



The Imperative Necessity of Erbil-Koya Highway Stretch

Abdulqader Othman Hamadameen^{1,*}

¹Department of Mathematics, Faculty of Sciences and Health, Koya University, Danielle Mitterrand Boulevard, Koya KOY45, Kurdistan Region – F.R. Iraq

Email: abduqader.othman@koyauniversity.org

Abstract

Human civilization encompasses all that humans have created, both materially and morally, within a specific time and place. Thus, building highway extensions represents a significant addition to the material aspects of civilization. Highways are a crucial component of human development, affecting societies in social, economic, environmental, urban, and cultural ways. Connecting Erbil with Koya via a highway is expected to affect the populations of both cities and their surrounding areas. This paper examines the role of highways in societal development, with a particular focus on Koya. We have demonstrated the importance of highway design through mathematical models using modern speed parameters, fuzzy logic, and control methods. Additionally, we proposed a method for managing highway speeds through radar and remote sensing technologies. The paper highlights the inevitable societal progress resulting from the Koya-Erbil highway connection.

Keywords: Economic and environmental impacts; Fuzzy control and techniques; Geographical location; Speed variations; Cultural exchange; Radar; Remote sensing; Social impacts; Traditional and contemporary speeds; Urban renaissance

1. Introduction

A highway is any major road designed for fast, long-distance travel, including controlled-access roads like autobahns and autoroutes [1] (See Figure 1, 2, 3).

Highway systems started to develop in the 20th century, with early advancements focusing on enhancing existing routes like fords, mountain passes, and swampy areas. In contrast, as early as 5000 BC, roads in England were built along ridges to avoid crossing rivers and bogs. The campaign for better roads in the U.S. occurred from the late 1870s to the 1920s, but the roads built then were not designed for high-speed vehicles. The British civil engineer Edgar Purnell Hooley was one of the first to specialize in highway engineering [2]. As highways evolve to meet the demands of modern, advanced vehicles—considering durability, load capacity, and safety—it's essential to manage vehicle control and regulate speed. Ensuring priority and maintaining quality control on highways have become unavoidable necessities. To ensure highways continue to benefit civilization rather than becoming a burden, it is crucial to employ flexible and effective methods.

Modern methods for optimizing transportation control emerged, with the initial development of controlled-access highways beginning in the first half of the 20th century [3].

During World War II, the longest illuminated stretch of roadway was built. In the 1930s, Edward M. Bassett was the first to use the term "freeway" for a specific type of highway. He also suggested categorizing roads into three main types: highways, parkways, and freeways, each with distinct characteristics. According to Bassett, parkways are intended for recreational use, while freeways are designed for efficient transportation [4].

Civilization encompasses all that humanity has created in both material and moral aspects. Highways are a crucial part of the material aspect of civilization. Therefore, civilizational advancement could not occur without the development of efficient transportation networks. Society and its advancement are dependent on the improvement of highway networks. As changes in production methods drive shifts in lifestyle, the need for effective transportation infrastructure becomes crucial. Therefore, the Erbil-Koya highway segment is an essential necessity

due to its impact on civilization, economic development, urban growth, and network connectivity. We will explore these factors in the upcoming sections.

The remainder of this study is as follows: The next section addresses highways and infrastructure. Section 3 examines the impact of geographical location on highway expansion. Section 4 outlines the benefits of the highway. Section 5 transitions from the imperative to the critical questions. Section 6 introduces fuzzy methodology, while Section 7 covers linguistic hedges related to speed. Section 8 addresses the fuzzy membership function for modern car speeds. Section 9 explores the fuzzy control system. Section 10 outlines the study's objectives, and the final section provides the conclusions.



Figure 1. Highway sign.



Figure 2. Highway model 1.



Figure 3. Highway model 2.

2. Highway systems and infrastructure

Highways, as a fundamental component of infrastructure, play a crucial and beneficial role in shaping the state's and society's overall infrastructure [5]. Highways are central to the infrastructure system, connecting with streets, bridges, public transportation, airports, water and waste management, solid waste disposal, electricity, telecommunications, and hazardous waste management, creating an integrated network.

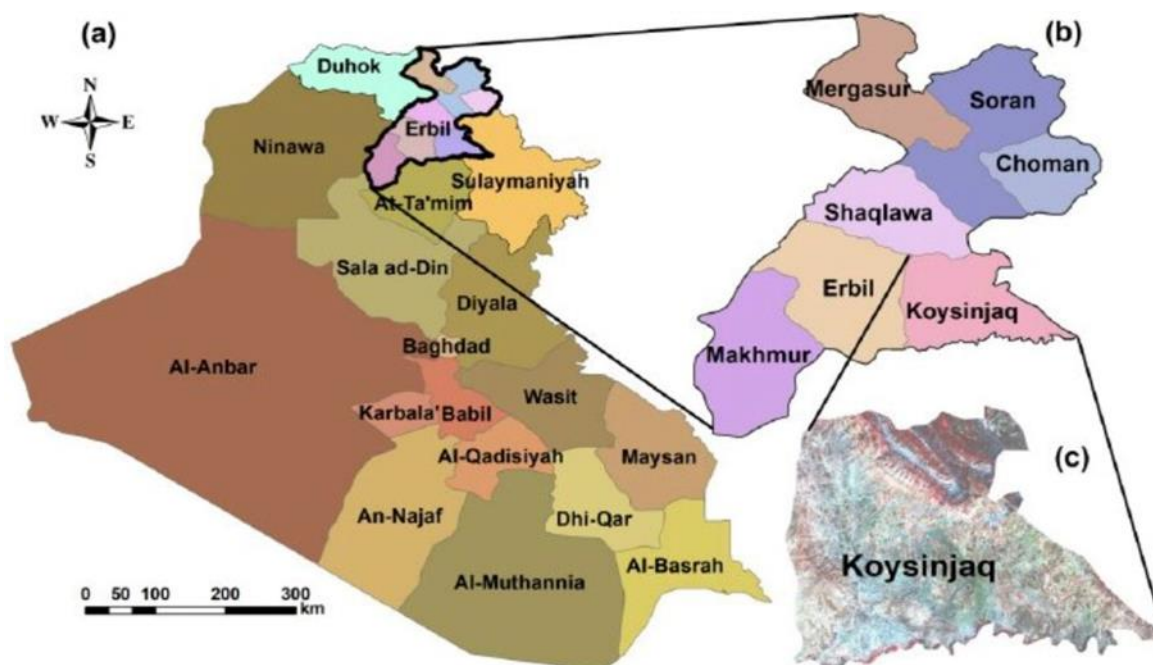
Infrastructure encompasses not just public works facilities but also understanding operational procedures, management strategies, as well as policies concerning development that address social needs and the physical environment. These components collectively facilitate transportation, manage water resources, and ensure safe waste disposal. It also encompasses the regulation of energy distribution where needed and the transfer of information within and between societies. This process revolves around a central network, with varying degrees of connectivity and influence [6]. Therefore, the development and construction of highways are closely connected to the aforementioned factors and positively affect them. As society evolves, the use of highways and the effectiveness of the highway network reflect this progress and advancement.

The literature on highways evaluates how transportation influences infrastructure and economic activity. Research regarding the effects of highway infrastructure within developing nations is increasingly expanding [7, 8].

This research often focuses on subjective congestion levels and their relationship to highway infrastructure. Allen and Arkolakis [9] investigated how endogenous congestion levels affect highway selection. According to Taylor et al. [10] building on Ossa [11], input-output linkages and international trade are crucial for evaluating infrastructure and highways. Recent findings show that domestic trade costs impact trade and welfare significantly; transportation improvements allow remote areas to specialize and export based on comparative advantage; and substantial welfare gains lead to significant distributional effects both within and across countries [7, 8].

3. The geographical location dictates the extension of the highway

The city of Koysinjaq is strategically positioned at the intersection of three key cities, making its geographical location particularly significant. Hamadameen [12] highlighted the central role of Koya, situated at the heart of the triangle formed by Erbil, Kirkuk, and Sulaymaniyah. This central placement means that highways link the corners and sides of this triangle, integrating the region fully in terms of geography, economy, administration, and demographics (See Figure 4(a), 4(b)).



(a)



(b)

Figure 4. (a): Koya location, (b): Koya location.

4. Positive effects of the highway

Highways have several positive impacts on both society and the state, affecting both material and moral aspects. Here are some of the key benefits:

A. Social impacts

Modern highways significantly reduce travel times between Koya and cities like Erbil, Sulaymaniyah, and Kirkuk compared to local streets. These highways facilitate efficient business, trade, and daily activities by providing well-organized routes for transporting goods. As a result, the social ties among Koya's residents become stronger and more interconnected. This enhanced connectivity allows Koya's population to benefit from the positive social, cultural, and urban influences of the regional capital while also experiencing reciprocal benefits from Erbil and other neighboring cities [13]. In other words, the social, cultural, and educational interactions between the cities will become more dynamic and mutually advantageous.

Highways shorten the distance between cities by reducing travel times. Additionally, increased road capacity can accommodate hidden traffic demand, leading to lower travel costs and higher usage. As goods or services become more available and produced on a larger scale, their prices typically decrease, making them more affordable [14]. Road and traffic planners need to make precise forecasts because rising traffic volumes and transportation demands are likely to lead to road congestion sooner than anticipated due to the increase in cars and trucks. When roads become overcrowded, drivers often resort to using their vehicles even when alternatives are available. Consequently, newly constructed roads may not always provide immediate relief from traffic congestion in every situation. Constructing highways through existing communities will strengthen community unity and lessen the differences between central areas and surrounding states. Additionally, it will foster greater convergence among states across various dimensions[15]. This will result in providing equal opportunities across all regions of the country. Consequently, it will improve the social dynamics within a community by fostering a shared vision, including individuals from diverse backgrounds, ensuring equal opportunities, and strengthening supportive relationships among people.

B. Economic impacts

Concerning the economic integration of Koya with the cities in the area r the impact of the highway network on the regional economy the impacts for this city can be outlined as follows:

1. Highways produce a range of economic impacts, mainly due to enhanced mobility and smoother transportation.
2. Highways enable companies and investors to access diverse business opportunities and commute easily between their homes and commercial or industrial locations, even if they are far apart.
3. Highways provide producers with access to a broader range of input suppliers.
4. Highways help lower costs, improve access to markets, and supply sources by speeding up transportation for producers. This facilitates consistent inventory management, smoother transactions, and greater price stability for consumers.
5. Some highways are built to address local transportation needs, whereas others link to national, regional, and international markets.
6. Highways boost economic activity by promoting construction and development through fresh infrastructure investments.

In general, highways affect five major categories of economic outcomes:

Variations in productivity levels.

1. Variations in economic output, including shifts in overall output, value added or per capita measures.
2. Alterations in employment levels.
3. Growth in earnings.
4. Shifts in population distribution.

Realistic examples demonstrate the connection in relation to highway construction and economic growth. For instance, the beneficial effect of highways on U.S. economic expansion during the 1970s demonstrates this connection [16]. Similarly, the economic growth in India from the 1970s to the 1990s also highlights the link between highway construction and economic development demonstrate that connecting major cities with their surrounding areas and rural regions through highways leads to economic growth. In summary, economic growth is directly linked to highway construction.

C. Environmental impacts

Although highways provide many benefits, they also have adverse environmental effects. Noise from highways grows louder with higher vehicle speeds, which can harm residents' hearing, particularly in residential areas and buildings close to the road. This noise intensifies due to the resonance caused by trucks, cars, and other vehicles passing through tunnels, underpasses, overpasses, and bridges. The resulting echo and resonance can have severe health impacts on vulnerable populations, including the elderly, patients, children, pregnant women, and fetuses [17]. Therefore, organizations involved in highway construction should implement strategies to reduce noise and minimize sound levels at nearby sensitive areas [18, 19].

In dealing with air quality issues, highways can play a role in reducing emissions. This is because higher speeds typically result in lower emissions compared to regular traffic, which involves frequent stops, starts, and inconsistent vehicle flow. However, air pollutant levels are relatively high near highways because of higher traffic

volume. Therefore, the likelihood of encountering air pollutants increases when highways are congested. Highways can lead to the fragmentation of habitats in residential areas. They also encourage urban sprawl and human activity in previously abandoned areas. Additionally, increasing the number of intersections rather than using underpasses and overpasses can exacerbate traffic congestion. Similarly, highways can reduce public transportation usage, which in turn leads to higher levels of pollution [20].

D. Impacts of the urban renaissance

One benefit of linking Koya to Erbil, especially through the highway, is the urban renaissance [21] happening in Koya. This revitalization is propelled by:

1. Restoring historic archaeological neighborhoods to meet modern urban standards while maintaining their archaeological significance.
2. Ongoing restoration of the city's residential areas, markets, and both public and private institutions to align with contemporary needs and standards.
3. Advancing the development of the city in both literary and scientific fields, while expanding Koya University in both horizontal and vertical dimensions. This will establish the university as a leading hub for strategic studies and research solutions.
4. Developing the outlying areas, with a particular focus on enhancing well-known areas.
5. Expanding the city into the mountainous regions to enhance its visual appeal and establish it as a desirable seasonal getaway. Redesigning the city center by reassessing its streets, markets, and possibly eliminating some commercial and service areas.
7. Restoring and enhancing the city's gardens.

Given the successful re-urbanization of the city and its suburbs, we should draw inspiration from and seek assistance from projects implemented in developed countries. This includes incorporating the construction of highways and looking at well-known examples of such projects, such as.

E. Impacts of multicultural exchange

Highways facilitate faster and easier movement, allowing individuals to encounter and interact with diverse cultures. As people engage with different societies, they are positively influenced by these cultures and, in turn, affect them. This interaction broadens their social perspectives and introduces new social ideas. This mixing leads to changes such as idea exchange, behavior adaptation, tradition blending, and language shifts [22]. As a result, respectful cultural interactions are promoted. On the other hand, cultural interactions play a pivotal role in influencing both individual and societal identities.

The rich cultural diversity in Koya fosters open-minded and unique interactions among its people, affecting future local and regional cultural exchanges through:

1. Sharing and exchanging ideas

The integration of varied cultural backgrounds fosters a dynamic exchange of ideas; helps develop a shared vision on various issues, and results in a scenario where viewpoints converge, leading to innovative solutions. This process crystallizes into the development of knowledge that enhances the culture of individuals and groups.

When cultures intersect, individuals and groups encounter new philosophies and belief systems that challenge existing viewpoints. To address these challenges and harmonize the cultural mix, they must develop a new vision and employ innovative, flexible approaches to find compromise solutions and resolve issues.

Different cultures offer extensive opportunities for the growth and development of individuals, groups, and societies, as long as interactions are conducted with respect.

2. Adjustment of behaviors

Through the intersection of different cultures, individuals or groups may adjust their behaviors, abandoning certain practices in favor of those that are common and acceptable across cultures, while also adopting new behaviors. To adapt to diverse cultures, individuals or groups must adopt new behaviors that align with the broader social and behavioral norms of the new environment. This cultural adaptation involves a range of emotions, including excitement, confusion, anxiety, acceptance, and satisfaction.

3. Integration of traditions

Blending traditions and fostering smooth coexistence help bridge gaps between different societal traditions. This integration results in a rich and diverse mix of traditions, leading to cultural fusion. Consequently, individuals experience a fusion of various cultural elements, shaping them into modern and well-rounded individuals. To achieve a blend of traditions, traditional customs must evolve with the times. Cultural integration influences both

the tangible aspects of traditions, like eating and dressing habits, and the intangible aspects, such as thought processes and problem-solving approaches. This fosters cross-cultural understanding and promotes tolerance.

4. Evolution of language

When cultures intersect, notable changes occur in communication methods. This is evidenced by the creation of new words and expressions, as well as linguistic development stemming from the merging of distinct identities and cultures. Consequently, this cultural blending influences dialects and introduces subtle variations between different languages.

5. Introduction of new vocabulary

Interactions of cultures lead to the creation of new words and expressions, enriching and expanding a globally diverse vocabulary used in communication and information exchange. This development adds depth and nuance to language, enhancing both the delivery and reception of information.

6. Impact on accents and dialects

Communication between individuals from different societies on a global scale affects local and native dialects. This phenomenon, observed when people interact across various cultures, influences changes in pronunciation and vocal rhythm, ultimately enhancing communication skills. Consequently, evolving dialects contribute to the sophistication and refinement of their users, while acknowledging and integrating the dialects of others.

7. Evolution of religious practices

Interaction and communication between individuals from diverse cultures and religions often lead to changes in religious practices and the emergence of new concepts, such as compatibility between religious beliefs. This includes the blending of beliefs from various religions and philosophies. These transformations and shared perspectives highlight the adaptive nature of religions as they interact with different cultures and societies.

8. Religious syncretism

When different religious practices are merged into a single belief system, it deepens an individual's understanding of their own essence, enhances respect for others, and fosters a greater sense of spirituality. This process, known as religious syncretism, occurs when individuals from diverse cultures come together.

9. Impacts on applied economics

Cultural convergence influences economic practices by driving innovation and growth. It leads to new strategies for managing resources and wealth, fosters mutual understanding among traders, and supports beneficial trade agreements and policies. Consequently, the intersection of cultures and shared visions directly and effectively drives desired social and economic changes.

5. From the imperative question to the critical question

We demonstrated highways' essential role in civilization and their vital significance in various areas. Similarly, we have examined in detail the factors that necessitate highways, including their role in connecting strategic locations, their social, economic, environmental, urban, and cultural impacts. Civilization represents all that humanity has created, both materially and morally, within a specific time and place. Given our responsibility for advancing civilization, including highways as a key element of its infrastructure, it is crucial to focus on constructing highways and connecting Koya to neighboring cities, especially to Erbil, the regional capital. This brings us to a pressing question: Which administrative bodies and leaders are responsible for addressing this urgent issue, and who is tasked with analyzing and communicating this matter within community?

We recognize that social scientists and mathematicians focus on formulating, analyzing, and logically interpreting questions. Formulating a question is crucial as it leads to defining the problem and developing research methodologies to solve it. Therefore, the issue presents certain research obstacles. These issues will be addressed by answering these questions:

1. What are the criteria and conditions for constructing and extending highways?
2. What considerations must be taken into account when construction begins, specifically concerning rivers, waterways, ports, railways, and airport runways?
3. Where should we add underpasses, overpasses, bridges, flyovers, and intersections?

Can these questions be effectively answered and the desired goals achieved using traditional methods, or is there a need to develop modern research methodologies and introduce innovative approaches? We will address these crucial and pressing questions in the upcoming sections.

6. Fuzzy methodology

Overlapping and ambiguous information can only be effectively represented and interpreted using fuzzy variables and the tools designed to handle these variables, which help in analyzing fuzzy data related to a problem. In non-

specific contexts, using traditional tools to interpret ambiguous information through fuzzy sets is challenging, as these tools often treat such information as if it were precise, accurate, and strictly defined [23].

Given the reality of various situations and experimental conditions, all methodologies incorporate some degree of flexibility and ambiguity. In practice, employing methods that handle data, sets, and fuzzy variables is often more realistic and broadly applicable compared to using specific data, sets, and deterministic variables [23]. Fuzzy sets and data allow us to address and model variables and information in a way that reflects the complexity of real-world problems. This approach enables us to explore and analyze the issue from multiple perspectives, capturing its various aspects more comprehensively.

Therefore, mathematicians turn to the following concepts and methods to resolve the issue and answer the questions:

1. Fuzzy concepts.
2. Conditional statements: IF... THEN.
3. Linguistic hedges of the speed.

A. Fuzzy concepts

A fuzzy concept varies within its possible application limits. It adapts from case to case and according to the specific needs and circumstances, rather than being fixed or rigid. The concept is ambiguous, lacking a fixed state and precise meaning. Despite this, the concept still carries a linguistic hedge meaning and cannot be fully understood without providing some specifications and details [24-26]. This concept leads researchers to use vague terms and qualifiers in their descriptions. Consequently, the concept is flexible, unlike a fixed notion and deterministic.

B. Fuzzy set expressions

An alternative approach for defining a set A is the membership method, which uses a zero-one membership function for A , denoted by, $\mu_{A(x)}$, where a fuzzy set in a universal X is defined by a membership function $\mu_{A(x)}$ with values in the interval $[0, 1]$ [24-29].

Each real number is linked to a fuzzy number via a fuzzy membership function. This function provides a means to map a deterministic number to a fuzzy number. Or, the fuzzy membership function converts real numbers into fuzzy numbers, incorporating them into the fuzzy system. Although fuzzy logic isn't actually "fuzzy" by nature, it offers a structured approach for dealing with ambiguity in data and numerical values. A fuzzy membership function effectively estimates ambiguity in data, while the fuzzy inference system, a key part of fuzzy logic, begins with assessing this ambiguity. In the next section, we will define membership functions and fuzzy sets mathematically and discuss triangular and trapezoidal fuzzy numbers.

C. Basic definitions

Based on studies by [24-29]. The following definitions have been listed which are necessary to next sections in the work.

Definition 1. Membership function: Consider a universal set X , and $\mathbf{T} = [0, 1] \subseteq \tilde{A} \subseteq X$, the membership defines the degree to which the element $x \in \tilde{A}$ belongs to $\tilde{A}$. Mathematically; $\mu_{\tilde{A}}: x \rightarrow \mathbf{T}, \forall x \in X$. Or, $\mu_{\tilde{A}} \subseteq \tilde{A} \times \mathbf{T}$, as illustrated in Figure 5.

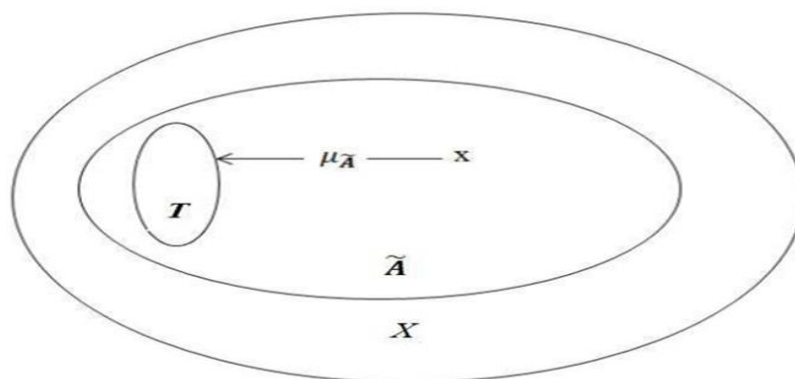


Figure 5. The membership function.

Definition 2. Fuzzy set: If X be a universal set, then $\tilde{A}$ is called a fuzzy set in X if $\tilde{A}$ and expressed as; $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) | x \in X\}$; where $\mu_{\tilde{A}}(x)$ is the membership function of $x \in \tilde{A}$.

Definition 3. A fuzzy set is normal if its maximum membership value is 1.

Definition 4. The Core (Modal): The Core of $\tilde{A}$ in X is the crisp set containing all elements with a membership grade of one. i. e. $Core(\tilde{A}) = \{x | \tilde{A}(x) = 1 \text{ and } x \in X\}$.

Definition 5. The Support: The support of $\tilde{A}$ in X is the set of all elements for which $\tilde{A}(x)$ is positive. That is, $Supp(\tilde{A}) = \{x \in X | \mu_{\tilde{A}}(x) > 0\}$.

Definition 6. The Trapezoidal fuzzy number (TpFN): A TpFN is $\tilde{A} = (a^L, a^U, \alpha, \beta)$, where $[a^L, a^U]$ is the modal set of $\tilde{A}$, and $[a^L - \alpha, a^U + \beta]$ its support part, as illustrated in Figure 6.

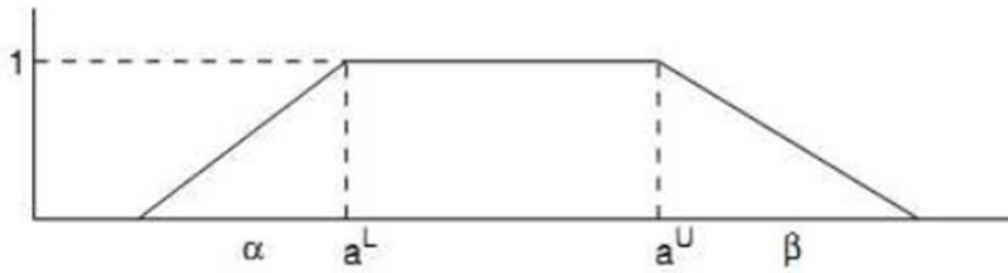


Figure 6. TpFN.

Definition 7. The Triangular fuzzy number (TrFN): If $a = a^L = a^U \in \tilde{A}$ then the TpFN is reduced to TrFN and denoted by $\tilde{A} = (a, \alpha, \beta)$, as shown in Figure 7.

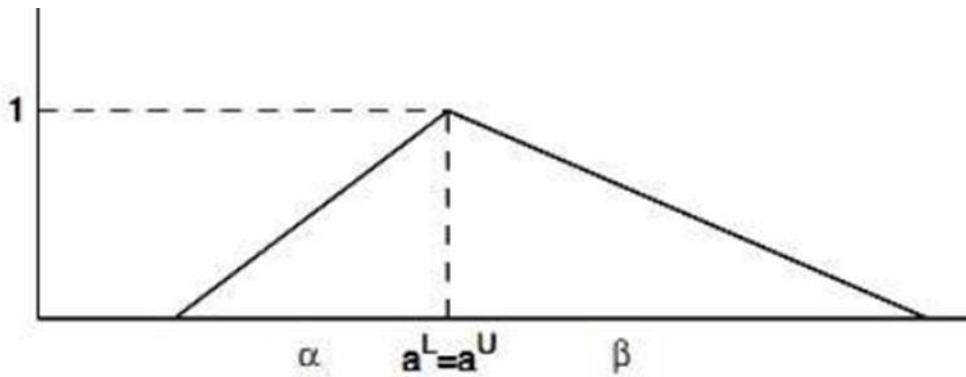


Figure 7. TrFN.

D. Conditional statements: IF... THEN

A compound statement is created by joining several statements using logical connectives like "if... then." The resulting statement is known as a compound statement, and the original statements that are combined to form it are referred to as its components [30].

Conditional statements, expressed as "IF... THEN," involve two statements, p and q . The compound statement $p \rightarrow q$ (read as "if p , then q ") is false only when p is true and q is false. This type of statement is known as a conditional statement. In this context, p is referred to as the hypothesis or antecedent, while q is called the consequent or conclusion [30].

7. Linguistic hedges of the speed

In applied linguistics and pragmatics, "hedging" involves using language to introduce ambiguity or caution, rather than precision. It adds vagueness to statements, reflecting uncertainty or a wish to soften the message [24].

Hedging in conversation allows a speaker to use synonyms and different formulations to express an idea in various ways. This approach helps clarify and minimize ambiguity by presenting thoughts with alternative words. Additionally, hedging offers flexibility in reducing, generalizing, and organizing information into specific patterns. Hedges are characteristics or conditions that modify or surround something, serving as a flexible means of

expression. They function as a tool in cognitive processes. Furthermore, hedges are used to classify items into various categories.

However, in many cases, an ambiguous fuzzy subset is typically linked with a notion of certainty. Mathematicians can fuzzify the traditional and modern speeds of a vehicle as linguistic variables (See Figures (8, 9)) by employing linguistic hedges such as:

- Fast.
- Slightly fast.
- Obviously fast.
- Very fast.
- Extremely fast.

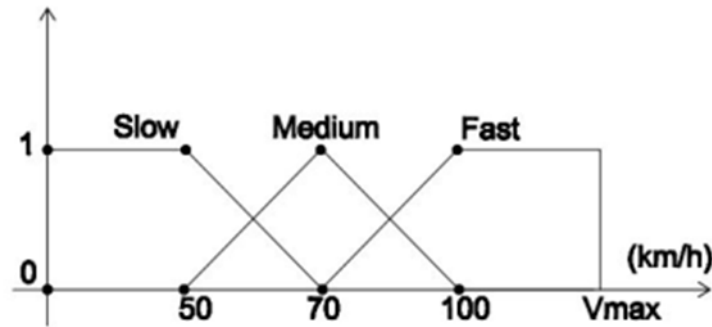


Figure 8. The classical speed of a vehicle represented as a linguistic variable.

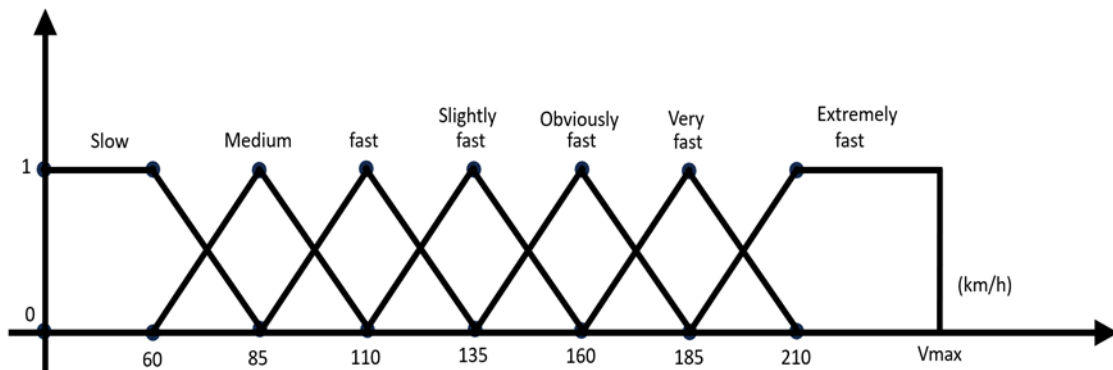


Figure 9. The contemporary speed of a vehicle as a linguistic variable.

8. Linguistic hedges of the speed Fuzzy membership functions of the modern speed of a vehicle

Referring to Figure 8, the membership functions for the linguistic hedges of the proposed contemporary speed are defined as follows:

A. Membership function for "slow":

$$\mu_{\bar{S}}(x) = \begin{cases} 1; 0 \leq x \leq 60 \\ \frac{85-x}{85-60}; 60 \leq x \leq 85 \\ 0; \text{Otherwise} \end{cases} \quad (1)$$

B. Membership function for "medium":

$$\mu_{\bar{M}}(x) = \begin{cases} \frac{x-60}{85-60}; 60 \leq x \leq 85 \\ 1; x = 85 \\ \frac{110-x}{110-85}; 85 \leq x \leq 110 \\ 0; \text{Otherwise} \end{cases} \quad (2)$$

C. Membership function for "fast":

$$\mu_{\bar{F}}(x) = \begin{cases} \frac{x-85}{110-85}; 85 \leq x \leq 110 \\ 1; x = 110 \\ \frac{135-x}{135-100}; 110 \leq x \leq 135 \\ 0; \text{Otherwise} \end{cases} \quad (3)$$

D. Membership function for “slightly fast”:

$$\mu_{\bar{S}\bar{F}}(x) = \begin{cases} \frac{x-110}{135-110}; 110 \leq x \leq 135 \\ 1; x = 135 \\ \frac{170-x}{170-135}; 135 \leq x \leq 170 \\ 0; \text{Otherwise} \end{cases} \quad (4)$$

E. Membership function for “obviously fast”:

$$\mu_{\bar{O}\bar{F}}(x) = \begin{cases} \frac{x-135}{170-135}; 135 \leq x \leq 170 \\ 1; x = 170 \\ \frac{185-x}{185-170}; 170 \leq x \leq 185 \\ 0; \text{Otherwise} \end{cases} \quad (5)$$

F. Membership function for “very fast”:

$$\mu_{\bar{V}\bar{F}}(x) = \begin{cases} \frac{x-170}{185-170}; 170 \leq x \leq 185 \\ 1; x = 185 \\ \frac{210-x}{210-185}; 185 \leq x \leq 210 \\ 0; \text{Otherwise} \end{cases} \quad (6)$$

G. Membership function for “extremely fast”:

$$\mu_{\bar{E}\bar{F}}(x) = \begin{cases} \frac{x-185}{210-185}; 185 \leq x \leq 210 \\ 1; x \geq 210 \\ 0; \text{Otherwise} \end{cases} \quad (7)$$

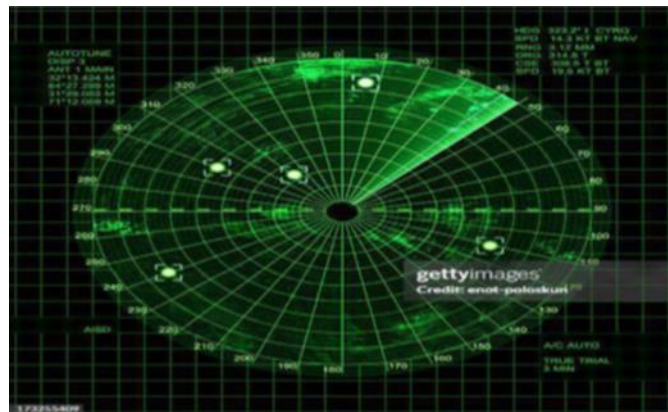
9. Controlling in fuzzy system

A control system based on fuzzy logic is a type of a management system that employs fuzzy logic. Unlike classical and digital systems, which use binary values (0 or 1), a fuzzy control system uses variables that range continuously between 0 and 1. This approach provides a more nuanced representation of truth, accommodating degrees of uncertainty and partial truths [31].

Fuzzy logic is widely used in machine control systems. Unlike traditional methods that categorize concepts as strictly true or false, fuzzy control evaluates them as partially true or false. This method enables solutions to be expressed in flexible, understandable terms, allowing operators to leverage their expertise more effectively. As a result, it supports the mechanization of tasks and their successful execution by both decision-makers and operators [29]. A controlled-access highway is designed for high-speed traffic, with all vehicle movement, including on-ramps and off-ramps, meticulously managed. This control is achieved through radars and remote sensing which utilize fuzzy membership functions to manage and interpret data effectively (See Figure 10 (a, b, c, d, e)).



(a)



(b)



(c)



(d)



(e)

Figure 10. (a): Radar and remote sensing, (b): Radar and remote sensing, (c): Radar and remote sensing, (d): Radar and remote sensing, (e): Radar and remote sensing

10. Desired goals and ambitions

Here are the main goals and contributions of extending the Erbil-Koya highway and how they are addressed:

1. Linking cities, towns, and nations.
2. Accelerating movement and enhancing communication.
3. Keeping pace with advancements in civilization.
4. Boosting internal and external trade.
5. Easing the movement of people and goods.
6. Aiding crucial projects in remote regions.
7. Promoting agricultural, industrial, and commercial development.
8. Increasing societal income through new job opportunities.
9. Raising per capita income by creating employment.
10. Advancing towards a technological society.

11. Conclusion

The highway is a crucial component of the physical infrastructure necessary for civilization, and its development will bring about significant societal changes. This paper explores the mathematical aspects of highway design through proposed linguistic hedges for modern speed, fuzzy methodology, and fuzzy control techniques. It also presents a technique for controlling highway vehicle speeds using radar and remote sensing. The work concludes that setting up and linking the road linking Koya and Erbil will achieve several key objectives, including: linking cities and surrounding towns and villages, accelerating movement and interaction, aligning with progress, boosting internal and trade, easing transportation of people and goods, and supporting key projects in remote areas, promoting agricultural, industrial, and commercial growth, increasing societal and per capita income through job creation, and advancing towards a technological society.

References

- [1] S. C. Council, "Road Safety Services," 2011.
- [2] R. Morton, *Construction UK: Introduction to an Industry*, 2002.
- [3] E.-C. Heine, "Cathedrals, pyramids and Hitler's highways: The construction site of the German Autobahn under National Socialism (1933–1942)," in *Producing Non-Simultaneity*, Routledge, 2017, pp. 202–228.
- [4] E. M. Bassett, "The Freeway-A New Kind of Thoroughfare," 1930.
- [5] J. Fulmer, "What in the world is infrastructure," *PEI Infrastructure Investor*, vol. 1, no. 4, pp. 30–32, 2009.
- [6] A. O'Sullivan, S. M. Sheffrin, and K. Swan, *Economics: Principles in Action*, 2003.
- [7] A. K. Coşar, B. Demir, D. Ghose, and N. Young, "Road capacity, domestic trade and regional outcomes," *Journal of Economic Geography*, vol. 22, no. 5, pp. 901–929, 2022.
- [8] P. Fajgelbaum and S. J. Redding, "Trade, structural transformation, and development: Evidence from Argentina 1869–1914," *Journal of Political Economy*, vol. 130, no. 5, pp. 1249–1318, 2022.
- [9] T. Allen and C. Arkolakis, "The welfare effects of transportation infrastructure improvements," *The Review of Economic Studies*, vol. 89, no. 6, pp. 2911–2957, 2022.
- [10] T. Jaworski, C. Kitchens, and S. Nigai, "Highways and globalization," *International Economic Review*, vol. 64, no. 4, pp. 1615–1648, 2023.

- [11] R. Ossa, "Why trade matters after all," *Journal of International Economics*, vol. 97, no. 2, pp. 266–277, 2015.
- [12] A. O. Hamadameen, "Multiobjective Stochastic Programming: The Case of Production of Cakes," in *2018 International Conference on Pure and Applied Science*, 2018.
- [13] K. J. Clifton and F. Moura, "Conceptual framework for understanding latent demand: Accounting for unrealized activities and travel," *Transportation Research Record*, vol. 2668, no. 1, pp. 78–83, 2017.
- [14] M. Salimi, M. A. Moradi, and M. Amidpour, "Modeling and outlook analysis of gasoline supply and demand and sensitivity analysis of main economic and social drivers," *Energy*, vol. 256, p. 124686, 2022.
- [15] F. Minooei, N. Sobin, P. M. Goodrum, and K. R. Molenaar, "Managing public communication strategies in accelerated highway construction projects," *Transportation Research Record*, vol. 2672, no. 26, pp. 1–10, 2018.
- [16] A. Chandra and E. Thompson, "Does public infrastructure affect economic activity?: Evidence from the rural interstate highway system," *Regional Science and Urban Economics*, vol. 30, no. 4, pp. 457–490, 2000.
- [17] O. A. E. Omer Awad Elbasha Mohamed Ahmed, "Construction of Bunds for Oil Storage Tanks," 2010.
- [18] K. M. Hedayat, J.-C. Lapraz, and B. Schuff, *The Theory of Endobiogeny: Volume 4: Bedside Handbook*, Academic Press, 2019.
- [19] I. Huhtaniemi, *Encyclopedia of Endocrine Diseases*, Academic Press, 2018.
- [20] R. Fuller et al., "Pollution and health: A progress update," *The Lancet Planetary Health*, vol. 6, no. 6, pp. e535–e547, 2022.
- [21] L. Porter, "Whose urban renaissance?," in *Whose Urban Renaissance?*, Routledge, 2009, pp. 241–252.
- [22] Q. Mgogo and O. Osunkunle, "Intercultural communication challenges and its effect on students' interpersonal relationships at a South African university," *Journal of Human Ecology*, vol. 72, no. 1–3, pp. 36–47, 2020.
- [23] L. A. Zadeh, "Fuzzy sets as a basis for a theory of possibility," *Fuzzy Sets and Systems*, vol. 100, pp. 9–34, 1999.
- [24] M. Z. Zia and M. Q. Zubair, "Solving multiobjective stochastic programming problems with fuzzy parameters using the ϵ -constraint method," *Computers & Industrial Engineering*, vol. 154, p. 107083, 2021.
- [25] A. O. Hamadameen and N. Hassan, "Pareto optimal solution for multiobjective stochastic linear programming problems with partial uncertainty," *International Journal of Mathematics in Operational Research*, vol. 12, no. 2, pp. 139–166, 2018.
- [26] A. O. Hamadameen and Z. M. Zainuddin, "A reciprocated result using an approach of multiobjective stochastic linear programming models with partial uncertainty," *International Journal of Mathematics in Operational Research*, vol. 7, no. 4, pp. 395–414, 2015.
- [27] J. N. Ismail et al., "Enhancing decision accuracy in DEMATEL using Bonferroni mean aggregation under Pythagorean neutrosophic environment," *Journal of Fuzzy Extension & Applications (JFEA)*, vol. 4, no. 4, pp. 281–298, 2023.
- [28] A. Al-Quran, F. Al-Sharqi, A. U. Rahman, and Z. M. Rodzi, "The q-rung orthopair fuzzy-valued neutrosophic sets: Axiomatic properties, aggregation operators and applications," *AIMS Mathematics*, vol. 9, no. 2, pp. 5038–5070, 2024.
- [29] F. Al-Sharqi, A. Al-Quran, and Z. M. Rodzi, "Multi-attribute group decision-making based on aggregation operator and score function of bipolar neutrosophic hypersoft environment," *Neutrosophic Sets and Systems*, vol. 61, no. 1, pp. 465–492, 2023.
- [30] A. Hamadameen, *Foundations of Mathematics*, Koya University, 2022.
- [31] P. Hájek, *Metamathematics of Fuzzy Logic*, Springer Science & Business Media, 2013.
- [32] A.-T. Nguyen et al., "Fuzzy control systems: Past, present and future," *IEEE Computational Intelligence Magazine*, vol. 14, no. 1, pp. 56–68, 2019.