Real Urban Intersection Design

Expanding on Complete Streets Chicago and the NACTO Urban Street Design Guide

By Michael King, R.A. and Rick Chellman, P.E., LLS

Agencies and cities worldwide are recognizing the need to change urban streets to not only prioritize vulnerable users such as pedestrians, but to resurrect the idea of shared public spaces. Our firm, Nelson\Nygaard Consulting Associates, worked with the City of Chicago, IL, USA and the Emirate of Abu Dhabi on the *Complete Streets Chicago Design Guidelines* and the *Abu Dhabi Urban Street Design Manual*, respectively. Both of these guidebooks place pedestrians as the first priority in the complete streets design process.

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In 2012, Nelson\Nygaard was engaged by the National Association of City Transportation Officials (NACTO) to lead the creation of its new publication, the *Urban Street Design Guide*, with Michael King, R.A. serving as project manager and Chester "Rick" Chellman, P.E., LLS (F) serving as a technical reviewer. As noted in the NACTO guide, growing urban populations will demand that their streets not only serve as corridors for the conveyance of people, goods, and services, but as front yards, parks, playgrounds, and public spaces.

This article synthesizes common themes found in these three publications, specifically the Intersections and Intersection Design Elements section of the NACTO *Urban Street Design Guide*.

Intersection Design Methodology

The intersection of two or more streets can be a point of conflict or meeting—a location to manage movement, or a chance encounter between friends. This dichotomy of use—conflict and meeting—is critical to understanding intersection design. To be successful, an intersection must accommodate and manage both.

Over the years, Nelson\Nygaard has developed an intersection design methodology that we have put to use on some of the most complicated locations in the world. The methodology has four parts: mapping, organization and operation, network, and rules of thumb. In all of our work we try to understand the situation first (problem definition), and then go about solving it. This approach allows one to alter the outcome based on altered inputs.

Every Good Analysis Begins with a Good Base Map

The intersection design methodology begins with a nine-step mapping exercise. The first five steps map generally static items:

- The first step maps the environs: property lines; buildings and their entrances; parking lots and driveways; transit nodes; and any other items inside and outside the rights of way in the context of the area being considered.
- The second maps the pedestrian realm: generally the area between the right of way and curb lines, including stoops, doorways, walkways, and other pedestrian-specific infrastructure.
- The third step maps what we term the interstitial area—items that bridge the gap between walking and driving such as bike lanes, parking lanes, bike parking, bus stops, landscaping, and street furniture.

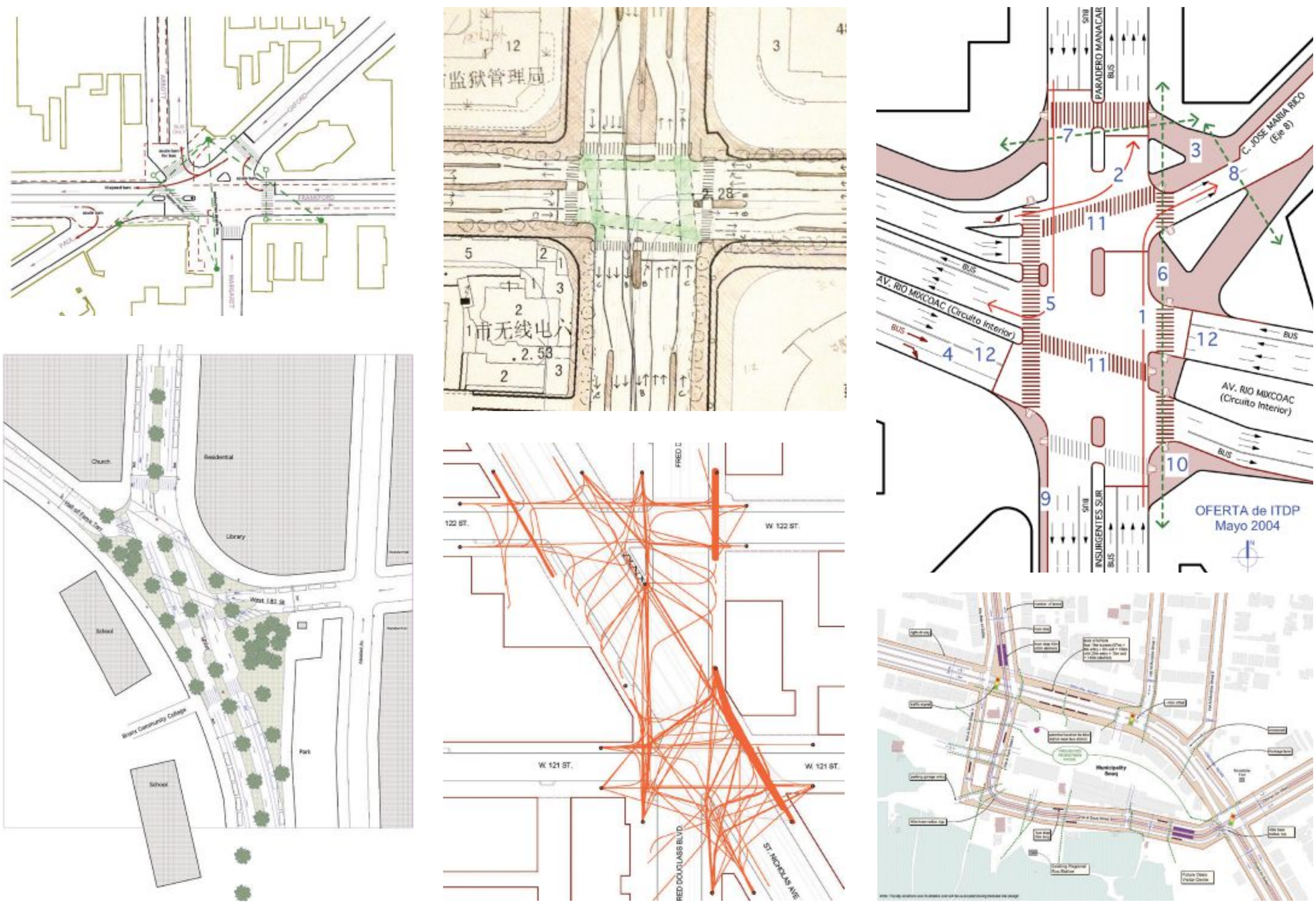

Figure 1. Sketches of various intersections around the world.

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An intersection designed for safe pedestrian crossings in Chicago, IL, USA.

- The fourth step is concerned with the roadway (what most would call the street): center line, median, travel lanes, transit lanes, crosswalks, stop lines, and other items within the curb lines.
- The fifth step maps hardware: catch basins, hydrants, pedestrian ramps, street lamps, traffic signals, tree pits, et al.

The next four steps deal with active items:

- The sixth step maps traffic flow by mode (auto, bike, transit, walk), auto and bike parking, bus stops, and places where people walk.
- The seventh map is a variation of map six, focusing on actual as opposed to prescribed uses. For this we use *tracking surveys* where we observe exactly where people cross the street, where they stop, talk, and window shop. The last we refer to as *staying*, as opposed to the more pejorative *loitering*.
- The eighth step is a further elaboration on map six, this time with volume and speed information.
- The ninth step is used if there are traffic signals whereby the traffic flows are mapped by signal phase.

It is through these last four maps that one can start to understand operations.

Spatial and Temporal Components of Intersections

With a good base map, it is possible to consider how the intersection is organized and operated. One of the first things to look for is extra space. For example, if a corner has a particularly large radius, then there will often be an unused triangle, which could become a traffic island/pedestrian refuge area. Turn lanes work best when mirrored by either a turn lane or median (so drivers must turn). Where on-street parking ends there could be a curb extension, and by the same token, sometimes parking *should* end to provide space for a curb extension. Unfortunately, many intersections worldwide have large expanses of excess asphalt that could be put to better use such as stormwater management, bicycle travel, green space, and other uses.

How the signal phases are organized is always of concern. Generally, one wants to adhere as close as possible to a natural and understandable phasing order, i.e. when one direction of traffic stops, the other one goes. This is especially important for people with limited or no vision who often rely on the sound of engines to judge when to cross the street. It is also better to favor the more vulnerable in signal phasing. Leading pedestrian and bicycle intervals do just this. Leading left turns do not.

Signal phasing brings up an interesting issue about responsibility. Left to their own devices, drivers would approach each intersection with caution and yield in a clockwise fashion, as they do at all-way stop signs and uncontrolled intersections. This is how signalized intersections work during power outages. When one introduces traffic control, one assumes the responsibility of increasing efficiency but not decreasing safety. If the phasing employed is not readily understood by the typical users, then perhaps it is not the safest. An over-abundance of explanatory signs is good evidences that things are too complex.

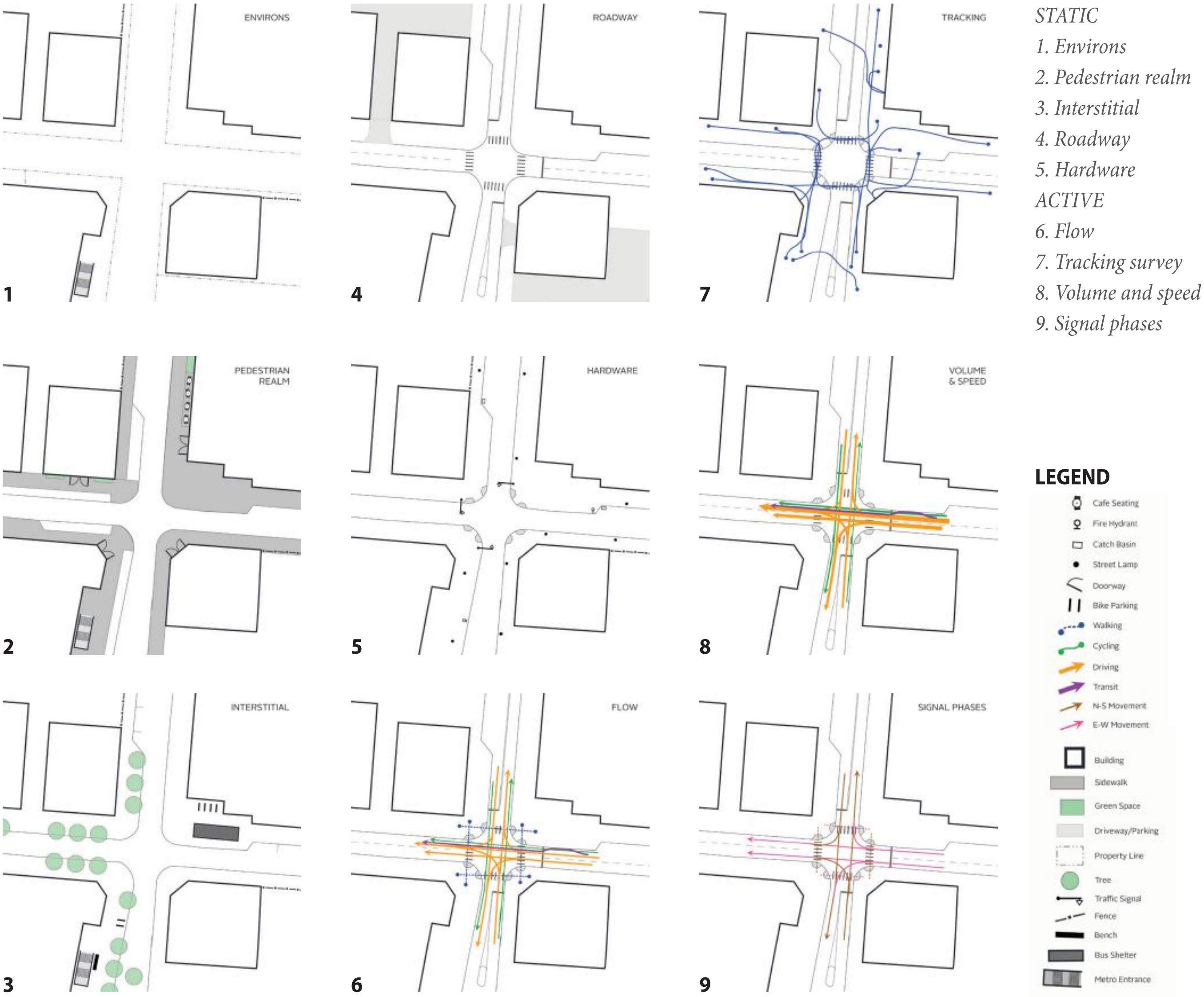

Figure 2. The nine analysis maps for intersection design.[1]

How an intersection is organized and operated impacts prioritization. Traffic signals can be organized to give preference to those walking (the most vulnerable) over those driving (the least vulnerable). Effective turning radii can be minimized and with it turning speeds. Turning speed is a critical component as it has a direct impact on pedestrian safety in crosswalks, yielding behavior, and visibility. Given the overlap between design vehicle and turning speed, one has the responsibility to accommodate users, but not at the expense of others.

Sight Triangles

How sight triangles are considered in intersection design provides a useful introduction into a technical matter. Sight triangles are calculated as the distance that one can see horizontally (peripheral vision) based on the speed they are traveling. The idea is that one should be able to see and react to objects, moving or otherwise along the roadway. This has been used to justify the removal of objects near the roadway that block sight lines.

In urban settings, however, sight triangles are less applicable and many of the best urban intersections have buildings and other features within what, in a rural setting, would be considered a sight triangle. Similarly, curb extensions can be used to move people waiting at the crosswalk to within the sight triangle.

There is a related phenomenon where higher-speed drivers experience a narrower field of vision out of simple necessity to keep their eyes on the road.

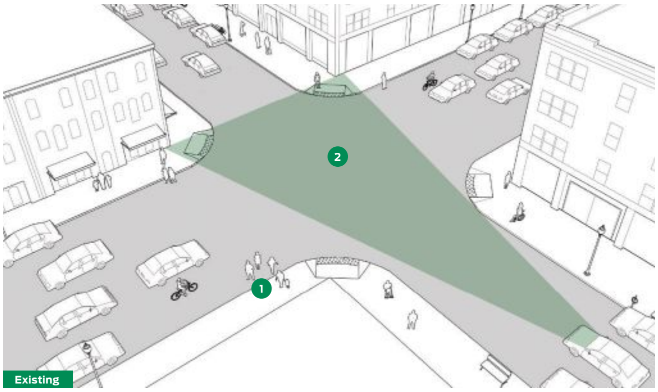

Figure 3. The image above shows the sight triangle of a driver traveling at higher speeds; only the far corner of the intersection is in view. The image below shows a lower speed sight triangle; the entire intersection is in view. In addition curb extensions place more people in view of the driver. [2]

Crashes

Many crashes occur at intersections, with their complex turning movements for vehicles, pedestrians, and others all vying for the same space. The methodologies presented here allow crashes to be a part of the base map information, which in turn allows the designers to consider solutions and mitigations in concert with all of the other aspects of the intersection.

We do not, by this, mean to imply that these solutions and proposals will be easy; often the reverse is true. However, crash history–by itself–should not be a determining factor in intersection design.

Turning Speed

Turning speed is a critical component of intersection design. *Complete Streets Chicago* recommends that turning speeds or passenger vehicles be held to 15 mph or less.[3] This can be accomplished by restricting the *effective* turning radii with smaller corner radii, curb extensions, and medians. It can also be accomplished through the use of smaller design vehicles, such as are typically found in cities (a 23-foot long delivery vehicle (DL-23) is depicted in Figure 6). Such vehicles can be used in place of the larger American Association of State Highway and Transportation Officials (AASHTO) *Green Book* 30-foot long single-unit truck (SU-30) where the larger truck is infrequently seen.

The formula for calculating turning speed is $R = V^2/15(.01\ E + F)$[4]
where:
R is centerline turning radius
V is speed in miles per hour (mph)
E is super-elevation. This is assumed to be zero in urban conditions.
F is side friction factor[5]

(mph)	E	F	R (ft.)
10	0	0.38	18[1]
15	0	0.32	47
20	0	0.27	99

Figure 4. Relationship between radius and turning speed, as calculated with the formula above.

Intersections Do Not Exist in a Vacuum

Because physical space in a city is not unlimited, there will usually be competing needs for the use of space. One particular example is street space, where sidewalks, plantings, parked and moving vehicles, utilities, and more all must be placed within the same corridor. These factors only increase in scope of consideration within intersections.

In order to ensure the continuing good, and hopefully improving, function of a city, decisions involving urban street design and change must also be fully informed by the existing and future needs, desires, goals, and plans that all city and other agencies may have for a particular area or feature. This is, of course, not the case for rural cross roads.

When analyzing a particular intersection, it is usually prudent to consider the surrounding intersections. For example, if one intersection has an excessive number of turning movements, the

Paul Lippens

Pedestrians crossing an intersection in Chicago, IL, USA.

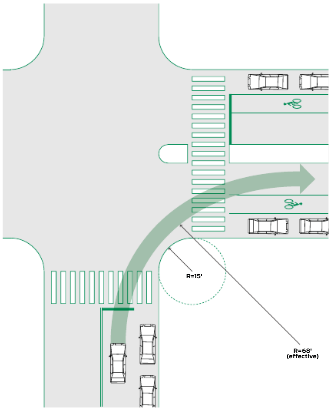

Figure 5. The corner radius and effective turning radii (green arrow – actual space available to make a turn) are often different, especially when on-street parking is present.[6]

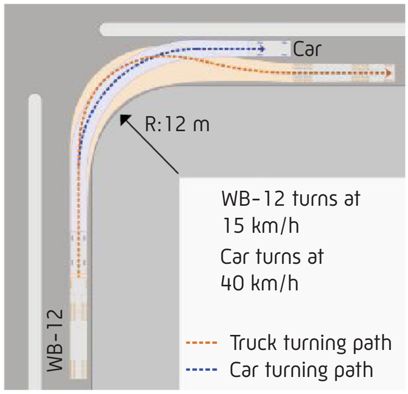

Figure 6. Corners designed for trucks allow higher car speeds.[7]

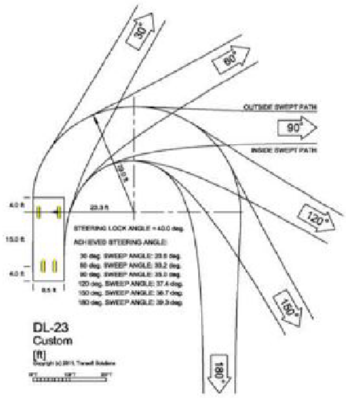

Figure 7. DL-23 Design Vehicle[8]

network, especially the nearby network, needs to be considered. It might be preferable to minimize turns at one location in order to balance out the system.

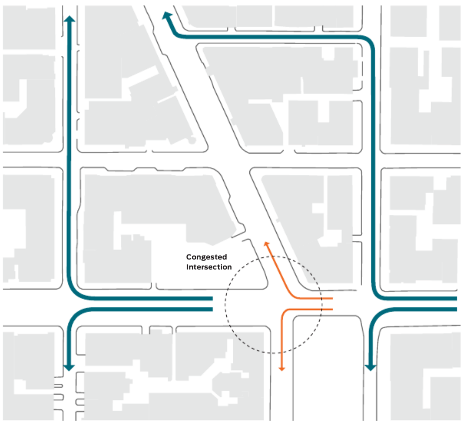

Figure 8. Intersections are best managed as part of a network. In this example, the congested intersection sits atop a Metro station, thus the imperative to re-route auto traffic.[9]

Rules of Thumb

Below is a list of general urban intersection design rules of thumb.[10] We have found that design is best guided by two things: direction (policies, priorities) and training (workshops, best practices, pilot projects). This list is part of the former. They are not meant to be directives, but rather points of inquiry.

- Design the intersection to be self-evident to all users
- Make the intersection as small as possible
- Align lanes so that the number of approach and departure lanes are equal
- Square off skewed intersections
- Manage driver speed, especially turning speed
- Limit opportunities for drivers to make sudden movements
- Minimize crossing distances
- Locate crossings along desire lines
- Locate crossings and waiting areas within sight triangles
- Organize bus stops to minimize transfer distances
- Merge cyclists with slow speeds and low volumes, separate cyclists from fast speeds and high volumes
- Prioritize cyclists over turning drivers
- Ensure sufficient queue space for cyclists
- Utilize predictable/natural signal phasing
- Minimize delay for all modes
- Prioritize signals for pedestrians, cyclists, and transit
- Ensure that signal timing works for both commuters and slower walkers
- Convert non-driving or cycling space to sidewalk or island
- Landscape or use sustainable materials for all spaces not used for walking, cycling, or driving

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An intersection in Abu Dhabi is a shared space for the community to hold Friday prayers.

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Pedestrians crossing an intersection in Abu Dhabi.

Conclusion

As evidenced by the *Abu Dhabi Urban Street Design Manual*, *Complete Streets Chicago,* NACTO's *Urban Street Design Guide*, and other guides, the transportation industry is pivoting to a new understanding of urban intersection design, and by extension urban street design in general. Using the techniques described in this article will help agencies and jurisdictions craft intersections to be as efficient, safe, and user-friendly as possible.

The principles and protocols described in this article have roots in the ground-breaking work of Jan Gehl and William "Holly" Whyte, who trained their designer eyes on how space is used, not how it is supposed to be used. This distinction is important, for people are sentient beings who react to and modify their behavior based on externalities. Intersections, seen through this lens, design themselves. One of the most important tasks of a designer is to observe. Through observation we discover self-organizing systems upon which designs can be structured. **itej**

References

1. Original artwork created by Lauren Cardoni.
2. National Association of City Transportation Officials. *Urban Street Design Guide*. New York, NY, USA: NACTO, 2013. p. 122-123.
3. Chicago Department of Transportation. *Complete Streets Chicago: Design Guidelines*. Chicago, IL, USA: CDOT, 2013. p. 101.
4. American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets*, 6th Edition (*AASHTO Green Book* 2011). Washington, DC, USA: AASHTO, 2011.
5. Based on values "assumed for low speed design" from *AASHTO Green Book* 2011, Figure 3-6.
6. The minimum centerline turn for a Passenger Car (P) is 21 feet, as per AASHTO Green Book 2011, Table 2-2b and Figure 2-1.
7. National Association of City Transportation Officials. *Urban Street Design Guide*. New York, NY, USA: NACTO, 2013. p. 118.
8. Abu Dhabi Urban Planning Council. *Abu Dhabi Urban Streets Design Manual*, Version 1.1. Abu Dhabi, United Arab Emirates: Abu Dhabi Urban Planning Council, 2012, p.6-3.
9. Chicago Department of Transportation. *Complete Streets Chicago: Design Guidelines*. Chicago, IL, USA: CDOT, 2013. p. 115.
10. National Association of City Transportation Officials. *Urban Street Design Guide*. New York, NY, USA: NACTO, 2013. p. 150.
11. Chicago Department of Transportation. *Complete Streets Chicago: Design Guidelines.* Chicago, IL, USA: CDOT, 2013. p. 100.

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