Investigate of Transition Curves with Lateral Change of Acceleration for Highways Horizontal Geometry

Eray CAN and Senol KUSCU, Turkey

Keywords: Lateral Change of Acceleration, Transiton Curve, Road Dynamic, Highways horizontal geometry

SUMMARY

Circular horizontal curves and simple superelevation application are used adequately for safety and comfort in design and application of roads without the need of high speed when combining alignments. Nevertheless they are just not appropriate for speed roads.

In the recent years with developments in sciences on account of high speeds on motorways and railways have got better the horizontal geometry of roads with respect to road dynamic. This condition are provided only suitable transition curves. Generally transition curves are used two straight lines with a circle but this conceive not adequate for high speed project and road dynamic. So it was necessary to investigations new solutions.

New transition curves are defined with lateral change of acceleration. This equation can be used all stipulation related to horizontal geometry and vehicle motion. New curve1 and curve 2 (Tari 1, Tari2) and classical transition curve (Clothoid and sinüzoidal) are compared with lateral change of acceleration. In this article known mathematics functions (curvature and superelevation functions) are examined for classical and new transition curve and then developed new programme.

Besides all transition curves which mentioned in this article are examined with diagrams of lateral change of acceleration. New and classical transition curves according to these diagrams are compared and understanded that suitable by known criterias. To give an example of new curve 1 (Tari 1) and sinüzoidal curve Programme codes and illustrated with diagrams.

Investigate of Transition Curves with Lateral Change of Acceleration for Highways Horizontal Geometry

Eray CAN and Senol KUSCU, Turkey

1. INTRODUCTION

Nowadays design and application of the highways and railways horizontal geometry is very considerable for high speed road projects. In design of the combining alignments using an arc of circular curves not adequate for safety and comfort wherefore effects of instantaneous centrifugal force. However this solution failed as the speed increased and it causes problem related to vehicle dynamic. Transition curves like clothoid and sinüzoid which is the mentioned in this article classical curves are used for better solutions for traveling security and comfort on highways and railways route design.

Transition curves are used for joining a straight lines with a circle (figure1.1) The function of these curves is provide to flexibility the effects of centrifugal force due to the reasons of sudden changes in curvature. Classical curves solve this problem partly. The ideal case regarding vehicle road dynamics is that there is no breaking points on the diagrams of curvature belongs to curved sections and diagrams of curvature and lateral change of acceleration should have contionus diagram. New transition curves; (curve 1 and curve 2) solve this problem exactly for remove to instantaneous effects of centrifugal force and no breaking points on the diagrams of lateral change of acceleration. (Tarı 1997) Besides this curves provides that security and travelling comfort for high speed route design in this projects.

In this article known mathematics functions; curvature, superelevation and lateral change of acceleration functions are examined for classical and new transition curve and then developed new programme. Besides all transition curves which mentioned in this article are examined with diagrams of lateral change of acceleration. Value of velocity, curve lengt, curve radius and superelevation are entered by all of the programme users in this new software. New and classical transition curves according to these diagrams are compared and understanded that suitable by known criterias. To give an example of new curve 1 (Tari 1) and sinüzoidal curve programme codes and illustrated with diagrams.

2. LATERAL CHANGE OF ACCELERATION

Lateral change of acceleration is very considerable criterion when designed to horizontal geometry for road vehicle dynamic. It is the change of resultant acceleration occurring along the curve normal respect to time. This changes are formed by unbalanced forces, vehicle mass and velocity moving on a curved orbit (Tarı 1997, Baykal 1996). Generally lateral change of acceleration is shown as;

$$z = \frac{da}{dT}\vec{n} \tag{2.1}$$

where;

z =lateral change of acceleration
a =resultant acceleration
T =time
n=unit vector along the curve normal

vehicles moving on a superelevated road are the gravitational force *(P=mg),* the centrifugal force *($F=mkv^2$)* and the motor force *($F_t=ma_t$).* according to figure 2.1 resultant force *(R)* of the gravitational and centrifugal forces can be divided D and F_n components. D component is balanced with the reaction of the road platform.

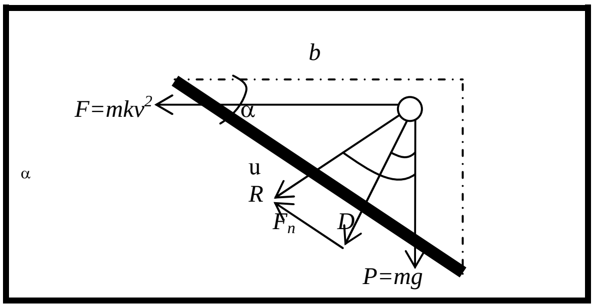

Figure 2.1 Forces acting on vehicle moving on superelevated road

F_n can be expressed according to figure 2.1,

$$F_n = m(kv^2 - g\tan\alpha)\cos\alpha \tag{2.2}$$

can be derived.

$$\tan\alpha = \frac{u}{b} \text{ and } \cos\alpha = \frac{b}{\sqrt{u^2+b^2}} \tag{2.3}$$

into (2.2)

$$\vec{a}_n = \left(kv^2 - \frac{g}{b}u\right)\frac{b}{\sqrt{u^2+b^2}} \tag{2.4}$$

can be derived.

Where,

u: superelevation (m)
b: horizontal width of the road platform (m)
g: gravitational acceleration (9.81 m/sn^2)
k: curvature of orbiting curve (1/m)
a_n: acceleration along the direction of the curve normal on an inclined road platform (m/sn^2)

$$\vec{a} = \frac{dv}{dT}\vec{t} + \frac{b}{\sqrt{u^2 + b^2}}(kv^2 - g\frac{u}{b})\vec{n} \tag{2.5}$$

in this equalization $\vec{t}$ is the unit vector along the direction of the tangent of curve. The equation of lateral change of acceleration is obtained as follows;

$$z = \frac{da}{dT}\vec{n} = \frac{bv}{\sqrt{u^2 + b^2}}\left(3ka_t + v^2\frac{dk}{dl} - \frac{kv^2u + gb}{u^2 + b^2}\frac{du}{dl}\right) \tag{2.6}$$

this equation of lateral change of acceleration can be used for all conditions related to road horizontal geometry and vehicle motion.

3. LATERAL CHANGE OF ACCELERATİON FUNCTIONS OF CURVES FOR MOTION WİTH CONSTANT VELOCITY MODEL

In this study classical curves (clothoid and sinusoidal) and new transition curves (curve1 and curve2) are examined with constant velocity model for vehicle motion. End of the study new and classical transition curves according to these researchs are compared and illustrated with analytical diagrams.

3.1 Investigate to Lateral Change of Acceleration Function of clothoid curve With Constant Velocity Model

Superelevation and curvature function of first clothoid curve can be expressed as,

$$\left.\begin{array}{l} k_{k,l}(l) = \dfrac{l}{L_1 R} \quad (3.1.1) \\ u_{k,1}(l) = \dfrac{ul}{L_1} \quad (3.1.2) \end{array}\right\} \quad 0 \le l \le L_1$$

the function of lateral change of acceleration of the recommended first clothoid curve is derived from (2.6) by taking consideration (3.1.1) ,(3.1.2) and using the transformation of variable of t=l/L and differentiated with respect l as follows; (Tarı 1997)

$$z_{k,1}(t) = \frac{L_1^2 v(v^2 - gR\tan\alpha_m)}{L^3 R(t^2 \tan^2\alpha_m + \frac{L_1^2}{L^2})^{3/2}} \qquad 0 \le t < \frac{L_1}{L}$$

where

$$\tan\alpha_m = \frac{u}{b} \tag{3.1.4}$$

l: Horizontal length of arc of orbital curve,
L: Total length of arc of orbital curve.

Superelevation and curvature function of the arc of circle can be expressed as,

$$k_{k,2}(t) = \frac{1}{R} \qquad u_{k,2}(t) = u \tag{3.1.5}$$

the function of lateral change of acceleration of the recommended arc of circle is derived from (2.6) by taking consideration (3.1.5) as follows;

$$z_{k,2}(t) = 0 \qquad \frac{L_1}{L} \leq t < \frac{L_1 + L_2}{L} \tag{3.1.6}$$

Superelevation and curvature function of second clothoid curve can be expressed as,

$$\left.\begin{aligned} k_{k,3}(l) &= \frac{1}{RL_3}(L-l) \quad (3.1.7) \\ u_{k,3} &= \frac{u}{L_3}(L-l) \quad (3.1.8) \end{aligned}\right\} \qquad L_1 + L_2 \leq l \leq L$$

the function of lateral change of acceleration of the recommended second clothoid curve is derived from (2.6) by taking consideration (3.1.7) ,(3.1.8) as follows;

$$z_{k,3}(t) = -\frac{L_3^2 v(v^2 - gR\tan\alpha_m)}{L^3 R((1-t)^2 \tan^2\alpha_m + \frac{L_3^2}{L^2})^{3/2}} \qquad \frac{L_1 + L_2}{L} \leq t \leq 1 \tag{3.1.9}$$

can be derived. (Tarı 1997)

Equalization of (3.1.3),(3.1.6) and (3.1.9) are considerated then examinated with analytical diagram by new programme. (figure 3.1.1) In this new programme;

Horizontal length of transition curve and arc of circle	$L_1=L_2=L_3=600m$
Superelevation	$u=0.15m$
Total length of arc of orbital curve.	$L=1800$
Radius	$R=1850$
Velocity	$V= 230$ km/sa

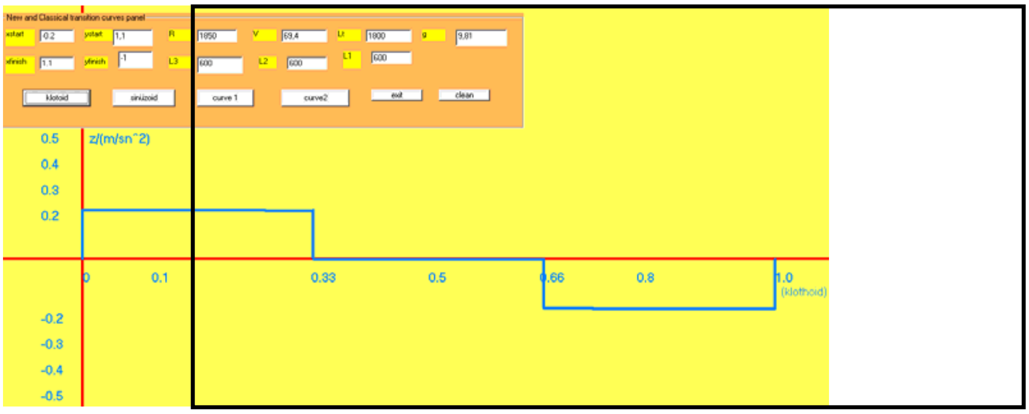

Figure 3.1.1 Analytic diagram for clothoid curve functions with constant velocity model

3.2 Investigate to Lateral Change of Acceleration Function of sinüzoidal curve With Constant Velocity Model

Superelevation and curvature function of first sinüzoidal curve can be expressed as,

$$k_{s,1}(l) = \frac{1}{R}\left(\frac{l}{L_1} - \frac{1}{2\pi}\sin\left(\frac{l}{L_1}2\pi\right)\right) \qquad 0 \le l \le L_1 \tag{3.2.1}$$

$$u_{s,1}(l) = u\left(\frac{l}{L_1} - \frac{1}{2\pi}\sin\left(\frac{l}{L_1}2\pi\right)\right) \tag{3.2.2}$$

the function of lateral change of acceleration of the recommended first sinüzoidal curve is derived from (2.6) by taking consideration (3.2.1), (3.2.2) and using the transformation of variable of $t=l/L$ and differentiated with respect l as follows; (Tarı 1997)

$$z_{s,1}(t) = \frac{N_{s,1}v(v^2 - gR\tan\alpha_m)}{R(1+Q_{s,1}^2\tan^2\alpha_m)^{3/2}} \qquad 0 \le t < \frac{L_1}{L} \tag{3.2.3}$$

$$Q_{s,1} = \frac{L_t}{L_1} - \frac{1}{2\pi}\sin\left(\frac{L_t}{L_1}2\pi\right) \tag{3.2.4}$$

$$N_{s,1} = \frac{1}{L_1} - \frac{1}{L_1}\cos\left(\frac{L_t}{L_1}2\pi\right) \tag{3.2.5}$$

can be derived.

Superelevation and curvature function of the arc of circle can be expressed as,

$$k_{s,2}(t) = \frac{1}{R} \qquad u_{s,2}(t) = u \tag{3.2.6}$$

the function of lateral change of acceleration of the recommended arc of circle is derived from (2.6) by taking consideration (3.2.6) as follows;

$$z_{s,2}(t) = 0 \qquad \frac{L_1}{L} \le t < \frac{L_1 + L_2}{L} \tag{3.2.7}$$

Superelevation and curvature function of second sinusoidal curve can be expressed as,

$$k_{s,3}(l) = \frac{1}{R}\left(\frac{(L-l)}{L_3} - \frac{1}{2\pi}\sin\left(\frac{(L-l)}{L_3}2\pi\right)\right) \tag{3.2.8}$$

$$u_{s,3}(l) = u\left(\frac{(L-l)}{L_3} - \frac{1}{2\pi}\sin\left(\frac{(L-l)}{L_3}2\pi\right)\right) \tag{3.2.9}$$

$$L_1 + L_2 \le l \le L$$

the function of lateral change of acceleration of the recommended second clothoid curve is derived from (2.6) by taking consideration (3.2.8) ,(3.2.9) as follows;

$$z_{s,3}(t) = \frac{N_{s,2} v (v^2 - gR\tan\alpha_m)}{R(1 + Q_{s,2}^2 \tan^2\alpha_m)^{3/2}} \qquad \frac{L_1 + L_2}{L} \le t \le 1 \tag{3.2.10}$$

$$Q_{s,2} = \frac{L - L_t}{L_3} - \frac{1}{2\pi}\sin\left(\frac{L - L_t}{L_3}2\pi\right) \tag{3.2.11}$$

$$N_{s,2} = -\frac{1}{L_3} + \frac{1}{L_3}\cos\left(\frac{L - L_t}{L_3}2\pi\right) \tag{3.2.12}$$

can be derived (Tarı 1997).

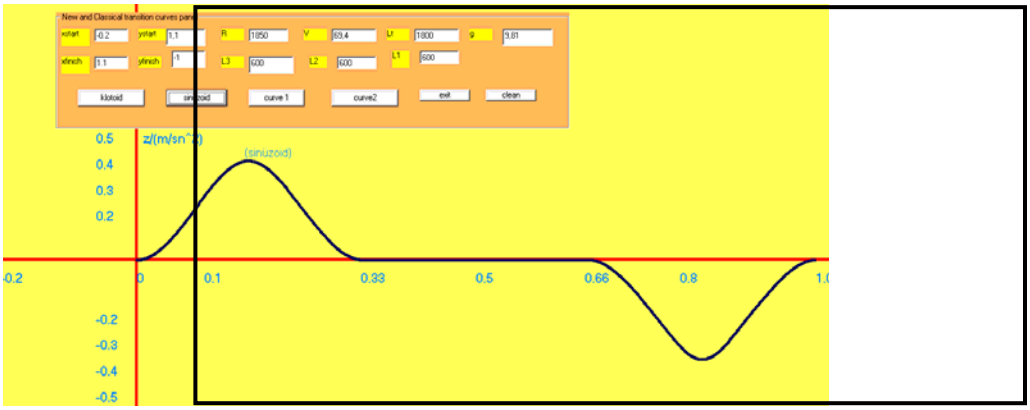

Figure 3.2.1 Analytic diagram for sinüzoid curve functions with constant velocity model

3.3 Investigate to Lateral Change of Acceleration Function of curve 1 With Constant Velocity Model

Superelevation and curvature function of first curve 1 can be expressed as,

$$k_{1,1}(l)=\frac{1}{R}\left\{a\left(\frac{l}{L_1}\right)^5+b\left(\frac{l}{L_1}\right)^4+c\left(\frac{l}{L_1}\right)\right\},\quad u_{1,1}(l)=\frac{ul^3}{L_1^3}\left(\frac{6l^2}{L_1^2}-\frac{15l}{L_1}+10\right)\qquad 0\le l\le L_1 \qquad (3.3.1)$$

the function of lateral change of acceleration of the recommended first sinüzoidal curve is derived from (2.6) by taking consideration (3.3.1) and using the transformation of variable of $t=l/L$ and differentiated with respect l as follows; (Tarı 1997)

$$z_{1,1}(t)=\frac{N_{1,1}v(v^2-gR\tan\alpha_m)}{R(1+Q_{1,1}^2\tan^2\alpha_m)^{3/2}}\qquad 0\le t\le\frac{L_1}{L} \qquad (3.3.2)$$

$$Q_{1,1}=\frac{6L^5t^5}{L_1^5}-\frac{15L^4t^4}{L_1^4}+\frac{10L^3t^3}{L_1^3},\quad N_{1,1}=\frac{30L^4t^4}{L_1^5}-\frac{60L^3t^3}{L_1^4}+\frac{30L^2t^2}{L_1^3} \qquad (3.3.3)$$

can be derived.

Superelevation and curvature function of the arc of circle can be expressed as,

$$k_{1,2}(t)=\frac{1}{R},\qquad u_{1,2}(t)=u \qquad (3.3.4)$$

the function of lateral change of acceleration of the recommended arc of circle is derived from (2.6) by taking consideration (3.3.4) as follows;

$$z_{1,2}(t)=0\qquad \frac{L_1}{L}\le t\le\frac{L_1+L_2}{L} \qquad (3.3.5)$$

Superelevation and curvature function of second curve1 can be expressed as,

$$\left.\begin{aligned} k_{1,3}(l)&=\frac{(L-l)^3}{RL_3^3}\left(\frac{6(L-l)^2}{L_3^2}-\frac{15(L-l)}{L_3}+10\right) \qquad (3.3.6)\\ u_{1,3}(l)&=\frac{u(L-l)^3}{L_3^3}\left(\frac{6(L-l)^2}{L_3^2}-\frac{15(L-l)}{L_3}+10\right) \qquad (3.3.7)\end{aligned}\right\}\quad L_1+L_2\le l\le L_1+L_2+L_3$$

the function of lateral change of acceleration of the recommended second clothoid curve is derived from (2.6) by taking consideration (3.3.6) ,(3.3.7) as follows;

$$z_{1,3}(t) = \frac{N_{1,2} v (v^2 - gR\tan\alpha_m)}{R(1+Q_{1,2}^2 \tan^2\alpha_m)^{3/2}} \qquad \frac{L_1 + L_2}{L} \le t \le 1 \tag{3.3.8}$$

$$\left.\begin{aligned} Q_{1,2} &= \frac{6(L-Lt)^5}{L_3^5} - \frac{15(L-Lt)^4}{L_3^4} + \frac{10(L-Lt)}{L_3^3} && (3.3.9) \\ N_{1,2} &= \frac{30(L-Lt)^4}{L_3^5} - \frac{60(L-Lt)^3}{L_3^4} + \frac{30(L-Lt)}{L_3^3} && (3.3.10) \end{aligned}\right\}$$

can be writen (Tarı 1997).

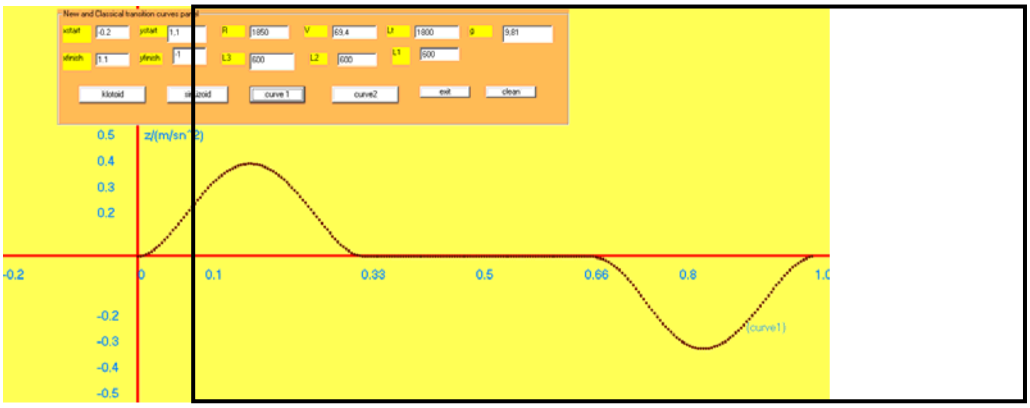

Figure 3.3.1 Analytic diagram for curve1 functions with constant velocity model

3.4 Investigate to Lateral Change of Acceleration Function of combined curve 2 With Constant Velocity Model

Superelevation and curvature function of combined curve 2 can be expressed as,

$$k_2(t) = \frac{823543}{6912R}(t^7 - 4t^6 + 6t^5 - 4t^4 + t^3) \quad u_2(t) = \frac{823543u}{6912}(t^7 - 4t^6 + 6t^5 - 4t^4 + t^3) \tag{3.4.1}$$

the function of lateral change of acceleration of the recommended first sinüzoidal curve is derived from (2.6) by taking consideration (3.4.1) and using the transformation of variable of *t=l/L* and differentiated with respect *l* as follows; (Tarı 1997)

$$z_2(t) = \frac{N_2 v (v^2 - gR\tan\alpha_m)}{LR(1+Q_2^2 \tan^2\alpha_m)^{3/2}} \qquad 0 \le t \le 1 \tag{3.4.2}$$

$$\left.\begin{aligned} Q_2 &= \frac{823543}{6912}(t^7 - 4t^6 + 6t^5 - 4t^4 + t^3) && (3.4.3) \\ N_2 &= \frac{823543}{6912}(7t^6 - 24t^5 + 30t^4 - 16t^3 + 3t^2) && (3.4.4) \end{aligned}\right\}$$

can be writen.

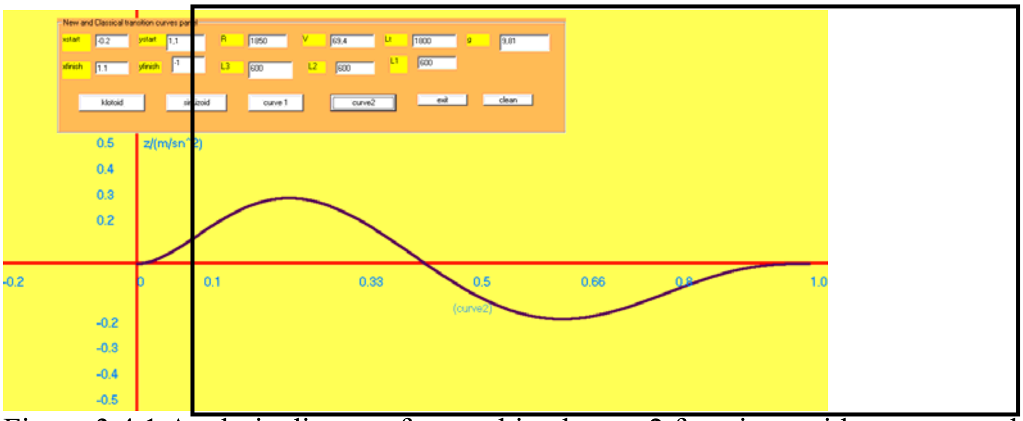

Figure 3.4.1 Analytic diagram for combined curve2 functions with constant velocity model

4. CONCLUSION

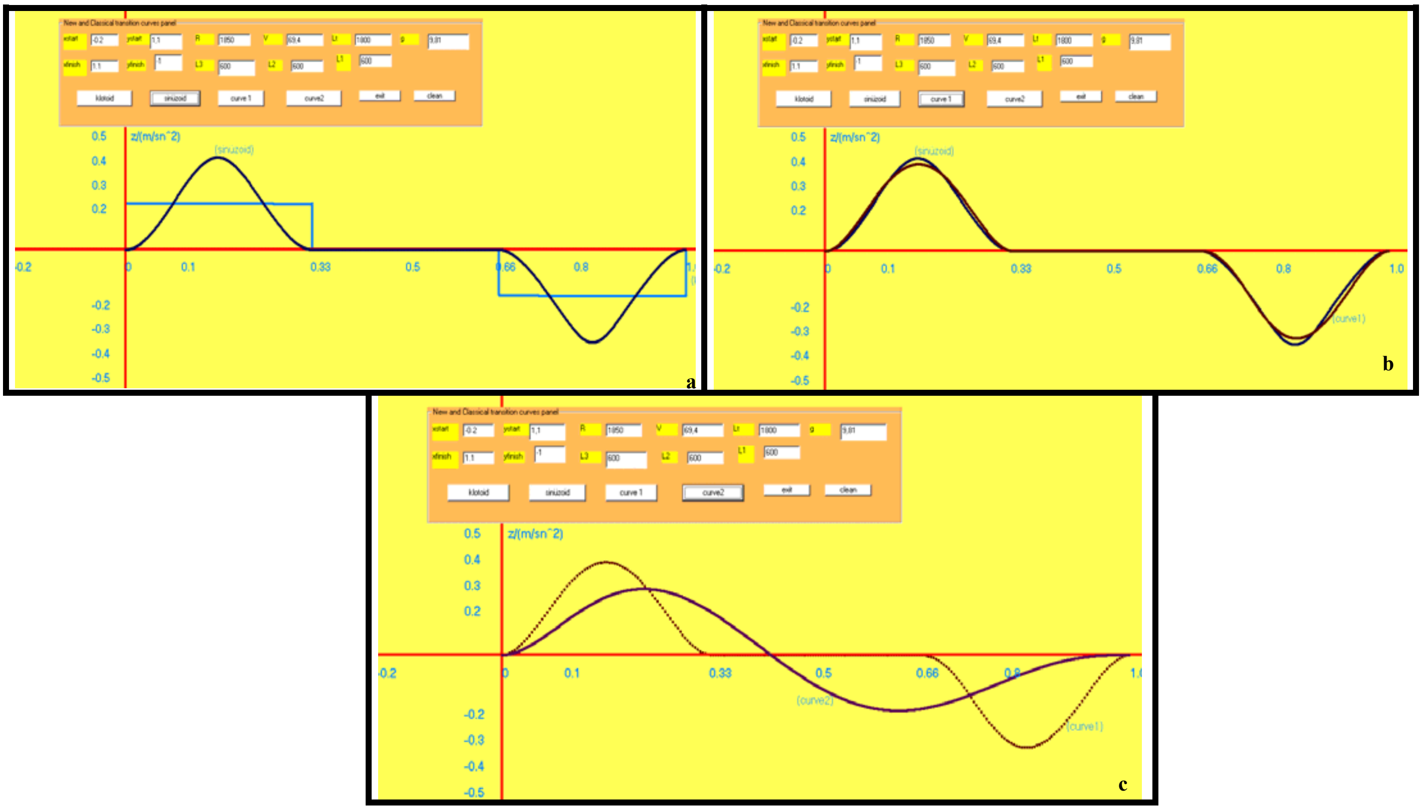

Figure 4.1 Analytic diagram for classical and new transition functions.

This study and new programme examined that new and classical transition curves according to these diagrams are understanded that suitable by known criterias for horizontal geometry of higways and railways. According to criterion 1, diagram of lateral change of acceleration functions of contunity and discontinuties in the form of jump very considerable for travelling comfort. This curves for suitable this criteria excep to clothoid curves (figure 4.1.a) (Tarı 1997). According to criterian 2 amplitudes of lateral change of acceleration is very considerable. In literature 0.3-0.6m/sec^3 values are the maximum values of lateral change of acceleration for travel comfort (Tarı 1997). Curve 2 more suitable than Sinüzoidal and curve 1 for criterian 2 (figure 4.1.b). According to criterian 3, break affect and irregular change of the lateral change of acceleration of diagrams at the point where transition curves and arc of circle are combined. Break affect is determined that differences between slope values of two tangents on this diagram at this point (Tarı 1997). Because of this, curve 2 is the best curve for travelling comfort and security for high speed highway and railway projects (figure 4.1.c). New programme support this criterians which are mentioned above.

```
Private Sub Command2_Click()      sinüzoidal curve
Dim xstart, xfinish, ystart, yfinish, R, V, Lt, L1, L2, L3, g
xstart = Val(Text1):xfinish = Val(Text2):ystart = Val(Text3):yfinish = Val(Text4):R = Val(Text5)
V = Val(Text6):Lt = Val(Text7):L1 = Val(Text8):L2 = Val(Text9):L3 = Val(Text10):g = Val(Text11)
Scale (xstart, ystart)-(xfinish, yfinish)
Line (0, ystart)-(0, yfinish), QBColor(12)
Line (xstart, 0)-(xfinish, 0), QBColor(12)
Dim x2, y2, Q1, N1, Q2, N2
For x2 = 0 To 1 Step 0.001
Q1 = (Lt * x2 / L1) - (1 / 2 * 3.14 * Sin(Lt * x2 / L1 * 2 * 3.14))
N1 = (1 / L1) - (1 / L1 * Cos(Lt * x2 / L1 * 2 * 3.14))
Q2 = ((Lt - Lt * x2) / L3) - (1 / 2 - 3.14 * Sin((Lt - Lt * x2) / L3 * 2 * 3.14))
N2 = (-1 / L3) + (1 / L3 * Cos((Lt - Lt * x2) / L3 * 2 * 3.14))
Select Case x2
Case 0 To (L1 / Lt): y2 = (N1 * V * (V ^ 2 - g * R * 0.1)) / (R * (1 + Q1 ^ 2 * 0.1 ^ 2) ^ 1.5)
Case (L1 / Lt) To ((L1 + L2) / Lt): y2 = 0
Case ((L1 + L2) / Lt) To (Lt / Lt): y2 = (N2 * V * (V ^ 2 - g * R * 0.1)) / (R * (1 + Q2 ^ 2 * 0.1 ^ 2) ^ 1.5)
Case Else
End Select
PSet (x2, y2), QBColor(1)
Next
Private Sub Command3_Click()      tarı 1
Dim xstart, xfinish, ystart, yfinish, R, V, Lt, L1, L2, L3, g
xstart = Val(Text1):xfinish = Val(Text2):ystart = Val(Text3):yfinish = Val(Text4):R = Val(Text5)
V = Val(Text6):Lt = Val(Text7):L1 = Val(Text8):L2 = Val(Text9):L3 = Val(Text10):gVal(Text11)
Scale (xstart, ystart)-(xfinish, yfinish)
Line (0, ystart)-(0, yfinish), QBColor(12)
Line (xstart, 0)-(xfinish, 0), QBColor(12)
Dim x3, y3, Q3, N3, Q4, N4
For x3 = 0 To 1 Step 0.004
Q3 = ((6 * Lt ^ 5 * x3 ^ 5) / L1 ^ 5) - ((15 * Lt ^ 4 * x3 ^ 4) / L1 ^ 4) + ((10 * Lt ^ 3 * x3 ^ 3) / L1 ^ 3)
N3 = ((30 * Lt ^ 4 * x3 ^ 4) / L1 ^ 5) - ((60 * Lt ^ 3 * x3 ^ 3) / L1 ^ 4) + ((30 * Lt ^ 2 * x3 ^ 2) / L1 ^ 3)
Q4 = (6 * (Lt - Lt * x3) ^ 5 / (L3 ^ 5)) - (15 * (Lt - Lt * x3) ^ 4 / (L3 ^ 4)) + (10 * (Lt - Lt * x3) ^ 2 / (L3 ^ 3))
N4 = (-30 * (Lt - Lt * x3) ^ 4 / (L3 ^ 5)) + (60 * (Lt - Lt * x3) ^ 3 / (L3 ^ 4)) - (30 * (Lt - Lt * x3) ^ 2 / (L3 ^
3))
Select Case x3
Case 0 To (L1 / Lt): y3 = (N3 * V * (V ^ 2 - g * R * 0.1)) / (R * (1 + Q3 ^ 2 * 0.1 ^ 2) ^ 1.5)
Case (L1 / Lt) To ((L1 + L2) / Lt): y3 = 0
Case ((L1 + L2) / Lt) To (Lt / Lt): y3 = (N4 * V * (V ^ 2 - g * R * 0.1)) / (R * (1 + Q4 ^ 2 * 0.1 ^ 2) ^ 1.5)
Case Else
End Select
PSet (x3, y3), QBColor(4)
```

Table 4.1 An example of new curve 1 (Tari 1) and sinüzoidal curve programme codes

REFERENCES

Baykal, O.: Concept of Lateral Change of Acceleration, *ASCE Journal of Surveying Engineering,* Vol.122, No.3, pp. 132-141, (1996)

Baykal, O.: Tarı, E., Çoşkun Z., Şahin, M., A New transition Curve Joining Two Straight Lines *ASCE* Journal of Transportation Engineering (1997),

Can, E., Kuscu, S.: Sürat Yollarında Kullanılan İkinci Nesil Geçiş Eğrilerinin Kullanılabilirliklerinin Değerlendirilmesi, 2. Mühendislik Ölçmeleri Sempozyumu, 23-25 Kasım 2005, İTÜ - İstanbul

Sharpe, R.J.: Thorne, R.W.: Numerical Method For Extracting An Arc Length Parameterization Parametric Curves, Computer Aided Design, Vol.14, No.2, pp 79-81. (1982)

Tarı, E.: The New Generation Curves, *ARI*, Vol.54, No.1, pp 34-41, (2003)

Tarı, E.: Baykal, O.: An Alternative Curve In The Use of High Speed Transportation Systems, *ARI*, Vol.51, N.2, pp.126-135, (1998)

Tarı, E.: Geçki Tasarımında Yeni Eğri Yaklaşımları, *Doktora tezi,* İTÜ Fen Bilimleri Enstitüsü, İstanbul, (1997).

BIOGRAPHICAL NOTES

Eray Can graduated from the Department of Geodesy and Photogrammerty Engineering at Zonguldak Karaelmas University in 1999. He received his Msc degree with the thesis about Highway horizontal geometry in 2005. He is PhD student and currently study on his PhD thesis in this university. His research interests are engineering surveying, highways and railways horizontal geometry. He is research assistant Department of Geodesy and Photogrammetry Engineering at Zonguldak Karaelmas University,Turkey.

Senol Kuscu is a Professor for Engineering Surveying science in the Department of Geodesy and Photogrammetry engineering at Zonguldak Karaelmas University. He received his Phd degree with thesis about Mining Subsidence and mining damage at Yıldız Technical University in 1983. His research interests are engineering surveying, project management and mining subsidence. He is head of the department of geodesy and photogrammetry engineering at Zonguldak Karaelmas University,Turkey.

CONTACTS

Research Assistant Eray Can
Zonguldak Karaelmas University
Engineering Faculty, Department of Geodesy and Photogrammety Engineering
67100 Zonguldak
TURKEY
Tel: +90 372 257 40 10-1468
Fax: +90 372 257 29 96
Email: can.eray@hotmail.com
Website: www.jeodezi.karaelmas.edu.tr/linkler/akademik/can

CONTACTS

Prof. Dr. Senol Kuscu
Zonguldak Karaelmas University
Engineering Faculty, Department of Geodesy and Photogrammety Engineering
67100 Zonguldak
TURKEY
Tel: +90 372 257 40 10-1468
Fax: +90 372 257 29 96
Email: can.eray@hotmail.com
Website: www.jeodezi.karaelmas.edu.tr/linkler/akademik/can