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Even Vertex in-Magic Total Labeling of Some 2-Regular Digraphs

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***Abstract:** Let D be a directed graph with p vertices and q arcs. A vertex in-magic total labeling (VIMTL) is a bijection $\boldsymbol{f}: \boldsymbol{V}(\boldsymbol{D}) \cup \boldsymbol{A}(\boldsymbol{D}) \rightarrow \{\mathbf{1}, \mathbf{2}, \ldots \boldsymbol{p}+\boldsymbol{q}\}$ with the property that for every $\boldsymbol{v} \in \boldsymbol{V}(\boldsymbol{D})$, $\boldsymbol{f}(\boldsymbol{v})+\sum_{\boldsymbol{u} \in \boldsymbol{I}(\boldsymbol{v})} \boldsymbol{f}((\boldsymbol{v}, \boldsymbol{u}))=\boldsymbol{M}$, for some constant M. Such labeling is Even if $\boldsymbol{f}(\boldsymbol{V}(\boldsymbol{D}))=\{\mathbf{2}, \mathbf{4}, \mathbf{6} \ldots, \mathbf{2} \boldsymbol{p}\}$.In this paper, we explore the Even Vertex In-magic total labeling (EVIMTL) of some 2-regular directed graphs.*

***Keywords:** Digraphs, Vertex In-Magic Labeling, Even Vertex In-Magic Total Labeling*

1. INTRODUCTION

Graph Labeling is one of the most growing areas in graph theory. In graph theory, the labeling of graphs noticed to be a theoretical topic. It is used in countless applications like coding theory, X-Ray crystallography and astronomy etc. Design of graph labeling is helpful to network security, network addressing and social network in communication network. A magic total labeling of a graph is a motivating research area.

Throughout this paper, $D=(V, A)$ is taken as a digraph with p vertices and q arcs. For a vertex $v \in V(D)$, the set $I(v)=\{u \mid(u, v) \in A(D)\}$ is called the in-neighbourhood of v. The in-degree of v is defined by $deg^{-}(v)=|I(v)|$.A general reference for graph theoretic notions is[1].

A labeling of a graph G is a mapping from a set of vertices(edges) into a set of numbers, usually integers. Many kinds of labelings have been studied and an excellent survey of graph labelings can be found in [2].

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In 1963, Sedlàček[4] introduced the concept of magic labeling in graphs. A graph G is *magic* if the edges of G can be labelled by a set of numbers$\{1,2,\dots q\}$ so that the sum of labels of all the edges incident with any vertex is the same.

In 2002,Macdougall et al.[3] introduced the notion of vertex magic total labeling (VMTL) in graphs. Let $G(V,E)$ be a graph with $|V(G)|=p$ and $|E(G)|=q$.A one-to-one map f from $V(G)\cup E(G)$ onto the integers $\{1,2,\dots,\mathrm{p}+\mathrm{q}\}$ is a VTML if there is a constant M so that for every vertex $x\in V(G)$,$f(x)+\sum f(xy)=M$, where the sum is taken over all vertices y adjacent to x.

In 2015,Alison M.Marr et.al[5] extended the study of VMTL in directed graphs, in the name 'vertex in-magic total labelings'. In the same year, Arumugam et.al[6] introduced the notion of E- super vertex in-magic total labeling(E-SVIMTL) in digraphs. A vertex in-magic total labeling of a digraph D is a bijection f from $V(D)\cup A(D)\rightarrow\{1,2,\dots,p+q\}$ with the property that for every vertex $v\in V(D)$, $f(v)+\sum_{u\in I(v)}f((v,u))=M$, for some constant M. Such a labeling is E-super vertex-in total(E-SVIMT) if $f(A)=\{1,2,3,..q\}$. A digraph D which admits an E- SVIMTL is called an E-SVIMTL digraph.

CT. Nagaraj et al[7] in introduced the concept of an Even vertex magic total labeling. A vertex magic total labeling is even if $f\big(V(G)\big)=\{2,4,\dots,2n\}$.A graph is called an even vertex magic if the graph has an even vertex magic total labeling.
C.T Nagaraj et al[8] also studied Even vertex magic total labeling of some 2-regular graphs.

In this paper we define a new labeling called Even Vertex-In Magic Total Labeling(EVIMTL).An Even Vertex-In Magic Total Labeling(EVIMTL) is a bijection $f:V(D)\cup A(D)\rightarrow\{1,2,\dots p+q\}$ with the property $f(V(D))=\{2,4,6\dots,2p\}$ and for every $v\in V(D)$,$f(v)+\sum_{u\in I(v)}f((v,u))=M$, for some constant M. A digraph that admits an EVITML is called an Even vertex-in magic total(EVIMT).From the definition of EVITML, it is easy to observe that $p\leq q$.

2. MAIN RESULTS

In this section, we verify the existence of Even vertex-in magic total labeling for some 2-regular digraphs.

Lemma 2.1. If a digraph $D(p,q)$ is an even vertex-in magic total (EVIMT), then the magic constant M is given by $M=\frac{(p+q)(p+q+1)}{2p}$.

Proof: Let f be an EVIMTL of D. Note that $M=f(v)+\sum_{u\in I(v)}f((v,u))$ for all $v\in V(D)$. Summing over all $v\in V(D)$, we get

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$$pM=\sum_{v\in V(D)} f(v)+\sum_{v\in V(D)}\sum_{u\in I(v)} f\big((v,u)\big)=\sum_{v\in V(D)} f(v)+\sum_{v\in V(D)}\sum_{u\in I(v)} f\big((v,u)\big)$$

pM=$[1+3+\cdots+2p-1]+[2+4+\cdots+2p]+[1+2+\cdots+(p+q)]-[1+2+\ \ldots+2p]$
$pM\ \ =[1+2+\cdots+(p+q)]=\frac{(p+q)(p+q+1)}{2}$ and
Hence $M=\frac{(p+q)(p+q+1)}{2p}$.

Theorem 2.1 The digraph $D=\overrightarrow{C_3}\cup\overrightarrow{C_{4t}}\,, t\geq 1$ admits EVIMTL with magic constant $8t+7$.

Proof:
Let the $V(D)=\{a_i : 1\leq i\leq 3\}\cup\{b_i : 1\leq i\leq 4t\}$ and $A(D)=\{(a_i, a_{i\oplus_3 1}) : 1\leq i\leq 3\}\cup\{(b_i, b_{i\oplus_{4t}1}) : 1\leq i\leq 4t\}$ be the vertex set and arc set of D respectively.

Define $f : V(D)\cup A(D)\to\{1,2,\ldots.8t+6\}$ as follows

$$f(u)=\begin{cases} 8t+2i & if\ u=a_i\ \ for\ 1\leq i\leq 3\\ 2i & if\ u=b_i\ \ for\ 1\leq i\leq 4t\end{cases}$$ and

$$f(e)=\begin{cases} 7-2i & if\ e=(a_i, a_{i\oplus_3 1})\ for\ 1\leq i\leq 3\\ 8t+7-2i & if\ e=(b_i, b_{i\oplus_{4t}1}) for\ 1\leq i\leq 4t\end{cases}$$

Now we prove f is an EVIMTL

Case 1: Suppose $v=a_i$
Then
$f(v)+\sum_{u\in I(v)} f\big((v,u)\big)=f(a_i)+f((a_i, a_{i\oplus_3 1}))=[8t+2i]+[7-2i]=8t+7.$

Case 2: Suppose $v=b_i$
Then
$f(v)+\sum_{u\in I(v)} f\big((v,u)\big)=f(b_i)+f((b_i, b_{i\oplus_{4t}1}))=[2i]+[8t+7-2i]=8t+7.$

The digraph $D=\overrightarrow{C_3}\cup\overrightarrow{C_{4t}}\,, t\geq 1$ admits EVIMTL with the magic constant $8t+7$.

Example 2.2 Consider the digraph $D=\overrightarrow{C_3}\cup\overrightarrow{C_{4t}}$ taking $t=4$.
Here $V(D)=\{a_i : 1\leq i\leq 3\}\cup\{b_i : 1\leq i\leq 16\}$ and $A(D)=\{(a_i, a_{i\oplus_3 1}) : 1\leq i\leq 3\}\cup\{(b_i, b_{i\oplus_{16}1}) : 1\leq i\leq 16\}$ be the vertex set and arc set of D respectively.

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Define $f: V(D) \cup A(D) \rightarrow \{1,2, \dots .38\}$ as follows

$$f(u) = \begin{cases} 32 + 2i & if\ u = a_i \quad for\ \ 1 \leq i \leq 3 \\ 2i & if\ u = b_i \quad for\ 1 \leq i \leq 16 \end{cases}$$ and

$$f(e) = \begin{cases} 7 - 2i & if\ e = (a_i, a_{i \oplus_3 1}):\ 1 \leq i \leq 3 \\ 39 - 2i & if\ e = (b_i, b_{i \oplus_{16} 1}) for\ 1 \leq i \leq 16 \end{cases}$$

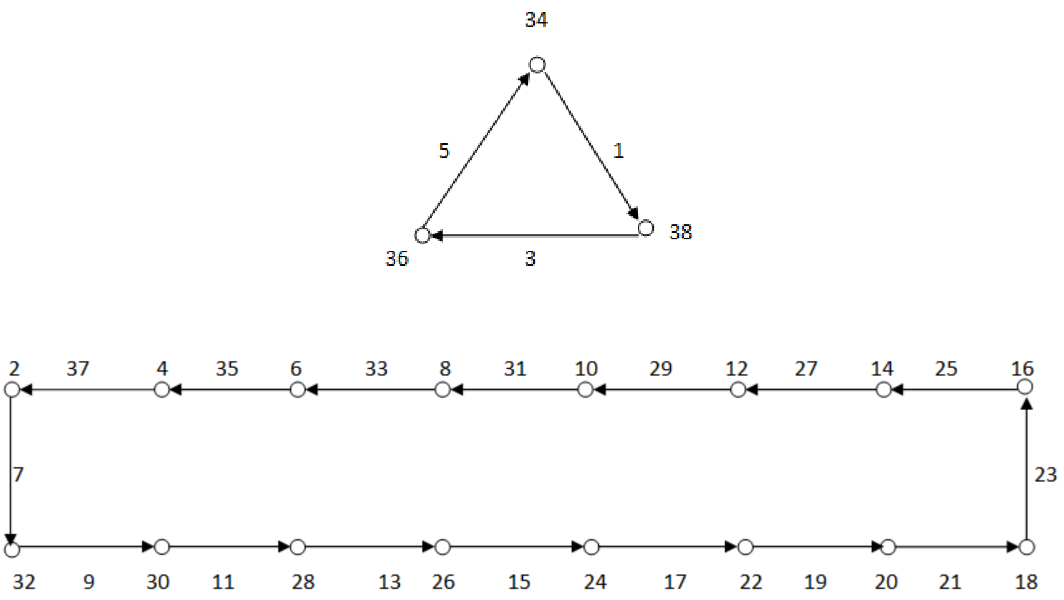

Figure 1: $\overrightarrow{C_3} \cup \overrightarrow{C_{16}}$ k = 39

Now we prove f is an EVIMTL

Case 1: Suppose $v = a_i$ for $i = 1,2,3$
Then $f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(a_i) + f((a_i, a_{i \oplus_3 1})) = [32 + 2i] + [7 - 2i] = 39.$

Case 2: Suppose $v = b_i$ for $1 \leq i \leq 16$
Then $f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(b_i) + f((b_i, b_{i \oplus_{16} 1})) = [2i] + [39 - 2i] = 39.$

The graph $C_3 \cup C_{4t}, t \geq 1$ is EVIMT with the magic constant 39.

Theorem 2.3 The digraph $D = \overrightarrow{C_3} \cup \overrightarrow{C_{4t+2}}, t \geq 1$ admits EVIMTL with magic constant $8t + 11$.

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Proof:
Let the $V(D) = \{a_i : 1 \le i \le 3\} \cup \{b_i : 1 \le i \le 4t+2\}$ and $A(D) = \left\{(a_{i\,,} a_{i\oplus_3 1}) : 1 \le i \le 3\right\} \cup \left\{(b_{i\,,} b_{i\oplus_{4t+2} 1}) : 1 \le i \le 4t+2\right\}$ be the vertex set and arc set of D respectively.

Define $f: V(D) \cup A(D) \to \{1,2, \dots .8t+10\}$ as follows

$$f(u) = \begin{cases} 8t+2i+4 & if\ u = a_i\ \ for\ 1 \le i \le 3 \\ 2i & if\ u = b_i\ \ \ for\ 1 \le i \le 4t+2 \end{cases}$$ and

$$f(e) = \begin{cases} 7-2i & if\ e = (a_i, a_{i\oplus_3 1}):\ 1 \le i \le 3 \\ 8t+11-2i & if\ e = (b_i, b_{i\oplus_{4t+2} 1}) for\ 1 \le i \le 4t+2 \end{cases}$$

Now we prove f is an EVIMTL

Case 1: Suppose $v = a_i$ for $1 \le i \le 3$
Then $f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(a_i) + f(\,(a_i, a_{i\oplus_3 1})) = [8t+2i+4] + [7-2i] = 8t+11$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 4t+2$
Then $f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(b_i) + f(\,(b_i, b_{i\oplus_{4t+2} 1})) = [2i] + [8t+11-2i] = 8t+11$.

The graph $C_3 \cup C_{4t+2}\,, t \ge 1$ admits EVIMTL with the magic constant $8t+11$.

Example 2.4 Consider the digraph $D = \overrightarrow{C_3} \cup \overrightarrow{C_{4t+2}}$ taking $t = 4$.
Here $V(D) = \{a_i : 1 \le i \le 3\} \cup \{b_i : 1 \le i \le 18\}$ and $A(D) = \{(a_i, a_{i\oplus_3 1}) : 1 \le i \le 3\} \cup \{(b_i, b_{i\oplus_{18} 1}) : 1 \le i \le 18\}$ be the vertex set and arc set of D respectively.

Define $f: V(D) \cup A(D) \to \{1,2, \dots .42\}$ as follows

$$f(u) = \begin{cases} 36+2i & if\ u = a_i\ \ for\ 1 \le i \le 3 \\ 2i & if\ u = b_i\ \ for\ 1 \le i \le 18 \end{cases}$$ and

$$f(e) = \begin{cases} 7-2i & if\ e = (a_i, a_{i\oplus_3 1})\ \ for\ \ 1 \le i \le 3 \\ 43-2i & if\ e = (b_i, b_{i\oplus_{18} 1})\ \ for\ \ 1 \le i \le 18 \end{cases}$$

Now we prove f is an EVIMTL

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Case 1: Suppose $v = a_i$ for $1 \leq i \leq 3$
Then
$f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(a_i) + f(\,(a_i\,, a_{i \oplus_3 1})) = [36 + 2i] + [7 - 2i] = 43.$

Case 2: Suppose $v = b_i$ for $1 \leq i \leq 4t + 2$
Then $f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(b_i) + f(\,(b_i\,, b_{i \oplus_{18} 1})) = [2i] + [43 - 2i] = 43.$

The graph $C_3 \cup C_{4t+2}\,, t \geq 1$ is EVIMT with the magic constant 43.

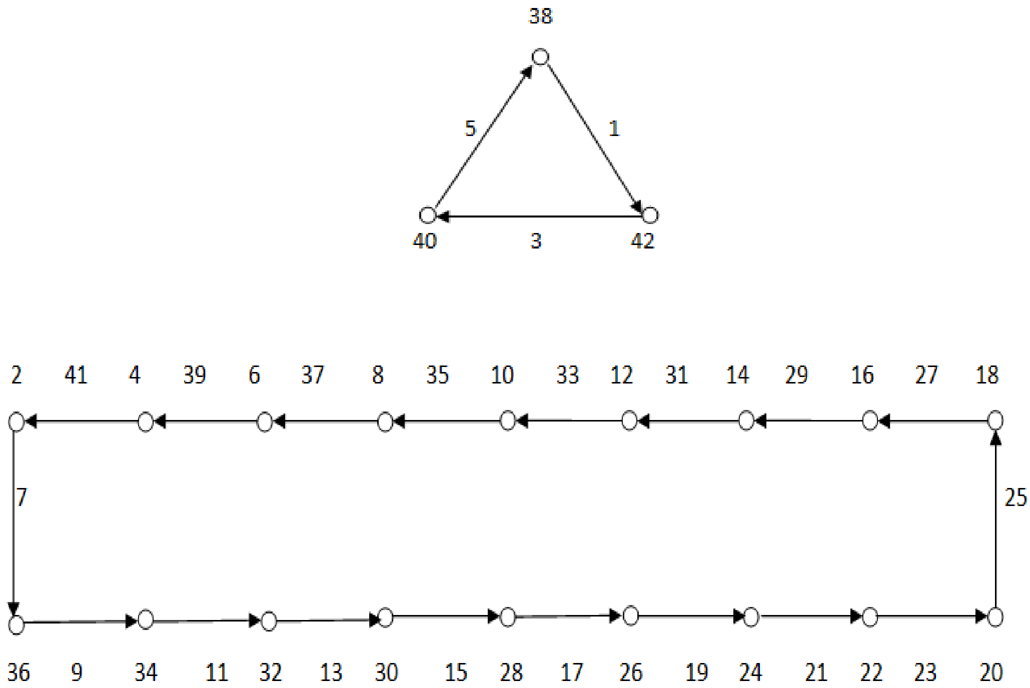

Figure 2: $\overrightarrow{C_3} \cup \overrightarrow{C_{18}}$ k = 43

Theorem 2.5 The digraph $D = \overrightarrow{C_4} \cup \overrightarrow{C_{4t+3}}\,, t \geq 1$ admits EVIMTL with magic constant $8t + 15$.

Proof:

Let the $V(D) = \{a_i : 1 \leq i \leq 4\} \cup \{b_i : 1 \leq i \leq 4t + 3\}$ and $A(D) = \{(a_{i\,,} a_{i \oplus_4 1}) : 1 \leq i \leq 4\} \cup \{(b_{i\,,} b_{i \oplus_{4t+3} 1}) : 1 \leq i \leq 4t + 3\}$ be the vertex set and arc set of D respectively.

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Define $f: V(D) \cup A(D) \to \{1,2, \ldots .8t+14\}$ as follows

$$f(u) = \begin{cases} 8t+2i+6 & if\ u = a_i \quad for\ \ 1 \le i \le 4 \\ 2i & if\ u = b_i \quad for\ 1 \le i \le 4t+3 \end{cases}$$

and

$$f(e) = \begin{cases} 9-2i & if\ e = (a_i, a_{i \oplus_4 1}):\ 1 \le i \le 4 \\ 8t+15-2i & if\ e = (b_i, b_{i \oplus_{4t+3} 1}) for\ 1 \le i \le 4t+3. \end{cases}$$

Now we prove f is an EVIMTL

Case 1: Suppose $v = a_i, 1 \le i \le 4$

Then $f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(a_i) + f(\,(a_i, a_{i \oplus_4 1})) = [8t+2i+6] + [9-2i] = 8t+15.$

Case 2: Suppose $v = b_i, 1 \le i \le 4t+3$

Then $f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(b_i) + f(\,(b_i, b_{i \oplus_{4t+3} 1})) = [2i] + [8t+15-2i] = 8t+15.$

The digraph $D = \overrightarrow{C_3} \cup \overrightarrow{C_{4t}}, t \ge 1$ admits EVIMTL with the magic constant $8t+15$.

Example 2.6 Consider the digraph $D = \overrightarrow{C_3} \cup \overrightarrow{C_{4t+3}}$ taking $t = 3$

Here $V(D) = \{a_i: 1 \le i \le 4\} \cup \{b_i: 1 \le i \le 15\}$ and $A(D) = \big\{(a_i, a_{i \oplus_4 1}): 1 \le i \le 4\big\} \cup \big\{(b_i, b_{i \oplus_{15} 1}): 1 \le i \le 15\big\}$ be the vertex set and arc set of D respectively.

Define $f: V(D) \cup A(D) \to \{1,2, \ldots .38\}$ as follows

$$f(u) = \begin{cases} 30+2i & if\ u = a_i \quad for\ \ 1 \le i \le 4 \\ 2i & if\ u = b_i \quad for\ 1 \le i \le 15 \end{cases}$$

and

$$f(e) = \begin{cases} 9-2i & if\ e = (a_i, a_{i \oplus_4 1}):\ 1 \le i \le 4 \\ 39-2i & if\ e = (b_i, b_{i \oplus_{15} 1}) for\ 1 \le i \le 15 \end{cases}$$

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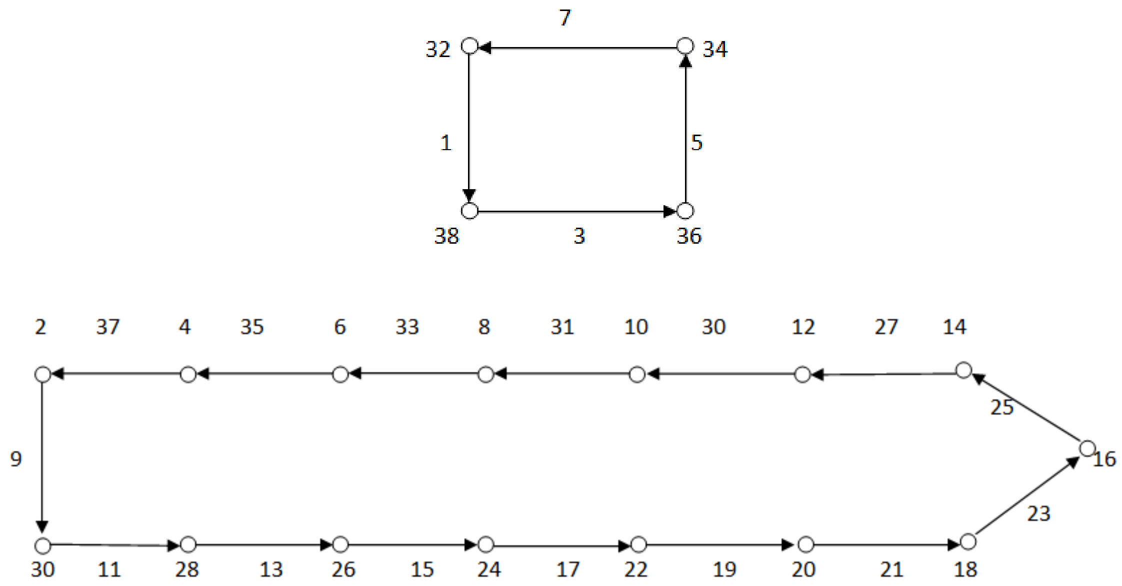

Figure 3: $\overrightarrow{C_4} \cup \overrightarrow{C_{15}}$ k = 39

Now we prove f is an EVIMTL

Case 1: Suppose $v = a_i$ for $1 \le i \le 4$

Then $f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(a_i) + f(\,(a_i\,, a_{i \oplus_4 1})) = [30 + 2i] + [9 - 2i] = 39.$

Case 2: Suppose $v = b_i$ for $1 \le i \le 15$

Then $f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(b_i) + f(\,(b_i\,, b_{i \oplus_{15} 1})) = [2i] + [39 - 2i] = 39.$

The graph $C_3 \cup C_{4t+3}, t \ge 1$ is EVIMT with the magic constant 39.

Theorem 2.7 The digraph $D = \overrightarrow{C_3} \cup \overrightarrow{C_{4t+1}}, t \ge 1$ admits EVIMTL with magic constant $8t + 11$.

Proof:

Let the $V(D) = \{a_i : 1 \le i \le 4\} \cup \{b_i : 1 \le i \le 4t + 1\}$ and $A(D) = \left\{(a_{i\,,} a_{i \oplus_4 1}) : 1 \le i \le 4\right\} \cup \left\{(b_{i\,,} b_{i \oplus_{4t+1} 1}) : 1 \le i \le 4t + 1\right\}$ be the vertex set and arc set of D respectively.

Define $f : V(D) \cup A(D) \to \{1,2, \dots .8t + 10\}$ as follows

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$$f(u) = \begin{cases} 8t+2i+2 & if\ u = a_i\ \ for\ 1 \le i \le 4 \\ 2i & if\ u = b_i\ \ for\ 1 \le i \le 4t+1 \end{cases}$$ and

$$f(e) = \begin{cases} 9-2i & if\ e = (a_i, a_{i\oplus_4 1}):\ 1 \le i \le 4 \\ 8t+11-2i & if\ e = (b_i, b_{i\oplus_{4t+1} 1}) for\ 1 \le i \le 4t+1 \end{cases}$$

Now we prove f is an EVIMTL

Case 1: Suppose $v = a_i$ for $1 \le i \le 4$
Then $f(v) + \sum_{u\in I(v)} f\big((v,u)\big) = f(a_i) + f(\,(a_i, a_{i\oplus_3 1})) = [8t+2i+4] + [9-2i] = 8t+11$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 4t+1$
Then $f(v) + \sum_{u\in I(v)} f\big((v,u)\big) = f(b_i) + f(\,(b_i, b_{i\oplus_{4t+1} 1})) = [2i] + [8t+11-2i] = 8t+11$.

The graph $C_3 \cup C_{4t+2}, t \ge 1$ admits EVIMTL with the magic constant $8t+11$.

Example 2.4 Consider the digraph $D = \overrightarrow{C_3} \cup \overrightarrow{C_{4t+1}}$ taking $t = 3$.
Here $V(D) = \{a_i : 1 \le i \le 4\} \cup \{b_i : 1 \le i \le 13\}$ and $A(D) = \{(a_i, a_{i\oplus_3 1}) : 1 \le i \le 4\} \cup \{(b_i, b_{i\oplus_{13} 1}) : 1 \le i \le 13\}$ be the vertex set and arc set of D respectively.

Define $f: V(D) \cup A(D) \to \{1,2, \dots .34\}$ as follows

$$f(u) = \begin{cases} 26+2i & if\ u = a_i\ \ for\ 1 \le i \le 4 \\ 2i & if\ u = b_i\ \ for\ 1 \le i \le 13 \end{cases}$$ and

$$f(e) = \begin{cases} 9-2i & if\ e = (a_i, a_{i\oplus_4 1})\ \ for\ \ 1 \le i \le 4 \\ 35-2i & if\ e = (b_i, b_{i\oplus_{13} 1})\ \ for\ \ 1 \le i \le 13 \end{cases}$$

Now we prove f is an EVIMTL

Case 1: Suppose $v = a_i$ for $1 \le i \le 4$

Then $f(v) + \sum_{u\in I(v)} f\big((v,u)\big) = f(a_i) + f(\,(a_i, a_{i\oplus_4 1})) = [26+2i] + [9-2i] = 35$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 13$

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Then $f(v) + \sum_{u \in I(v)} f\big((v,u)\big) = f(b_i) + f(\,(b_i\,, b_{i\,\oplus_{13} 1})) = [2i] + [35 - 2i] = 35.$

The graph $C_3 \cup C_{4t+1}, t \geq 1$ is EVIMT with the magic constant 35.

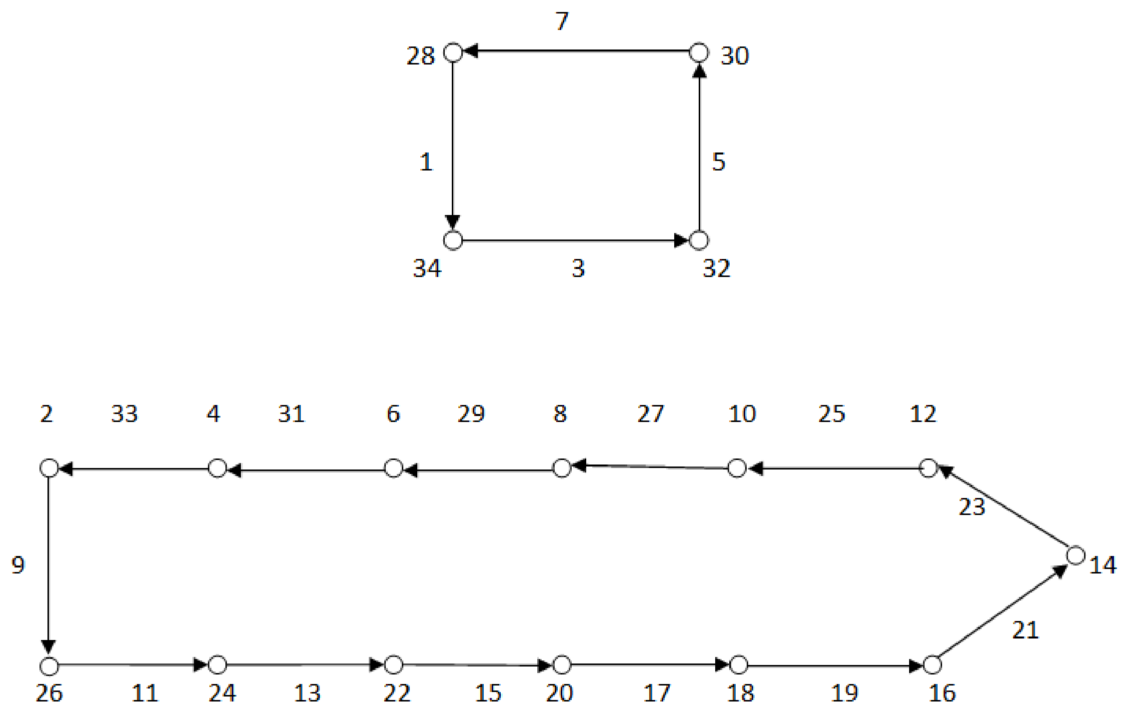

Figure 4: $C_4 \cup C_{13}$ $k = 35$

3. CONCLUSIONS

In this paper we have discussed some cycles of graphs that admits EVIMTL. In future we can prove different types of graphs which satisfy EVIMTL.

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