InterchangeandCGSJ:classificationssystemconsiderations,trafficsafety,andoperationsoverview.

ABSTRACT

ThepaperpresentssystemconsiderationsandclassificationcriteriaofinterchangegeometricdesignbasedonthenewIsraeliInterchangedesignguidelines(VOLUMEIIIofgeometricdesignstandardsforrural(interurban)highwaysandurbanfreeways).

Thepapergivesamethodologicaloverviewofinterchangessystematicalwarrantinordertoadjustandessentiallyconstructanappropriateinterchangethatconnectstwointersectinghighways.Thiswarrantreferstothenumberoflegs,partiality,functionalclassification,andaccesscontroltypeofintersectinghighwayszone(inthefinalstageofconstruction)basedonhighwayclassification.Thepaperalsocoverssystemconsiderationsforimplementingacompactgradeseparatedjunction(CGSJ)inamajorhighway,andtrafficoperation,safetyinsights.

Keywords:*interchange,classification,safety,highway,system*

INTRODUCTION

Aninterchangeisasystemofinterconnectinghighwaysincombinationwithoneormoregradeseparationsthatprovidesthemovementsoftrafficflowbetweentwoormorehighwaysondifferentlevels.Crossingconflictsareeliminatedbygradeseparationsandturningconflictsareminimizeddependingoninterchangefunctionalclassificationandconfiguration.Thedriverisrequiredtoselectasuitablespeed,accelerateanddecelerate,andchooseappropriatelanesinordertomakemerginganddivergingmaneuvers.Anotherdefinitionofinterchangerefersto"amaterialobjectwhoseformisdeterminedbythephysicsofmotorizedmovementandeconomicsofconstruction,aswellasthesemioticcodingofdrivingintoabinarychainofswitchingoperationsintendedtoreduceanxietyandequivocation"(Kozlovsky2019).

Thebasicprinciplesofinterchangedesignassistthedrivertopasswithminimumdisturbanceofexitingandenteringtrafficwithoutdifficultythatthethroughhighwayisthecorrectoneforthedriver'sdestination.Ahigh-qualitydesignenablesthedrivertounderstandtheoperationoftheinterchangewithoutbeingmisledorsurprisedbyanydesignfeature.Routecontinuity,provisionofadequatesightdistance,anduniformityofsigningareimportantfeaturesinthismanner.

Themajorobjectivesofinterchangegeometricdesignproceduresare:(1)Aframeworkofareliabledesignthatenablesacomprehensivedesignprocess.(2)Distinctionbetweeninterchangetypes,basedonintersectinghighways'classification.(3)Generatingsystematicconceptsanddesignelement softheinterchangecomponentsinordertoproducetheentireinterchangeschemebasedontheimplementeddesigncriteria.(4)Determinationofaccesscontroltyperelatedtointersectinghighways’zone.

Thispaperpresentsprinciplesofclassifications,systems’considerations,andtrafficoperationandsafetyaspects,whicharebeneficialforinterchangeandcompactgradeseparatedjunction(CGSJ)geometricdesigncomparedtosignalizedintersections.Alsodiscussedarespacingcriteriabetweeninterchanges.Inpractice,choosinganappropriateinterchangeforasiteiscriticalforimprovingtheefficiencyofthetransportationsystem.

LITERATURE REVIEW: interchange safety, complexity, guidancesigns, and operational performance

Transportinterchangesplayakeyroleasurbantransportnetworkfocalpointsandenhancepublictransportoperation(Lopez-Lambas,Monzon2010).Physicalexpensesandpsychologicalacknowledgementarealsoinfluencedbythedesignandoperationofinterchange(TerzisandLast2000).

Guidancesignseffectsoninterchangedesignanddrivingperceptions

AbreuandBazrafshan(2013)foundthatsatisfactionlevelsaresignificantlyinfluencedbytheuseofguidancesigns.Hernandezetal.(2016)implementedacasestudyofMoncloaurbantransportfour-leveldirectionalinterchange(MadridSpain)toadvisethattheinformationprovisionofguidancesignsandthecomponentsofinterchangeinternaldesignhaveadirectimpactonaspectsrelatedtosafetyperformanceandsecurityconditionsprincipallyduringdaytime.

HamaokaandMatsubara(2019)emphasizedtheimportanceofinterchangedesignanditslinkagetopossiblehigherrisksofwrong-waydrivingsuchas“exitatpreviousinterchange”and“overruntheobjectiveinterchange”.Theyemphasizedthesignificanceoffullyseparatedconditionsformerginglane(“inflowlane”)anddiverginglane(“outflowlane”)andtheadequatelocationofsignpostatthe“demergingsection”(priortomerginginfluencearea).

Lietal.(2018)presentedacomprehensiveevaluationandclassificationofinterchangediagrammaticguidesigns'complexityinordertounderstandhowwelldriverscanperceivethem.Theinterchangedegreeofcomplexityaffectstheramificationofdiagrammaticguidesigns.Theyconcludedthatinordertoimprovetrafficsafetyanddriverunderstandingitisbettertosimplifythehighlycomplexsignsbysplittingandrepeatingthesettingsandarrangingauxiliarymarkings.

Additionally,signinglocatedaheadoftheinterchangecouldprovideinformationthatpreparesdriverstodecideonthepropermaneuversinadvance(Doctoretal.2009).Evensignconsistencyalongtheinterchangedhighwaycorridorwhichisperformedbylaneassignmentarrows,diagrammaticalle gend,andletterheightcouldreducetheroaduserworkload.

Complexinterchange:trafficsafety,signingandinterchangeclassificationrelevance

SadiaandPolus(2013)presentedaninterchangecomplexitymodel(ICM)basedondrivingworkloadininterchangesinordertoevaluatecrashpotential.Themorecomplextheinterchangeis,thedriverdependsuponmoreworkloadresources.TheICMresultsrevealedthatcomplexinterchangeswhichreceivedhighICI(InterchangeComplexityIndex)ratingshavemoretrafficcrashes.Thereasonsarehighworkloaddemandofdriversandincreasedrisksofdrivingfaults.InterchangesthatincorporatehighAverageAnnualDailyTraffic(AADT)contributetohighworkloadandincreaseriskbecauseinterchangedesignbecomescomplicatedinordertotransfertrafficvolumes,butisalsoexposedtomoreinteractionsbetweendriverswhichcorroborateshighprobabilityofcrash.

Complexinterchangesusuallydonothaveconventionallayoutpatternslikediamondandcloverleafserviceinterchanges.Suitablerampseparationisessentialforclearandsimpleguidesigning.Clearsigningisrequiredifserviceinterchangeandspecificallyservicerampsareclosetoasysteminterchange.Suchaschemeincreasesinterchangedesigncomplexityanddriversneedtoperceivethecorrectwayoftheirroute(Doctoretal.2009).

Overall,whendesigningcomplexinterchangestakingtheentirecorridorintoconsideration(andnotjustthesingleinterchange)canimprovetrafficsafetyandoperationoftheregionaltransportationsystem,andminimizecontradictedexpectationsofthedrivers.

Singlepointurbaninterchangevs.tightdiamondinterchange

Yueetal.(2019)presentedastudywhichconcentratesonoperationalefficiencyevaluationofdiamondserviceinterchanges:singlepointurbaninterchange(SPUI)vs.tightdiamondinterchange(TDI).TheseinterchangesarecommoninU.S.duetotheiracceptablesafetylevelandoperationalperformance(Jonesetal.2003).AnalyticalmodelsofcapacityanddelaysandsimulationoutputsrevealedthatSPUIwithfrontageroad(SPUI-F)islessefficientthanTDIindelayoperationalperformance,however,TDIissuperiorfortransferringheavyvehicles.QueuelengthadvancementisfasterinSPUI,andresultsinearlierseverecongestion.ThesefindingsstilldonotaborttheadvantageofSPUIspecialgeometrywhichenablesduallefttturnsandspecificallyitsefficiencyofheavyvehiclesleftturnsscenarios.ThefewerconflictpointsofSPUImightimplyinsupplementaltrafficsafetyadvantage.

Selectionofinterchange,gradeseparation,andintersectionbasedonclassificationofintersectinghighways

IRC(2017)recommendsonthefeasibilityofcompleteinterchangesalongruralandurbancorridorsaspresentedinTable1.Theguidelinesdonotspecifywhethertheinterchangeissysteminterchangeorminor(access)interchange,neitherproposeadifferenttransportationsolutionratherthaninterchange.Theroadcategoryofurbanandruralcorridorobtainsidenticalrecommendationineachcell, suchthatonetablecoversbothroadtypology.

Table 1: Guiding principles for assessing the feasibility of complete interchanges along rural and urban corridor (IRC 2017).

RoadTypology	Rural:ODR/ MDR Urban: Collector.	Rural:State Highway Urban:Sub-Arterial.	Rural:National Highway. Urban: Arterial.	Rural: Expressway. Urban: Expressway.
Rural:ODR/MDR. **Urban:Collector.**	Highlynotrecommended	NotRecommended	Generallynotrecommended	Recommendedbasedonsitecondition.
Rural:StateHighway. **Urban:Sub-Arterial.**	NotRecommended	Generallynotrecommended	Recommendedbasedonsitecondition.	GenerallyRecommended
Rural:National Highway. **Urban:Arterial.**	Generallynotrecommended	Recommendedbasedonsitecondition.	Generally Recommended	Recommended
Rural: Expressway. **Urban: Expressway.**	Recommendedbasedonsitecondition.	GenerallyRecommended	Recommended	HighlyRecommended

ODR:OtherDistrictRoad;MDR:MajorDistrictRoad.

Table2presentsamoredelegateguidetotheselectionofinterchange,gradeseparation,andintersectionbasedonroads'classification(TAC2017).InCanadianhighwaydesignguidelinesifinterchangeisrecommendedthereisnospecification,whethertheinterchangeissysteminterchangeorminor(access)interchange.Expresswaysareurbanfreeways. Arterialsintheinterurbansystemaremajorhighwaysorregionalhighways.Theruralandurbancorridorscouldincludetheroadcategories:local,collector,arterial,andfreeway.

Table2:Selectionofinterchange,gradeseparation,andintersectionbasedonroads'classification(basedonTAC2017).

IntersectingRoad	ConsiderationBasedonClassification

	Rural	Urban
Freeway/Freeway	(A)Interchangeinallcases.	(A)Interchangeinallcases.
Freeway/Expressway	Variesbyjurisdiction	(A)Interchangeinallcases.
Freeway/Arterial	(B)Normallyinterchange,but onlygradeseparationwheretrafficvolumeislight.	(C)Normallyinterchange,but onlygradeseparationwhereinterchangespacingistooclose.
IntersectingRoad	**ConsiderationBasedonClassification**	
	Rural	**Urban**
Freeway/Collectororlocal	(D)Normallygradeseparation oralternativelythecollector/localmaybeclosed.	(E)Normallygradeseparation, butaninterchangemaybejustifiedto:(1)relievecongestion,or (2)servehighdensitytrafficgenerators.
Expressway/Expressway	Variesbyjurisdiction	(A)Interchangeinallcases.
Expressway/Arterial	Variesbyjurisdiction	(F)Normallyinterchangeorintersection(refertoCorG).
Expressway/Collectororlocal	Variesbyjurisdiction	(G)Normallygradeseparation,butanintersectionmaybejustifiedto:(1)relievecongestion,or (2)servehighdensitytrafficgenerators.
Arterial/Arterial	(H)Normallyintersection,but aninterchangemaybejustifiedwhere:(1)capacitylimitationcausesseriousdelay,or(2)injuryandfatalityratesarehigh,or(3)onearterialmaybeupgradedtoafreewayinthefuture.	(H)Normallyintersection,but aninterchangemaybejustifiedwhere:(1)capacitylimitationcausesseriousdelay,or(2)injuryandfatalityratesarehigh,or(3)onearterialmaybeupgradedtoafreewayinthefuture.

Arterial/Collectororlocal	(I)Normallyintersectionoralternativelythecollector/local maybeclosed.	(H)Normallyintersection,but aninterchangemaybejustifiedwhere:(1)capacitylimitation causesseriousdelay,or(2)injuryandfatalityratesarehigh,or(3)onearterialmaybeupgradedtoafreewayinthefuture.**OR** (I)Normallyintersectionor
IntersectingRoad	**ConsiderationBasedonClassification**	
	Rural	**Urban**
		alternativelythecollector/localmaybeclosed.
Collectororlocal/Collectoror Local	(J)Normallyintersectionoralternatively,oneroadmaybe closed.	(J)Normallyintersectionoralternatively,oneroadmaybe closed.

AASHTO(2018)presentsseveralinterchangetypesthatareadaptableonfreewaysandthepossible classificationofintersectinghighwaysinruralsuburbanandurbanzones(Figure1).Theinterchangetypeclarifieswhethertherecommendedinterchangeissysteminterchange(ifbothintersectinghighwaysarefreeways)orminor(access)interchangesuchascloverleafordiamondorintegratedbetweenthetwo(iftheminorintersectinghighwayisarterialorcollectororlocal).

INTERCHANGECLASSIFICATIONS

Thereisavarietyofinterchangetypesoptionsforthehighwayengineer.Theclassificationoftheintersectinghighwaysisaprimefactorintheselectionofthemostsuitableinterchange.

Theconventionalcriteriaforinterchangeclassificationare:(1)Numberoflegs;(2)Functionalitylevelinthehighwaysystem;(3)Partialitylevel.

Additionalfactorsforselectingthemostappropriateinterchangeare:systemsconsiderationsanddesignconsistency,adjacentlanduse,designspeed,trafficvolumeandtrafficcomposition,trafficcontroldevices,topography,rightofwayandpropertyrequirements,andenvironmentalconsiderati ons(TACATC2017).Thesefactorsaffecttheconventionalcriteriapresentedasfollows.

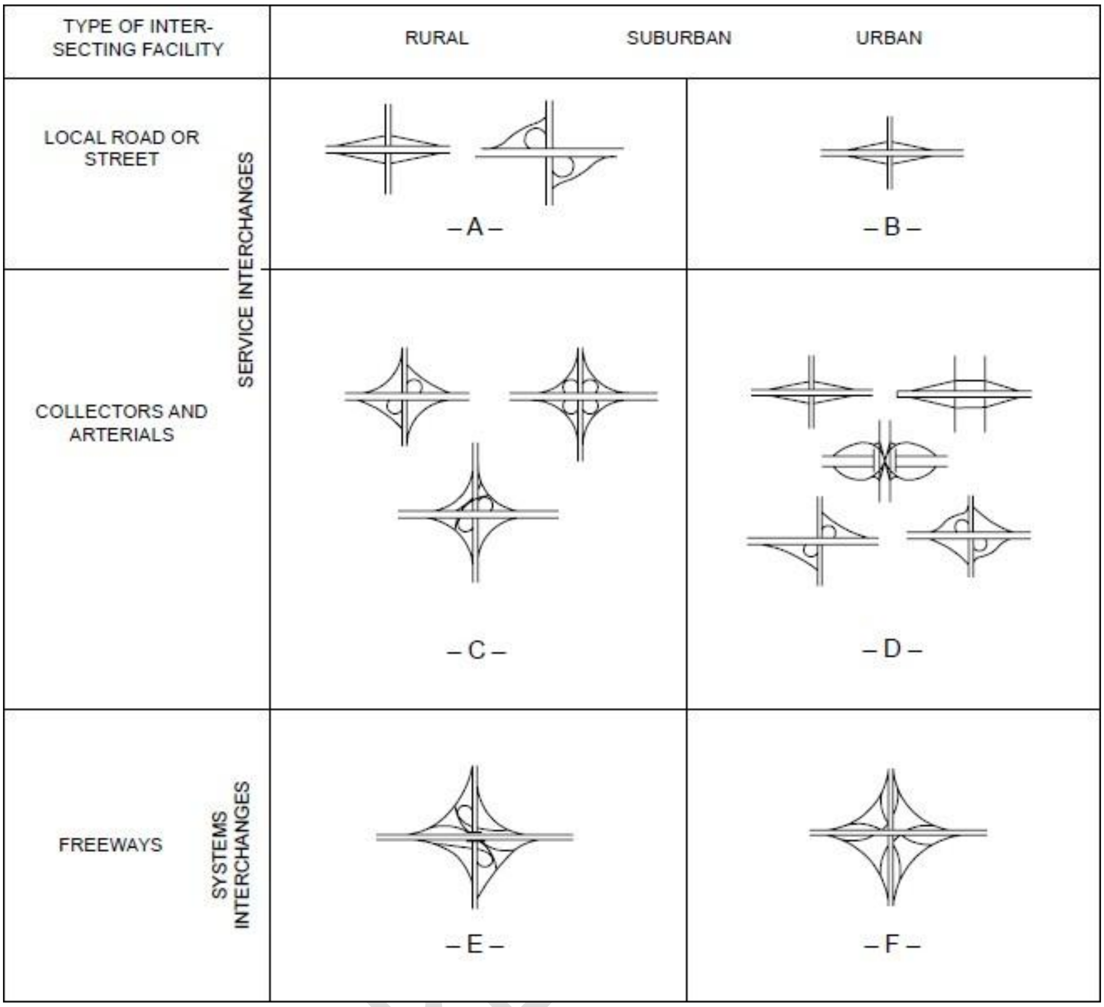

Figure1:Adaptabilityofinterchangesonfreewaysasrelatedtotypesofintersecting facilities (AASHTO 2018).

Numberoflegs

Thebasicconfigurationofaninterchangeisdeterminedbythenumberoflegsintersectingtheinter change:

Interchangeswith3legs:oneoftheintersectinghighwaysendsintheinterchange.Interchangeswit

h4legs:twohighwaysarecontinuousonbothsidesoftheinterchange.

Interchangeswithmorethan4legs(notrecommended):morethantwohighwaysintersectinthei nterchange.Thegeometricalsolutionofthisinterchangetypeisunique,generallybyintegratinga configurationfromprevioustypes(3and4legs).

<u>Partiality</u>

Aninterchangecanbepartialorfull,basedontheavailabletrafficmovements.

Apartialinterchangeenablessomeofthetrafficmovementsbetweentheinterchangelegs,suchthatpairsofspecificmovementsandreversedonesareapplicable.

Afullinterchangeenablestrafficmovementsfromeverylegtoallotherlegs.

<u>Interchangefunctionalclassification</u>

Therearetwotypesofinterchangeswithdifferentfunctionalclassification:

Access(orminororservice)interchange: Interchangethatconnectshighwayswhileatleastoneoftheintersectinghighwaysisnotfullyinterchanged.Theminorhighwayhaspartialaccesscontrolandthereforeincludesacertainlevelofaccessibility.Itenablesnongrade-separatedconnectionsfromtheramps,i.e.rampswithsignalizedintersections.Therampedgefunctionsasalegofanintersection(signalizedorunsignalizedorroundabout).

System(ormajor)interchange: Interchangethatconnectstwofullyinterchangedhighways(fullaccesscontrolhighways)i.e.highwayswithoutintersections.Allrampsinasysteminterchangebeginorendwithrampterminalsandnotwithintersections.Therampsofsysteminterchangedarefullydirectionalorsemi-directionalandthereforedesignedforahighleveloftrafficflowandhigherdesignspeedsthanrampsofaserviceinterchange.

Thedifferencebetweenaccessandsysteminterchangeimpactstheselectedinterchangeconfigurationandramptypes.

<u>Constructionconsiderations</u>

Itappearsthatanintermediatestageofconstructionwouldinquireapartialdesignoftherampswhiletheiredgesconnecttoanintersectionandnottoarampterminalduetobudgetconstraints,rightofway,andzoneconstraints.Suchinterchangecanstillfunctionasasysteminterchangeeventhoughsomerampscharacterizeaserviceinterchange.

ThemajorconfigurationsbasedonthenumberoflegsandfunctionalityarepresentedinTable3.ExamplesaregiveninFigure2,andFigures3a,3b.Eachconfigurationcouldhaveadifferentversionoramixedversionofseveralconfigurations(anintegratedinterchange)basedondesignconsiderations,andotherconstraintsthatthehighwayengineermighttakeintoaccount.

Table3:Majorconfigurationsofinterchangesbasedonthenumberoflegsandfunctionality.

Interchangeclassification	**Threelegsintersection**	**Fourlegintersection**
Systeminterchange	Directinterchange(T,Y(fork)),Trumpet,pear.	Directinterchange(fullyorpartial),windmill,fullcloverleaf(parclo).
Serviceinterchange	Twithintersection,halfdiamond	Diamond,Partialcloverleaf(parclo),twolevelrotary.

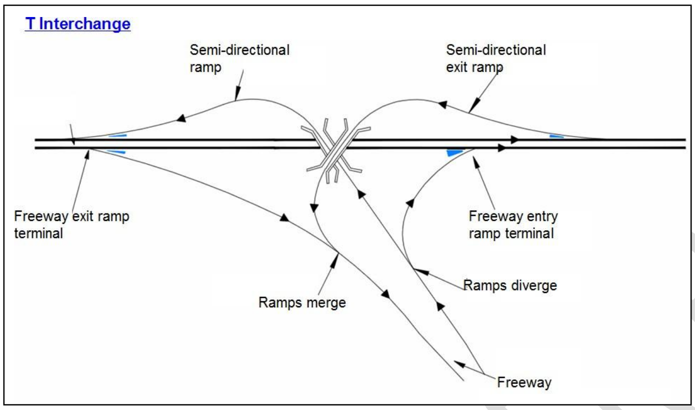

Figure2:Examplesof3-leginterchangecomponents(Tinterchange).

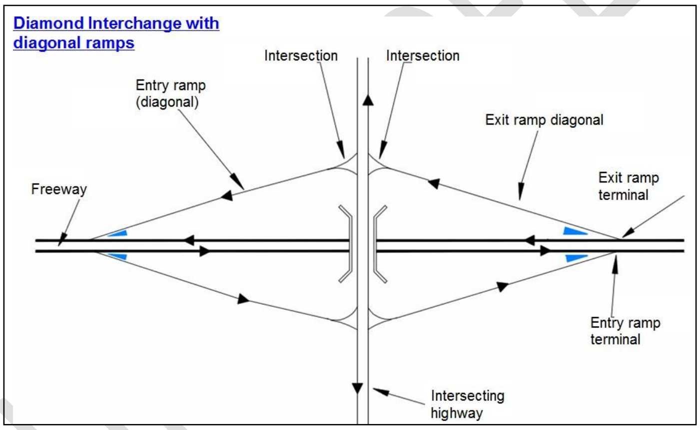

Figure3a:Exampleof4-legserviceinterchangecomponents(diamondwithdiagonalramps).

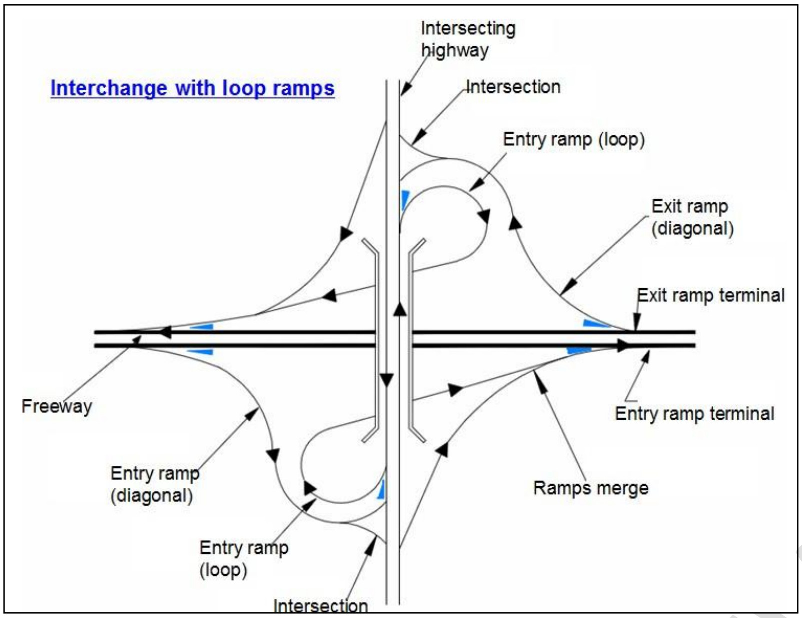

Figure3b:Exampleof4-legserviceinterchangecomponentswithloopramps.

A SYSTEMATICAL WARRANT FOR INTERCHANGECONSTRUCTION:HIGHWAYCLASSIFICATIONANDACCESSCONTROL

Thebasiccriterionwhichdeterminestherequisiteofinterchangeconstructionistheclassification ofintersectinghighwaysincludingtheircorrespondinglevelofaccesscontrol.Thedecisionofimplementingfullaccesscontrol,specifically,constructionofafreewayorfullyinterchangedhighwaysignifiesawarrantforgradeseparationoraninterchange,betweenintersectinghighways.

Table4indicatestheaccesscontroltypeofintersectinghighwayszonebasedonIsraelInterchange designguidelines(Bassan2022),basicallybetweeninterurbanhighwaysorbetweenaninterurbanhighwayandurbanarterial.Thistablerepresentsthefinalstageofconstruction.Themajorconsiderationsforgenerating Table4aremobilityandaccessibilityinthehighwaynetwork.Itsoutcomeis partiallybasedonTable4(TAC2017)andFigure1(AASHTO2018)butreferstohighways'classificationinIsrael(Bassanetal.2015)andprovidesmoreinformationandflexibilitytothehighwayengineerinselectingthehighwaycontroltype.

TheaccesscontroltypeofintersectinghighwayszoneaccordingtoIsraelihighwaydesignguidelinesare:

(1) **System(major)interchange(A).**

(2) **Service(access,minor)interchange(B).**

(3) **Compactgrade-separatedjunction(C):**acompactinterchangewithlimitedzone,lowerdesigncriteria.Itisutilizedforintersectingfullaccesscontrol(fullyinterchanged)highwayandminorroadwithlowhierarchy.Theminorintersectingroadusuallyincludesareducedtrafficvolume:10%ofthetrafficvolumetravelingonthemajorintersectinghighway.

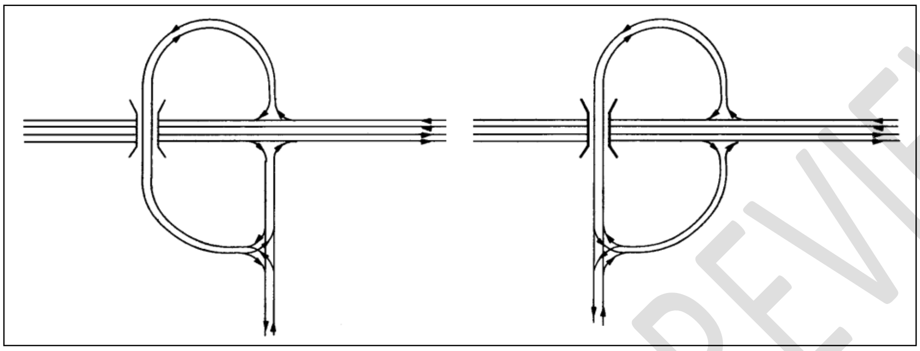

Figure4:Compactgradeseparatedjunction.

(4) **Intersection(D)**

D1:Signalizedintersection.

D2:Unsignalizedchannelizedintersection.

D3:Unsignalizedintersectionwithtrafficsigns..D4:R

oundabout.

(5) **Gradeseparation(E):**Crossingoftwohighwaysonseparatedgradeswithouttheoptionoftrafficpassingbetweenthem.Thegradeseparationcreatesunderpassandoverpasswithoutconnectingramps.Itmaintainssafetyandmobility.

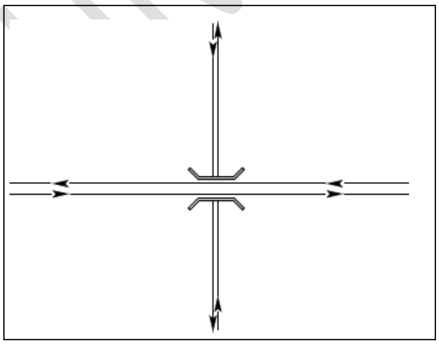

Figure5:Gradeseparation.

(6) **Connectiontoserviceroad(F)**:Theminorroadisdisconnectedfromtheinterchangedhighwaybecauseithaslocalaccesspurposesonly.

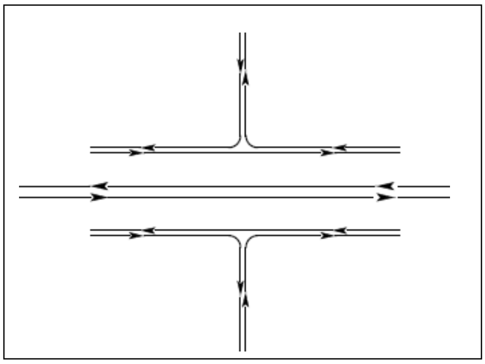

Figure6:Connectiontoserviceroad.

Table4:Recommendedaccesscontroltypeofintersectinghighwayszoneinfinalstagebasedonhighwayclassification.

HighwayCategory[1]	**Freeway**				
Freeway	A	**UrbanFreeway**			
UrbanFreeway	A	A	**MajorHighway**		
MajorHighway[2,3]	AorB	AorB	B	**Minor(Regional)Highway**	
Minor(Regional)Highway	BorE	BorE	BorCorD1orD2withrightturningroadway	B[4]orCorD(D1,D2,D4)	**Localandaccessroad**
Localandaccessroad(low-volumeroads)	EorF	EorF	CorD2withrightturningroadwayorF	CorD(D1,D2,D4)	D(D2,D3,D4)
UrbanArterial	E	BorE	BorD1	BorD(D1,,D4)	D

ClarificationstoTable4:

(1) HighwayclassificationcharacteristicsarepresentedinIsraelCountryReport(Bassanetal.2015)
.

(2) Majorhighwayisalwaysdivided(2-way)initsfinalstageofconstruction.

(3) Designspeedof110km/hour(ortargetspeedof100km/hour)necessitatesfullyinterchangedmajordividedhighway(byAorBorC).Intersectingzonetypeofbothmajorhighwayswouldbeserviceinterchange(B)infinalstageofconstructionandsignalizedintersection(D)inintermediatestageofconstruction.

(4) Assumingbothregionalhighwaysaredivided(two-way)inthefinalstageofconstruction.

SYSTEMCONSIDERATIONSOFCOMPACTGRADESEPARATEDJUNCTION(CGSJ)ONMAJORHIGHWAYS

Major(divided)highwayshaveanimportantroleintheinterurbanhighwaysystem.Thehighway transfersconsiderablyhightrafficvolumesbutenableslimitedaccesstoadjacentland-useandsuburbanareas.

Ingeneral,theaccesstothemajorhighwayisimplementedbysignalizedintersectionsorun-signalizedintersectionsorbysolitaryrightturnsorbycompactgradeseparatedjunctions. Employingmultipleintersectionswithleftturnsalongthemajorhighwaymightinfluencetrafficflowbycausingdelaystothepassinginterurbantrafficandsafetydifficulties.Safetyissuescouldengageside-frontvehiclecrashes,andpedestrianinjurieswhilecrossingtheintersectioninordertoreachabus-stop.Also,adecreaseofairpollutioncanbegainedduetowaitingtimeofnon-electricvehiclesinreducednumberofsignalizedintersectionsalongthehighwaycorridor.

Typicalsolutionsforalleviatingtrafficflowandsafetycouldbeasfollows:

1) Implementingcompactgradeseparatedjunctions(CGSGs).

2) Supplementingserviceroadsbetweenintersectionswhichareconnectedtoresidentialorcommercialareas.

3) IntegrationofCGSJsandservice(frontage)roadsbyprovidingaccesstoland-useandasaresult,connectingserviceroadstoCGSJsandconvertingotheradjacent(full)intersectionstosolitaryrightturnintersections.ThehighwayengineercouldthereforeconsiderimplementingCJSJ(i.e.withgradeseparation)insteadoftheat-gradeexistingnearbyintersectionswhichnecessitateleftturnmovements.

4) Applyingsignalizedintersectionswithrelativelydistantspacings(above2.0kilometers)andconvertingotheradjacentintersections(whicharelocatedbetweenthesignalizedintersections)tosolitaryrightturnintersections.Moreover,access(minor)roads,couldbephysicallyseparatedfromthemajorhighwaybyconnectingthemtoserviceroads.

Figure7presentsaschematicsolutionofimprovingtrafficflowalongthemajor(two-way)dividedhighway.AccordingtothistypicalexampletwocentralintersectionswereconvertedtoCGSJwithaserviceroadwhichisconnectedtotheminorroads.Twoexternalintersectionswereconvertedtoright-turns'intersectionswithpedestrianoverpassorunderpass.Theadditivetravellengthforarrivaltotheaccessroads(leadingtoresidentialorcommercialzone)canbe6kilometers(3kilometersplus3kilometersbackandforthrespectively)orequivalently4.5minutesoftravelingintargetspeedof80km/hour(Bassan2016).Thetrafficdelaysofpassingtheinnerwithdrawnintersectionsshouldbereducedaccordinglyfromtheadditivetraveltime.

OPERATIONALANDSAFETYINSIGHTS

Thecapacityandtrafficoperationlimitationsofsignalizedintersectionareadominantwarranttoconvertittoaninterchangeortoacompactgradeseparatedjunction(CGSJ).WhentheLOSofcertainmovementswithintheintersectionbecomesEofFandmostfocusedtrafficengineeringandsafetyimprovementshavebeenexamined(suchasaddinglanes,separationofrightturns,staggeredintersectionetc.),theimplementationofCGSJorinterchangemightbeconsidered.

Potentialdelays,conflictsofcrossingmovementsandleftturnmaneuvers,andcollisionsinhighvolumeat-gradeintersectionsmightincurcostsintermsofwaitingtime,operatingandmaintenancevehiclecosts(fuel,tires,repairs,vehiclewear)andparticularlytrafficaccidents.TheconversiontoaninterchangeortoCGSJhasacertainconstructioncostbutshouldimpactthecostsduereductionofdelaysandinterruptiontotrafficflow,reductionofacceleration,decelerationandbrakingmaneuvers,andreductionofcollisiondamageandfatalities.Thetraveldistanceisusuallyhigherinaninterchange,however,reductionofdelayscompromisesonthisissue.

Asfarasinterchangeispreferred,theinterchangespacinginfluencestheoperationalandsafetyperformanceofhighwaysystem.Freewaycollisionratesmightalsoincreaseasinterchangespacingdecreases,especiallyinthesuburbanandurbanareas.Sufficientinterchangespacingshouldbedeterminedbythedistancerequiredforweavingmaneuvers,speedchangelanes,(auxiliarylanes),andtheapplicableplacementofdirectionalandmessagesigns.

Adetailedeconomicanalysisenablestodeterminetheoptimalstagesofconstructionofanewinterchange.AninterchangeandalsoCGSJmaybeamorecosteffectivealternativethanasignalizedintersectioninreplacinganon-signalizedintersectionundertypicalruralorsuburbanhighwayconditions.

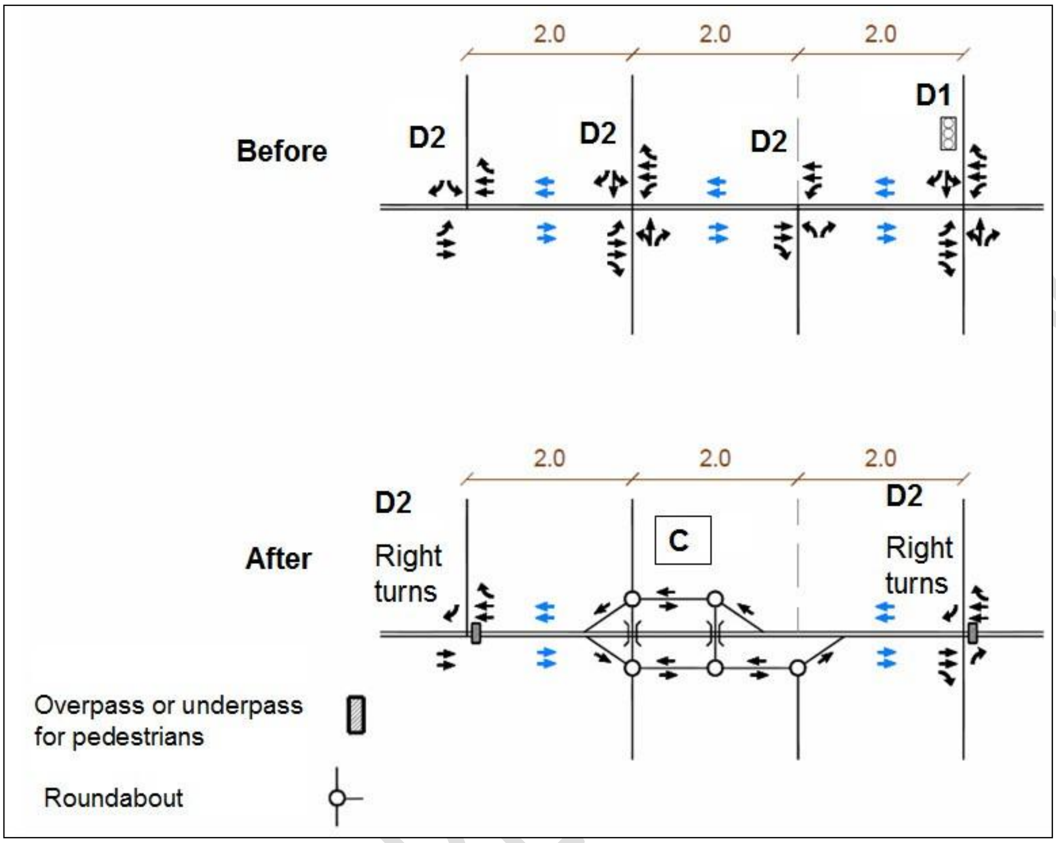

Figure7:Typicalexampleofsystemimprovementsoftrafficflowalongamajor(two-waydivided)highwaywithcompactgradeseparatedjunction.

<u>SUMMARYANDCONCLUSION</u>

Thepaperpresentscriteriaofinterchangeclassificationsuchasnumberoflegs,functionalitylevelinthehighwaysystemandpartialitylevel.Theseprinciplesareutilizedtogenerateasystematicalwarrantforinterchangeconstruction.Thisqualitativewarrantwhichisrelatedtohighwayclassificationandaccesstrafficcontrol,indicateswhichaccesscontroltypes(oftheintersectinghighways'zone)aresuitableforaspecificcategoryoftwocrossinghighwaysintheinterchange.

Theproposedaccesstrafficcontrolsolutionsare:(A)System(major)interchange,(B)Service(access,minor)interchange,(C)Compactgrade-separatedjunction(CGSJ),(D)Intersection,(E)Gradeseparationand(F)Connectiontoserviceroad.

Afteranappropriateaccesscontrolsolutionisdetermined(particularlytheselectionbetweenaninterchange,CGSJ,orsignalizedintersection),thehighwayengineershouldevaluateseveralalternativeconfigurationsolutionsanddecideonthemostfeasibleonebasedonoperation(trafficflow),safety,andeconomicconsiderations.

ThepaperalsodiscussessystemconsiderationsofCGSJonmajorhighways.DissolutionoftheintersectionbyCGSJorinterchangewillalleviatetrafficflowonthemajorhighwaybyrecoveringtheconflictsofcrossingmovementsandleftturnmaneuvers.Onheavilytraffickedruralhighways,particularlyaccompaniedbyland-usedevelopment,collisionratescannotbereducedbyfocusedgeometricorbytrafficcontrolimprovementsoftheintersection.InsuchcasesCGSJ(relativelyinferiorinterchange)mightbepreferredduetolowerconstructioncostthanaconventionalinterchange.

Overall,geometricdesignandtrafficengineeringprinciplesaswellasfreewaysystemconsiderationssuchas:maintainingsingleexitfromeachdirectionoftravel,maintainingexitsandentriesfromtheright,maintainingappropriatesightdistancefordriversapproachingtheinterchange(Bassan2022),keepingbasiclanesandlanebalancecriteria,properdesignof:weavingsections,accelerationanddecelerationlanes'length,ramps'influencezones(merge/diverge),consistencyofinterchangecomponents,andavoidingchanginglanesforcontinuingthethroughroute(i.e.routecontinuity(Leisch1977,Kozlovsky2019))arecrucialfortheoperationalandsafetyperformanceofinterchangesinthehighwaysystem.Alsoroadsafetyaudits(RSAs)duringpreliminaryanddetaileddesignstagesmightimprovethedesignofsimple(minor(service))ormajor(system)interchangesandcomplexinterchangesasanintegralpartoftheinterurbanhighwaysystem.

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