

DDI's Can Move More Than Cars

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In January, 2016, a Diverging Diamond Interchange (DDI) opened at US 36/McCaslin Boulevard serving Louisville and Superior, Colorado. At the Grand Opening, the Mayor of Superior called this the “coolest interchange in the country”. There are now 64 DDI’s open in the U.S., but what sets this one apart is its multi-modal design. By considering all modes during the design process, DDI’s can provide efficient and pleasant traveling experiences to all users.

Superior and Louisville are located between Denver and Boulder (see Figure 1) adjacent to US Highway 36, which is the main thoroughfare between Denver and Boulder. US 36, the Boulder – Denver Turnpike, opened as a four-lane highway in 1951. Superior and Louisville were served by the first exit off the new highway, just east of Boulder. Like many interchanges at the time, it was constructed as a diamond interchange.

By 2003 Superior had grown from a couple hundred residents in the 1950’s to approximately 12,000, with Louisville growing to over 20,000 residents. Traffic volume growth necessitated the addition of a loop to the southwest corner of the interchange. This helped for southbound to eastbound traffic bound for Denver which really benefitted the residents of Louisville. To benefit Superior residents traveling north to Boulder, a loop in the northeast corner was needed. Somewhere along the way to planning the second loop on the north, Louisville said they didn’t have enough room. Loops take a lot of room and this is the problem when communities grow up around traditional diamond intersections - buildings and other development grow up around them and it makes it much harder for the construction of loops.

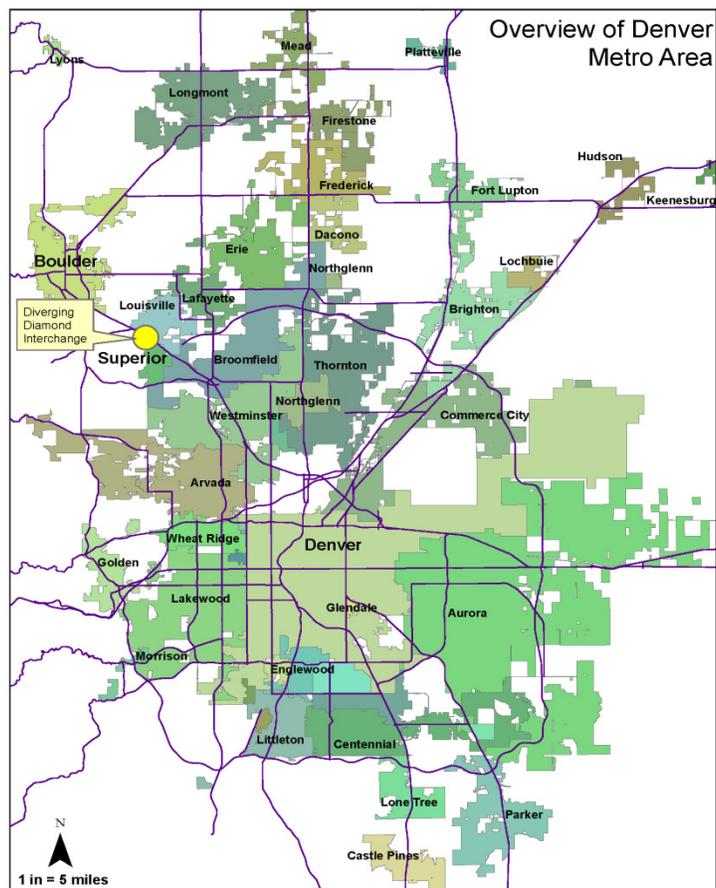


Figure 1: Location Map

In 2011 Superior, Louisville and the Colorado Department of Transportation (CDOT) jointly sponsored a study to examine alternatives for improving the interchange. Initially, addressing traffic concerns was the main focus. 42,000 vehicles per day crossed the bridge and over 50,000 daily

vehicles passed through the interchange. The study found that the infrastructure at the current US 36/McCaslin interchange was failing to serve the existing travel demand, with several movements at the interchange operating at a failing level of service (LOS) F, with excessive congestion and delay. This operational deficiency is further compounded by design deficiencies that impact current traffic movement and safety (Figure 2):

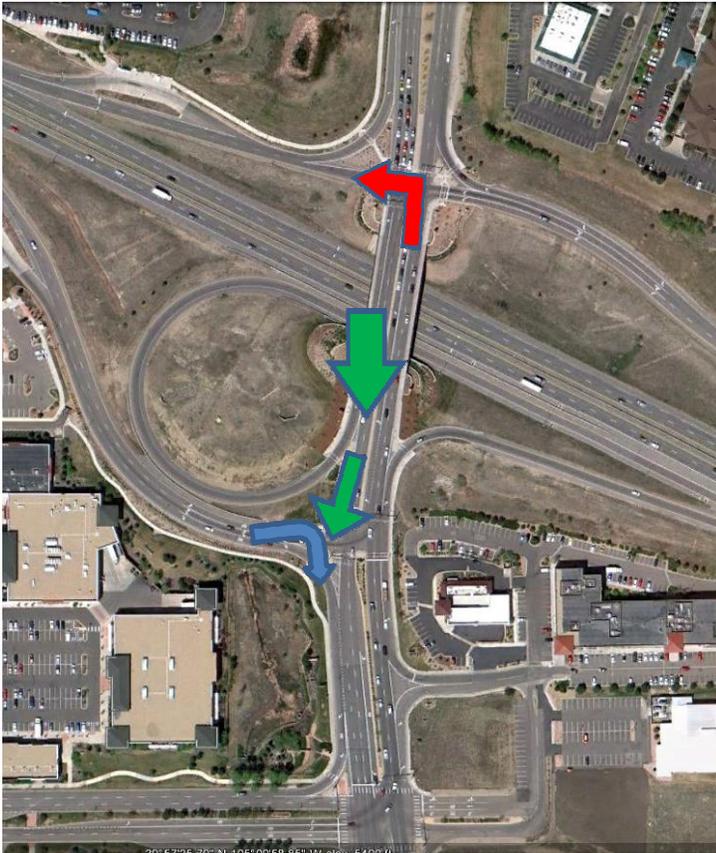


Figure 2: Existing Operational Deficiencies

- The northbound left turn from McCaslin onto US 36 experiences queues in the morning that extend back through both the eastbound ramp intersection and the Marshall Road intersection. On weekday mornings upwards of 600 vehicles per hour make this movement.
- The location of the westbound US 36 on-ramp and the eastbound US 36 loop ramp require all vehicles accessing US 36 from the north to use the right-most southbound lane. This lane imbalance results in queues in the morning that extend back to the Dillon Road intersection, north of the interchange.
- The close spacing between the eastbound off ramp and Marshall Road and the configuration of the free right turn lane between the ramp and Marshall Road creates a weave section that results in queues in the afternoon that extend back through the westbound ramp intersection.

As alternative interchange configurations were being identified, the diverging diamond interchange concept was suggested.

Diverging Diamond Interchange History and Design Features

The first DDI's were constructed in France in the 1970's. In the US, FHWA started promoting the concept around 2004 and several state DOT's began considering the DDI as an alternative on various interchange projects, with the Missouri DOT constructing the first DDI in the US at Springfield in 2009.

Since then construction of DDIs has exploded. Today there are over 60 in the US and at least that many in planning or under construction. The DDI connecting Superior and Louisville is the second in Colorado. The first was in Grand Junction, which is in the western part of the state. US 36/McCaslin is the first DDI in the Denver metro area and there are already three more planned or under construction.

DDIs (also referred to as double crossover diamond interchanges) are commonly implemented to reduce delays, especially for sites with heavy left-turning movements to or from the freeway. At

DDIs, traffic crosses over for both inbound movements to the interchange, allowing drivers to use the opposing side of the road between the two interchange signals and then enter the freeway on-ramps without travelling through a second signal. The DDI design eliminates the need for a left-turn phase dedicated to turning on to the freeway on-ramps. This phase often causes significant queuing between the ramp terminals and spillback into upstream intersections. The signalized crossover intersections operate with just two phases, with each phase dedicated to the alternative opposing movements. The two-phase operation allows for shorter cycle lengths and reduced lost time per cycle compared to three- or four-phase operation at conventional diamond interchanges.

A DDI has only 14 conflict points and two crossing points compared with 26 conflict points for a conventional diamond interchange. The DDI geometry also has traffic calming features that reduce speeds while maintaining capacity which may lead to fewer and less severe crashes than a conventional diamond. Wrong-way movements onto the freeway ramps are also virtually eliminated.

DDIs can be less costly to build than conventional diamond interchanges with the same capacity. Left-turn lanes are eliminated, so bridge structures can be narrower in width. Compared to partial cloverleaf configurations, DDI's are significantly cheaper and require much less right-of-way.

Moving Traffic With The US 36/McCaslin DDI

The US 36/McCaslin Interchange Study evaluated the DDI configuration along with adding an additional left-turn lane or roundabout at the north ramp, constructing a single-point urban interchange or a split diamond configuration. The DDI was found to have better operational performance and a better cost-benefit ratio than the other configurations. A plan view of the DDI is shown in Photo 1.



Photo 1: As-Constructed Aerial View

Moving Bus Riders

A Park-n-Ride is located just west of the US 36/McCaslin, with parking lots located on the north and south sides of US 36 connected with a pedestrian overpass. Prior to the DDI construction, eastbound buses pulled off the off-ramp, stopped to pick-up and un-load passengers and traveled through the traffic signal at the diamond interchange to return to the freeway. In the westbound direction, buses got off US 36, travelled through the signalized intersection at the McCaslin bridge, and picked up/dropped off passengers just off the westbound on-ramp. But ramps “diverge” at a diverging diamond interchange and through movements at the ramp termini are not allowed. To accommodate the large number of busses traveling through the interchange, the project team designed bus lanes that were grade-separated at the eastbound off-ramp and westbound on-ramp (see Photos 2 & 3). These features allow buses to bypass the traffic signals, saving more than a minute on each run. With 10,000 bus riders traveling through these underpasses, riders reap 170 hours per day in travel time savings.



Photo 2: Eastbound Bus Underpass



Photo 3: Westbound Bus Underpass



Photo 4: Bus Stop Locations

The project team also had to deal with the location of bus stops on the DDI bridge since a north-south bus route runs on McCaslin and there are a number of transfers between this route and the US 36 bus routes. Near side (of the crossover intersections) bus stops was the choice due to pedestrian desire lines (Photo 4).

The bus improvements were a part of the larger US 36 Express Lanes project, which has a significant BUS Rapid Transit (BRT) component. This project added an

Express Lane in each direction on US 36 for buses, HOVs and vehicles willing to pay a toll. This 18

mile stretch of US 36 now has a commuter bikeway, six upgraded bus stations, ITS and Active Traffic Management. The BRT improvements include a new fleet of branded buses (the Flatiron Flyer, see Photo 5), simplified schedules and more frequent service. The US 36 Express Lanes connect with Express Lanes on I-25. Bus travel times between Boulder and Denver have been reduced to 30 minutes, faster than auto travel times. With the completion of the project in 2015 and implementation of the BRT improvements, including the US 36/McCaslin DDI bus lanes, bus ridership has increased 45% over pre-project levels.



Photo 5: New Station & Branded Vehicle

Moving Pedestrians

Interchanges are typically not pleasant environments for pedestrians. With high speed ramps to cross and conflicts with left-turning vehicles, pedestrians are often put in harm's way. With the DDI configuration, the project team faced a tough decision: where to accommodate pedestrians – on the outside of the bridge or down the center. After considering the geometry of the crossovers intersections and the potential conflicts of putting walks on the outside of the bridge, the team chose to provide a center walkway (Photo 6). Realizing pedestrians would be in the middle of moving traffic, the team went to great lengths to enhance the pedestrian experience. The 12-ft wide colored concrete walkway was protected by concrete barriers with embedded lighting. As a signature statement for the DDI project, a basket-handle arch was constructed to create a canopy over the walkway (Photo 7). Modern bus shelters were added at each end of the walkway (Photo 8).



Photo 6: Center Walkway with Arch

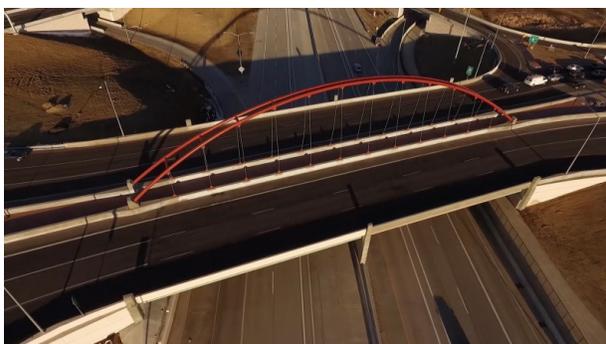


Photo 7: Basket-Handles Arch



Photo 8: Bus Shelter

Moving Bikes

McCaslin Boulevard is a 4-mile long corridor incorporating bike lanes its entire length except for the bridge over US 36. McCaslin also connects to important regional corridors along Marshall Road and the Coal Creek Regional Trail. The bridge was the missing link in an extensive trail network. Since the DDI project needed to widen the McCaslin bridge to accommodate a sixth lane, the project team felt this would be an opportune time to include additional width for bike lanes. The ultimate bridge widening was 26 feet which included 7-ft wide bike lanes

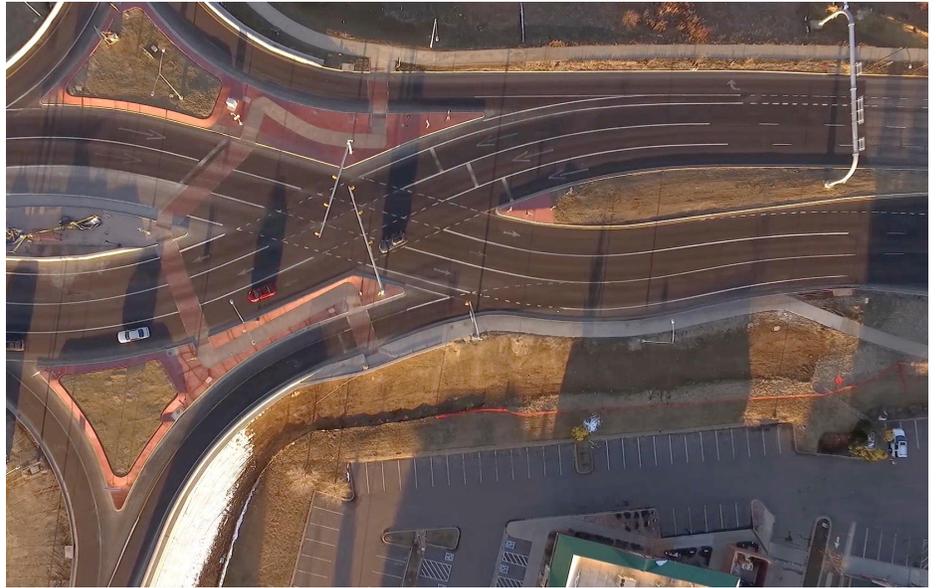


Photo 9: Pedestrian & Bike Facilities

(Photo 9). But few DDIs had bike lanes so again the project team was faced with another decision: outside or center? The team decided to have bikes travel with the flow of traffic, so the bike lanes crossover with the travel lanes ending up adjacent to the center walkway's concrete barriers. Although this results in a longer distance to travel, bikes have no conflicts with left-turning vehicles. In addition, with spacing and timing of the crossover traffic signals, good cyclists can often make it through both signals without stopping. For those cyclists that want a more protected environment, the center walkway is easily accessible.

While north-south travel is accommodated by the bike lanes on the bridge, east-west travel is accommodated by pedestrian/bike underpasses. The US 36 Commuter Bikeway was constructed as part of the US 36 Express Lanes project and is a 12-ft wide concrete trail that runs along US 36 for 16 miles. In the vicinity of McCaslin, it was constructed on the north side of US 36. To avoid conflicts with vehicular traffic at the US 36 ramps and at McCaslin, it uses the bus underpass of the westbound on-ramp, goes under the McCaslin bridge and then travels through an underpass of the westbound off-ramp.

On the south side, the Town of Superior is developing a multi-use trail corridor along US 36 as well. The DDI includes a pedestrian/bike underpass of McCaslin with a trail connecting to the McCaslin BRT Station to the west. A future trail will extend east from this underpass to the Coal Creek Regional Trail.

Does it Work?

The US 36/McCaslin was converted to the DDI configuration in October, 2015. Initial public reaction was bewilderment, confusion and anger since construction was on-going with lane closures a daily occurrence. In early January, 2016 all lanes of traffic were opened and the traffic signal timing optimized. Drivers immediately realized the benefits of a free flowing interchange and quickly adapted to the new traffic configuration. The crossover signals operate on a 100-second cycle for most



Photo 10: US 36/McCaslin DDI with Arch

of the day and are coordinated with adjacent signalized intersections. 80-second cycles operate during evenings. Late night operations include rest on green for the northbound direction at the south crossover and rest on green for the southbound direction at the north crossover. The right-turns off the freeway ramps are signalized, while the left-turns off the freeway are Yield control. Traffic appears to flow much better than the previous configuration, although certain movements (left-turns to and from the ramps) gained much more than others (north and southbound through movements, right-turns from the ramps).

While it is too early to assess safety, there have only been a few crashes since January, 2016, all relatively minor. There is a noticeable decrease in speeds on the bridge which should reduce the severity of any crashes that do occur.

Bicyclists and pedestrians are using the new facilities, but with winter weather it's difficult to tell whether numbers have increased.

The most gratifying result is the 45% increase in bus ridership on the US 36 bus routes. While a lot of other factors contributed to this increase, the DDI bus ramps certainly played a role. One bus driver when asked what he likes best about the new US 36 BRT improvements replied "the McCaslin bus lanes and underpasses".