in the RS T24 Pro-G, the windows are made from GRC boards which are the door leaf and door frame construction. c) Construction findings on floors and foundations. As for the floor itself, the floor is generally plaster-made and covered with tiles, ceramics, granite, carpet, etc. However, in the RS T24 Pro-G, the floor is plaster and covered and made with GRC board with a checkered tile pattern measuring 60x60 m<sup>2</sup>. Next, the GRC plank floor is finished using water-resistant and colored paint. Even the RS T24 Pro-G floor paint can have various colors in gradations, for example, rainbow colors. Meanwhile for the foundation, because the RS T24 Pro-G material is relatively light, the foundation is constructed with the material.

All of the materials used in RS T24 Pro-G construction (namely PVC pipes and GRC boards) are materials that are easy to obtain in urban and rural communities at affordable prices. Both materials are easy to destroy or reuse, thus supporting sustainable construction aspects. After simple house construction has been carried out, another alternative can also be implemented, namely T-36 house construction through the following stages, namely: 1) The preparation process includes several activities, such as land clearing; land measurement; and bow plank installation. 2) Foundation work, including; Earth excavation work for foundations, embankment work, based material, installation of stone foundations (river or mountain type), and earth embankment work. 3) Reinforced concrete work for casting tie foundation beams, ring beams, terrace columns, and practical columns. Process scope: concrete molding, reinforcement, using cement labeled SNI, fine aggregate using appropriate technological machines. 4) Installation work, including Wall installation, plastering, and floor finishing. 5) Window and door work. 6) Ceiling and roof work. 7) Work on plumbing installations, including Installation of clean water installations, installation of dirty water pipes, and sanitation. 8) Lastly, paint, either wood or wall paint. 9) Electrical processing process so that electronic use is safe. 10) Locking and hanging work. The construction here for windows can also install the glass neatly so that there are no gaps that allow strangers to enter the room.




The overall trial construction of a simple house is appropriate and has a time span that is not that long. The design is made to see the effectiveness and quality of the building. Furthermore, what is unique or special about this invention is that this simple house has a construction made from PVC pipes as the main structure of the building (tie foundation beams, columns, tie beams which are assembled with PVC steel) and wall and roof building components made from GRC which are connected to the components. PVC with bolts. The house building structure according to this invention has technical and non-technical advantages, including being able to provide strength, lightweight, rust resistance, and non-flammability; dampens electric currents (as good insulation), is resistant to chemicals and is easy to shape and adapt to all forms of house building designs and is relatively affordable. The following is an innovation in the structure and construction of a simple house made from PVC pipes, light steel, and GRC boards (RS Pro-G).

Based on the trial result simple house implementation construction made from PVC, the prototype components functionality was ensured to be implemented well and according to the design made. When everything has been applied correctly. The entire system operates by the design and the results are very supportive, starting from making foundations, working on tying foundation beams, doors, windows, walls, floors, or other things that are assembled according to the initial design of the prototype. The predetermined sizes of PVC pipes and GRC boards are very helpful in the construction process. The result is quite a solution. Because these materials price is very affordable. The building construction uses environmentally friendly basic materials and is resistant to any weather, including the rainy season and summer (Almed et al., 2016).

The urgent reason why you use PVC pipes is because the durability of PVC pipes is around 30 years. One of the advantages is that its potential can reach permanent limit house needs in general. Likewise, GRC boards are a material that is strong enough for semi-permanent buildings and flexible to use for building construction. These two basic materials' qualities are beyond doubt. People are only given the option to choose any thickness according to their needs. Residential construction made from GRC and PVC has positive and supportive implications for the concept of a simple house. Such as: 1) Environmentally friendly, because GRC board shelves can be made into wall shelves on which ornamental plants pots then be placed in a position to adjust sun direction. 2) Both GRC and PVC pipe materials are recyclable materials that can be recycled so they do not create new waste.



Table 3: Innovation Findings for Simple House Elements and Components

Simple house element	Innovation building component
	<p>a. Foot Elements (Foundation):</p> <ol style="list-style-type: none"> <li>1) Foundation: brick;</li> <li>2) Bottom bond tie foundation beams beam; PVC pipes are cast with sand cement and reinforced with iron reinforcement;</li> <li>3) Floor: Plastered and 6mm GRC boards painted in color with road marking paint.</li> </ol>
	<p>b. Body elements that include</p> <ol style="list-style-type: none"> <li>1) Columns and ring beams: PVC pipes are cast with sand cement and reinforced with iron reinforcement;</li> <li>2) Wall; Papa GRC;</li> <li>3) Door and window openings: GRC Board and Ribbon Glass &amp; Ice Glass.</li> </ol>
	<p>c. Head Element (Roof):</p> <ol style="list-style-type: none"> <li>1) Ceiling or ceiling: Fabric, GRC;</li> <li>2) Roof frame: PVC pipe (cast with sand cement and iron reinforcement) or light steel;</li> <li>3) Roof covering: 6mm GRC board &amp; Tile paint.</li> </ol>

Source: (Suparwoko, Teguh, M., & Aldiansyah, 2022)

This development has various innovations. First, innovation in the use of materials, technology, and architecture in simple residential construction, including: Using bricks for foundations, PVC pipes and concrete without gravel, and walls with GRC boards. Meanwhile, the appropriate technological innovation used in the construction process includes two things: a) Technology for installing brick foundations using a hoe and spat for mortar and fitting. b) Wall and roof installation technology that uses a grinder/saw and electric drill as well as fastening bolts.

Second, product innovation is easy, fast, and affordable. Includes: 1) Building component innovations such as brick foundations, reinforced concrete PVC pipe frames, GRC board walls, GRC plank floors with road marking paint or floor paint, and finally GRC roofs with concrete PVC roof frames. 2) Cheap and fast construction seen from the manufacture of doors without frames and glass windows with very thin GRC frames, and 60x240 GRC sheets for roofs with bolted construction.

The Simple House (SH) construction results made from PVC or PVC pipes (SH Pro-G) and GRC boards have the potential for structural durability that needs to be tested further. The semi-permanent house advantage can produce development innovations that are livable and have an environmentally friendly character because the basic materials are easily recyclable and earthquake-resistant. The technology uses fast and effectively produce aesthetically pleasing RS products that are an alternative worthy of simple home construction for people in all circles.

## 5. Conclusion

The newest construction alternative is simple house construction made from PVC pipes and GRC boards. The development of innovation through prototype design is intended to ensure that planning is right on target and implementation of development is by the results of studies by researchers. The innovations discovered by researchers (including foundations, space frames using PVC pipes, and roof material and construction), have contributed as an alternative to building simple houses for various groups of people, especially low-income people with relatively affordable material prices.

PVC pipe and GRC board materials have some advantages: 1) the material is easy to obtain in various urban and rural areas throughout Indonesia, 2) the price of the material is relatively affordable; 3) materials are environmentally friendly because they can be recycled, 4) the manufacture of RS Pro-G is carried out using the right technology so that it is easy for most craftsmen or workers in Indonesia.

RS T24 Pro-G is a simple building that is easy to build easily and with affordable material prices and uses appropriate technology, which means the equipment used is quite simple and plentiful and is commonly used by craftsmen in Indonesia. The use of RS T24 Pro-G needs to be socialized to the wider community. It is necessary to complete research on the structure of the SH T24 Pro-G to support complete safety and building reliability.

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# Blockchain for Vehicle Registration, Transferring and Management Process in Sri Lanka

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## Abstract

In Sri Lanka, the widespread occurrence of fraudulent activities in vehicle registration processes presents notable challenges, especially regarding ownership disputes and discrepancies in vehicle history. This study first investigates the drawbacks of the existing manual registration system, which leads to delays in registration, ownership transfer, and modification processes, thus contributing to fraudulent activities in the secondary vehicle market. These challenges arise from centralized storage systems, which are vulnerable to single points of failure and data integrity compromise due to third-party involvement. To address these deficiencies, as a solution, this paper recommends the adoption of blockchain technology, utilizing its decentralized and distributed nature to ensure the security, reliability, and transparency of vehicle information management. Specifically, a blockchain-based system is proposed and developed on the Ethereum network, incorporating smart contracts to streamline key functions of the Sri Lankan government's vehicle registration process. These functions include new vehicle registration, reproducible certificate issuance, ownership transfers, modifications, and comprehensive vehicle history maintenance. The system provides public access to vehicle details, including historical data, via a user-friendly mobile application. Ultimately, this study contributes to establishing a secure and reliable method that simplifies the vehicle registration process, mitigating security breaches and data tampering risks.

**Keywords:** Vehicle Registration, Smart Contract, Blockchain, Ethereum

## 1. Introduction

Vehicle ownership has become a fundamental necessity in modern society, extending beyond mere transportation utility to encompass various stages, including registration and maintenance throughout the vehicle's lifecycle. By 2022, Sri Lanka registered 8,352,213 new vehicles, with a vehicle ownership rate of 4.07 per 100 people (Statistical Pocket Book, 2023). Vehicle registration, record maintenance, and tracking in Sri Lanka are managed by the Registry of Motor Vehicles (RMV) under the Department of Motor Traffic, involving authentication, verification, modification, and transfer of ownership. However, the current system is not fully

digitized, leading to significant vulnerabilities and a high prevalence of vehicle-related fraud due to systemic loopholes. A major vulnerability lies in the centralized database where sensitive data is administered, making the system's security heavily reliant on employee integrity and vulnerable to exploitation by corrupt third parties, such as brokers. This risk extends to manipulating registration certificates, which can be duplicated and misused, with fraudulent vehicle registrations being a critical issue. If a registration certificate is lost, the vehicle's market value can decrease significantly compared to the average market price, as the new certificate is marked as 'duplicate,' discouraging potential buyers due to complications in ownership validation. Additionally, centralized databases face severe security threats, including cyber-attacks and single points of failure, leading to substantial losses. Thus, both human and technical vulnerabilities pose significant threats to the security and reliability of the existing system. Therefore, there is a compelling need for a system impervious to third-party manipulation, ensuring enhanced security and reliability in vehicle registration and management processes.

Blockchain technology is fundamentally based on a decentralized distributed ledger approach. Prominent cryptocurrencies like Bitcoin and Ethereum are built upon this technology. Additionally, blockchain facilitates the deployment of smart contracts consisting of executable code, thereby eliminating third-party involvement and mitigating data manipulation in transactional processes. This ensures enhanced data security, transparency, and reliability. Consequently, blockchain technology finds extensive application in finance, supply chain management, and asset management—sectors characterized by high demand (Guerreiro et al., 2020; Zakhary et al., 2019).

The concept of blockchain can be effectively applied to vehicle information management, providing secure and reliable solutions to address prevalent issues such as double-spending in the vehicle registration process. This paper proposes a blockchain-based system designed to overcome the vulnerabilities inherent in the existing vehicle registration and tracking system in Sri Lanka. The primary focus of the proposed system is to restrict third-party data manipulation.

This system allows the RMV to replace traditional paper-based registration certificates with digitalized certificates. It generates QR code-based vehicle registration certificates by inputting the necessary details for registering vehicles, altering data, and updating vehicle information at the vehicle owner's request. These digital certificates are secured through a hash generated via block mining. The distributed ledger system further ensures the security of vehicle transaction records, wherein multiple nodes validate each transaction. A prototype was developed and tested within a controlled environment as proof-of-concept. This prototype comprises a web portal for the RMV and a mobile application for external parties, such as buyers, police, and insurance agents, who require validation of vehicle information.

The rest of this paper is structured as follows: Section 2 reviews the relevant literature on existing frameworks for vehicle registration and information management processes alongside an overview of blockchain technology. Section 3 outlines the proposed system. Section 4 details the implementation process. Section 5 presents the discussion, and finally, Section 6 provides the conclusion.

## **2. Related Work**

This section begins with an overview of blockchain technology and the existing vehicle registration framework in Sri Lanka—subsequently, the discussion shifts to the current applications of blockchain-based vehicle data management and related approaches.

### *2.1 Blockchain for Data Security, Privacy and Transparency*

Blockchain technology, introduced in 2008, has gained significant attention, particularly in connection with the Bitcoin cryptocurrency. This technology operates as a secure ledger comprising hashed blocks stored across decentralized and distributed nodes within a peer-to-peer network. When a transaction occurs, multiple nodes validate it using a consensus procedure. Each node retains a copy of every transaction within the blockchain, enhancing the system's resilience against attacks. Each block contains a ledger of transaction records that are validated by nodes through a process known as mining, typically within seconds. This distributed architecture

and thorough ledger management ensure that data on any single node cannot be manipulated, preventing unauthorized third-party interventions.

Public nodes participating in the mining process are motivated through rewards for their contributions to creating each new block. Each block references the preceding block's hash and incorporates a nonce value, enhancing security, as shown in Figure 1. The SHA256 algorithm generates a binary cryptographic hash, effectively addressing issues such as double-spending in asset and financial transactions (Zhang et al., 2019).

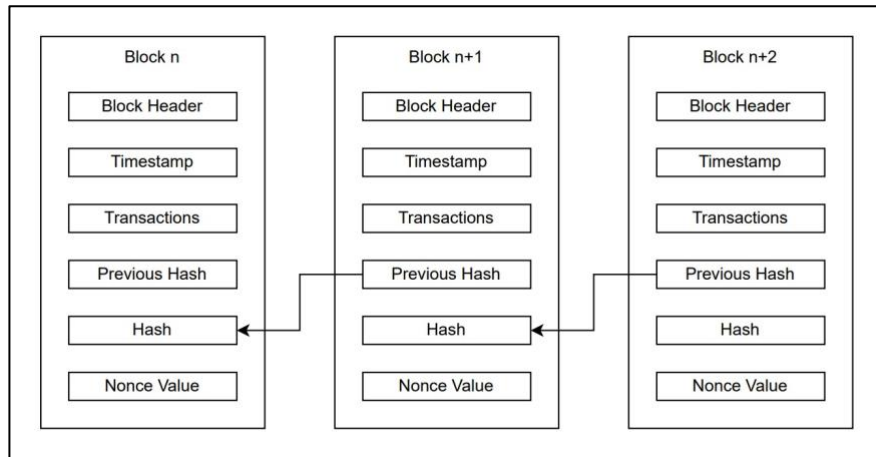


Figure 1: Block creation in Blockchain

### 2.1.1. Smart Contracts

Smart contracts are self-executing programs designed to facilitate, verify, and enforce agreements among multiple parties using blockchain technology. These contracts ensure the security and integrity of agreements, making breaches practically impossible. Smart contracts streamline processes and reduce associated costs by eliminating the need for intermediaries. Once a smart contract is deployed on the blockchain, users can interact with its functionalities by paying with cryptocurrencies. Similar to cryptocurrency transactions, smart contract transactions are validated through a mining process, provided the specified conditions are met. If the conditions are not satisfied, the network nodes discard the relevant transaction block. Ethereum is currently the most prominent blockchain platform for implementing smart contracts, utilizing the Solidity programming language.

### 2.1.2. Consensus Algorithms

Transactions on the blockchain must be securely executed and verified, which is achieved by implementing a consensus protocol that dynamically reaches an agreement based on a majority vote. However, this scenario can be exposed to the propagation of false messages, which can undermine the consensus process. This challenge, known as the "Byzantine Generals Problem (BGP)," can be mitigated by ensuring that a majority of honest participants agree. Blockchain systems address the BGP probabilistically through various consensus algorithms, including:

- **Proof of Work (PoW):** In this method, the right to add a valid block to the blockchain is determined by solving a computationally intensive problem, such as finding a nonce value. Cryptocurrencies like Bitcoin and Ethereum employ this algorithm to create new blocks.
- **Proof of Stake (PoS):** This protocol selects validators based on the number of tokens they hold and are willing to "stake" as a deposit. The probability of being chosen to validate the next block is proportional to the size of the stake, thereby influencing the voting weight.
- **Proof of Authority (PoA):** This approach relies on a predefined set of validators selected based on their identity and reputation rather than staking tokens or solving complex problems. PoA is noted for its high scalability.
- **Practical Byzantine Fault Tolerance (PBFT):** In this model, a leader node broadcasts a request to

validators (or miners), who then sign and send commit messages. Upon completion of the requested service, the client receives a reply, ensuring the integrity and consistency of the transaction.

### 2.1.3. Permissionless and Permissioned blockchains

Blockchain technology can be classified into three broad categories. Public blockchains allow any individual to read, send, and receive transactions, operating on a permissionless basis where every node can participate in the consensus process. This openness ensures data transparency by making public data available on a distributed and decentralized network. Permissioned blockchains, on the other hand, restrict participation to identifiable and explicitly authorized nodes. These blockchains can enhance confidentiality but often at the expense of resilience and robustness. In private blockchains, write permissions are typically limited to a single participant or organization, while read permissions can be either public or restricted. Consortium blockchains involve a set of pre-approved nodes or multiple trusted organizations to manage verification. Although they offer a balance between decentralization and control, consortium blockchains may be more vulnerable to compromise than fully decentralized public blockchains due to their semi-decentralized structure.

## 2.2 Existing Framework in Sri Lanka for Vehicle Registration

Government agencies typically employ centralized vehicle registration systems to manage extensive data volumes effectively. This study examines such a system implemented in Sri Lanka. Specifically, the Ministry of Transport has published vehicle statistics from 2017 to 2022, as illustrated in Table 1, highlighting the substantial data they manage (Department of Motor Traffic, n.d.).

The vehicle registration process in Sri Lanka is predominantly employee-oriented. Individuals manually submit vehicle registration requests, which are verified and processed by administrative personnel according to the vehicle owner's details. The initial phase of vehicle registration requires submitting various legal documents to confirm ownership. Once ownership is verified, the RMV registers the new vehicle, and a vehicle registration certificate is issued. A similar procedure is followed for ownership transfers, and in cases of vehicle modifications, a separate certificate is issued after recording the modifications in the system.

However, these procedures are time-consuming and prone to security vulnerabilities, including potential system failures and the risk of certificate duplication.

Table 1: Vehicle records of Sri Lanka

Record Type	Year					
	2017	2018	2019	2020	2021	2022
Vehicle Population	7,247,122	7,727,411	8,095,224	8,223,467	8,252,973	8,352,213
New Registration	451,653	479,340	367,303	202,628	33,850	20,510
Ownership Transfers	708,201	666,752	675,018	482,732	671,298	612,877

The RMV website offers an e-service allowing users to access registered vehicle details (Registered Vehicle, n.d.). This service primarily supports the administrative functions of the RMV, facilitating the management of the vehicle registry. Data is stored in a centralized database, with backup servers in place to ensure fault tolerance. A transaction fee is required for any vehicle-related transactions.

## 2.3 Vehicle Registration and Information Management using Blockchain

When examining the crucial tasks of resolving issues and improving functionality, existing literature consistently emphasizes the potential effectiveness of blockchain technology. In 2019, a proposal surfaced for a blockchain-based car registration system. This system utilizes a permissioned Hyperledger Fabric blockchain as its platform for deploying the Ethereum smart contract. The analysis targeted the Portuguese national registry entity,

addressing various aspects such as registering new vehicles, facilitating ownership transfers, managing guarantees, overseeing lease contracts, and handling vehicle seizures (Rosado et al., 2019). A similar study conducted in Bangladesh (Hossain et al., 2020) emphasized the essential data requirements for such a system and examined the impact of the implemented distributed ledger on vehicle management. Another study proposed a blockchain-based system integrating multiple agencies associated with vehicles (Pandey et al., 2021), focusing on the Indian context and the functionalities of the regional transport office. This system was built upon Hyperledger Fabric, with a subsequent performance evaluation. Notably, the study highlighted the importance of embedding access control mechanisms within the contract rather than relying solely on the fabric. Additionally, past research has explored blockchain applications for tracking the history of used cars in China (Chen et al., 2020; Masoud et al., 2019) and for business process control related to vehicles (Guerreiro et al., 2020; Zakhary et al., 2019).

Blockchain-based systems have been barely explored in the context of Sri Lanka, with limited attention primarily directed towards land authentication and transportation challenges (Jayabodhi et al., 2020; Jayalath et al., 2020; Yapa et al., 2018). One notable proposal involves developing a system only for maintaining vehicle records, which utilizes the Ethereum platform alongside smart contracts for data management within a distributed ledger system (Samarakkody, 2021). This system allows for the secure storage and transparent access of vehicle history data, involving key stakeholders such as automotive manufacturers, insurance entities, and dealers. Utilizing the InterPlanetary File System (IPFS) facilitates the storage of substantial data volumes within the blockchain. Despite these advancements, Sri Lanka's transition to complete digitalization remains incomplete, presenting ample opportunities for further integration of blockchain technology. Therefore, our focus lies in examining the potential integration of blockchain technology within government institutions such as the Registry of Motor Vehicles (RMV) and exploring its practical implementation. Especially, focusing on digitalizing the vehicle registration, ownership transfers, modifications and vehicle data validation, i.e., main functionalities using blockchain to provide more secure solution to overcome the existing problems of the vehicle registration system of Sri Lanka.

### 3. System Design

The system primarily handles five key functionalities: new vehicle registration, transfer of vehicle ownership, updating vehicle modifications, generation of vehicle certificates, and access to vehicle information. The system model is shown in Figure 2.

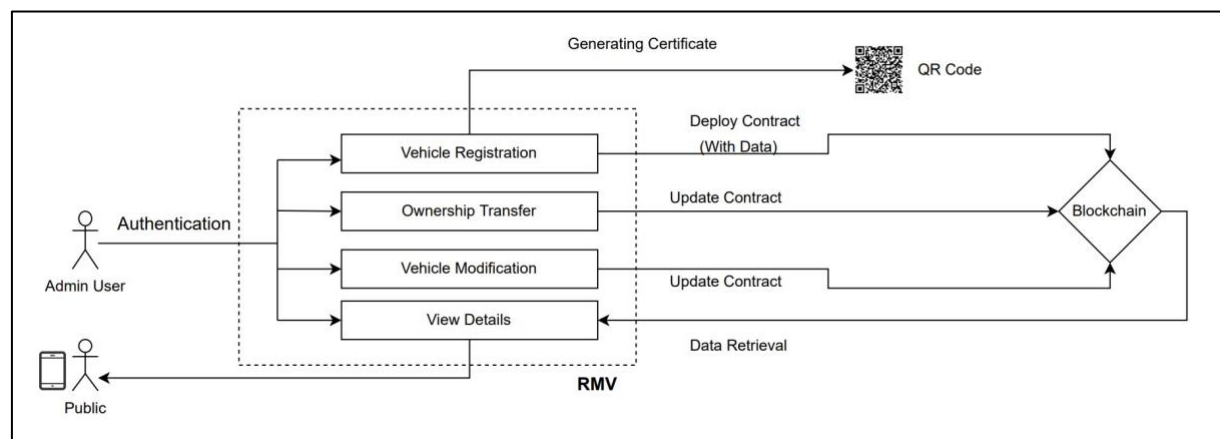


Figure 2: Abstract view of proposed system model

#### 3.1 Vehicle Registration Process

The core process of our system involves registering newly purchased vehicles, following these steps:

- **User Authentication:** Initially, the system verifies the administrative user's credentials. Once confirmed, access is granted to the factory contract. Also, authentication via the browser-based Metamask wallet is required during login.



- **Vehicle Registration:** After user authentication, a vehicle contract is created. This is done by providing the vehicle's number plate to the factory contract. The administrative user inputs all vehicle data into the vehicle smart contract.
- **Hashing and Storing:** Blocks are created to maintain the blockchain's integrity once the data is provided. These blocks are then added to the blockchain ledger by a specific node. A transaction cost is incurred for block mining.
- **Certificate Generation:** The system generates certificates using the vehicle contract address on the blockchain. This is done seamlessly by the system's backend, resulting in QR-embedded certificates.

### 3.2 Vehicle Ownership Transfer

In the process of transferring vehicle ownership, a parallel authentication procedure is conducted, distinct from registration. This authentication process entails the following procedures:

- **Certificate Update:** The existing certification undergoes modification to get the relevant details of the new owner without creating a new certificate. Additionally, the date of ownership transfer is recorded.
- **Maintain Vehicle History:** As an additional step, the vehicle ownership is recorded along with the owners' personal details in every transfer.

### 3.3 Vehicle Detail Modification

In this step, updates are limited to changes such as vehicle colour and engine number in the vehicle contract. Instead of maintaining a history of modifications, the date of the latest update is recorded.

### 3.4 Accessing Vehicle Details

Administrative users are granted access to the vehicle data through the system. This access permits viewing data of a particular vehicle and all vehicles registered within the system. Public access to vehicle details is facilitated through a dedicated mobile application, which retrieves and displays the data from the blockchain.

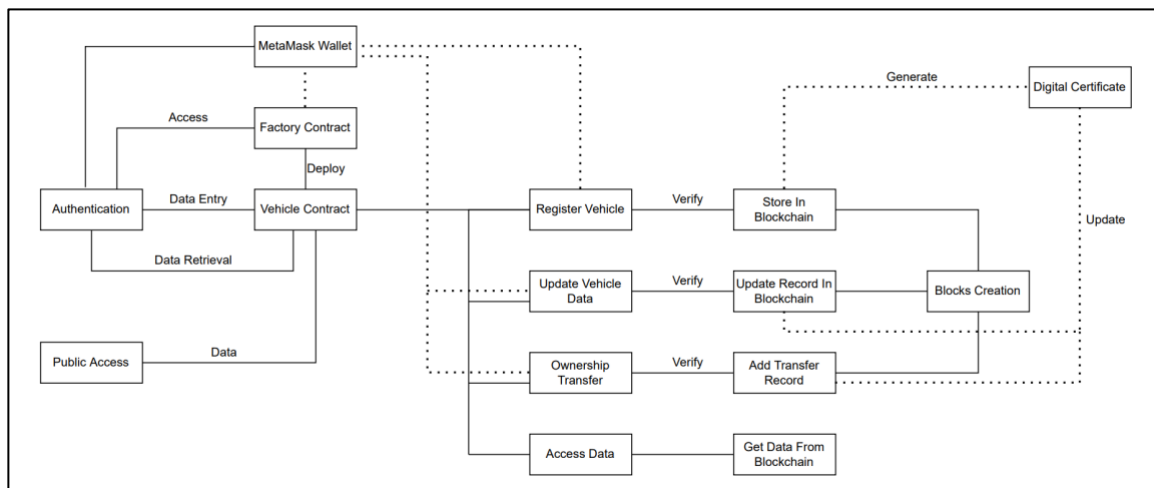


Figure 3: Detailed functional program

## 4. Implementation

This section provides a detailed interpretation of the proposed system's implementation process, including the contract's deployment and the tools and technologies utilized. The section is divided into two subsections: the first elaborates on the main system components (web portal, blockchain, and mobile application), and the second focuses on the testing procedures. An overview of the system architecture is presented in Figure 4.

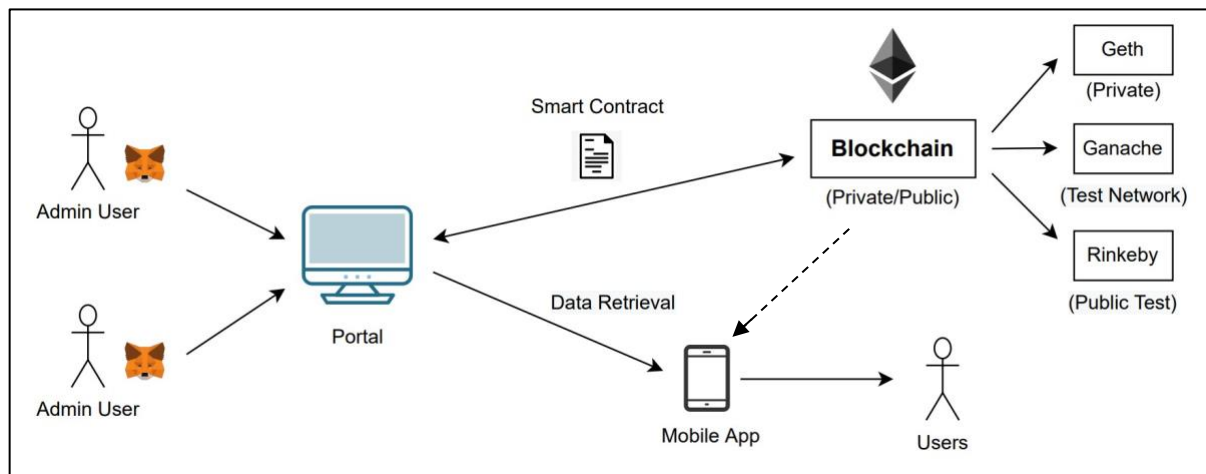


Figure 4: Vehicle registration system architecture

The smart contract is initially deployed to the blockchain as a factory contract. Upon receiving specific requests, this factory contract generates individual vehicle contracts for each vehicle, maintaining a comprehensive record of all deployed vehicle contracts, each encapsulating detailed information about a particular vehicle. These deployments are facilitated through the Truffle framework. The Registry of Motor Vehicles (RMV) administration directly interacts with the factory contract using an Application Binary Interface (ABI), allowing for the authorized deployment of vehicle contracts. Both factory and vehicle contract functionalities, encompassing data reading and writing operations, are executed using Web3.js. The vehicle contract updates with the new value for minor vehicle modifications, such as changes in colour. In contrast, transferring vehicle ownership preserves historical data within the smart contract. Furthermore, a contract-embedded access control mechanism is implemented to prevent unauthorized deployment or data manipulation by external entities.

Several key tools and technologies were employed in the implementation of the blockchain-based system. The system leverages the Ethereum platform's smart contract functionality, utilizing Solidity for smart contract development facilitated by the Remix Integrated Development Environment (IDE). The Ganache blockchain was utilized for testing, while the Rinkeby test network served as the public blockchain environment. The Ethereum node was originally configured using Geth, which was also instrumental in creating a private blockchain. Accounts (nodes) were established, and specific miners were designated in this private blockchain to validate transactions. The system's frontend was developed using React.js, whereas the backend was constructed with SpringBoot. The Flutter framework was selected for the mobile application due to its cross-platform capabilities. Transactions within the system were conducted using the Metamask digital wallet and Ethers.

#### 4.1 System Components

The vehicle registration system mainly consists of three components: a web portal, a mobile application, and an Ethereum network.

- **Web portal:** All the vehicle-related transactions, including the certificate generation, are done using this interactive web portal (Figure 5). Designed specifically for use by the RMV administration, this interactive portal facilitates seamless access for authorised personnel to perform essential functions within the system.
- **Mobile application:** Caters to the broader public, offering convenient access to vehicle data by scanning QR codes. This application empowers users to swiftly validate and retrieve pertinent information regarding registered vehicles by utilising the Infura API to connect to the Rinkeby test network and cloud-based storage for key-value pairs when interfacing with Geth.
- **Ethereum:** A decentralised blockchain platform supported by the Ether cryptocurrency. The smart contract governing the vehicle registration system is implemented by utilising the Ethereum network's reliable infrastructure, guaranteeing secure and transparent transaction processes.

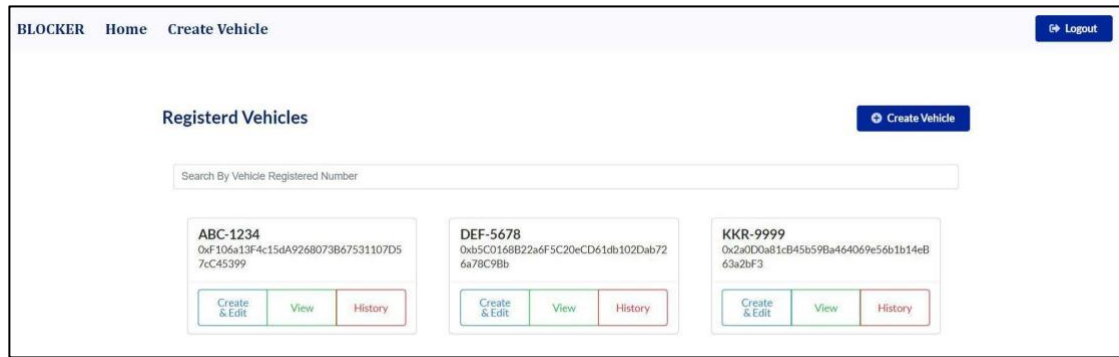


Figure 5: Web portal

#### 4.2 Testing the Developed System

After developing the contract, the Ganache private blockchain was employed to conduct preliminary smart contract testing. Subsequently, the Rinkeby test network was utilized to evaluate system functionalities against the public Ethereum network, as actual ethers are requisite for deployment on the Mainnet. Ethers were acquired from the Rinkeby Faucet to facilitate testing and deposited into the Metamask digital wallet. Comprehensive testing encompassed both private and public blockchain environments. Following this phase, the Geth/Go Ethereum tool was used to configure the system for demonstrative purposes. Geth, a command-line interface, facilitates connectivity to the Ethereum Mainnet and enables the establishment of private blockchain instances, including allocating mining permissions to designated nodes and managing user accounts.

The research presents a hypothetical scenario involving two vehicle owners, wherein three distinct accounts within the RMV system were established using Geth, with two nodes designated as miners for transaction validation within the private blockchain environment. Utilizing these nodes, all primary transactional processes inherent to the system were systematically executed, including the successful completion of data retrieval tasks via the mobile application interface, thereby encompassing the full spectrum of system functionalities (Figure 6).

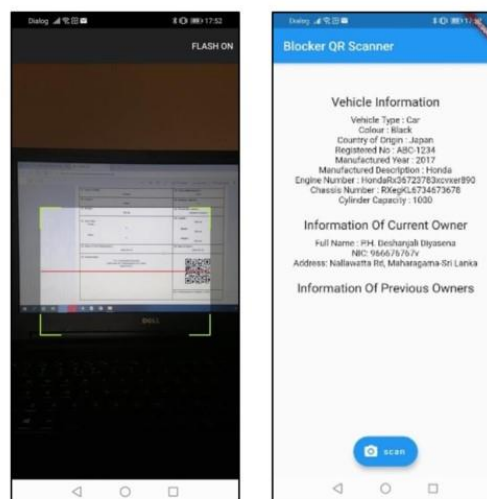


Figure 6: Mobile application

As another evaluation method, expert reviews were collected by presenting different scenarios that cover the functionalities of the implemented system. Through this discussion, experts were able to provide their independent opinions from various aspects. The reviews were collected from six experts: four IT and systems development professionals, one RMV official, and one blockchain technology specialist, all of whom have experience with the existing RMV system (so, can also be considered as end-users of the proposed system). The feedback highlighted several positive aspects of the system, including its efficiency, reduced processing time,

ease of use, enhanced data security and privacy, and increased transparency in vehicle registration processes. Additionally, the experts offered valuable recommendations for future improvements, suggesting enhancements in the quality of the user interfaces, scalability of the system, and extending its application to encompass the entire vehicle ecosystem. This constructive feedback is instrumental in guiding future development and ensuring the system meets the evolving needs of all stakeholders.

## 5. Discussion

Blockchain technology offers a robust framework for ensuring security, privacy, and transparency, making it particularly promising for applications across various domains, including asset management. Among the widely utilised assets globally, vehicles hold significant market value, a trend observed even within the context of Sri Lanka, prompting the imperative for enhancing reliability and trustworthiness in vehicle registration processes, which this study addresses through a blockchain-based system. Leveraging blockchain introduces a distributed ledger mechanism that effectively addresses critical gaps inherent in traditional systems, notably including issues such as certificate duplication and reliance on intermediaries, ensuring secure management of vehicle-related information. The system's architectural design aligns with essential transactional workflows within the Registry of Motor Vehicles (RMV), encompassing key functionalities such as new vehicle registration, ownership transfer, vehicle modifications, and information retrieval seamlessly integrated into the blockchain infrastructure. By implementing a contract-based process control mechanism, the proposed system effectively mitigates vulnerabilities such as third-party interference and data manipulation, enhancing the overall integrity of the registration process while fostering increased trust and reliability. Transitioning from paper-based certificates with digitised, reproducible certificates not only enhances accessibility and transparency but also ensures that the public can securely retrieve vehicle details. Evaluation of the proposed system encompasses hypothetical use cases tested across both public and private test networks, with transaction processing demonstrating remarkable efficiency within the private network. For example, the current system might take days to process a vehicle registration, whereas the blockchain system can achieve this in approximately 15-17 seconds, despite the inherent delay of block mining time. Furthermore, expert reviews were collected as an evaluation method to assess and compare the novel system with the existing system under different criteria. It emphasized several advantages that this system offers to the people, especially, the safety of the registration data, the efficiency and the ease of use.

It is essential to acknowledge that utilising the Ethereum platform necessitates transactional costs, denoted in Ethers (or Wei) as the gas price per transaction but the cost is much lower when compared to the current transaction fees. The potential for widespread adoption and actual implementation of the RMV system will also be a challenge due to the lack of resources (e.g., funds, crypto literacy) and initiations to digitalizing the services in Sri Lanka.

The system's expansion to accommodate direct customer requests and transition towards a comprehensive business-to-customer application is expected as part of future work. Additionally, exploring the feasibility of integrating multiple third parties, such as insurance agencies and manufacturers, into the blockchain ecosystem to oversee the entire vehicle lifecycle within the Sri Lankan context is a pertinent avenue for future research and development.

## 6. Conclusion

The proposed blockchain-based system presents a transformative approach to vehicle registration and management in Sri Lanka, addressing the critical vulnerabilities of the existing centralized system. By leveraging the decentralized and secure nature of blockchain technology, the system ensures enhanced data security, transparency, and reliability, effectively mitigating issues like certificate duplication and third-party manipulation. The prototype's successful implementation and testing demonstrate significant improvements in efficiency and user accessibility, promising a robust solution for vehicle-related fraud and data integrity challenges. Although the transition to this advanced system poses challenges, such as resource constraints, the potential benefits underscore its importance. Future developments aim to integrate additional stakeholders and

expand the system's capabilities, further solidifying its role in revolutionizing vehicle lifecycle management in Sri Lanka.

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# Does Electronic Banking Affect Bank Performance in Tanzania? Evidence from Listed Commercial Banks

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## Abstract

This paper aimed at examining the effect of electronic banking (mobile banking, internet banking and automated teller machine) on profitability of listed commercial banks in Tanzania. The findings show that there is a positive insignificant relationship between the internet banking and bank profitability. This may be explained by hefty initial costs incurred by banks in investments for appropriate infrastructure in facilitating internet banking channel. Regarding the mobile banking and usage of automated teller machines, the study depicts that both have statistically significant positive relationship with profitability at all conventional levels of significance, the avenue that provides extra incentive for commercial banks to utilize the transaction flow to generate more profits and serve costs which would have been incurred for conventional banking practices. These findings are of great importance to managers of commercial banks in Tanzania to understand the effect of electronic banking on profitability of commercial banks, and this may assist them in making decision on adoption of electronic banking, and further enlighten the policy makers in the banking industry on the effect of electronic banking on banks profitability, which, in a way, may provide guidance in designing appropriate policy for electronic banking adoption by commercial banking in Tanzania.

**Keywords:** Internet Banking, Mobile Banking, Automatic Teller Machine, Profitability

## 1. Introduction

Growth in technology has transformed how financial institutions provide financial services to their customers globally (Lawrence & Donald, 2023). Furthermore, the transformation has coincided with increased competition and operational costs which has instigated financial institutions to adopt emerging technologies and innovations to gain competitive advantage (Dermaku et al., 2023). Consequently, commercial banks have transitioned from manual banking to digital banking channels (Aigbovo & Orobator, 2022). Such a transition has seen the emergence of Internet Banking, Mobile Banking, Point of Sales Devices and Automated Teller Machines which

aimed at providing self-services, reliability, and accessibility as customer can withdraw and deposit 24/7 (Hidayat & Kassim, 2023).

The banking Industry has been evolving over the decades despite being dominated by manual services which required a customer to physically approach the brick-and-mortar branches to access financial services (Lugano, 2016). Such limited scope of service had inhibited the portfolio of commercial banks in utilizing the market potential as customers faced long queues, time consuming processes, and congestions which reduced convenience and efficiency (Lugano, 2016). However, the staggering growth of banks and increased competition in the banking sector forced commercial banks to become innovative in reducing costs and improve profitability (Hussain *et al.*, 2021). On this note, Kingu (2021) suggested that electronic banking channels have been opted as a strategy to reduce operational costs associated with running a conventional branch. Likewise, empirical evidence shows that servicing customer transactions through electronic banking channels is 12% and 1% cheaper in India and USA respectively as compared to servicing a customer's transaction through a conventional branch (Malc *et al.*, 2023). Consequently, commercial banks have achieved higher profitability after transitioning to electronic banking through reduced operation costs through customer self-service (Moghni *et al.*, 2020). Moreover, convenience provided to customers in terms of full-time access to financial services has further boosted the ability of banks to utilize profits (Omutonu & Osiemo, 2023).

Electronic banking involves provision of financial services to bank customers through digital channels such as Internet Banking, Mobile Banking, Point of Sales Devices and Automated Teller Machines (Chauhan *et al.*, 2022; Levy, 2022). Electronic banking has brought about benefits to both the customers and the commercial banks. For the former, electronic banking has reduced transaction costs, increased convenience, and facilitated access to financial services anytime and anywhere (Hidayat & Kassim, 2023). Likewise, for the latter, electronic banking has reduced overhead costs associated with operating physical bank branches as customers can be serviced virtually. Furthermore, it enhanced efficiency and has increased banks' portfolio as more services can be provided across multiple channels (Sullivan & Wang, 2020).

Globally, financial institutions in developed economies have heavily invested in the electronic banking channels as compared to counterparts in developing economies (Mohammed *et al.*, 2022). Such investment has materialised in increased adoption as evident in 80% of adult population in developed countries prefer electronic banking leaders being USA with 90% adoption rate followed by UAE (90%), Scandinavia nations (80%), and Great Britain (76%) (Stevanovic, 2020). Accordingly, such high adoption rates signify that commercial banks in developed economies have taken advantage of emerging financial technologies to utilize provision of financial services (Chauhan *et al.*, 2021).

In Africa, electronic banking has been spearheaded by mobile banking which has experienced a surge in usage as it accounts over 75% of the entire online traffic, this can explain why commercial banks opt for mobile banking apps as compared to internet banking (Digital Banking Transformation Report, 2023). Specifically, over USD 495 Billion is transacted through mobile money in Africa annually which accounts for over 65% of the total mobile transactions globally (GSMA, 2021). However, few nations have pioneered digital banking in Africa notably Kenya where access to banking services through digital platforms has increased from 26% in 2006 to over 87% percent in 2021 (Harvard Business Review, 2021). Likewise, South Africa and Mauritius and have achieved over 64% internet and mobile penetration whilst amassing over 70% and 90% of banked population respectively which has simplified the adoption of electronic banking (de Bel *et al.*, 2020). Despite the progress over 90% of transactions in Africa are done through cash payments whilst digital channels only account for an average 5-7% of total transactions (Mc Kinsey, 2022). This low average is a result of the continent having over 50% of unbanked population (Digital Banking Transformation Report, 2023). Furthermore, low internet penetration of a mere 26% has complicated the ability of African economies to utilize electronic banking opportunities (de Bel *et al.*, 2020).

In Tanzania, the banking sector has evolved from a state-dominated sector into a liberalized sector to include the private sector in the financial sector (Marobhe, 2019). Such reforms at the beginning of 1990s brought about emergence of competition and laid foundation for the incorporation of commercial banks in the economy (Kapaya *et al.*, 2020). Despite the introduction of commercial banks, the banking sector remained staggering and

focused on few service portfolios such as formation of credit registry, providing micro and rural loans, develop financial markets, and provide long term financing among other services (Balele *et al.*, 2018). Despite the influx of commercial banks from 29 in 2000 to over 59 banks by 2022 the banking industry was struggling with low returns as they lacked innovation and technology strategy. However commercial banks transitioned to digital innovation through electronic banking to reduce risk, reduce operational costs, increase financial services accessibility, and increased efficiency (Kapaya *et al.*, 2020). Consequently, the introduction of electronic banking in the past decade has seen an increase in profitability among the commercial banks which may be attributed to servicing a broader market, increased convenience to customers, and reduction in operating costs of servicing customers through branches.

To further maximize the profit potential, provision of banking services through electronic channels has gradually increased in recent years. The improvement is evident as transactions volumes processed over electronic channels have increased two-fold from an estimated 133 Million transactions in 2016 to approximate 304 Million transactions in 2021 (BOT, 2021). The drastic improvement in financial technology has instigated financial institutions to heavily invest and integrate innovative technologies in provision of financial service (Rootman & Kruger, 2020). Nonetheless, emergence of bottle-neck competition in the banking sector has necessitated early adoption of digital banking channels as a vital tool to gain competitive advantage and acquire product and service differentiation in the market (Mbegu *et al.*, 2019). Such technological innovations have led to emergence of electronic banking channels in terms of Mobile Banking, Internet Banking, ATMs and PoS channels that have presented banks with abundant opportunities such as service accessibility, market expansion, customer convenience, operational efficiency and cost savings which have a high potential to enhance revenue and profitability (Njogu, 2014).

In appreciating the role of electronic banking, various scholars in Tanzania have pursued the concept in an attempt to widen the knowledge of the notion of electronic banking and its direct influence on commercial banks. In light of this, Mbegu *et al.*, (2019) drew attention to trend analysis of increase in internet banking customers and effectiveness of fees collection through electronic banking channels. Likewise, Kiunsi (2013) examined the benefits of electronic banking channels on time saving, cost saving, and convenience.

Moreover, Magoma *et al.* (2020) conducted a trend analysis of growth in mobile banking and retail banking channels. Also, the study analyzed the trends of loan ratio through electronic banking channel. Furthermore, Lugano (2016) envisaged on the impacts of electronic banking on banking operations of commercial banks in Tanzania.

Despite the scholarly insights on the effect of electronic banking channels on various operations of commercial banks, there is an extensive debate and scant retrievable empirical evidence on how electronic banking channels in Tanzania enhance the profitability of commercial banks in Tanzania. This study aims at examining the influence of mobile banking on the profitability of listed commercial banks in Tanzania.

## **2. Related Literature**

### *2.1 Theoretical Underpinnings*

#### **2.1.1. Expectation Confirmation Theory**

The theory was developed by classical scholar Richard Oliver in a series of academic articles between 1977 and 1980 and the theory has since been applied in marketing, psychology, and information system discipline (Bhattacharjee, 2001). Subsequently, technology scholars and practitioners have applied the theory to examine the continuous usage of emerging technologies among customers and institutions (Rahi & Ghani, 2019). The basic assumption of the theory is that continuous use of emerging technologies relies on the customer's perceived usefulness and perceived performance which are then compared to the performance expectations.



Consequently, should a customer perceive the performance outcome of a technology to be in line with expected performance standards, then satisfaction is achieved thus triggering continuous use. Specifically, Continuance Intention and post-adoption satisfaction are functions of perceived usefulness and Expectation Confirmation. The theory is applicable to the study as it examines how continuous utilization of electronic banking channels is an outcome of the technologies meeting the performance expectations and perceived usefulness of the commercial banks in terms of profitability. The theory is composed of four main components; perceived usefulness, expectation confirmation, customer satisfaction, and continuance intention. Expectation confirmation can be referred to as the extent to which a customer perceives that expected performance standards are confirmed throughout the course of actual usage of a technology service. Accordingly, customers will be satisfied with electronic banking if the services meet the performance expectations (Tsai *et al.*, 2014; Hoehle *et al.*, 2012). Nonetheless, perceived usefulness can be referred to as the extent to which customers have a high confidence and belief that an emerging technology can fulfill the performance expectations (Mc Kennie *et al.*, 2006).

### 2.1.2. Technology Acceptance Model

To understand, predict and explain why people accept or reject information systems; researchers have developed and used various models to understand the acceptance of users of the information systems. The technology acceptance model (TAM) that was adopted by Yani, E., Lestari, A. F., Amalia, H., & Puspita, A. (2018), is one of the most cited models that researchers used to study underlying factors that motivate users to accept and adopt a new information system.

The primary goal of TAM is to provide an explanation of factors affecting computer applications' acceptance in general. In addition, this model helps researchers and practitioners to identify why a particular system is unacceptable (Yani *et al.*, 2018). Using an information system is directly determined by the behavioral intention to use it, which is in turn influenced by the users' attitudes toward using the system and the perceived usefulness of the system. Attitude and perceived usefulness are also affected by the perceived ease of use. Technology acceptance model is used to explain how banks adopt electronic banking.

## 2.2 Empirical Literature

Mobile banking is an emerging platform that has enabled customers to access financial services through mobile cell phones. In assessing the relationship between mobile banking and financial performance, Fentaw and Thakkar (2022) ascertained a strong effect of mobile banking on profitability of Egyptian banks.

Kumar *et al.* (2020) in their study on analyzing the Mobile Banking adoption framework in India, and found that perceived ease of use and perceived usefulness have a positive influence on the adoption of mobile banking, and ultimately such adoption motives have improved the volume of transactions through mobile channels thus leading to profitability.

In Kenya, Karimi *et al.* (2021) conducted a study of the agility of mobile banking and performance of commercial banks, and found that 34% of variation in performance of commercial banks was explained by agility (an opportunity for banks to utilize as it provides the flexibility to the customer in accessing the financial services any place, any time even after conventional working hours) in mobile banking. These studies explicate that mobile banking has allowed commercial banks to maximize their clientele base by servicing them without incurring extra costs as the case with conventional branches. Moreover, cost saving is seen to have impacted both the clients and the commercial bank as majority of services can be executed literally anywhere. Considering that mobile banking allows for payments of bills and cash withdrawals and deposits anytime of the day and even on weekends, it provides extra incentive for commercial banks to utilize the transaction flow to generate profits.

While Ghose and Maji (2022) reported a positive influence of internet banking channel on profitability of the commercial banks in India, conversely, Phan *et al.* (2020) established that adoption of electronic banking has negatively impacted the Indonesian banking industry. Likewise, in Amman Stock Exchange, Al-Amameh (2023)

shows that investment in ICT such as internet banking has a significant relationship with bank cost efficiency which leads to higher profitability performance.

Sadia *et al.* (2020) suggested that Internet banking enhanced customer's satisfaction through bank's website design and communication responsiveness. Such components have attracted more customers to subscribe to internet banking services as the website is user-friendly and provides more efficient communication with customers. Consequently, such convenience yields improved profitability of the banks.

Consistent with Sadia *et al.* (2020), Subahudin and Shahrom (2023) established that website design is among the major determinant of customer satisfaction through internet banking, and they revealed that satisfaction of customers through internet banking increases client business. Consequently, the studies embrace that commercial banks can leverage on emerging technologies such as artificial intelligence, internet banking applications, and electronic websites to increase their market reach and maximize profits.

Pertaining to Automated Teller Machine (ATM) various studies have been conducted to ascertain its impact on profitability for commercial banks. In light of this, Le and Ngo (2020) conducted a cross-country analysis to measure the determinants of bank profitability, and found that ATM enhances financial performance of commercial banks as a result of cost reduction since servicing transactions through an ATM is cheaper than servicing a transaction through a conventional branch. Likewise, in Nigeria, Jimoh (2019) confirmed that ATMs have a strong positive influence on the profitability of deposit banks. The performance was an outcome of the electronic channel increasing access to financial services to customers through reliability and convenience of ATM machines.

In ascertaining the effect of Point of Sales' transactions on profitability ratios, Ezie *et al.* (2023) established that POS transactions have a significant relationship with profitability in Nigeria. The concept of PoS is further examined by Madugba *et al.* (2021) who revealed that PoS transactions volume has a significant relationship with profitability of commercial banks in Nigeria. On the other hand, Awolusi and Aduaka (2020) conducted a survey on the impact of electronic banking on financial services in Ghana, and found that the use of PoS has a significant relationship with profitability. Moreover, Efuntade and Efuntade (2023) analyzed the relationship between electronic business and profitability, and established that PoS terminals have no co integration with electronic banking fees.

On the one hand, Jimoh (2019) conducted a study on the effect of electronic banking on the financial performance indicators of commercial banks in Nigeria, and found that Point of Sales (PoS) channels have a strong positive influence on profitability ratios of commercial banks in Nigeria. On the other hand, Mohammed *et al.* (2022) ascertained the effect of payments systems innovations on profitability of Nigerian Commercial Banks and report a strong effect of PoS on profitability which provide reliable, viable, and credible payments systems to customers.

### **3. Method and Data**

#### *3.1 Data*

The study deployed a hand collected secondary data from quarterly and annual financial reports of the listed commercial banks from the respective banks' websites. The study adopted purposive sampling since the banks used in the study are specifically selected because they are currently the only listed commercial banks in Tanzania offering electronic banking services since. The selected banks include Cooperative Rural Development Banks (CRDB), Kenya Commercial Bank (KCB), National Microfinance Bank (NMB) and Dar Es Salaam Commercial Bank (DCB). The financial reports show annual and quarterly profitability of the commercial banks in terms of Earnings per Share, and the amount of transactions processed through electronic banking channels ranging from Mobile banking, Internet Banking and Automated Teller Machine.

### 3.2 Variable Description

Table 1 below provides the measurement of variables used in the study

Table 1: Measure of Variables

Construct	Indicator	Abbreviation	References
<b>Independent Variables</b>			
<b>Mobile Banking</b>	Measured by the Natural logarithm of transaction volumes through Mobile Banking of Listed commercial bank <i>j</i> in year <i>t</i> .	$LnMOB_{jt}$	Fentaw and Thakkar (2022)
<b>Internet Banking</b>	Measured by the Natural logarithm of transaction volumes through internet banking of Listed commercial bank <i>j</i> in year <i>t</i> .	$LnINT_{jt}$	Carlos and Ronald (2020)
<b>Automated Teller Machines</b>	Measured by the Natural logarithm of transaction volumes through ATM machines of Listed commercial bank <i>j</i> in year <i>t</i> .	$LnATM_{jt}$	Mahardini et al. (2022); Carlos and Ronald (2020).
<b>Control Variable</b>			
<b>Bank Size</b>	Measured by the natural logarithm of the total assets of Listed commercial bank <i>j</i> in year <i>t</i> .	$LnSIZE_{jt}$	Abaenewe (2013)
<b>Dependent Variables</b>			
<b>Profitability of Commercial Banks</b>	EPS- Measured by the company's net profit divided by the number of outstanding common shares of Listed commercial bank <i>j</i> in year <i>t</i> .	$EPS_{jt}$	Olatinwo et al. (2022); Madugba et al (2021).

## 4. Analytical Approach

In ascertaining the relationship between bank profitability measures and the mobile banking channels, the study applied a panel data regression. Likewise, the study conducted Hausmann specification test to determine whether fixed effects or random effects regression are adopted. Similarly, Levin-Lun-Chu unit root tests were conducted as a pre-requisite test to check if the variables used are stationary at level, require lags or differencing to avoid spurious results. Moreover, the study adopted pairwise correlation to test for multicollinearity among the independent variables.

### 4.1 Model Specification

The following regression model was specified;

$$EPS_{jt} = C + \beta_1 LnMOB_{jt} + \beta_2 LnINT_{jt} + \beta_3 LnATM_{jt} + \beta_4 LnPoS_{jt} + \beta_5 LnSIZE_{jt} + \varepsilon_{jt} \dots (1)$$

**Where:**

$EPS_{jt}$  = Earnings Per Share (EPS) of Listed Commercial Bank *j* in year *t*.

$LnMOB_{jt}$  = Measured by the Natural logarithm of transaction volumes through Mobile Banking of Listed Commercial Bank *j* in year *t*.

$LnINT_{jt}$ : Measured by the Natural logarithm of transaction volumes through internet banking of Listed Commercial Bank *j* in year *t*.

$LnATM_{jt}$ : Measured by the Natural logarithm of transaction volumes through ATM machines of Listed Commercial Bank  $j$  in year  $t$ .

$\beta_5 LnSIZE_{jt}$  = Measured by the Natural logarithm of Total Assets of Listed Commercial Bank  $j$  in year  $t$ .

$C$  is Constant

$\epsilon_{jt}$  is the Error Term

#### 4.2 Diagnostic Regression Tests

##### Panel Unit Root Test

The study conducted a Panel unit root test using Levin-Lun-Chu test to check whether the variables are stationary. This test was conducted for the sole objective of controlling for spurious results that may arise if regression tests are conducted with variables that are non-stationary. The results of the test presented in Table 2 showed that all variables could not achieve stationarity at level, so the variables were transformed at 1<sup>st</sup> difference, and thus the data became fit for regression.

Table 2: Levin-Lun-Chu test Panel Unit root test

Variable	Unadjusted t*	Adjusted t*	P value	Results
Internet Banking	-14.8629	-12.0831	0.0000	Stationary at 1 <sup>st</sup> Difference
Mobile Banking	-2.4517	-1.759	0.0393	Stationary at 1 <sup>st</sup> Difference
ATM	-13.1452	-9.765	0.0000	Stationary at 1 <sup>st</sup> Difference
Bank Size	-11.2955	-9.496	0.0000	Stationary at 1 <sup>st</sup> Difference

##### Multicollinearity Test

A pair-wise correlation was conducted to check for the presence of multicollinearity between the independent variables, and the findings in Table 3 show that there is no presence of multicollinearity between the main independent variables i.e. internet banking transaction value, mobile banking transaction value, and ATM transaction value which allows the panel regression tests to be conducted with potential objective results.

Table 3: Pair Wise Correlation

	1	2	3	4
Internet Banking (1)	1			
Mobile Banking (2)	-0.021	1		
ATM (3)	-0.0624	0.1181	1	
Bank Size (4)	-0.131*	0.1589**	0.1440**	1

Significance level; \*P<0.10, \*\*P<0.05, \*\*\*P<0.01

#### 4.3 Panel Regression Results

Panel regression results in Table 4 reveal that the estimate of Internet Banking Transaction Value is positive (4.6283) but with an associated p-value of 0.582 and thus insignificant at all conventional levels of significance.

The results are consistent in all four models as they show an insignificant relationship between internet banking transaction values and profitability as measured by EPS. The insignificant relationship can be explained by hefty initial costs incurred in investments for appropriate infrastructure in facilitating internet banking channel. This notion is also supported by Hossain, (2021) whose results showed that commercial banks adopting electronic banking channels experienced a deterioration in their financial performance indicators in the initial year as a result of the high infrastructure costs in setting up the operations of the channel. The results are also in line with Aduaka and Awolusi (2020) who asserted that Internet Banking transaction values have an insignificant relationship with profitability among commercial Banks in Nigeria.

In light of this, the findings in this study signify that the listed commercial banks in Tanzania have yet to recoup their high initial investment costs and that may explain its low contribution towards EPS. However, the commercial banks in the long run may eventually recoup the costs and thus contribute highly towards the profitability of the commercial banks through increasing the earnings per share.

Regarding the mobile banking transaction value, the results in Table 4, for all four models, depict that mobile banking transaction value has a statistically significant relationship with profitability at all conventional levels of significance affirming that mobile banking is a vital component in increasing profitability as commercial banks leverage on the accessibility and convenience offered by mobile phones to services its market. Mobile banking is an emerging platform that has enabled customers to access financial services through mobile cell phones. The notion is further supported by Kumar *et al.* (2020) who analyzed the Mobile Banking adoption framework in India, and found that perceived ease of use and perceived usefulness have a positive influence on the adoption of mobile banking. Such adoption motives have improved the volume of transactions through mobile channels thus leading to improved profitability. It is worth noting that agility of mobile banking is an opportunity for commercial banks to utilize as it provides the flexibility to the customer in accessing the financial services any place, any time even after conventional working hours.

The findings, therefore, elucidate that mobile banking may allow commercial banks to maximize their clientele base by servicing them without incurring extra costs as the case with conventional branches. Moreover, cost saving may also impact both the clients and the commercial bank as majority of services can be executed literally anywhere. Considering that mobile banking allows for payments of bills and cash withdrawals and deposits anytime of the day and even on weekends, it provides extra incentive for commercial banks to utilize the transaction flow to generate profits.

Panel regression analysis, further, reveals a positive value of the estimated ATM Transaction Value of (15.0059) with an associated p-value of 0.121 indicating insignificant relationship with EPS at all conventional levels of significance. On contrary, the results in model 2 and 3 show that ATM transaction values have a significant relationship with EPS at 10% and 1% significant levels respectively. The results, therefore, signify that banks leveraging on Automated Teller Machine (ATM) eventually achieve more profitability, the results which are in line with Le and Ngo (2020) who conducted a cross-country analysis to measure the determinants of bank profitability, and established that Automated Teller Machine (ATM) has a strong impact on profitability of banks. This finding imply that ATM can enhance financial performance of commercial banks as a result of cost reduction emanating from the use of the same because servicing transactions through an ATM is cheaper than servicing a transaction through a conventional bank branch. Likewise, Awolusi and Aduaka (2020) established that ATM is also a vital source of revenue, hence, resulting in high profitability. Furthermore, the results coincide with findings by Jimoh (2019) who confirmed that ATMs have a strong positive influence on the profitability of deposit banks in Nigeria.

Table 4: Ordinary Least Square (OLS) Regression

VARIABLES	EPS (1)	EPS (2)	EPS (3)	EPS (4)
Internet Banking Transaction Value	4.6283 (0.582)	3.735 (0.664)	-	10.8753 (0.142)

Mobile Banking Transaction Value	8.2501*** (0.003)	-	8.1876*** (0.003)	8.764*** (0.001)
ATM Transaction Value	15.0059 (0.121)	18.5075* (0.059)	17.543** (0.039)	-
Bank Size	3.7134 (0.858)	36.625** (0.042)	8.3557 (0.660)	13.3775 (0.500)
Constant	-352.6628 (0.133)	-731.946*** (0.000)	-360.529* (0.083)	-384.628* (0.072)
Year Dummies	Included	Included	Included	Included
Observations	192	192	192	192
R Squared	0.3175	0.2926	0.3143	0.314
Prob > F	0.0000	0.0000	0.0000	0.0000

## 5. A Concluding Remark

This paper aimed at examining the effect of Electronic Banking on profitability of listed commercial banks in Tanzania. The findings show that there is a positive insignificant relationship between the internet banking and bank profitability. This may be explained by hefty initial costs incurred by banks in investments for appropriate infrastructure in facilitating internet banking channel. The banks are probably yet to recoup their high initial investment costs and that may explain its low contribution towards EPS.

Regarding the mobile banking the study depict that mobile banking has a statistically significant relationship with profitability at all conventional levels of significance. Mobile banking is considered an emerging platform that enables customers to access financial services through mobile cell phones, a device which is owned by over 70% of adult Tanzanians. Therefore, considering that mobile banking allows for payments of bills and cash withdrawals and deposits anytime of the day and even on weekends, it provides extra incentive for commercial banks to utilize the transaction flow to generate more profits.

Furthermore, the study reports a positive significant relationship between the use of automated teller machine and bank performance, implying that ATM can enhance financial performance of commercial banks as a result of cost reduction emanating from its use because servicing transactions through an ATM is considered cheaper than servicing a transaction through a conventional bank branch.

The findings of this study are of great importance to managers of commercial banks in Tanzania to understand the effect of electronic banking on profitability of commercial banks in Tanzania, and this may assist them in making decision on adoption of electronic banking. This may also enlighten the policy makers in the banking industry on the expected effect of electronic banking on banks profitability, which, in a way, may provide guidance in designing appropriate policy for electronic banking adoption by commercial banking in Tanzania.

Subsequently, the study recommends bank managers to focus on adopting internet banking channels in providing financial services, and put sound investments in the digital platforms to increase bank revenue which can ultimately offset their initial investment costs. Furthermore, due to emerging need of cost saving among commercial banks, the findings recommend banks to adopt cost-effective alternative solution through mobile banking channel, which is proven effective and efficient elsewhere.

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# Data Science Self-Efficacy Assessment Tools: A Foundational Guide to Evaluating Progress

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## Abstract

Data science education research faces a notable gap in assessment methodologies, leading to uncertainty and unexplored avenues for enhancing learning experiences. Practical assessment is crucial for educators to tailor teaching strategies and support student confidence in data science skills. We address this gap by developing a data science self-efficacy survey to empower educators by identifying areas where students lack confidence, enabling the design of targeted plans to bolster data science education. Collaboration among computer science, business, and statistics experts was instrumental in crafting a comprehensive survey that caters to the interdisciplinary nature of data science education. The survey evaluates 13 essential skills and knowledge areas, synthesized from literature reviews and industry demands, to provide a holistic assessment framework for educators in the field. Rigorous reliability and validity tests were conducted to ensure the survey's robustness and efficacy in accurately assessing student proficiency.

**Keywords:** Data Science, Self-Efficacy, Assessment Tools

## 1. Introduction

Data science has experienced remarkable global demand, solidifying its position as one of the fastest-growing professions worldwide. However, this demand is met with a shortage of freshly graduated, qualified data scientists, raising concerns for academia and industries (Davenport & Patil, 2022; Haben & Hinton). Additionally, research on data science education assessments is lacking, leaving many uncertainties surrounding students' pre-graduation skills. This paper addresses this limitation and develops a data science self-efficacy survey to evaluate and quantify individuals' confidence levels in applying data science skills to build data-driven solutions, intending to enhance the learning experience within data science education. Also, remedial activities were proposed to boost students' confidence based on individual confidence levels. Survey development followed a modified Vinay approach, which guided the construction of customized assessments for data science aligned with organizational needs (Vinay, 2024). This was carried out by collaborating with computer science, business, and statistics experts, crafting a comprehensive lens that caters to the interdisciplinary nature. The survey evaluated 13 items representing applying data science life cycle steps and using related interdisciplinary

skills to fulfill step requirements identified from literature reviews. The survey comprises 48 questions organized into eight sections, answered with a 5-point Likert scale from strongly disagree to agree strongly. The survey was distributed to students and researchers in six educational institutions in Kansas (KS), the United States of America (USA), and Kuwait (KT). Pilot results showed that the survey has high reliability, stability, and suitability. The final analysis indicates that 11.56% of students report low confidence, 11.54% report high confidence, and the majority express moderate confidence. Lower confidence levels were found around "model development" and "model evaluation," which can be tied to "analysis and calculation skills," "optimization skills," and "technical and computing skills." To boost students' confidence using the remedial suggestions, individualized support sessions should be used to discuss student concerns, address any questions or misunderstandings they may have, and offer personalized guidance and encouragement. Additionally, peer support groups can show students that they are not alone and provide opportunities to encourage one another during regular check-ins. Highly confident students need opportunities for advanced learning through independent research, creative projects, or leadership roles within the learning environment, thus encouraging confident participants to share their knowledge and expertise with their peers.

## 2. Limitations

A primary limitation of this study is the biases or inaccuracies that self-efficacy assessments carry. Self-efficacy often focuses on specific tasks or domains, which may not fully capture an individual's overall sense of efficacy across different situations. Moreover, self-efficacy is inherently subjective and self-reported, lacking objective measurement and increasing the prevalence of bias or inaccuracies. Our small size and distributed populations can present significant limitations in research papers by compromising generalizability, statistical power, comparability, external validity, and replicability.

## 3. Background

### 3.1. Confidence and Learning

Confidence plays a pivotal role in students' academic success and overall well-being. Social Cognitive Theory suggests that self-efficacy, or belief in one's ability to succeed, significantly influences behavior and performance. Students with low confidence often exhibit hesitancy, self-doubt, and reluctance to engage in academic tasks. Interventions targeting low-confidence students should build self-efficacy through incremental successes, constructive feedback, and role modeling (Locke, 1987). Additionally, fostering a supportive classroom environment that encourages risk-taking and emphasizes growth mindset principles can empower students to develop resilience and confidence in their abilities (Works, 2017). Self-determination theory posits that autonomy, competence, and relatedness are fundamental psychological needs that drive motivation and well-being. To support moderate-confidence students, educators can provide opportunities for autonomy by offering choices and promoting student agencies in their learning process.

Furthermore, scaffolding instruction and targeted interventions tailored to individual learning needs can enhance students' sense of competence and foster a positive learning experience (Deci & Ryan, 2012). High-confidence students typically believe in their abilities and may seek challenges or leadership roles. However, excessive confidence without corresponding competence can lead to overestimating skills and performance (Hornstra et al., 2023). The Zone of Proximal Development suggested that learning occurs most effectively within the "zone" where tasks are challenging yet achievable with appropriate support. Educators can support high-confidence students by providing opportunities for intellectual challenge and promoting metacognitive skills, such as self-reflection and self-regulation. Encouraging collaboration and peer feedback can also help high-confidence students better understand their strengths and areas for improvement (Training, 2017).

### 3.2. Data Science Assessment Pathway

Vinay proposed a nine-step assessment pathway to create a customized data science assessment aligned with organizational goals using these competencies. These steps include identifying critical competencies,

categorizing and prioritizing, defining competency levels, developing assessment tools, scoring and evaluation rubrics, integrating organizational goals, feedback mechanisms, implementation and training, and iterative refinement. We incorporated the first five steps to develop our survey, which were relevant to our goal of creating an assessment process for academia (Vinay, 2024).

In our study, developing an instrument for assessing self-efficacy confidence in data science requires carefully considering the specific skills, tasks, and challenges relevant to the field. Here's a step-by-step foundational guide to help you create such an instrument:

1. **Define the Scope:** Determine the specific areas within data science that you want to assess. This could include programming skills, statistical knowledge, machine learning expertise, data visualization proficiency, problem-solving abilities, etc.
2. **Review Existing Literature:** Look for existing self-efficacy scales or instruments related to data science or similar fields. This can provide insights into relevant constructs and items that you might include in your instrument. Adaptation of existing scales can be a time-saving approach.
3. **Item Generation:** Generate a pool of items/questions that reflect the skills and tasks you want to measure in data science. These items should be clear, specific, and cover a range of difficulty levels. Consider consulting with data science experts to ensure the items' relevance and validity.
4. **Pilot Testing:** Administer the initial set of items to a small sample of individuals representing your target population (e.g., students and professionals in data science). Collect feedback on the clarity, relevance, and difficulty of the items. Use this feedback to refine the items and eliminate any ambiguities.
5. **Validity and Reliability:** Assess the validity and reliability of your instrument. Validity ensures that the instrument measures what it intends to measure, while reliability ensures consistency in measurement. You can use techniques such as factor analysis to assess construct validity and Cronbach's alpha to measure internal consistency reliability.
6. **Finalize the Instrument:** Based on the results of pilot testing and validity/reliability analyses, finalize the items for your instrument. Ensure that the instrument is comprehensive yet concise enough to be administered efficiently.
7. **Scoring:** Determine the scoring mechanism for your instrument. This could involve assigning numerical values to responses (e.g., Likert scale) or using a categorical scoring system. Consider whether reverse scoring is necessary for specific items to prevent response bias.
8. **Administration:** Decide on the method of administration for your instrument. It could be administered online or in person, depending on your resources and the preferences of your target population. Ensure to work with the Institutional Review Board (IRB) within your institution, county, state, and country.
9. **Data Collection:** Administer the instrument to your target population and collect the responses. Ensure that participants understand the instructions and have enough time to complete the instrument accurately.
10. **Analysis and Interpretation:** Analyze the collected data to assess self-efficacy and confidence in data science. Calculate descriptive statistics (e.g., mean, standard deviation) to understand the distribution of scores. Compare scores across different groups (e.g., novices vs. experts) to identify patterns and trends.
11. **Validation:** Validate the instrument by comparing scores with external criteria (e.g., performance on data science tasks and academic achievement). This can provide evidence for the validity of your instrument.
12. **Iterative Improvement:** Continuously evaluate and refine your instrument based on feedback and further research findings. This iterative process helps ensure the instrument's effectiveness and relevance over time.

By following these steps, you can develop a robust instrument for assessing self-efficacy confidence in data science that can be used for research, education, or professional development purposes.

## 4. Method

### 4.1. Design

This study employed a quantitative approach to develop a self-efficacy survey to assess students' confidence levels in utilizing data science skills and knowledge. The experiment consisted of two phases: survey development and survey implementation. In the development phase, a framework inspired by Vinay's data science assessment pathway guided the process through four key stages (Vinay, 2024) (Malallah, Weese, & Alsalmi, 2023; Malallah, Weese, Shamer, et al., 2023). First, a comprehensive literature review was conducted to understand the current landscape of data science assessment. No scientific research directly addressing data science assessment was found, prompting the creation of a foundational framework for survey development. Second, a thorough literature review was conducted to identify the requisite knowledge and skills for a data scientist, guided by educator and industry recommendations. Data saturation determined the depth of the review. The third stage aimed to establish a coherent sequence of data science concepts within the survey, satisfying interdisciplinary needs. This involved identifying the appropriate data science cycle to guide the arrangement of concepts. Finally, the survey questions were crafted in stage four, drawing from the intersection of the data science cycle steps and the necessary knowledge to fulfill them. The research implementation phase spanned eight weeks. Initially, the survey underwent review and modification based on feedback from experts in statistics, computer science, and business analytics. Subsequently, the survey was distributed online to 163 participants enrolled in data science and data analytics courses across collaborating universities in the USA, Kuwait, and KSA. A pilot study involving 33 randomly selected students from the same population, not included in the analysis, was conducted. Participants were required to complete an online consent form before beginning the survey, with an expected survey completion time ranging between 25 minutes and 40 minutes.

### 4.2. Sample

The sample encompassed a diverse population of 163 individuals engaged in various data science disciplines, comprising 64.7% males and 32.4% females. Participants represented fields such as computer science, statistics, mathematics, and business; they were drawn from six educational institutions, including four universities and two community colleges. Geographically, 32% of participants hailed from the USA, 38% from Kuwait, and 29% from Saudi Arabia. Among the participants, 25% were researchers. The remainder were students (46.4% seniors, 21.4% juniors, and 7.1% first-year students). A notable portion of the sample, 42.4%, possessed prior working experience, albeit only 21% had worked within the technology sector. Regarding educational background, 26% of participants had never taken research courses before, 3% had never taken statistics classes, 8.8% had never taken coding classes, and 44% had never taken machine learning/artificial intelligence (AI) courses. Additionally, 32% had never enrolled in business analytics courses. The remaining participants had varying degrees of exposure to these subjects as part of their curriculum through one or multiple courses (see Figure 1).

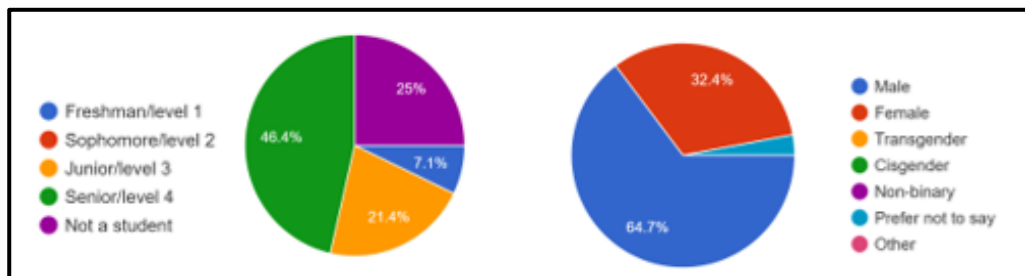


Figure 1: Sample Population

Source: Authors' creation

### 4.3. Keywords, Database, and Criteria

The literature reviews were conducted using specific keywords tailored to each investigation area. The first literature review searched "assessment||self-efficacy" + "data science." The second literature review used the

keywords "knowledge ||skills" + "literature review" + "data science ||data science education ||teaching ||learning ||teaching and learning." The third literature review utilized the keywords "data science||statistic|| mathematics ||computer Science ||business" + "life cycle." Searches were conducted in Google, Google Scholar, and ScienceDirect. Various source types were considered, including conference papers, journals, and blogs. The results were meticulously filtered by isolating abstracts and titles aligned with the search criteria. Studies that did not primarily focus on data science were excluded from the analysis. The search was refined to include only results from 2020 to 2024, except in cases concerning the data science life cycle. Furthermore, research on specific medical fields (e.g., medicine, dentistry, nursing, health professions, neuroscience, pharmacology, toxicology, pharmaceutical science, cancer, effect, and psychological studies) was excluded.

#### 4.4. Instruments

The survey was carefully developed based on thorough analyses from literature reviews (see the Results section). Table 1 presents the investigation's final findings, outlining the 13 elements assessed. Column 2 categorizes these elements as data science life cycle steps and interdisciplinary skills utilized within those steps. The last column specifies the questions targeting each skill. Table 2 contains the survey questions—48 items that evaluate the 13 distinct aspects identified in Table 1. Responses are assessed using a 5-point Likert scale ranging from strongly disagree to agree strongly.

Table 1: The Data Science (DS) Skills and Knowledge of DS Life Cycles

#	Concept	Description	Examples	Questions
1	DS life cycle step 1	Domain knowledge and research design		Q1-Q7
2	DS life cycle step 2	Data planning and data collection		Q8-Q12
3	DS life cycle step 3	Data cleaning, wrangling, and feature engineering		Q13-Q19
4	DS life cycle step 4	Feature selection		Q20-Q28
5	DS life cycle step 5	Model design		Q29-Q35
6	DS life cycle step 6	Model evaluation		Q36-Q40
7	DS life cycle step 7	Communicate and propose action		Q41-Q48
8	Researching and Planning Skill	The ability to formulate well-defined questions, creating a road map for successful project execution while incorporating critical thinking, strategic reasoning, and the ability to navigate, follow, and evaluate both the process and the outcome	Domain Knowledge - Scientific Research Knowledge & Ethic Knowledge.	Q1-Q6, Q19-Q20, Q34, Q42, Q47
9	Analysis & Calculation Skill	The capability to comprehend and utilize statistical concepts and mathematical operations for analysis	Statistical Proficiency Mathematics Proficiency.	Q16, Q18, Q20-Q23, Q26, Q28, Q32, Q34, Q38-Q40.
10	Optimization Skill	The capacity to pinpoint weaknesses within a problem and devise solutions to bolster and enhance it, thereby optimizing efficiency and effectiveness while also facilitating growth to meet or surpass specified requirements and expectations	Optimization – Scalability – Quality - Continuous learning and adaptability - Analytical thinking and problem-solving	Q10, Q19, Q24-Q27, Q31, Q34, Q36-37
11	Technical & Computing Skills	The ability to utilize computing skills, including general computing, advanced machine learning, and AI, along with technical knowledge, to effectively leverage technology for developing innovative solutions	General computing, Machine Learning, AI proficiency, technical knowledge	Q7, Q16, Q18, Q20-Q24, Q27-Q29, Q30-Q34, Q37-Q40
12	Data Management & Handling Skill	The ability to comprehend data structures and the language of data manipulation technology to harness technology effectively for managing and manipulating both small and big data sets to explore and prepare data, ensuring its accuracy and usability.	Data handling, Management, and Database proficiency - Big Data, Data Preparation, and Exploration proficiency.	Q8-Q15, Q17-Q18, Q25, Q27, Q31, Q33, Q36, Q41-Q42, Q48.
13	Business & Communication Skill	Proficiency in translating and aligning business strategies into actionable technical findings, effectively communicating them to stakeholders		Q4, Q16-Q17, Q20, Q23, Q28-Q29, Q34, Q43-Q48

Source: Authors' Creation

#### 4.5. Instruments Rubric

The instrument's rubric outlines thresholds for confidence levels using a 5-point Likert scale by categorizing responses. Self-efficacy confidence scores obtained from the survey were divided into three levels: 1–2.9 (low confidence), 3–3.6 (moderate confidence), and 3.7–5 (high confidence). This categorization applies specifically to the sample analyzed in this paper and may not be generalized to all populations. Future studies aiming to replicate this research should categorize results into three quartiles to determine an appropriate threshold for the data.

Table 2: Data Science Self-Efficacy Survey

#	Questions
1	Creating a plan and designing an effective strategy to develop necessary solutions in a data science project.
2	Establishing realistic timelines and defining achievable milestones using the data science life cycle.
3	Exploring a domain to acquire the necessary knowledge for a specific data science project.
4	Exploring trends and preparing reviewed literature and other scholarly justification from the data science project
5	My ability to formulate investigative questions that align with the nature of the problem.
6	My ability to consider ethical implications related to data privacy, bias, and fairness throughout the process.
7	Creating clear documentation for code, models, and any essential insights made during the project.
8	Articulating the investigated problem and identifying suitable and trustworthy data sources to help derive insights.
9	My ability to design an efficient data collection method while identifying challenges that might arise in the collection process.
10	My ability to [iteratively] adapt modifications to the data collection and cleaning process in response to new findings.
11	My ability to identify and use suitable tools for data collection.
12	My ability to effectively handle the collection of both big and small, structured, unstructured, numerical, quantitative, and qualitative data.
13	Understanding the structure and characteristics of diverse datasets.
14	Merging or joining datasets from different sources to create a unified dataset.
15	Using appropriate tools to visualize data distributions of missing values, duplicate values, inconsistency types, and outliers.
16	My ability to inform decisions to standardize or normalize values as needed, depending on project requirements.
17	In making informed decisions on handling invalid data. Based on the visualized data distributions and stakeholders' requirements.
18	My ability to validate and ensure data quality after cleaning to determine whether the data is cleaned, structured, and ready for feature extraction.
19	My ability to identify when there is a need to create subsets based on project requirements.
20	My ability to understand the meaning of each feature and the relationships between features by communicating with domain experts, ensuring a comprehensive understanding of the features.
21	In applying exploratory data analysis to understand the dataset better using basic statistics (Central Tendency Descriptive Summary), Principal Component Analysis (PCA), or Self-Organizing Map (SOM)
22	Use descriptive statistics and machine learning measures to rank features based on their relationship with the target variable.
23	My ability to filter the features using selection techniques like Forward Selection, Backward Elimination, Recursive Feature Elimination, or Akaike information criterion (AIC), Schwarz or Bayesian Information Criterion (SIC), and Likelihood results selection.
24	My ability to experiment with multiple techniques to find the most effective approach for a specific model.
25	Creating new features by transforming existing ones to enhance the model outcome.
26	(If necessary), in applying transformations to variables, such as transforming values from categorical to numerical data, to strengthen model efficiency.
27	In removing redundancies and selecting features to improve model efficiency.
28	My ability to identify trends and patterns detecting anomalies or novel patterns in the data.
29	My ability to develop a model-building and validation plan.
30	Choosing the appropriate tools suited for model development.
31	Evaluating trade-offs between model complexity, interpretability, and performance.
32	Determining when to use statistical inference, simulation, classification, regression, or clustering methods.
33	Customizing my dataset to match the suitable learning algorithm (supervised, unsupervised).
34	My ability to choose suitable machine learning or statistical models based on the nature of the problem that can minimize the loss function.
35	Identifying when sampling is needed and selecting appropriate sampling methods.
36	That I can scale the model to handle larger datasets.
37	Performing hyperparameter tuning and addressing potential biases or imbalances during model building.
38	Performing validation techniques (e.g., cross-validation) to assess the model's generalization ability.
39	Defining metrics for evaluating model performance, such as accuracy, precision, and recall metrics.
40	Performing diverse analyses on the developed model and its outcome, such as hypothesis testing, estimation, prediction intervals, and determining the significance of relationships.
41	Generating appropriate data visualizations for model outcomes.
42	Using the model's outcomes to inform insight.
43	My ability to provide explanations for model outcomes.
44	Interpreting my result to the lowest denomination so that non-academic readers understand it.
45	Connecting my results to exciting trends and literature to draw inferences when applicable.
46	Combining complex visualized structures, encompassing multidimensional and hierarchical data, to create a non-complex, meaningful, and in-sightful representation of our results through data storytelling.
47	My ability to tailor visualizations to the specific needs and understanding of different audiences, including non-technical stakeholders.
48	My ability to follow best practices for data visualization, including appropriate chart selection, color usage, and labeling

Source: Authors' Creation

## 5. Results

This study analyzed students' confidence in building data-driven solutions in a data science education environment to deliver a coherent assessment. The following research questions were considered, and the responses were analyzed through repeated measures (analysis of variance [ANOVA] and descriptive statistics) using Statistical Package for Social Science (SPSS) software and Excel.

### 5.1. Research Questions

**RQ1:** What specific data science skills and knowledge are essential for students to acquire to align with the demands of the industry?

**RQ2:** What are the key steps involved in the process of constructing data science solutions?

**RQ3:** How can insights from industry needs and solution-building methodologies inform the creation of a tailored survey?

**RQ4:** How reliable is the survey? (Instrument reliability and validity)

**RQ5:** Which skills and steps do students feel less confident about, as identified through the survey? (Instrument analysis)

**RQ6:** How can interventions be designed to address these areas?

*RQ1 - What specific data science skills and knowledge are essential for students to acquire to align with the demands of the industry?*

The literature reviews below were used to design and set the survey content. Table 3 lists the 136 created data science skills, knowledge, and tool ability. The first 39 were taken from Vinay's work (Vinay, 2024), the next 50 items from Usama Fayyad's and Hamit Hamock's work (Fayyad & Hamutcu, 2020), and the remaining from Guoyan's work (Li et al., 2021). The list was clustered and filtered to generate the final list, which has eight categories presented in Table 1, Skills 8–13.



Table 3: The Identified Items from the Literature Reviews

1. Programming Languages	16. Iterative Refinement	Indicators
2. Data Processing Frameworks	17. Critical Thinking	28. Adaptability to Industry Trends
3. Machine Learning Libraries	18. Optimization Strategies	29. Problem-Solving Relevance
4. Data Visualization Tools	19. Interdisciplinary Collaboration	30. Strategic Decision Support
5. Database Management Systems (DBMS)	20. Continuous Learning	31. Rapid Technological Advancements:
6. Version Control Systems	21. Industry Contextualization	32. Expanding Methodological Landscape
7. Big Data Technologies	22. Relevant Data Variables	33. Lifecycle of Data Science Projects
8. Cloud Platforms	23. Customized Modeling Approaches	34. Adapting to Diverse Data Types
9. Integrated Development Environments	24. Understanding Business Objectives	35. Embracing Interdisciplinary Knowledge
10. Automation and Workflow Management	25. Data Privacy and Compliance	36. Professional Development:
11. Problem Formulation	26. Effective Communication with Stakeholders	37. Adoption of New Tools and Frameworks:
12. Hypothesis Generation	27. Identification of Key Performance Indicators	38. Peer Collaboration and Knowledge Sharing
13. Data Exploration		39. Proactive Problem-Solving:
14. Statistical Analysis		
15. Machine Learning Application		
40. Basics of the scientific method, research methods, hypothesis formulation	57. Probability basics, descriptive, inferential, and Bayesian statistics, stochastic processes and time series, causality, sampling	74. Stochastic Processes, Time Series, Survival Analysis
41. Problem identification.	58. Data Preparation and Transformation	75. Virtualization/ Containerization
42. Basic math	59. Data Cleaning	76. Cloud Platforms
43. Calculus	60. Data Exploration and Visualization	77. Statistical
44. linear algebra	61. Unsupervised Learning	78. Mathematical/Numeric
45. Data structures and Algorithms	62. Supervised Learning	80. ML Libraries
46. Databases and Data Processing Systems	63. Reinforcement Learning	81. Development Environments
47. Software Engineering and Development	64. Parallel and Distributed Computing	82. Visualization
48. Operating Systems	65. Text Mining and Natural Language Processing	83. RDBMS and SQL
49. Deep Learning	66. Statistical Sampling	84. NoSQL and NewSQL
50. Descriptive Statistics	67. Linear programming,	85. Data Warehousing
51. Inferential Statistics	68. Nonlinear optimization	86. Querying and Presentation
52. Bayesian Statistics	69. Data Preparation and Transformation	87. Infrastructure
53. Stochastic Processes, Time Series, Survival Analysis	70. Data Cleaning	88. Processing and Execution
54. Statistical Sampling	71. Data Exploration and Visualization	89. Access
55. Linear programming,	72. General-Purpose Programming Languages	90. Integration
56. Nonlinear optimization	73. Computing Fundamentals	
91. Data Mining	103. Business Intelligence	114. SQL
92. Big Data	104. Scalability	115. Python
93. Statistics	105. Mathematical Optimization	116. R
94. Algorithms	106. Data Architecture	117. Apache Hadoop
95. Data Engineering	107. Automation	118. Java
96. Agile Methodology	108. Artificial Intelligence	119. Tableau
97. Extract Transform Load	109. Data Management	120. Apache Spark
98. Data Modeling	110. Operations Research	121. Scripting
99. Data Warehousing	111. Deep Learning	122. SAS
100. Data Visualization	112. Data Quality	123. Microsoft SQL Servers
101. Database Administration	113. Machine Learning	124. Apache Hive
102. Relational Databases		125. Amazon Web Services
		126. C++, C
		127. MATLAB
		128. Scala
		129. NoSQL
		130. Power BI
		131. Object-Oriented Programming
		132. Apache Kafka
		133. Microsoft Azure
		134. PostgreSQL
		135. Apache Cassandra
		136. PyTorch

Source: Authors' Creation

Google Scholar shows seven results, and ScienceDirect shows 73. All were excluded except one. Twenty-five results were found from Google Scholar. Two were chosen as they included extensive literature reviews with new information, and data saturation was satisfied. Vinay (2024) introduced a comprehensive framework to assess and categorize the essential competencies of proficient data scientists. This framework—which stemmed from a literature review exploring technical proficiency, analytical thinking and problem-solving, domain-specific knowledge, continuous learning, and adaptability in data science—provides valuable insights into the field. Vinay defined critical skills for proficient data scientists. The 39 competencies he identified were: Technical proficiency (1–10); analytical thinking and problem-solving (11–20); domain-specific knowledge (21–30); and continuous learning and adaptability (31–39). Although we did not use all his competencies directly, we cross-referenced them with other resources in the following steps (Vinay, 2024).

Fayyad and Hamock, in their study, introduced a comprehensive Data Science Knowledge Framework to foster industry standardization and the creation of measurement and assessment methodologies. Emphasizing data science's dynamic and multidisciplinary nature, the authors constructed the framework through an extensive literature review, identifying pivotal topics and technologies crucial for analytics and data science professionals. The findings were systematically organized into a hierarchical knowledge structure (Fayyad & Hamutcu, 2020).

Guoyan Li et al. analyzed the data science and analytics skills gap in the Industry 4.0 reports to identify the critical technical skills and domain knowledge required for data science in today's manufacturing industry. The authors used Emsi job posting and profile data to gain insights into the trends in manufacturing jobs, leveraging data science (Li et al., 2021).

The process of clustering 136 items was extensive. The list contained various categories, making it challenging to perform definitive clustering without specifying a purpose or desired level of granularity. Several options were available for clustering: domain, function, level of expertise, and tool/technology. We clustered the terms by skill, as it is our objective. We clustered the groups several times, and with every iteration, we merged groups until 14 categories remained: domain knowledge, scientific research method, statistical proficiency, mathematics proficiency, optimization/continuous learning and adaptability, data preparation and exploration, machine learning, general computing, technical proficiency, data management handling and database proficiency, business proficiency and communication, big data, analytical thinking and problem-solving and ethic. The categories have been reduced to eight after being validated by the experts.

*RQ2- What are the critical steps involved in the process of constructing data science solutions?*

A data science life cycle embodies an iterative series of steps crucial for project or analysis delivery, tailored to each project's unique needs. Although no standardized workflow exists for data science, selecting appropriate steps is essential for survey coherence and suitability. Four models were identified and compared for common factors to address this, ultimately revealing eight key steps presented in Table 1.

Table 4 and Figure 2 showcase the identified data science models, where each row represents a model with its associated steps. Model (a) emphasized a data science education lens, encompassed the holistic data life cycle, and integrated workflow with environmental and social considerations such as regulations and ethics (Stodden, 2020). Model (b), viewed statistically, identified seven crucial steps in the data investigation process, including framing the problem, data gathering and processing, exploration, and visualization, model consideration, and communication of findings (LEE et al., 2022). Model (c), from a business and computer science perspective, leveraged Microsoft's Team Data Science Process (TDSP) framework for collaborative learning, and aimed to convert data into actionable insights (Saltz & Hotz, 2020). Model (d), which adopted a computer science and statistic lens, relied on CRISP-DM, guided data mining projects through six phases, from understanding business objectives to deploying models into operational systems (Gupta, 2022).

All models began with problem understanding, progressed through data acquisition and comprehension, and concluded with communication, either as a standalone step or integrated within the evaluation, depending on the model. While tasks such as feature engineering were categorized differently in various models, expert feedback determined the sequence, and the last row served to structure the survey flow and cluster competencies.

Table 4: Identified Data Science Life cycle models

Model	Sequence								
a [11]	Acquire	Clean			Use/ reuse			Publish	
b [12]	Frame problem	Consider and gathering	Process data	Explore & visualize		Consider models		Communicate & propose action	
c [13]	Business understanding	Data acquisition and understanding		Deployment	Modeling Feature engineer	Modeling training	Modeling evaluation		
d [14]	Business understanding	Data understanding		Data preparation Data cleaning: Data integration Data transformation: Data reduction: Data discretization: Feature engineering		Modeling	Evaluation		
	Domain knowledge and research design		Data collection	Data wrangling	Feature engineering	Feature selection	Model design	Model evaluation	Communicate and propose action

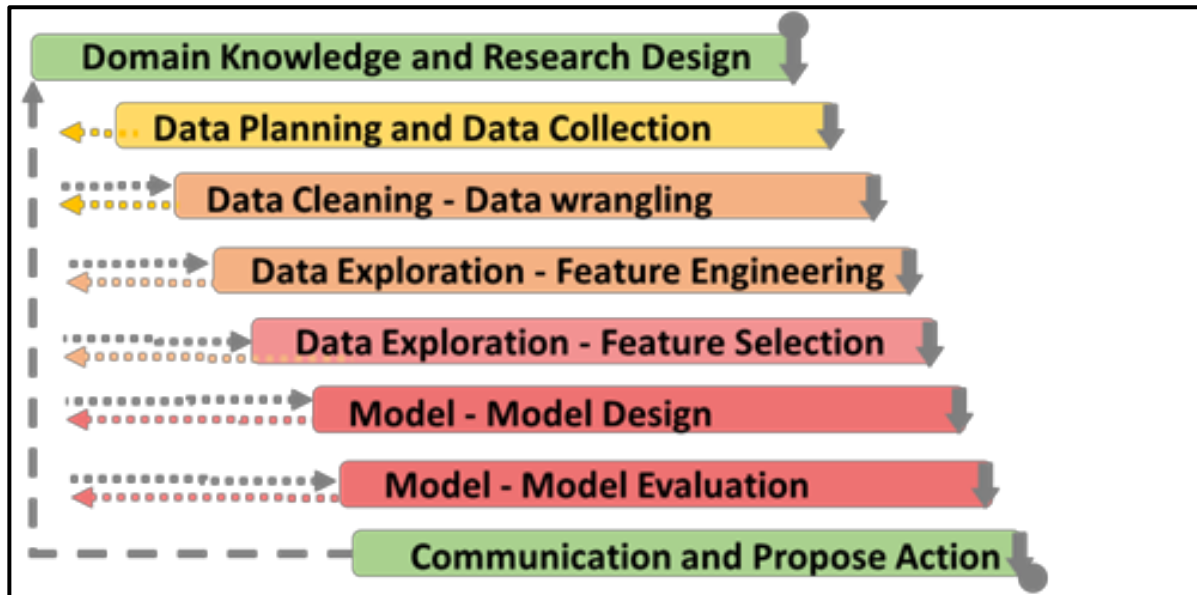


Figure 2: Identified Data Science Life cycle models

Source: Authors' Creation

RQ3 - How can insights from industry needs and solution-building methodologies inform the creation of a tailored survey?

Table 5 presents the fundamental elements necessary for crafting pertinent questions. It aligned the identified skills with the data science steps to create a question flow that effectively fulfills dual purposes. Based on this approach, the final formulated questions are presented in Table 2.

Table 5: The Used Skills and Data Science Steps to Construct the Survey Questions

DB Cycle/Skills	Researching & Planning	Analysis & Calculation	Optimization Skill	Technical & Computing Skills	Data Management & handling	Business & Communication
Domain Knowledge & ...	x			x		x
Data Planning & Data ..	x		x		x	
Data cleaning, wrangling.		x	x	x	x	x
Feature Selection		x	x	x	x	x
Model design		x	x	x	x	x
Model evaluation	x	x		x		x
Communicate & propose.	x				x	x

Source: Authors Creation

RQ 4 - How reliable is the survey? (Instrument reliability and validity)

The pilot stage was subjected to validation through Cronbach's alpha testing to evaluate the reliability of survey statements; the validity was assessed using the Pearson correlation coefficient, presented in Tables 6 and 7. The calculated Cronbach's  $\alpha$  coefficient resulted in a value of 0.915, indicating a high level of internal consistency among the survey items. This implied strong reliability, with the items collectively measuring the intended construct effectively, surpassing the widely accepted threshold of 0.7. Furthermore, the Cronbach's  $\alpha$  coefficient was separately computed for the 13 sections, revealing internal consistency validity within the range of .6–.8. All scales exhibited convergent validity, with correlations among items exceeding 0.3, indicating robust convergent validity statistically, except for the correlation between Q28 and Q21, which was not statistically significant ( $p = 0.45$ ). Assessment of internal consistency validity using the Pearson correlation coefficient showed correlations ranging from .57 to 0.90 for the survey statements. All correlation coefficients were statistically significant at the 0.01 level, highlighting the high internal consistency and validity of the questionnaire.

Table 6: Person Correlations of All the Questions

	S1Q1	S1Q2	S1Q3	S1Q4	S1Q5	S1Q6	S1Q7	S2Q8	S2Q9	S2Q10	S2Q11	S2Q12	S3Q13	S3Q14	S3Q15	S3Q16	S3Q17	S3Q18	S3Q19	S4Q20
Pearson Correlation	.901	.759	.832	.814	.679	.705	.713	.820	.789	.836	.808	.812	.793	.751	.733	.792	.834	.827	.704	.693
	S4Q21	S4Q22	S4Q23	S4Q24	S4Q25	S4Q26	S4Q27	S4Q28	S5Q29	S5Q30	S5Q31	S5Q32	S5Q33	S5Q34	S5Q35	S6Q36	S6Q37	S6Q38	S6Q39	S6Q40
	.577	.692	.590	.816	.751	.687	.740	.861	.818	.855	.792	.660	.719	.696	.825	.759	.704	.723	.831	.873
	S7Q41	S7Q42	S7Q43	S7Q44	S7Q45	S7Q46	S7Q47	S7Q48												
	.822	.854	.790	.823	.879	.839	.716	.789												
**. Correlation is significant at the 0.01 level (2-tailed).																				
*. Correlation is significant at the 0.05 level (2-tailed).																				

Source: Authors' Creation

Table 7: Cronbach Alpha for the 13 Sections

	Domain Knowledge	Data Collection	Data Wrangling	Feature Selection	Model design	Model evaluation	Communicate & propose
Items	7	5	7	9	7	5	8
Cronbach's $\alpha$	.821	.639	.701	.741	.787	.707	.791
	Researching & ..	Analysis & Calc ..	Optimization Skill	Technical & Computing	Data Management..	Business & ..	All
Items	11	13	10	19	18	14	48
Cronbach's $\alpha$	.617	.656	.721	.671	.787	.707	.915

Source: Authors' Creation

*RQ 5 - Which skills and steps do students feel less confident about, as identified through the survey? (Instrument analysis)*

Four of the 130 participants did not complete the survey and were excluded. Table 8 results were scrutinized based on gender (male, female), major (computer science, statistics, business, math, non-STEM), and the 13 identified skills/steps (see Table 1). Significant findings corresponding to associated p-values were highlighted. The effect size, denoted by eta-squared ( $\eta^2 = SS_{effect} / SS_{total}$ ), was classified as small, moderate, or large. Notably, bold font indicated a large effect ( $\eta^2 = .14$ ), underlined results indicated a moderate effect ( $\eta^2 = .06$ ), and no markings denoted a small effect ( $\eta^2 = .01$ ). The abbreviation "M" represented the mean, and "SD" represented the standard deviation. The analysis revealed a significant difference in scores ( $F(4,152) = .549, p = .00$ , partial-eta-squared = .086). All main interactions reached statistical significance at the .05 level—except for the data planning, feature selection, and model evaluation scores. The effect size was small for data planning and feature selection and moderate for domain knowledge, data cleaning, model design, and communication. Confidence levels exhibited similar means for data planning ( $M = 3.5, SD = .9$ ) and data cleaning ( $M = 3.5, SD = .8$ ), followed by a lower but comparable trend between domain knowledge ( $M = 3.4, SD = .8$ ) and communication ( $M = 3.4, SD = 1$ ).

Group interactions did not show any significant differences. Descriptive analysis of group interactions revealed that the highest domain knowledge scores were observed near male statistics majors and female business majors ( $M = 3.4$ ). The lowest was found among non-STEM females ( $M = 2.7, SD = .0$ ). For data planning, the highest scores were attributed to male computer science majors and female statistics majors ( $M = 3.8$ ). The lowest scores were observed among non-STEM females ( $M = 2.3, SD = .0$ ). Regarding data cleaning, male business majors scored the highest ( $M = 3.08, SD = .4$ ), while the lowest scores were among non-STEM females ( $M = 2.9, SD = .0$ ). Female statistics groups attained the highest scores in feature selection ( $M = 3.4, SD = .7$ ). In model design, statistics majors consistently achieved the highest scores, followed by computer science and business majors, with similar scores, and then math, and finally non-STEM. Female statistics students displayed almost the highest confidence levels compared to males across all skills and steps. Notably, computer science was intermediate, with business majors scoring higher than females in the same major. Female math and non-STEM students displayed the lowest scores in all areas. Research skills were most confidently identified with math (73%) and least with math again (61%), along with non-STEM. As expected from non-STEM students, analysis skills were highest among statistics and business majors and lowest among math students. Research skills were most confidently identified with math (73%) and least with math again (61%), along with non-STEM. As expected from non-STEM students, analysis skills were highest among statistics and business majors and lowest among math students. Lastly, business and statistics majors achieved the highest scores for business knowledge skills, with a confidence level of 72%, while computer science scored the lowest at 67%. The results indicate that 11.56% identified themselves with.

Table 8: Mean of Participants Confidence level Over the 13 Sections

	Domain Knowledge & Research design		Data Planning & Data collection		Data cleaning, wrangling & Feature Engineering		Feature Selection		Model design		Model evaluation		Communicate & propose action		Researching & Planning Skill		Analysis & Calculation Skill		Optimization Skill		Technical & Computing Skill		Data Management & handling Skill		Business & Communication Skill		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Gender																											
Computer Science	M 3.1	3.0	3.8	3.4	3.6	3.4	3.3	3.2	3.2	3.0	3.1	3.0	3.4	3.3	68.0%	68.5%	62.0%	63%	70%	65%	72%	63%	74%	67%	67%	66%	
	SD 0.7	0.9	0.9	1.0	0.7	0.9	0.7	0.9	0.8	0.8	0.9	1.1	0.9	1.0	9.6	11.0	11.0	12.5	8.1	9.8	15.5	17.3	14.5	17.2	11.5	13.6	
Statistics	M 3.4	3.2	3.4	3.8	3.4	3.7	3.0	3.4	3.0	3.3	3.1	3.3	3.4	3.6	68.2%	75.3%	61.1%	68%	63%	68%	61%	69%	67%	73%	65%	72%	
	SD 0.9	0.6	0.9	0.4	0.9	0.6	0.8	0.7	0.7	0.8	1.0	0.9	1.1	0.8	12.0	7.4	11.0	9.4	9.5	7.9	15.4	13.1	17.0	11.3	13.2	8.9	
Business	M 3.2	3.4	3.6	3.4	3.8	3.6	3.3	3.2	2.9	3.0	3.2	3.2	3.7	3.4	73.1%	68.9%	67.4%	66%	66%	64%	67%	65%	73%	69%	72%	66%	
	SD 0.4	0.7	0.5	0.8	0.4	0.7	0.5	0.8	0.6	0.9	0.8	0.9	0.6	1.0	6.6	9.8	8.1	10.7	6.1	7.7	11.2	15.2	8.7	14.0	7.8	12.7	
Math	M 3.3	2.9	3.5	3.1	3.5	3.0	3.3	2.8	3.4	2.7	3.3	2.8	3.4	3.1	73.5%	61.4%	65.2%	55%	68%	59%	65%	71%	61%	68%	59%		
	SD 1.0	0.9	1.0	1.1	0.9	1.0	0.9	0.8	0.8	0.7	1.1	1.0	1.2	1.1	12.2	12.3	12.2	11.2	10.3	9.5	17.0	18.0	18.2	18.5	14.7	13.3	
NoneSTEM	M 3.1	2.7	3.4	2.3	3.3	2.9	3.2	2.5	2.9	2.0	3.0	2.0	3.1	2.5	61.1%	63.6%	63.7%	51%	62%	48%	63%	51%	64%	59%	62%	56%	
	SD 0.9	0.0	0.8	0.0	0.8	0.0	0.9	0.0	1.3	0.0	1.2	0.0	1.1	0.0	9.1	0.0	14.1	0.0	11.0	0.0	20.7	0.0	15.9	0.0	14.9	0.0	
Total	M 3.4	3.3	3.5	3.5	3.6	3.4	3.3	3.2	3.2	3.0	3.3	3.1	3.4	3.3	69%	68%	64%	61%	66%	61%	66%	61%	70%	66%	67%	64%	
	SD 0.8	0.9	0.9	1.0	0.8	0.9	0.8	0.8	0.9	0.9	0.9	1.0	0.9	1.0	9.89	8.10	11.28	8.75	8.99	6.98	16.0	12.3	14.9	12.2	12.4	9.69	
	M 3.4		3.5		3.5		3.2		3.1		3.2		3.4														
	SD 0.8		0.9		0.8		0.8		0.9		1.0		1.0														

Source: Authors' Creation

Figure 3 illustrates that 11.56% of cases fall within the low confidence range; moderate confidence accounts for 11.54%, and high confidence is 76.92%. Lower confidence levels were observed, particularly in model design, followed by feature selection and model evaluation, which can be attributed to deficiencies in analysis and calculation, optimization, and technical and computing skills. Conversely, higher confidence levels were associated with research design, data management, and data cleaning, possibly indicating stronger proficiency in these areas.

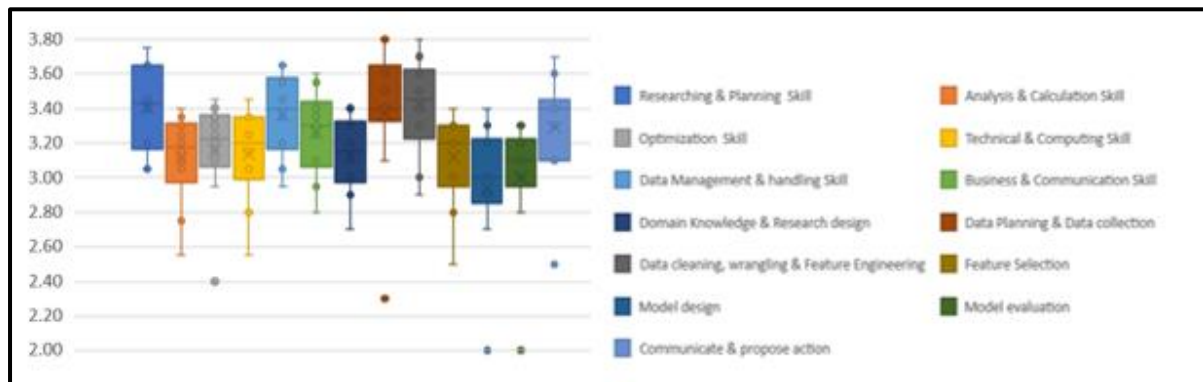


Figure 3: Students' Confidence Level in Using Data Science Skills for Building Data-driven Solutions

Source: Authors' Creation

Note style: Note. M = mean; SD = standard deviation

### 5.2. A Suggested Intermediate Plan to Support Confidence in Data Science Education

An intermediate plan was derived from the background section to bolster confidence in using data science skills across various proficiency levels. Following the application of survey data, educators in data science can pinpoint specific skills or steps in the data science life cycle that require particular attention during instruction. Educators can select activities tailored to their classes upon identifying the skills/knowledge and the corresponding confidence levels.

**Low confidence:** (1) Individualized Support Sessions: Schedule one-on-one meetings with participants to discuss their concerns and address any questions or misunderstandings they may have confidently. Offer personalized guidance and encouragement to help boost their confidence. (2) Additional Learning Resources: Provide supplementary materials—articles, videos, or tutorials—to reinforce key concepts and provide alternative explanations. Recommend books or online courses that align with participants' learning needs and preferences. (3) Peer Support Groups: Facilitate peer support groups where participants can collaborate, share experiences, and provide encouragement to one another. Encourage group members to discuss challenges openly and offer constructive feedback and support. (4) Regular Check-Ins: Conduct regular check-ins with participants to monitor progress, address new concerns, and provide ongoing support and encouragement. Use these opportunities to celebrate small victories and acknowledge participants' efforts and improvements.

**Moderate confidence:** (1) Clarification Sessions: Organize group or question-and-answer sessions where participants can ask questions, seek clarification, and discuss areas of uncertainty. Provide clear explanations and examples to reinforce understanding and address common misconceptions. (2) Practice Opportunities: Offer practice exercises, quizzes, or problem-solving tasks to allow participants to apply their knowledge and skills in a supportive environment. Please provide feedback and guidance to help participants identify areas for improvement and build confidence in their abilities. (3) Mentorship Program: Pair participants with mentors or more experienced peers who can offer guidance, advice, and encouragement. Encourage mentors to provide personalized support and share their own experiences and strategies for success. (4) Self-Reflection Activities: Encourage participants to reflect on their learning journey, identify strengths and growth areas, and set achievable goals for themselves. Provide prompts or reflection questions to guide their self-assessment and encourage deeper engagement with the material.

**High confidence: (1) Advanced Learning Opportunities:** Offer advanced workshops, seminars, or projects for participants confident in their abilities and eager to challenge themselves further. Provide opportunities for independent research, creative projects, or leadership roles within the learning community. **(2) Peer Teaching Sessions:** Encourage confident participants to share their knowledge and expertise with their peers through peer teaching sessions or mini-workshops. Facilitate opportunities for participants to develop their presentation and communication skills while helping others learn. **(3) Professional Development Resources:** Provide access to professional development resources such as webinars, conferences, or networking events to help participants further their skills and expertise. Offer guidance on career pathways, industry trends, and continued growth and advancement opportunities. **(4) Recognition and Rewards:** Acknowledge and celebrate participants' achievements and contributions within the learning community. Offer certificates of achievement, badges, or other forms of recognition to acknowledge their dedication and accomplishments.

## 6. Conclusion

The field of data science is experiencing rapid global growth, yet there is a notable shortage of qualified data scientists, posing concerns for academia and industries alike. Moreover, the lack of research in data science education assessments leaves uncertainties about students' skills before graduation. This paper addresses these gaps by developing a data science self-efficacy survey to gauge individuals' confidence levels in applying data science skills and proposing activities to boost confidence based on their levels. The survey—developed with input from computer science, business, and statistics experts—evaluates 13 items representing data science life cycle steps and related interdisciplinary skills. Distributed to students and researchers across six educational institutions, pilot results indicated high reliability and stability. Analysis revealed varying confidence levels among participants, with the majority exhibiting moderate confidence. Remedial suggestions include individualized support sessions and peer support groups for those with low confidence. High-confidence individuals are encouraged to pursue advanced learning opportunities and share their expertise with peers.

## 7. Future Work

The survey will compare results across a broader sample from various continents, enabling a more comprehensive understanding of trends and variations in data science proficiency across diverse geographical regions. Further investigation will be conducted regarding the threshold scale.

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