3-Arms Stack Type Traffic Interchange: Solution to Traffic Congestion: Twin City, Odisha, India

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Abstract:

The traffic congestion in cities like Cuttack and Bhubaneswar has increased the rate of road accidents and fatalities since last two decades, and has posed as an concomitant traffic management fiasco in the cities. Road accidents are increasing exponentially with increase in traffic volume synchronized with population rise. Traffic congestion imposes travel time, economic loses, air pollution and above all air pollution. The future transport structure and conjecturing the demand for future has become the crux of traffic interchange modeling is implemented in the present study. The ground survey was undertaken by using DGPS and total station during peak hours and found to be minimum 3.5 times rise in the PCU within 30 years. Amongst the concurrent interchange models under the site configuration and the constraints are explored. The 3-Arm stack type traffic interchange model has been considered in the present scope of study for the future traffic demand, geotechnical soil exploration and present land use pattern using GIS methodology. MX Road Software has been used for the design of the 3-Arm stack interchange model has been developed along with cost estimate. Under the development of the smart twin city, the traffic interchange model is considered to be best fit for ameliorating the future traffic congestion.

Keywords: Highway, Stack Interchange, Intersection, T-Junction, at grade junction, Traffic Capacity, Passenger Car Unit

1. Introduction:

T-Junction is the critical part of traffic corridor which manages the conflict between the present complex escalated traffic along the critical road section that accommodates the vehicular, pedestrian traffic. For successful and flawless traffic flow, a 3 Arms (T-Junction) in different levels or a3 Arms at-grade intersection can be converted to

Fig 1: The sketch of present status at Badambadi T-Junction
stack type interchange of traffic is one of the most feasible grade-separated structure. It
improvises the past partially grade separated structures or at grade rotary or Trumpet
management of the frequency, numeral and harshness of impending conflicts amongst
vehicles, bicycles and the amblers. The optimum goal is to achieve safety, adequate volume
flow depending upon speed, type and time, available lodgings, terrain, network and
neighbors depending upon terrain and concurrent legs. Above all stress should be levied
upon environmental sustainability, ecosystem and cost effectiveness.

Presently interactions are the signalized, un-signalized and roundabouts, the major
traffic controlling systems. Intersections are also classified as 3-way, to 6-way depending
upon the arms (road segments). 3-Arms Stack Type Traffic Interchange is a junction between
3 arms at different elevations. They are adopted to control the conflicting and merging
traffics in urban cities. Depending upon the traffic volume, topography, intersecting legs, and
speed, road patterns (three or four or multi-legged junctions) are designed to reduce traffic
conflict, confusions and reduce accidents. Designers opt for geometric design of intersections
like common raised crossing, split raised crossing and priority inter sections depending upon
traffic volume, characteristics (like segregated left turning lane), and nature of transporting
means (MUD code of practice part-2 and IRC: 37-2018)\(^1\). The traffic management is being
done as passive (zero or marked signal control), semi (Channel formation or rotaries) or
active (channels or grade separated rotaries). However a good designer should stress upon
adequate sight distances, minimization of weaving spaces, traffic confusions and conflicts,
longitudinal section, left turning movements and transverse gradient designs.

![Fig 2: Study area Badambadi square to Link Road, Cuttack](image-url)
Present Problem Areas:

The twin city of Odisha, Bhubaneswar (present capital) and Cuttack (past capital) is linked by 30km NH -16 (past NH-5) along the east coast of India. The right arm of NH -16 is connected to Cuttack city and left wings to the Bhubaneswar city. A large numbers of T junctions are present that link the cities with NH-16. The busiest 3-T junction is Link road that connects to main bus stand at Badambadi (Fig -1). This urban corridor is having 38.0m right of way and a signing example of grade T-Junction. The existing grade junction is overloaded as the present traffic flow rate hourly passenger car unit (PCU) is 9445Nos and the projected hourly PCU for 30year is 45005No (Fig 2). The figure emphasizes, the load of traffic shall be too high to accommodate in at grade Junction. Traffic at link road (Madhupatana) connect to Badambadi area comprising numerous automobile and bus stops, depots which are yet to be restructured owing to messy polices and defective traffic management with proscribed halts. Due to frequent snarls during busy hours, vehicles are taking about 35 minutes to cover a distance of merely 500m at both Badambadi and Link road junctions.

It has posed a dire necessity of an interchange. A Trumpet / partially grade separated structure /rotary / Turbine/ Pinavia / Cloverleaf /Diamond Shape etc. are the possible options. From first sight it is presumed about non-feasibility of the previous options with the existing topography, terrain between two major rivers the Mahanadi, the Kathajodi. They are at close vicinity to the junction and non-availability of land. Options are tried for the 3-Arms T-Junction to accommodate the growing traffic. From the GIS study it is observed that the land use (LU) pattern is urban comprising of bus terminals, office buildings, market places, rail line crossing and thickly built-up area etc. The existing junction cannot be optimized as at grade. The LU pattern at the junction area are the forcing drags to have option for construction of a stack type interchange. The design should overcome the site challenges of inadequate space availability, Chaotic and illegal parking, existing EC railway track, Kathajodi Bridge and embankments, existing structures (important), rail bridges, transit rail line to Paradeep and non-availability of land in the vicinity.

Solution options:

Considering the ground constraints, a stack type interchange (3rd level flyover) is opted to cater the traffic congestion and smooth traffic trespass. Streamlining the traffic flow from shock wave during peak hour possibly could be managed by constructing a stack type interchange. Only stack type interchange can be constructed within the availability of (RoW)
right of way i.e. acquired road space for carriages way + allied necessities + upcoming extension, along its alignment.

Important factors to be considered shall be to save spaces, improve aesthetic view and smartness to the road system. The construction must expand urbanization which shall generate more employment, sustainability and business etc. At-grade intersections (on freeways) can be eliminated by introducing interchanges. It improves safety enactment and surge traffic volume. Interchanges on roadways can be initiated which is short of full-access regulation to improve similar operations. On successful implementation of the 3-T interchange will meaningfully diminish the travel time and induced costs in contrast to the At-grade intersections. Therefore, an interchange is warranted. This will escalate road – user benefits which can outweigh the service life costs over the interchange.

2. **Review of Literature**

Towards fag end of 20th century, the fatalities due to road accidents in India had increased from 11.14 persons during 1995-99 to 42.41 persons by 2003-04 (Panda et al., 2008)[2]. Present traffic arrangement causing problems in part of Commissionerate police of Cuttack to monitor and finding resolution of the traffic congestion, reduction of travel time, fast and safe journey as the problem is rising complex day by day. Single way circular loop need extra travel path for few passenger but its paybacks for travelling an incorrect ramp, better efficiency and suppleness to identify linked ramps compensate its demerits, (Gajjar et al., 2014[3]). Noise level at link road was highest among all the artery roads of Cuttack and optimum value of noise pollution level (NPL), Traffic noise index (TNI) and Noise climate (NC) were 151.6 dB, 123.5 dB (A) and 25.6 during 03PM to 06PM in 2013,(Swain B. K. et al., 2014[4]).The Cuttack was only one township in the Mahanadi delta but after independence (1950) two major cities and six major townships have developed within the delta (Mishra S. P. et al., 2017[5]).The modern Inside Turning Left Interchange - ITL Inter-change junctions are fitting compromise for the interchange of paths in highway, to best fit the traffic volume by using minimum land area and reducing the cost of construction but applicable to four arm stack interchange only but silent about three arm as in Link road T- junction (JovanovićA., et al., 2020)[6]

3. **Road Statistics of Odisha**

Government Odisha data reveals 1143226 numbers of vehicles are plying on roads in Odisha. Statistical data from Ministry of Road Transport and Highways has been collected for the
decade 2008-2017 for two wheelers, cars/jeeps, Auto- rickshaw, Buses, (trucks lorries), other vehicles (tractor, mini trucks etc.) and other traffic objects were considered).

A study was made on the data received from CEIC and found that the number of accidents is highest by the two wheeler users followed by cars, jeeps and taxies. Traffics are safe by traveling through buses. The trend has shown that the number of accidents is increasing. The numbers of death due to the accidents within the decade 2003 to 2019 is increasing at an exponential rate (Fig -3).

![Accident and fatalities statistics Odisha (2003-2019)](image)

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<td>3885</td>
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Fig 3: The number of accidents and the deaths from road accidents in Odisha (2003-2019); Source: NIC data (updated).

3.1 Cuttack city connectivity Network

Bhubaneswar has been considered as a smart city being coupled with progress and culture of the Cuttack. The infrastructural activities of Bhubaneswar city is stressed upon but Cuttack, a twin city is given less importance. Being the old capital city, Cuttack is connected to east, west, north towns of the state Odisha. A 3arms (T-Junction) is at Badambadi, Cuttack in the state of Odisha, India required a stack type interchanges due to high traffic volume at the Junction. NH-16 (National Highway)(posthumous NH-5) connecting from the Mahanadi bridge to Kathajodi bridge within Cuttack City. Shifting the paradigm from golden triangle to the Golden Quadrilateral in Odisha, the millennium city, Cuttack shall emerge out as novice fourth city. The NH-16 is linking from Chennai (old Madras city) to Kolkata (old Calcutta). Similarly the NH- 55 (posthumous NH-42)is joining the Cuttack city (coastal district)with Sambalpur (western districts). Also the Asian Highway interlink number 45 runs through the twin city. There are many feeder State Highways those are connecting the Cuttack city to Kendrapada, Jagatsinghpur, Paradeep, Talcher, Jajpur, Angul, and nearby many suburban towns in and around Cuttack district. The T-junction at Link road shall serve as the major dispersal road for the above major NH, SH, arterials and urban freeways to
thousands of conveyance and carriage vehicles inclusive the national highway traffics. The mode of communications within the city and nearby places is primarily through town buses, three wheelers, local taxis (Uber or OLA) and DTS city buses. An Inter-state bus terminus (ISBT) is under construction at Balikudato sack the pressure off the bus terminus at Badambadi. At present the Cuttack city is well connected to Bhubaneswar and Dhenkanal due to the creation of two bridges adding to the traffic flow to the city.

4. Methodology:

The existing at grade Junction (3-Arms) at Cuttack link road can accommodate future traffic demand or need a grade separated structure is the present question (IRC:37 :2018, and IRC: SP 87 2019). It is not sufficient to study and estimate the traffic flow, travel demand and projection. The necessity for future requirement and availability of the right of way (RoW) accommodated by the Topographical features, soil strata, parking and traffic characteristics at this location needs attention from the answers like (a) Why the interchange is required? (b) What is the capacity of interchange? (c) Is the existing at grade junction overloaded?

Different methods are proposed for ameliorating the traffic congestion and smooth management of time and cost. But the selection of a suitable interchanges needs ground realities. Methodology applied in the present study is given in the schematic diagram (Fig 4)
Fig 4: The methodology of the research design of the study

4.1 Necessity of interchanges:

Interchange removes the necessity of at-grade intersections on freeways. The interchanges, improve the safety recital by increasing the traffic capacity. Interchanges, on implementation on roads improve traffic operations without full-access mechanism. But interchanges when designed and operated efficiently; can efficiently reduce the travel time and transportation costs in comparison to at-grade intersections. Hence, an interchange is vindicated connecting Badambadi area to Link road. The analysis divulges that the road – user benefits will outweigh the costs over the service life of the interchange. The viable answer to the constraints can be taken as guiding principle in abstracting an interchange is:

a. At all crossings of highway of the major hierarchy to be developed as fully access controlled.
b. The express way standards to be developed at all main crossings on highways.
c. The major crossings of similar capacity at arterial roads and NH to be accommodated.

Failing to the above constraints the at-grade intersection, the interchange cannot cater to the volume of traffic shall be consequential of congestion and frequent stalemate at the intersections i.e. when total traffic of all the arms of intersection exceeds 10,000 PCU per hour. The may lead to upsurge in the accidents rate at an at-grade intersection in spite of other traffic controls or improvement measures. Similarly the topography compels for an interchange as alternative that can be constructed economically (Boneson et al., 2003[9], Abadi et al., 2016)[10].

4.2 Grade Separated Structure:

An overpass (flyover) is a bridging road having similar structure which over-crosses another road. The over pass for the pedestrian overpass permits amblers safe passage over roads with full of activity without disturbing the vehicular traffic. Overpasses consents an unobstructed flow of traffic from involvement with vehicular and ordinary traffic. Stack interchanges are made up of many over passes. In the present case, the stack interchange to be studied whether cost provoking over long term effect.

4.3 Stack Interchange:

A stack interchange is a free-flowing category of interchanges or grade-separated road junctions. It is a uni-directional interchange. The stacks exclude the glitches of weaving and have the capability of highest vehicle tress-pass capacity among different types of 3-way interchanges. These interchanges need highly expensive structures for the ramps in the flyover. The stack interchanges are considered to be dis-popular among those who are living nearby and among natives of the out lookers of the city or those interchanges face extensive local disagreement.
4.4 Channelized T-junction (dividing Island):

A channelized T-junction with dividing islands are applicable for lower traffic volumes. The constraints are more conflicting area, traffic merger within less angles, low speed bypass, more traffic consciousness and require large areas (Fig 5).

![Channelized T-junction diagram](image)

Fig 5: Channelized T-junction (dividing Island) Left turn routes, Typical rotary & trumpet interchange

4.5 Rotary Interchange:

This type of design is particularly useful where a number of roads intersect at the interchange and in locations where sufficient land is available. It requires that construction of two bridges and generally necessitated more land than for a diamond layout. The main highway passes over or under the rotary intersection and turning movements are accommodated by the diagonal ramps (Fig-5).

4.6 Trumpet Interchange:

Show a typical 3-leg interchanges which takes the shape of trumpet. Trumpet is the simplest interchange from adaptable to ‘T’ or ‘Y’ intersections of the two right turning movements; one is negotiated by a loop while the other is by a semi-direct connection. Diagonal ramps are provided for left turning movements. There can be several variations of the design depending on the type of connection provided. The type of connection provided for the right turning movements should be based on traffic volume. The ramps catering for heavy traffic volumes should preferably be provided with direct connections (Fig-5).

The junction at Badambadi is a 3 Arms Junction, more than 10,000PCU, restricted RoW (only 38m). Trumpet, rotary or partially grade separated structures are not feasible on available RoW. Ground trotting of feasibility of construction of grade separated structures was under survey and the land required for each type like rotary and as per norms of IRC-92: 2017 was considered. Since Land acquisition and quantity as per norm was not satisfied (Table 1), Hence a 3-Arms stack type interchange can only alternative to accommodate the inflated traffic volume.
Table 1: The land constraints for construction of partially graded separate structure / Grade separated structure / Rotary.

<table>
<thead>
<tr>
<th>#</th>
<th>Junction Type</th>
<th>Approximate Land Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Partially grade separated structure</td>
<td>30,000 Sq m</td>
</tr>
<tr>
<td>2</td>
<td>At grade rotary</td>
<td>1,80,000 Sq m</td>
</tr>
<tr>
<td>3</td>
<td>Trumpet</td>
<td>44,000 Sq m</td>
</tr>
<tr>
<td>4</td>
<td>3Arms Stack Type</td>
<td>10800 Sq m</td>
</tr>
</tbody>
</table>

Source: As per IRC- 92 2017, Guide lines for Interchange in Urban Areas

The models of interchange like partially grade separated, at grade rotary, trumpet need very large areas of land for the infrastructural constructions within the link road area that restrict the option for the other types of interchanges except the 3arm stack type interchange.

5. 3-Arm Stack Type 3rd level Interchange:

Within the RoW 38.0m the Stack Interchange can be constructed. The ground level is six lane standard to each direction, most significant thing is no conflict point at all on each direction, the second level flyover is stated from link road side 300m away from the junction point and landed at right turn direction (at Dolmundai). The third level fly over is started from link road side 600m away from the Junction and left turn and landed at Khannagar side. Each level vertical clearance minimum 5.5m required. Both 1st level and second level fly over are 2lane standard (7.5m). Each lane is of unidirectional traffic flow and non-conflict point at junction influence area. The capacity of traffic flow will very high. Hence no congestion will interrupt the traffic movement (Jovanic G., 2020[11]).

6. Project Planning and Formulation:

6.1 Collection of Data for Design:

For design of a suitable interchange, the necessities are topographical data, traffic study, soil investigation, ROR and Maps. The methodology used for collection of the in-situ topographic data is collected by using DGPS and Total station instrument. The stretch is highly busy during 6.0AM to 10.0PM, during this time no survey work was possible. Hence topographical survey work is done during night time from 10.0PM to 5.0AM, for safety and security. The local police had extended their hands to complete the survey work in time.

6.2 Traffic Survey:

Turning movement survey conducted at Junction Influence. Automatic traffic count for each direction is not possible, hence 2persons are engaged at each arm of the junction, total 6nos of persons in a shift and 24hour traffic count conducted for three days. The pick hour traffic of each arm derived from traffic count data. Traffic count is conducted on 14th Dec 2019 to 16th Dec 2019. This is the winter season traffic which is lean period at Cuttack city. Though the Indian condition traffic is mixed, here maximum traffic is Bus, Cars and Auto. The monsoon period is the pick season of traffic and traffic adds during the festive seasons.
6.3 Geotechnical Investigation:

For pavement design Sub grade CBR test conducted and for overlay of flexible pavement design FWD test conducted. For design of foundation to the flyover sub soil exploration were done. Since the site is at the apex of the Mahanadi delta, the soil is constructed of old alluvium minimum up to 1500m (As per Kathajodi Bridge Project report) so the design must stand on mat foundation like adjacent other multistoried structures.

![Fig 6: The projected traffic data of the proposed 3-Arm stack type traffic interchange at Link road](image)

6.4 Land Records and MAP:

From Land records it is found the Odisha Public Works Dept. has 38.0m right of way only. The land use pattern is urban and thickly dense high tower buildings along the road side. Hence there is, no chances of land acquisition. Hence within the RoW the junction required is to be developed. All the land adjacent to the present road is private or railway so land acquisition shall be the great hindrances.

6.5 Design 3-T stack type junction:

**Horizontal Alignment Design:** Using Bentley MXROAD Software the surveyed data collected by total station are plotted. The Junction influence portion is the least minimum radius of curvature is found to be of only 20meter if the fly over alignment is at existing center. So for increasing the radius of curvature the alignment of the structure was fixed at the extreme end of the RoW. Hence the radius of curvature increased to 40metre, which is very tough to construct the proposed design of the interchange. The elements of structure need to take special care during structural arrangement of stack interchange.

Bentley MXROAD is popular software used as a modeling tool which enables the designer a prompt and precise design of different types of roads. By using the MXROAD software, one can swiftly design projects with alternatives for a model road structure. The concluding design substitute is carefully chosen. One can automatically have the design detail processes, within less time and cost. The software, MXROAD applies 3D string modeling technology which is a powerful but short technique to create 3D surfaces. The operable database within the software allows designers to generate and interpret 3D- models concurrent AEC platforms.
or in common Windows. Projects can be designed within one environment, store it, and open in another without data loss. This stimulates optimum productivity 3-D designers.

**Design of Vertical Alignment:** The ground level of the road is almost flat, the 2nd level Fly over vertical gradient is kept under 2.5% and vertical clearance is maintained 5.5meter. The span arrangement of the structure at Junction influence is maintaining minimum length to provide minimum girder thickness. Instead of RCC girder, It is more effective of steel girder for keeping girder height. 3rd level fly over similarly designed within 2.5% gradient (Fig 6).

**6.6 Junction Design:**

From the existing traffic data the projection of PCU/ hour after 30years tells that it will be 45005 PCU/hour. Hence a stack interchange can be a better option (Steinmetz et al., 2017).

**Pavement Design:** Using IRC-37 2018 flexible pavement design has been done for 8% sub-grade CBR and minimum traffic 20MSa for six lane road as per IRC SP 87 2019, 30mm BC, 65mm DBM, 250mm WMM & 200mm GSB provided for flexible pavement on approach and DBM & BC provided over the deck slab of structure.

**Foundation Design:** The sub soil exploration data tells us there are no rocks below 40meter from the ground level, hence pile foundation provided for the structures.

**Result and Discussion**

The stack interchange if constructed, the visual drawings the given picture below (Fig 7 (a) & (b) and Fig 8 (a) & (b).

![Fig 7(a): proposed alignment plan](image)

![Fig 7(b): 3-D Elevation of 3-Arms Stack Interchange](image)
Discussion:

The complex interchanges are of competence that comprises many lanes (four or more in each direction) and transports unusual traffic sizes through a network of firmly spread out ramps or connectors https://www.fhwa.dot.gov/publications/research/safety/13047/008.cfm. Under implementation of the present design will solve the long term problem of traffic congestion till Badambadi Bus stand was started. The problem is turning a dungeon for accidents and traffic congestion. The detailed features include in the stack interchange are given below. Under implementation of the present design will solve the long term problem of traffic congestion till Badambadi Bus stand was started. The problem is turning a dungeon for accidents and traffic congestion. The detailed features include in the stack interchange are given below. The proposed 3levels intersection length are level-1 has no fly distance, level-2 has 0.600km and level-3 has 1.200 km distance for fly. The summary of levels and estimate of the proposed project is appended below.

Level 1:

a. Ground level road : (Slip roads)
b. Link Road Side : Slip Road 2 x 10m carriageway
c. Dolmundai – Link Road: Side Slip Road 1x7.0m (Rt. Side), 10.0m (Left)
d. Khannagar – Link Road: Slip Road 1x7.0m (Left Side) 1x10.0m (Right)

Level 2:

a. Road: (Fly over)
b. Link road to Dolmundai: Fly over length 0.600km and 7.5m width
c. Level 3 road: (Fly over)
d. Link road to Khannagar: Fly over length 1.200km and 7.5m width

Probable cost estimates:

The probable estimated cost of expenditure for the project shall be:

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<th>Description</th>
<th>Cost</th>
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<td>II. Fly Over</td>
<td>Rs 1010.5 Million INR</td>
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<td>III. Misc. Expenditure</td>
<td>Rs 100.0 Million INR</td>
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<td>IV. Total cost</td>
<td>Rs 1322.0 Million INR</td>
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Conclusion:

Present proposed architecture of the interchange can house the future demand of increased traffic volume under space constraint and shall provide applicability for smooth transition of vehicles at the junctions to avoid any delay in travel time, confusions, conflicts and accidents. The present study can be an addendum to the proposed plan for the smart city development of the twin city project.

Reference:


