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Diverging Diamond Interchange

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Abstract: *Transport system and roads always plays vital role in the development of a city. With virtue of this, TranSystems has been at the forefront for the development and design of Diverging Diamond Network with an option of several open to traffic and number of others under design consideration. There are various considerations for when to choose a DDI and how to prepare an effective design. Considerations like assessing whether it would be very effective under existing conditions, crossover design strategies, pedestrian accommodations, right turn issues, traffic signal operation. DDI can be a very cost effective solutions in retrofit situations due to ability to work with existing bridge structure. DDI proved to be very effective in a situation where majority of the crossroad traffic is approaching or going to the freeway and also proved to be effective in traffic on cross road. Thus it had proved effective in reducing traffic volumes and enhancing quality of accessibility to a larger extent in the present scenario. The project will henceforth provide an overview of various elements of DDI and its design considerations taken into account.*

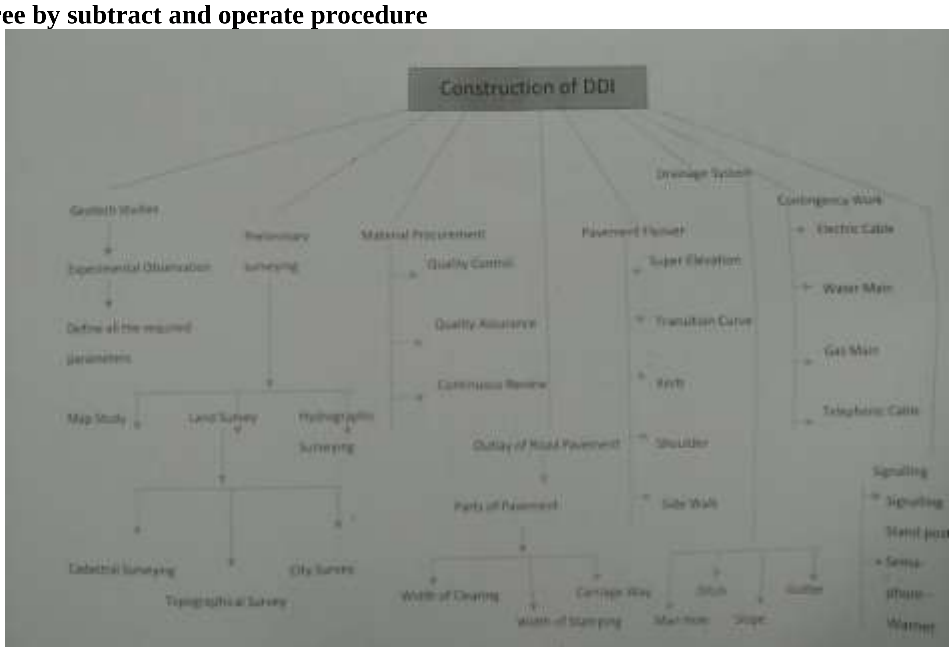
I. Introduction

Design Problem statement
Design of a Diverging Diamond Interchange Network at Chandikhole (Odisha)

Interchange Redesign Concept

Flyover	Ramp	Outer Connection Ramp	Direct Connection Ramp	Speed Change Lane	Loop
A flyover crosses over another road allowing vehicles to cross through it to facilitate traffic movements from one part to other.	An interconnecting roadway of a traffic interchange on which a traffic may enter or leave a designated roadway.	A ramp used by traffic designated for left turn movements from one of the roadways through it separated by a grade through roadway.	A ramp which does not deviate much from the intended direction. It avoids the loop for right turning movement. It is the direct connection ramp for left turning.	Acceleration lane/ Deacceleration lane An acceleration lane enable a vehicle entering a road to increase its speed. A deacceleration lane enable a vehicle leaving though traffic to decrease its speed.	A one way turning roadway that curves about 270 degree to the left to accommodate a right turning movement.

Function decomposition
Function tree by subtract and operate procedure



Product metric model

Model selection by performance specifications

Completely New Network	Modification On The Existing Network
The figure shows the completely new construction of the diamond diverging network system.	The modified fig shows that without being constructing the new network we can modify the network to convert it to a diamond diverging network system
It will not be cost effective because we can create The network by modify it. Unnecessary Preliminary survey will be required.	It will be cost effective and the construction process will be finished much sooner than the figure -1
Huge demolish of building will be required.	Without being demolish of building the network construction can be carried out.
Provide bicyclist lane with three lane of the network	A separate lane is provide for the bicyclist.
Safety is less and more conflicting point which can reduce the traffic safety	Safety is more due to providence of the separate lane for bicyclist and interconnected passage for people.
No provision of the bus stop in that completely new model	Having the bus stop provision for the people.

CONSTRUCTION SPECIFICATION

ACTUAL SYSTEMMETRIC MODEL

6 lane network with median=22m	**16.5cm**
NH 2 side lane with median =15.4m	**11.6cm**
Point 3=kalinagar point to chandikhol chowk=80m	**60cm**
Point 4=paradeep point to chandikhol chowk=80m	**60cm**
Other 2way lane for turnout 7.5m	**6cm**
Height of the bridge = 8m	**10cm**
Point 1 to first diverging portion=30m	**14cm**
Distance between the two turnout=70m	**45cm**
Point 2 to second diverging portion=30m	**14cm**
Point 1 to left turnout =15m	**12cm**
Point 2 to left turnout=20m	**15cm**

II. Design And Layout

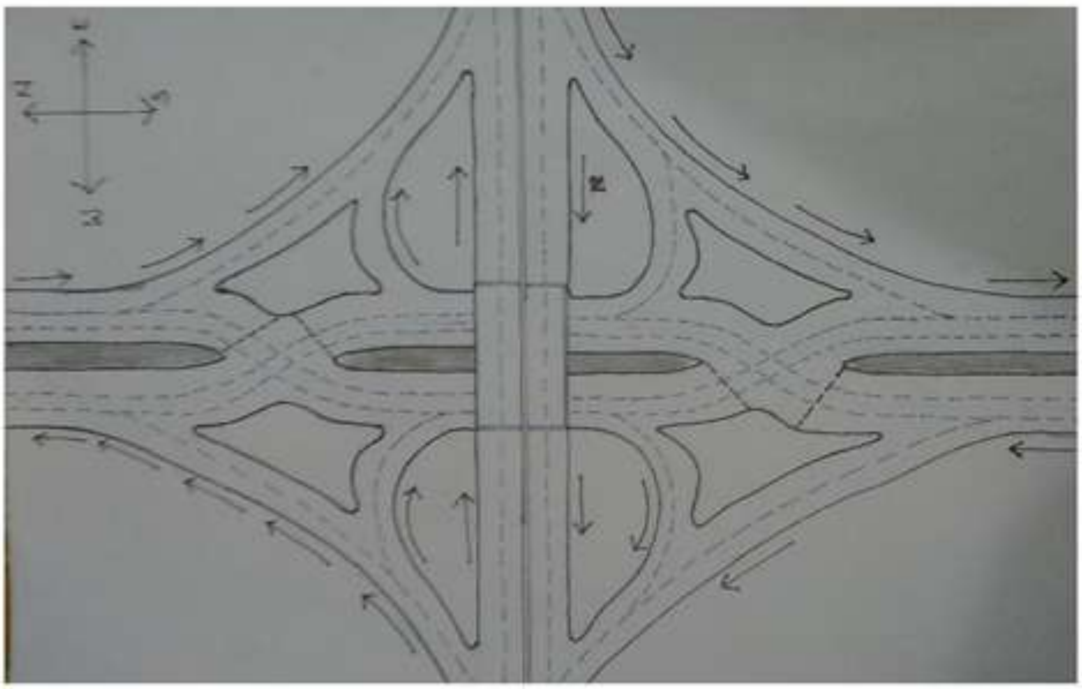


FIGURE -1

Analytical and numerical model solutions

Cross section elements

- Considering the **Design Speed** for the interchange to be 45km/h and minimum to be 30km/h.
- **Topography**- Rolling Terrain
- **Traffic Volume**

Traffic volume in terms of number and PCU values

ZONE 1 Flow Rate of One Hour (9am to 10am)

DIRECTION 1 CHANDIKHOL TO BHUBANESWAR

DIRECTION 2 BHUBANESWAR TO CHANDIKHOL

Vehicle category	**Direction 1**		**Direction 2**		**Total**	
	Number	**PCU**	**Number**	**PCU**	**Number**	**PCU**
Car//Van	125	125	110	110	235	235
Mini Bus	11	33	18	54	29	87
Bus	23	69	28	84	51	153
2 Wheeler	120	60	98	49	218	109
Mini Truck	68	204	50	150	118	354
Truck	65	195	48	144	113	339
3 Wheeler	19	19	23	23	42	42
Cycle	32	6	25	5	57	11
Total vehicles	463		400		863	
Total PCU	711		619		1330	

AVERAGE TRAFFIC FLOWING IN ONE DIRECTION IS=1330/2=665

TV=TOTAL VOLUME =PCU*4=665*4=2660

TDV =TOTAL 24 HOUR TRAFFIC=2660*17.11=45512

TOTAL 7 DAY TRAFFIC OBTAIN=45512*7.012=319130

AVERAGE TOTAL VOLUME=319130/7=45590

TOTAL YEAR VOLUME =AADT=45590*1.395=63598

Traffic volume in terms of number and PCU values
ZONE -2 Flow Rate of One Hour (9am to 10am)
DIRECTION 1=CHANDIKHOL TO BHUBANESWAR
DIRECTION 2=BHUBANESWAR TO CHANDIKHOL

Vehicle category	**Direction 1**		**Direction 2**		**Total**	
	Number	**PCU**	**Number**	**PCU**	**Number**	**PCU**
Car//Van	105	105	130	130	235	235
Mini Bus	12	36	9	27	21	63
Bus	18	54	21	63	39	117
2 Wheeler	82	41	112	56	194	97
Mini Truck	75	225	58	174	133	399
Truck	67	201	42	126	109	327
3 Wheeler	26	26	20	20	46	46
Cycle	35	7	25	5	60	12
Total vehicles	420		**417**		**837**	
Total PCU	695		**601**		**1296**	

Cross slope or camber

Camber provided = 2% i.e. 1 in 50 (Transverse slope is in ratio 1 vertical to 50 horizontal)

- Type of pavement surface- High bituminous surface
- Amount of rainfall- Moderate

Design of camber
As per IRC code Interchange carriageway with kerbs = 7.5 m (2 lanes)
For Bituminous surface,
Rise of crown with respect to the edges = (7.5/2) * (1/50) = 0.075 m
Diagram of Combination of straight and parabolic shape

- Carriage way width= 7.5 m
- Traffic separators of medians = 1.5 m
- Total width of roadway which includes carriageway and other things = 15 m

Sight distance
(a) Stopping Sight Distance
Calculating the safe stopping sight distance for design speed of 45 kmph for two way traffic on a four lane road?
Assuming as per IRC coefficient of friction 0.37 and reaction time of driver 2.5 sec
Stopping distance = lag distance + braking distance
= vt + (v^2/2gf)
V=45 kmph or v=12.5 mps
t=2.5 sec, g= 9.8m/s^2, f=0.37
Stopping distance = 12.5*2.5 + ((12.5^2)/2*9.8*0.37)
= 52.79 m

- Stopping distance when there are two lanes= stopping distance= 52.79 m
- Stopping distance for two way traffic when there are four lanes= stopping distance= 2*52.79= 105.58 m

When the ground is not level, then the gradient or slope is to be taken into consideration.
Assuming the gradient to be 4 percent (As per IRC specification in interchange)
(i) For descending gradient of 4%
V= 45 kmph; n= -4%= - 0.04
Stopping Distance= 0.278vt + ((v^2)/254(f-0.04)
= 0.278*12.5*2.5 + ((45^2)/254(0.37-0.04)
= 55.42 m
(ii) For ascending gradient of 4%
Stopping Distance= 0.278vt + ((v^2)/254(f+0.04)
= 0.278*12.5*2.5 + ((45^2)/254(0.37+0.04)
= 50.71 m

(b) Overtaking Sight Distance
Design speed= 45kmph
V = 45/3.6 = 12.5 m/s
Considering the speed of overtaken vehicle V_b= (12.5-4.5) = 8mps
From IRC code,
A= 4.2 kmph/sec
t= 2.5 sec

$d_1 = 0.28V_b t$
where $d_{1=}$ Distance travelled by overtaking vehicle A during the reaction time t seconds of driver from position A_1 to A_2
=0.28*29*2.5
= 20.3 m
$d_2 = 0.28V_b T + 2s$
where d_2= Distance travelled by the vehicle A from A_2 to A_3 during the actual overtaking operation, in time T sec
T = sqrt. (14.4s/A)
s= minimum spacing between 2 vehicles
s= $(0.2V_b + 6)$
= (0.2*29 + 6)
= 11.8 m
T = sqrt. ((14.4*11.8)/4.2)
= 6.36 sec
d_2= 0.28*29*6.36 + 2*11.8
= 75.24 m
$d_3 = 0.28VT$
where d_3= Distance travelled by on-coming vehicle C from C_1 to C_2 during the overtaking operation of A
= 0.28*45*6.36
= 80.136 m
OSD on one way traffic road= $d_1 + d_2$= 20.3+75.24=95.54 m
OSD on two way traffic road= $d_1 + d_2 + d_3$ =20.3+75.24+80.136 = 175.67 m

(c) Safe Sight distance
From IRC code for design speed 45 km/hr will be 100 m (Approx.)

Horizontal Curves
When a vehicle traverses a horizontal curve, the centrifugal force acts horizontally outwards through the centre of gravity of the vehicle. Centrifugal force P is given by the equation:
$$P = Wv^2/gR$$
Here P = Centrifugal force, kg
W= weight of the vehicle, kg
R= radius of circular curve, m
V= speed of vehicle, m/sec
g= acceration due to gravity=9.8 m/sec^2
As per IRC specification, minimum radius of horizontal curves for design speed of 45 kmph may be taken as 90 m and absolute minimum radius for design speed of 30 kmph may be 60 m. It can be calculated from $R_{ruling} = V^2/(127(e + f))$
Design of Superelevation
Step 1: The superelevation for 75% of design speed is calculated by neglecting the friction
$e = V^2/225R$
$= 45^2/(225*90)$
= 0.10
Step 2: If the calculated value of e i.e. 0.10 is less than 0.07, then the value is accepted. If not, then provide maximum superelevation equal to 0.07.
Step 3: Check the co-efficient of friction
$f = ((V^2/127R)-0.07)$
$= ((45^2/127*90)-0.07)$
= 0.107
As the value is less than 0.15, the design is safe with a superelevation of 0.07.

Raising of outer edges of the pavement with respect to centre line
E= (B*e)/2; where B is the carriageway width
= (7.5*0.07)/2
= 0.26 m

Extra widening at curve
$W_e = (nl^2/2R) + (V/9.5 \text{ sqrt. } R)$

Assuming, n= no. of lanes= 2; Wheel base of the truck, l = 6 m

$W_e = (2*6^2/2*90) + (45/9.5*\text{sqrt. } 90)$

$= 0.90$ m

Total pavement width on curve = 7+0.9= 7.9 m

Horizontal Transition Curve

The IRC recommends the use of the spiral as transition curve in the horizontal alignment as spiral curve satisfies the requirement of ideal transition and its geometry property makes the calculation simple and easy in the field.

Calculation of length of transition curve:

(a) Length of transition curve by rate of change of centrifugal acceleration

$L_s = 0.0215*V^3/C*R$

where L_s is length of transition curve; C is allowable rate of change of centrifugal acceleration, m/sec^3; R is the radius of circular curve

C=80/ (75+V)

= 80/ (75+ 45)

= 0.66

As the value of C is between 0.5 and 0.8, it is accepted for the design.

Radius of horizontal curve= 90 m

$L_s = (0.0215*45^3) / (0.66*90)$

= 33 m

(b)Length of transition curve by the rate of introduction of superelevation

Superelevation e = 0.07

Allowable rate of introduction of superelevation = 1 in 150 (IRC recommended)

Total raise of outer edge of pavement with respect to centre line

E= (e*B)/2

= (0.07*7.9) / 2

= 0.27 m

$L_s = (E*N)/2$

= 0.27*150

= 40.5 m

(c) Minimum value of L_s as per IRC for rolling terrain= $(2.7*V^2)/R$

$= (2.7*45^2)/90$

= 60.75 m

Adopt the highest value of the three a,b,c as the design length of transition curve= 60.75 m

Shift, S= $L_s^2/24R$

$= 61^2/ (24*9)$ = 1.7 m

Set-back distance

(i) For SSD

The minimum clearance or setback distance needed m= CD and half the central angle α'/2= angle AOD

The distance d between the centre line of the pavement and centerline of the inside lane may be taken as one-fourth the width of pavement at curve for two lane pavement= 7.9/4= 1.9 m

α/2=180*S/ (2π(R-d))

=180*52.79/ (2π (90-1.9))

=17.24 deg

Set back distance $m' = R-(R-d) \cos \alpha'/2$

= 5.85 m

Required clearance from the centre line to provide SSD of 52.79m is 6 m.

(ii) For OSD

S= 95.54 m

L_c = 60.75 m

R= 90 m

d= 1.9 m

$\alpha/2=180*L_c/ (2\pi(R-d))$

=180*60.75/ (2π (90-1.9))

= 19.75 deg

Set back distance $m' = R-(R-d) \cos \alpha'/2 + (S-L_c)/2 * \sin \alpha'/2$

= 7.08 + 5.87
= 13 m

Minimum setback distance required from the centre line of the road on the inner side of the pavement to provide an OSD of 95.54 m = 13 m
Design of vertical alignment
As per IRC specification, for Plain or Rolling terrain the ruling gradient should be 3.3% (1 in 30); Limiting gradient should be 5% (1 in 20); Exceptional gradient should be 6.7% (1 in 15) and a minimum gradient of about a slope of 1 in 200 or 0.5% may be needed on inferior surfaces.
Vertical Curves-
Generally simple parabolic curve is used as summit curve instead of circular arc as it is found that it give good riding comfort and also a parabola is very easy for arithmetical manipulation for computing ordinates.
Length of summit curve

(i) For SSD
Assuming L>SSD,

$$L= NS^2/ (\text{sqrt. } 2H + \text{sqrt. } 2h)^2$$

Here L= Length of summit curve, m
S= SSD, m
N= deviation angle
H= Height of eye level of driver above roadway
h= height of subject above pavement
Taking gradients of ramps as ascending 4% gradient and 6% descending gradient
$n_1 = +4/100$; $n_2 = -6/100$
Deviation angle N= 0.04-(-0.06)
= 0.1
$L = N*S^2 / 4.4$
$= 0.1* 52.79^2 / 4.4$
= 63.33 m > 52.79 m   Assumption is OK
Length of summit curve = 63.33 m
(ii) For OSD
Assuming L>OSD,
$L= NS^2/9.6$
$= 0.1*95.54^2 / 9.6$
= 95.08 m
As this value is less than OSD of 95.54 m so now assume L<OSD
L= 2S-(9.6/N)
= 2*95.54-(9.6/0.1)
= 95 m which is less than OSD
Length of summit curve = 95 m
Length of Valley Curves

Considering the same gradient, N= -0.1; V= 45 kmph= 12.5 mps; C= 0.6 m/sec^3
(C is change of centrifugal acceleration as per IRC recommended)
(i) Comfort condition
$L = 2(Nv^3 /C)^{0.5}$
$= 2(0.1*12.5^3 / 0.6)^{0.5}$
= 36 m
(ii) Head light Sight distance condition
If L>SSD
$L= N*S^2 / (1.5 + 0.035*S)$
$= (0.1*52.79^2) / (1.5+0.035*52.79)$
= 83.24 m
Assumption correct. So length of valley curve = 83.24 m
Street Lightening Spacing
Designing a Street Lighting System considering the street width =15m, Mounting height= 7.5m, Lamp size= 6000lumen and Luminaire type II.
Average Lux= 6.0
Ratio= Pavement width/ Mounting height =15/7.5 =2

From IRC specification, coefficient of utilization = 0.44
Assuming a maintenance factor =0.8
Spacing = (Lamp lumen * co-efficient of utilization *maintenance factor) / (Average Lumen *Width of road) = (6000*0.44*0.8) / (6*15 l) =23.2m

Design of surface drainage
Design of surface drainage may be divided into 2 phases –
1. Hydrologic analysis
2. Hydraulic analysis

Hydrologic analysis
Rational formula is widely used to estimate the peak runoff water for highway drainage.
$Q=C*i*A_d$
Where, Q= runoff (m^3/s)
C= runoff coefficient
i= Intensity of rainfall (mm/sec)
A_d= Drainage area
Considering,
A_d =15 hectares
Weighted value of runoff coefficient of various surfaces =0.37
Time of concentration =19.33 min (Refer from graph and table, also hydrology book S.K.Garg)
So from the graph, the value corresponding to 19.33 min duration and 25 years period, the rainfall intensity of chandikhole can be computed as 125 mm/hr
i= 125 / (60*60) =0.0347 mm/sec
Runoff, $Q= C*i*A_d$
=0.371 * 0.0347 *15
=0.193 m^3/sec

Hydraulic analysis
Cross Section
Area of cross section of flow in the drawn is given as A= Q/V
Assuming suitable speed of flow =0.8 m/s (IRC specification)A= 0.193/0.8 =0.241 m^2 Assuming bottom width of drain as 0.5m, slope of 1 vertical to 1.5 horizontal and depth of flow as d, so top width =(0.5 + 3d)m
Area of cross section of flow in drain is given by,
0.241= (0.5 + 0.5 +3d)*d/2
i.e. $1.5d^2 + 0.5d - 0.241 = 0$
On solving, d =0.267 m
Allowing a free board of 0.15 m, depth of the side drain =0.267 +0.15 =0.417 m

A. Slope of drain
The longitudinal slope can be found by using Manning's Formula,
$V = (1/n)*R^{0.67}*S^{0.5}$
V=0.8 m/s
n= 0.162
Wetted perimeter = (sqrt. $(d^2 + 1.5d^2)$) *2 +b =1.462 m

$$R = \frac{Area}{Wetted\ Perimeter} = \frac{0.241}{1.462} = 0.164$$

$V= (1/n)*R^{0.67}*S^{0.5}$
$S^{0.5}= V * n/ R^{0.67}$
$= (0.8 * 0.162) / 0.164^{0.67}$
= 0.0672
S= 0.00452 i.e. 1 in 221
Therefore, provide a longitudinal slope of 1 in 220

III. Conclusions

It was determined that construction of Diverging Diamond Interchange would be most reasonable and beneficial for this location. A DDI is a type of interchange which is designed to increase capacity, decrease congestion and minimize new construction cost. It is different from traditional interchanges that would typically encounter when entering or existing an interstate freeway. They allow for free left turn movements, meaning that left turning vehicles will not cross in front of opposite traffic which results in reduction in travel time, fuel consumption and improved safety. It is also expected that area would draw more corporations due to innovative and attractive infrastructure design and therefore creating more jobs and stimulating more investment in the local community.

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