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Optimization of Shortest Path Problem using Dijkstra's Algorithm in Imprecise Environment

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Abstract: Dijkstra algorithm is a widely used algorithm to find the shortest path between two specified nodes in a network problem. In this paper, a generalized fuzzy Dijkstra algorithm is proposed to find the shortest path using a new parameterized defuzzification method. Here, we address most important issue like the decision maker's choice. A numerical example is used to illustrate the efficiency of the proposed algorithm.
Keywords: Dijkstra Algorithm; Generalized Trapezoidal Fuzzy Number; Shortest Path Problem.

1. INTRODUCTION

The shortest path problem (SPP) is the heart of a network's flow. In real life network, the main objective is to send the product with efficiently and with minimum budget between two predefined nodes. Dijkstra algorithm [9] is a widely used algorithm to find the shortest path between two specified nodes in a network problem. Crisp numbers are used to represent the costs traversing of edges to the network problem. Due to price fluctuation, bad weather and traffic problem, the information related to the edges of the network are vague in nature. To address this vagueness, Zadeh [1] was introduced the concept of fuzzy set. In last three decades, numerous research papers have been published in the domain of shortest path problem (SPP). Okada et al. [2] proposed possibility theory to solve the fuzzy SPP. Keshavarz et al. [3] demonstrated the techniques to convert generalized the fuzzy SPP in to a bi-level programming problem and its solution. A multiple constraint network problem was solved by Dou et al. [4]. Deng et al. [5] proposed Dijkstra algorithm using the ranked mean integration definition of fuzzy numbers to solve fuzzy SPPs. Furthermore, some works [6,7] based on heterogeneous forms of heuristic algorithm-based fuzzy arc values in network have been done. But decision makers choice was missing. Nayeem et al. [8] addressed decision makers choice in their work. In this paper, we have proposed parameterized fuzzy Dijkstra algorithm to solve fuzzy shortest path problem. In this fuzzy shortest path problem, the length of the edges is represented by generalized trapezoidal fuzzy number. A new defuzzification method is discussed based on total λ-integral value. Here decision maker can take a decision according their choice based on the value of the parameter λ.

2. MATHEMATICAL PRELIMINARIES

2.1 Fuzzy Set

Let X denotes a universal set. Then the fuzzy subset A in X is a subset of order pairs $\tilde{A}=\{(x,\mu_{\tilde{A}}(x)):x\in X\}$ where $\mu_{\tilde{A}}:X\to[0,1]$ is called the membership function which assigns a real number $\mu_{\tilde{A}}(x)$ in the interval $[0,1]$ to each element $x\in X$. A is non-fuzzy and $\mu_{\tilde{A}}(x)$ is identical to the characteristic function of crisp set. It is clear that the range of membership function is a subset of non-negative real numbers.

2.2 Generalized Fuzzy Number (GFN)

The generalized fuzzy number $\tilde{A}$ is a fuzzy subset of real line R, whose membership function $\mu_{\tilde{A}}(x)$ satisfies the following conditions:

(1) $\mu_{\tilde{A}}(x)$ is a continuous mapping from R to the closed interval $[0,1]$.

(2) $\mu_{\tilde{A}}(x)=0$ where $-\infty<x\le a$;

(3) $\mu_{\tilde{A}}(x)$ is strictly increasing with constant rate on $[a,b]$

(4) $\mu_{\tilde{A}}(x)=w$ where $b\le x\le c$;

(5) $\mu_{\tilde{A}}(x)$ is strictly decreasing with constant rate on $[c,d]$;

(6) $\mu_{\tilde{A}}(x)=0$ where $d\le x<\infty$.

Note: $\tilde{A}$ is a convex fuzzy set. It will be normalized for $w=1$.

If w = 1, the generalized fuzzy number $\tilde{A}$ is called a trapezoidal fuzzy number (TrFN) denoted

$\tilde{A}=(a,b,c,d)$.

(i) If $a=b$ and $c=d$, then $\tilde{A}$ is called crisp interval $[a,b]$.

(ii) If $b=c$, then $\tilde{A}$ is called a generalized triangular fuzzy number (GTFN) as $\tilde{A}=(a,b,c;w)$

(iii) If $b=c$, $w=1$ then it is called a triangular fuzzy number (TFN) as $\tilde{A}=(a,b,c)$.

(iv) If $a = b = c = d$ and $w = 1$, then $\tilde{A}$ is called a real number a.

2.3 Generalized Trapezoidal Fuzzy Number (GFN)

A GTrFN $\tilde{A} \equiv (a,b,c,d;w)$ is a fuzzy set of the real line R whose membership function $\mu_{\tilde{A}} : R \to [0,w]$ is defined as

$$\mu_{\tilde{A}}^{w}(x) = \begin{cases} \mu_{L\tilde{A}}^{w}(x) = w\left(\frac{x-a}{b-a}\right) & for\ a \le x \le b \\ w & for\ b \le c \le c \\ \mu_{R\tilde{A}}^{w}(x) = w\left(\frac{d-x}{d-c}\right) & for\ c \le x \le d \\ 0 & otherwise \end{cases}$$

where $a < b < c < d$ and $w \in (0,1]$

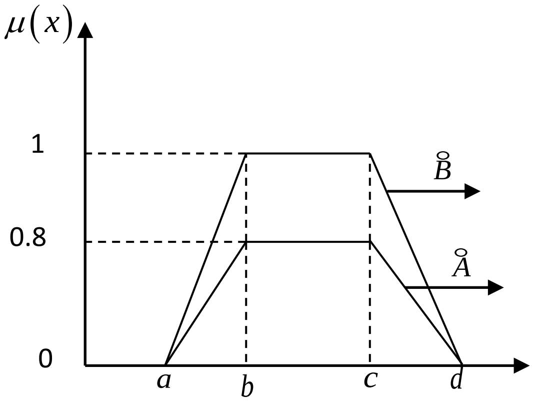

Figure 1: Two generalized trapezoidal fuzzy number $\tilde{A}$ *and* $\tilde{B}$

Figure 1 shows two different GTrFNs $\tilde{A} \equiv (a,b,c,d;w)$ and $\tilde{A} \equiv (a,b,c,d)$ which denote two different decision maker's opinions for different values of $w, 0 < w \le 1$. The values of w represents the degree of confidence of the opinion of the decision maker.

2.4 Defuzzification of Fuzzy Numbers with Respect to Their Total Integral Value

Let $\lambda \in [0,1]$ be a pre-assigned parameter called the degree of optimism. The graded mean[10] value (or, total λ-integral value) of $\tilde{A}$ is defined as $I_{\lambda}(\tilde{A}) = \lambda I_R(\tilde{A}) + (1-\lambda) I_L(\tilde{A})$ where $I_R(\tilde{A})$ and $I_L(\tilde{A})$ are the right and left interval values of $\tilde{A}$ defined as

$$I_L^w(\tilde{A}) = \left(\int_0^w \left(\mu_{L\tilde{A}}^w\right)^{-1} \alpha d\alpha\right) \Big/ w$$

$$I_R^w(\tilde{A}) = \left(\int_0^w \left(\mu_{R\tilde{A}}^w\right)^{-1} \alpha d\alpha\right) \Big/ w$$

Now, for GTrFN $\tilde{A} \equiv (a,b,c,d;w)$

$$\left(\mu_{L\tilde{A}}^w\right)^{-1} \alpha = a + \frac{\alpha}{w}(b-a) \text{ and } \left(\mu_{R\tilde{A}}^w\right)^{-1} \alpha = d - \frac{\alpha}{w}(d-c)$$

Therefore, the left and right integral values are $I_L^w(\tilde{A}) = \left(\frac{a+b}{2}\right)$ and $I_R^w(\tilde{A}) = \left(\frac{c+d}{2}\right)$

Hence the total λ-integral value of $\tilde{A}$ is $I_{\lambda}^w(\tilde{A}) = \left[\lambda\left(\frac{c+d}{2}\right) + (1-\lambda)\left(\frac{a+b}{2}\right)\right]$

The total λ-integral value is a convex combination of the right and left integral values through the degree of optimism. The left integral value is used to reflect the pessimistic viewpoint and the right integral value is used to reflect the optimistic viewpoint of the decision-maker. A large value of λ specifies the higher degree of optimism. For instance, when $\lambda = 1$, the total integral value $I_1^w(\tilde{A}) = \left(\frac{c+d}{2}\right) = I_R^w(\tilde{A})$ represents an optimistic viewpoint. On the other hand, when $\lambda = 0$, the total λ-integral value is $I_0^w(\tilde{A}) = \left(\frac{a+b}{2}\right) = I_L^w(\tilde{A})$ represents a pessimistic viewpoint. When $\lambda = 0.5$ the total λ-integral is $I_{0.5}^w(\tilde{A}) = \left(\frac{a+b+c+d}{4}\right)$. It reflects a moderately optimistic decision-makers viewpoint and is the same as the defuzzification of the fuzzy number $\tilde{A}$.

3. PROPERTIES

Property: 3.1

(a) If GTrFN $\tilde{U} = (u_1,u_2,u_3,u_4;w)$ and $y = ku$ (with $k < 0$) then $\tilde{y} = k\tilde{u}$ is a GTrFN $(ku_1,ku_2,ku_3,ku_4;w)$.

(b) If $y = ku$ (with $k < 0$) then $\tilde{y} = k\tilde{u}$ is a GTrFN $(ku_1,ku_2,ku_3,ku_4;w)$.

Proof:

(a) When $k > 0$ with the transformation $y = ku$, we can find the membership function of fuzzy set $\tilde{y} = k\tilde{u}$ by α-cut method.

α-cut of $\tilde{U}$ is

$$\left[\left(\mu_{L\tilde{U}}^w\right)^{-1}\alpha, \left(\mu_{R\tilde{U}}^w\right)^{-1}\alpha\right] = \left[u_1 + \frac{\alpha}{w}(u_2-u_1), u_4 - \frac{\alpha}{w}(u_4-u_3)\right]$$

for any $\alpha \in [0,1]$

i.e. $u \in \left[u_1 + \frac{\alpha}{w}(u_2-u_1), u_4 - \frac{\alpha}{w}(u_4-u_3)\right]$

So $y(=ku) \in \left[ku_1 + \frac{\alpha}{w}(ku_2-ku_1), ku_4 - \frac{\alpha}{w}(ku_4-ku_3)\right]$.

Thus, we get the membership function of $\tilde{y} = k\tilde{u}$ as

$$\mu_{\tilde{y}}^{w}(x)=\begin{cases} w\left(\dfrac{y-ku_1}{ku_2-ku_1}\right) & for\ \ ku_1\le y\le ku_2\\ w & for\ \ ku_2\le y\le ku_3\\ w\left(\dfrac{ku_4-y}{ku_4-ku_3}\right) & for\ \ ku_3\le y\le ku_4\\ 0 & otherwise\end{cases}$$

(b) Similarly, we can prove that $y=ku$, $k<0$ then

$$\mu_{\tilde{y}}(x)=\begin{cases} w\left(\dfrac{y-ku_1}{ku_2-ku_1}\right) & for\ \ ku_2\le y\le ku_1\\ w & for\ \ ku_3\le y\le ku_2\\ w\left(\dfrac{ku_4-y}{ku_4-ku_3}\right) & for\ \ ku_4\le y\le ku_3\\ 0 & otherwise\end{cases}$$

Property 3.2

If $\tilde{A}_1=(a_1,b_1,c_1,d_1;w_1)$ and $\tilde{A}_2=(a_2,b_2,c_2,d_2;w_2)$ then $\tilde{A}_1\oplus\tilde{A}_2$ is a fuzzy number $(a_1+a_2,b_1+b_2,c_1+c_2,d_1+d_2;\min(w_1,w_2))$.

Proof:

With the transformation $y=x_1+x_2$ we can find the membership function of fuzzy set $\tilde{y}=\tilde{A}_1\oplus\tilde{A}_2$ by α -cut method.

α - cut of $\tilde{A}_1$ is

$$\left[\left(\mu_{L\tilde{A}_1}^{w_1}\right)^{-1}\alpha,\left(\mu_{R\tilde{A}_1}^{w_1}\right)^{-1}\alpha\right]=\left[a_1+\frac{\alpha}{w_1}(b_1-a_1),d_1-\frac{\alpha}{w_1}(d_1-c_1)\right]$$

$\forall\ \alpha\in[0,1]$

i.e. $x_1\in\left[a_1+\dfrac{\alpha}{w_1}(b_1-a_1),d_1-\dfrac{\alpha}{w_1}(d_1-c_1)\right]$.

α -cut of $\tilde{A}_2$ is

$$\left[\left(\mu_{L\tilde{A}_2}^{w_1}\right)^{-1}\alpha,\left(\mu_{R\tilde{A}_2}^{w_1}\right)^{-1}\alpha\right]=\left[a_2+\frac{\alpha}{w_2}(b_2-a_2),d_2-\frac{\alpha}{w_2}(d_2-c_2)\right]\ \ \forall\ \alpha\in[0,1]$$

i.e. $x_2\in\left[a_2+\dfrac{\alpha}{w_2}(b_2-a_2),d_2-\dfrac{\alpha}{w_2}(d_2-c_2)\right]$.

So, $y(=x_1+x_2)\in\left[\begin{matrix}a_1+a_2+\dfrac{\alpha}{w}\left((b_1-a_1)+(b_2-a_2)\right),\\ d_1+d_2-\dfrac{\alpha}{w}\left((d_1-c_1)+(d_2-c_2)\right)\end{matrix}\right]$ where $w=\min(w_1,w_2)$. Therefore, we have

$$\alpha=w\left(\frac{y-a_1-a_2}{b_1+b_2-a_1-a_2}\right),\ a_1+a_2\le y\le b_1+b_2\text{, and}$$

$$\alpha=w\left(\frac{d_1+d_2-y}{d_1+d_2-c_1-c_2}\right),\ c_1+c_2\le y\le d_1+d_2$$

So, we have the membership function of $\tilde{y}=\tilde{A}_1\oplus\tilde{A}_2$ is

$$\mu_{\tilde{y}}(x)=\begin{cases} w\left(\dfrac{y-a_1-a_2}{b_1+b_2-a_1-a_2}\right) & for\ \ a_1+a_2\le y\le b_1+b_2\\ w & for\ \ b_1+b_2\le y\le c_1+c_2\\ w\left(\dfrac{d_1+d_2-y}{d_1+d_2-c_1-c_2}\right) & for\ \ c_1+c_2\le y\le d_1+d_2\\ 0 & otherwise\end{cases}$$

Thus we have

$\tilde{A}_1\oplus\tilde{A}_2=(a_1+a_2,b_1+b_2,c_1+c_2,d_1+d_2;\min(w_1,w_2))$ .Note: If we have the transformation $\tilde{y}=k_1\tilde{A}_1\oplus k_2\tilde{A}_2$ (k_1,k_2 are (not all zero) real numbers) then the fuzzy set $\tilde{y}=k_1\tilde{A}_1\oplus k_2\tilde{A}_2$ is the following GTrFN:

(i) $k_1>0,k_2\ge 0$ or $k_1\ge 0,k_2>0$

$\tilde{y}=(k_1a_1+k_2a_2,k_1b_1+k_2b_2,k_1c_1+k_2c_2,k_1d_1+k_2d_2:w)$

(ii) $k_1>0,\ k_2\le 0$ or $k_1\ge 0,k_2<0$,

$\tilde{y}=(k_1a_1+k_2d_2,k_1b_1+k_2c_2,k_1c_1+k_2b_2,k_1d_1+k_2a_2:w)$

(iii) $k_1<0,\ k_2\ge 0$ or $k_1\le 0,k_2>0$,

$\tilde{y}=(k_1d_1+k_2d_2,k_1c_1+k_2c_2,k_1b_1+k_2b_2,k_1a_1+k_2a_2:w)$

4. DIJKSTRA'S ALGORITHM

Let $G=(V,E)$ be a connected graph. Let a and b be any two vertices of G where $'a'$ is the starting point and b be the ending point. Let $L(x)$ denote the label of the vertex $'x'$ which represents the length of the shortest path form the vertex $'a'$ to $'x'$ denote the weight of the edge $e_{ij}=(v_i,v_j)$

Step 1: Let $P=\phi$, where P is the set of vertices having permanent labels and T = {all vertices of the graph G }. Initially set the permanent label to $a, i.e., L(a)=0, L(x)=\infty\ \forall\ x\in T$ and $x\ne a$.

Step 2: Select the vertex v in T which has the smallest label, which is called the permanent label of $v(i.e., u(v))$; then $P=PU(v)$ and $T=T-\{v\}$

Then find the smallest label in T .The new label of vertex x in T is

$L(x)=\min\{\text{old } L(x),L(v)+w(v,x)\}$

5. APPLICATION TO AIRPORT'S CARGO GROUND OPERATION SYSTEM

As the volume of cargo traffic has grown and the demand for cargo transport continues to rise, surface congestion has become an increasing problem, within an airport's cargo terminal. If an airport terminal's internal operations and service systems are inefficient, there will be a delay in ground operations. Therefore, cargo operations time needs to be shortened and passengers' luggage must be processed before cargo goods in order to maintain customer satisfaction. Fig.2.shows an international airport cargo terminal's ground operation procedures network. With the set of nodes $\mathrm{N}=\{\mathrm{A,B,C,D,E,F}\}$, the fuzzy activity time for each activity is shown in table 1.

Table 1: Fuzzy activity time for each activity

Activity	Fuzzy activity time	λ – Integral Value
$A-B$	(1,3,3,7;0.8)	$4\lambda+(1-\lambda)1.6$
$A-C$	(2,3,3,4;0.6)	$2.1\lambda+(1-\lambda)1.5$
$B-C$	(3,5,6,8;0.8)	$5.6\lambda+(1-\lambda)3.2$
$B-E$	(2,4,5,6;0.8)	$4.4\lambda+(1-\lambda)1.6$
$C-D$	(1,3,3,4;0.8)	$2.8\lambda+(1-\lambda)1.6$
$B-D$	(1,2,3,6;0.6)	$2.7\lambda+(1-\lambda)0.9$
$D-E$	(1,3,4,5;0.6)	$2.7\lambda+(1-\lambda)1.2$
$D-F$	(1,2,2,5;0.8)	$2.8\lambda+(1-\lambda)1.2$
$E-F$	(4,5,5,8;0.8)	$5.2\lambda+(1-\lambda)3.6$

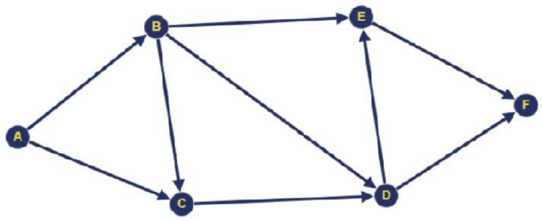

Fig-2. Airport cargo terminal's ground operation network

Activity	λ – Integral Value				
	$\lambda=0$	$\lambda=0.25$	$\lambda=0.5$	$\lambda=0.75$	$\lambda=1.0$
$A-B$	1.6	2.2	2.8	3.4	4
$A-C$	1.5	1.65	1.8	1.95	2.1
$B-C$	3.2	3.8	4.4	5	5.6
$B-E$	1.6	2.3	3	3.7	4.4
$C-D$	1.6	1.9	2.2	2.5	2.8
$B-D$	0.9	1.35	1.8	2.25	2.7
$D-E$	1.2	1.575	1.95	2.325	2.7
$D-F$	1.2	1.6	2	2.4	2.8
$E-F$	3.6	4	4.4	4.8	5.2

Solution: Now using Dijkstra's algorithm to find the shortest path from vertex A to vertex F for $\lambda=0$ integral value.

Step 1: $P=\varphi$ and $T=\{A,B,C,D,E,F\}$

Let the label of $A, i.e, L(A)=0$ and $L(x)=\infty\ \forall\ x\in T(x\neq A)$

Step 2: $V=A$, the permanent label is $L(A)=0$

$\therefore \quad P=\{A\}$ and $T=\{B,C,D,E,F\}$

$\therefore$

$L(B)=$
$\min\{\text{old } L(B), L(A)+w(A,B)\}=\min\{\infty,0+1.6\}=1.6$

$L(C)=$
$\min\{\text{old } L(C), L(A)+w(A,C)\}=\min\{\infty,0+1.5\}=1.5$

$L(D)=$
$\min\{\text{old } L(D), L(A)+w(A,D)\}=\min\{\infty,0+\infty\}=\infty$

Similarly, $L(E)=L(F)=\infty$

We see that the minimum label is $L(C)=1.5$

Step 3: $V=C$, the permanent label is $L(C)=1.5$

$\therefore \quad P=\{A,C\}$ and $T=\{B,D,E,F\}$

$\therefore$

$L(B)=$
$\min\{\text{old } L(B), L(C)+w(C,B)\}=\min\{1.6,1.5+\infty\}=1.6$

$L(D)=$
$\min\{\text{old } L(D), L(C)+w(C,D)\}=\min\{\infty,1.5+1.6\}=3.1$

$L(E)=$
$\min\{\text{old } L(E), L(C)+w(C,E)\}=\min\{\infty,1.5+\infty\}=\infty$

$L(F)=$
$\min\{\text{old } L(F), L(C)+w(C,F)\}=\min\{\infty,1.5+\infty\}=\infty$

We see that minimum label is $L(B)=1.6$.

Step 4: $V=B$, the permanent label is $L(B)=1.6$

$\therefore \quad P=\{A,B,C\}$ and $T=\{D,E,F\}$

$\therefore$

$L(D)=$
$\min\{\text{old } L(D), L(B)+w(B,D)\}=\min\{3.1,1.6+0.9\}=2.5$

$L(E)=$
$\min\{\text{old } L(E), L(B)+w(B,E)\}=\min\{\infty,1.6+1.6\}=3.2$

$L(F)=$
$\min\{\text{old } L(F), L(B)+w(B,F)\}=\min\{\infty,1.6+\infty\}=\infty$

Hence, the minimum label is $L(D)=2.5$.

Step 5: $V=D$, the permanent label is $L(D)=2.5$

$\therefore \quad P=\{A,B,C,D\}$ and $T=\{E,F\}$.

$\therefore$

$L(E) =$

$\min\ \{\text{old } L(E), L(D) + w(D,E)\} = \min\{3.2, 2.5+1.2\} = 3.2$

$L(F) =$

$\min\ \{\text{old } L(F), L(D) + w(D,F)\} = \min\{\infty, 2.5+1.2\} = 3.7$

Hence, the minimum label is $L(E) = 3.2$

Step 6: $V = E$ the permanent label is $L(E) = 3.2$

$\therefore \quad P = \{A,B,C,D,E\}$ and $T = \{F\}$

$$\therefore \quad L(F) = \min\ \{\text{old } L(F), L(E) + w(E,F)\} = \min\{3.7, 3.2+3.6\} = 3.7$$

Hence, the permanent label of F is 3.7 which is the shortest path distance from the vertex $'A'$ to $'F'$

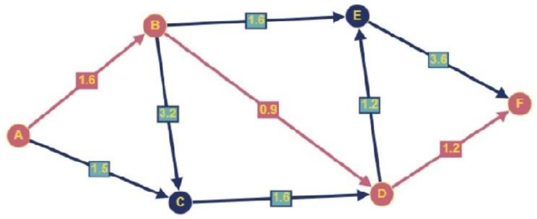

Fig-3. Optimum shortest path of Airport cargo terminal's ground operation network for Integral Value $\lambda = 0$

Using Dijkstra's algorithm, the optimum solution are as follows for different $\lambda-$ integral value

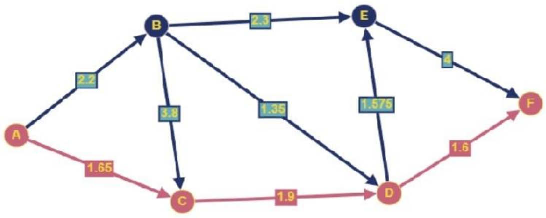

Fig-4. Optimum shortest path of Airport cargo terminal's ground operation network for Integral Value $\lambda = 0.25$

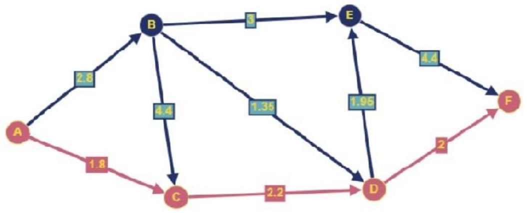

Fig-5. Optimum shortest path of Airport cargo terminal's ground operation network for Integral Value $\lambda = 0.5$

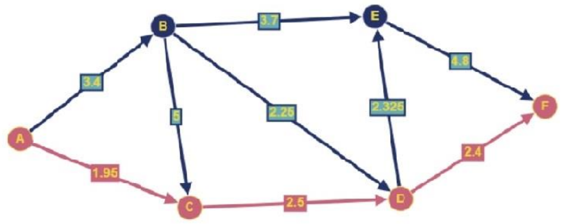

Fig-6. Optimum shortest path of Airport cargo terminal's ground operation network for Integral Value $\lambda = 0.75$

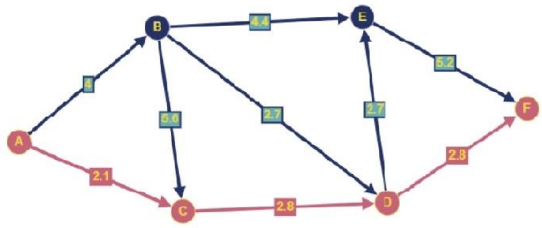

Fig-7. Optimum shortest path of Airport cargo terminal's ground operation network for Integral Value $\lambda = 1.0$

The optimal solution of the fuzzy project network model for different values of λ are presented in table 2.

Table 2. optimal solution of the fuzzy Airport cargo terminal's ground operation network

Test	Critical Path	Duration	Model Figure
Optimistic i.e $\lambda = 1$	A-C-D-F	7.7	Fig-7
About optimistic i.e $\lambda = 0.75$	A-C-D-F	6.85	Fig-6
Moderate i.e $\lambda = 0.5$	A-C-D-F	6	Fig-5
About pessimistic i.e $\lambda = 0.25$	A-C-D-F	5.15	Fig-4
Pessimistic i.e $\lambda = 0$	A-B-D-F	3.7	Fig-3

6. CONCLUSION

This paper presents a simple approach to solve a Cargo network problem with fuzzy number (generalized trapezoidal fuzzy number) activity times that are more realistic than crisp ones. On the basis of $\lambda-$ integral value, the fuzzy Cargo network problem is transformed into a crisp Cargo network problem. We than solved the cargo problem by Dijkstra's algorithm. Here decision maker may obtain the optimal project duration according to his/her expectations of optimistic/pessimistic/moderate

7. ACKNOWLEDGMENTS

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A Design of Blockchain Based Smart Contract for Tendering

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Abstract: Information technology is the backbone for all 21st century organizations that are looking forward to offer better customer service and gain competitive advantage. Today, blockchain technology is being adopted by a number of organizations such as financial services, healthcare, agriculture and even government. . However, the tendering sector have not been able to take advantage of the new blockchain technology, owing to the absence of blockchain based frameworks and a model for secure tendering. This study focuses on block-chain with its BYOE (Bring Your Own Encryption) concept in the procurement sector. The research comes up with a design of a blockchain based smart contract model for organizations in Kenya following ASD approach. In addition a discussion of challenges and opportunities of Blockchain based tendering is also presented.

Keywords: model, blockchain, byoe, tendering, contract

1. INTRODUCTION

Blockchain is a decentralized public ledger based on P2P networks, which has attracted wide attention in distributed application systems in recent years (Guo, *et al*., 2021). In this technology, a tamper resistant digital platform for data storage and sharing is realized by applying the chain-block structure and establishing a trusted consensus mechanism to synchronize data changes.

At the same time, the decentralization, traceability and immutability of on-chain information storage makes blockchain a trusted machine with high reliability and security (Wang, *et al*., 2021). Based on these characteristics, researchers began to analyze the application of blockchain in various fields, such as the Internet of Things, supply chain management, voting system and bidding system. Blockchain in application can improve the availability of data and reduce costs, while maintaining the openness and transparency of the application (Wang, *et al.*, 2021).

Transparency is considered to be a prerequisite for ensuring the accountability of public officials and in regards, there is broad agreement that the effectiveness of transparency can be further strengthened by involving blockchain technology (Shin, and Ibahrine, 2020). Such technology could be effective in raising success, reducing risks in complex contracts, strengthening procurement and contracting practices, holding officials accountable and in general, strengthening supply chain process.

A blockchain-based solution is a good fit for use cases such as tendering where multiple parties having low levels of trust, transact with each other. The technology is applicable in areas where same transaction is stored across disparate systems or databases (Raj, *et al.*, 2018).

In recent years, electronic bidding has become an efficient and convenient service, which aims to provide an open and safe bidding environment for suppliers to protect the public interest (Wang, et al., 2021). Tendering and bidding is a kind of commodity trading behavior which enables an organized selection of excellent transaction by the tendering organization. Compared with traditional offline bidding, it has an obvious difference in efficiency, in-formation collection and other aspects, and is better in the identity authentication of the bidding object, confidentiality of the bidding content, fairness of the bidding process and other aspects (Li, *et al*., 2021).

Emerging blockchain technology combined with smart contracts could revolutionize traditional E-bidding systems in a decentralized and autonomous manner (Wang, et al., 2021). It paves the way for a secure, immutable and auditable E-bidding process, while maintaining strong accuracy and completeness.

2. STATEMENT OF THE PROPLEM

The use of decentralized applications is poised to disrupt many sectors in the near future. Nonetheless procurement is among key areas still underserved by adoption of latest technologies such as blockchain. The Kenyan tendering ecosystems lacks behind because the technology is still new, having been introduced by Nskamoto (2008). Their exist possibilities that distributed applications Dapps are permeating to different sectors, tendering included. While the Dapp applications became much needed in Kenya, there is still absence of a clear framework and model to guide the realization of a blockchain based smart contract model for tendering.

3. STUDY OBJECTIVE

This research focuses on coming up with a design of a blockchain based smart contract model tailored to reduce corruption in tendering while ensuring efficiency and openness.

3.1 LITERATURE SURVEY

A smart contract is a piece of self-executing code that can be stored, and executed, on the blockchain. A smart contract is deterministic, verifiable, and doesn't rely on any trusted third party. Entities can enter into an agreement with all of the terms transparent to them (Dannen, 2017). The same integrity checks that keep the transactions on the blockchain from being edited are also in effect here. This means that when entities enter into the agreement, they can be sure that no party will edit the terms of that agreement at a later date.

Smart contracts also have state and memory storage and so can hold assets in their own right. Implying that they can be used to hold funds in escrow in instances of asset transfer between parties (Sklaroff, 2017). The applicability of this goes far beyond the crypto-currencies that are currently popularizing the blockchain. The limitations of smart contracts are entirely in the expressiveness of the language supported by the blockchain (Primorac, 2016). With a Turing complete language, as is employed by Ethereum, smart contracts can be used to execute a number of functions. Therefore, smart contracts provide a trust less environment for asset exchange.

Blockchain-based smart contracts are proposed contracts that could be partially or fully executed or enforced without human interaction. One of the main objectives of a smart contract is automated escrow. An IMF staff discussion reported that smart contracts based on blockchain technology might reduce moral hazards and optimize the use of contracts in general. But "no viable smart contract systems have yet emerged." Due to the lack of widespread use their legal status is unclear (Wang, *et al*., 2018).

Smart contracts are computerized transaction protocols that execute terms of a contract (Szabo, 2017). Smart contracts extended the functionality of electronic transaction methods, such as point of sale (POS), to the digital realm. Smart contracts permit trusted transactions and agreements to be carried out among disparate, anonymous parties without the need for a central authority, legal system, or external enforcement mechanism (Mao *et al*, 2018).

According to (Korpela, *et al*., 2017) blockchain can have a significant impact on business, it can be a powerful tool in establishing trust. Blockchain based smart contract model for tendering process will ensure Greater transparency, Enhanced security, improved traceability, Increase efficiency and speed and reduced costs.

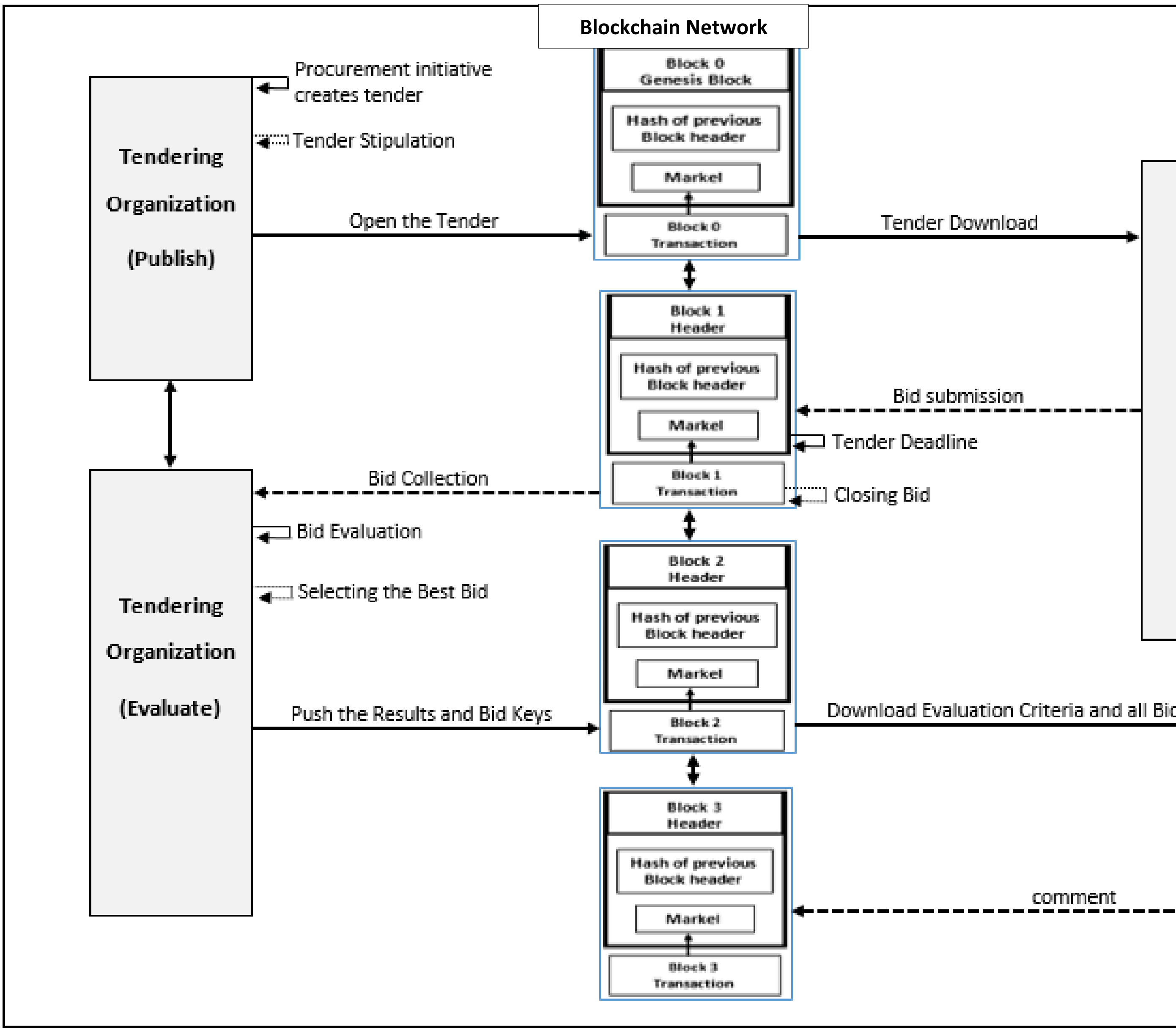
3.2 The Conceptual Design

A tendering organization will create a tender as a smart contract and place it on the blockchain. The smart contract will include the certified public key of the tendering organization along with bid evaluation code. A prospective bidder can download the tender from the blockchain. The respective bidder reviews the tender and consider the tendering specification and make a bid proposal, then the bidder generates a bid in response to the tender (smart contract). The actual bid is encrypted by the bidder's generated symmetric key (bid key: SKBidder).

The symmetric key is then encrypted by the public key of tendering organization: (SKBidder). Half of the (SKBidder) is included as part of the submission and the second half would be communicated to the tendering organization at the tender submission deadline. The bidder will push the bid as a smart contract to the blockchain. The bid is signed by the bidder's certified signature key. This key is certified by the tendering organization when the bidder register as an authorized bidding company - a process out of the actual tender opening and allocation process

When the deadline for bid submission expires, the smart contract on the blockchain stops accepting new bids. The tendering organization can download the submitted bids, and they can decrypt the bids if they have full (SKBidder). At the tender closing date, tendering organization will run the evaluation code and select the best bid. The result of the evaluation is pushed to the blockchain. At this stage, the tendering organization can make (SKBidder) of all bidders public on the blockchain. The illustration of the working concept of the blockchain model for procurement is illustrated in figure 1 below.

The tender organization will push the results of the bid evaluations along with bidder's keys to the blockchain. This information is crucial for independent auditing of the tendering process. Interested parties can access the tender details from the blockchain (where this data will reside in perpetuity) along with the bid evaluation code. Interested parties can download the tender contract that contains the code for bid evaluation criteria. Interested parties just have to run the evaluation code that will read the bids from the block and evaluation them. The results of the evaluation will show whether the bidding process was fair (auditing tender allocation to the stated best bidder)


Blockchain Network
Tendering Organization (Publish)
Procurement initiative creates tender
Tender Stipulation
Open the Tender
Block 0 Genesis Block
Hash of previous Block header
Markel
Block 0 Transaction
Tender Download
Block 1 Header
Hash of previous Block header
Markel
Block 1 Transaction
Bid submission
Tender Deadline
Closing Bid
Bid Collection
Tendering Organization (Evaluate)
Bid Evaluation
Selecting the Best Bid
Push the Results and Bid Keys
Block 2 Header
Hash of previous Block header
Markel
Block 2 Transaction
Block 3 Header
Hash of previous Block header
Markel
Block 3 Transaction
comment

4. ASSUMPTIONS

For parties to be involved in monitoring the organization activities, they need efficient tools and intuitive assessment that gives clear results. To build such an environment, blockchain and smart contracts show great potential. In this research the tendering process is will be implemented in the blockchain environment to provide an open and fair tendering scheme.

The design outlined is limited to four standard users: Admin, Biding organization, Bidder, and Third parties. In order to describe the various functional requirements that users have on the model, user stories from a focused group need to be written. The user stories need to be simplified to the bare minimum requirements, while still keeping the PoC at a viable level of usability and security.

5. RECOMMENDATION

The Government should move towards creating a legal framework for Ethereum and other digital currencies. Although many governments as shown in the literature are now considering launching their own Bitcoin-like cryptocurrency, the process should include sensitizing citizens and financial organizations. This will in addition encourage adoption of the blockchain based smart contracts model for tendering process among organizations.

6. CONCLUSION

For parties to be involved in monitoring the organization activities, they need efficient tools and intuitive assessment that gives clear results. To build such an environment, blockchain and smart contracts show great potential. In this study, the tendering process will be implemented in the blockchain environment to provide an open and fair tendering scheme.

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