CITY OF Grand Junction
COLORADO

PUBLIC WORKS
& UTILITIES

December 16, 2005

Walker Parking Consultants
Donald R. Monahan, P.E.
5350 S. Roslyn Street, Suite 220
Greenwood Village, CO 80111

Re: Design Exception #DE33-05 - Rood Avenue Parking Structure Parking Dimensions

Dear Mr. Monahan,

Please find attached the committee's decision for the above referenced request. This design exception has been approved, as requested. You may use this decision to proceed through the development review process for this exception.

If you have any questions concerning this decision, please feel free to contact the Development Engineer in charge of your project or Tim Moore, Public Works Manager at (970) 244-1557.

Sincerely,

Sandi Nimon

Sandi Nimon
Sr. Administrative Assistant

Xc: Mike Curtis, P.E.
Roy Blythe, Blythe Design

DESIGN EXCEPTION #DE 33-05

To: Mark Relph, Director of Public Works & Utilities
Bob Blanchard, Director of Community Development
Rick Beaty, Fire Chief

From: Tim Moore, Public Works Manager

Copy to: Mike Curtis, Project Engineer

Date: December 12, 2005

RE: Rood Ave. Parking Structure – Parking Dimensions

DESCRIPTION OF THE SITUATION

Blythe Design and Walker Parking Consultants have reviewed the dimensional requirements in TEDS Chapter 4 and found that they are overly generous compared to other national standards including the Institute of Transportation Engineers, the Parking Consultants Council of the National Parking Association and the Urban Land Institute. As a result, the design team is requesting a TEDS exception to Chapter 4 in the Manual.

Site Description:

The City of Grand Junction and the Downtown Development Authority plan to build a parking structure on the south side of Rood Ave. between fourth and fifth Streets. The parking structure will occupy the middle section (300' long) while the ends of the block will be left vacant for other development purposes.

EXCEPTION CONSIDERATIONS

1. **Will the exception compromise safety?**
   Staff does not believe the proposed exception will impact the safety of the parking structure users. This exception will meet National Parking Standards as referenced in Walker Parking Consultants letter dated November 15, 2005.

2. **Have other alternatives been considered that would meet the standard?**
   The parking design layout would be limited to 60-degree angle parking.

3. **Has the proposed design been used in other areas?**
   The City/County Parking Garage and St. Mary's Hospital parking modules dimensions don't meet TEDS Chapter 4. Field measurements of both modules were taken and are attached. The Rood Ave Parking Structure proposes parking module dimensions are more generous that either of the two existing parking structures.

The Rood Ave Parking Structure proposes parking module dimensions are more generous that either of the two existing parking structures.

4. **Will the exception require CDOT or FHWA coordination?**
No

5. **Is this a one-time exception or a manual revision?**
This issue should be considered by the GVRTC group for modifications to the manual.

Staff Recommendation
Staff recommends approval of this exception as requested.

Recommended by: ____________________

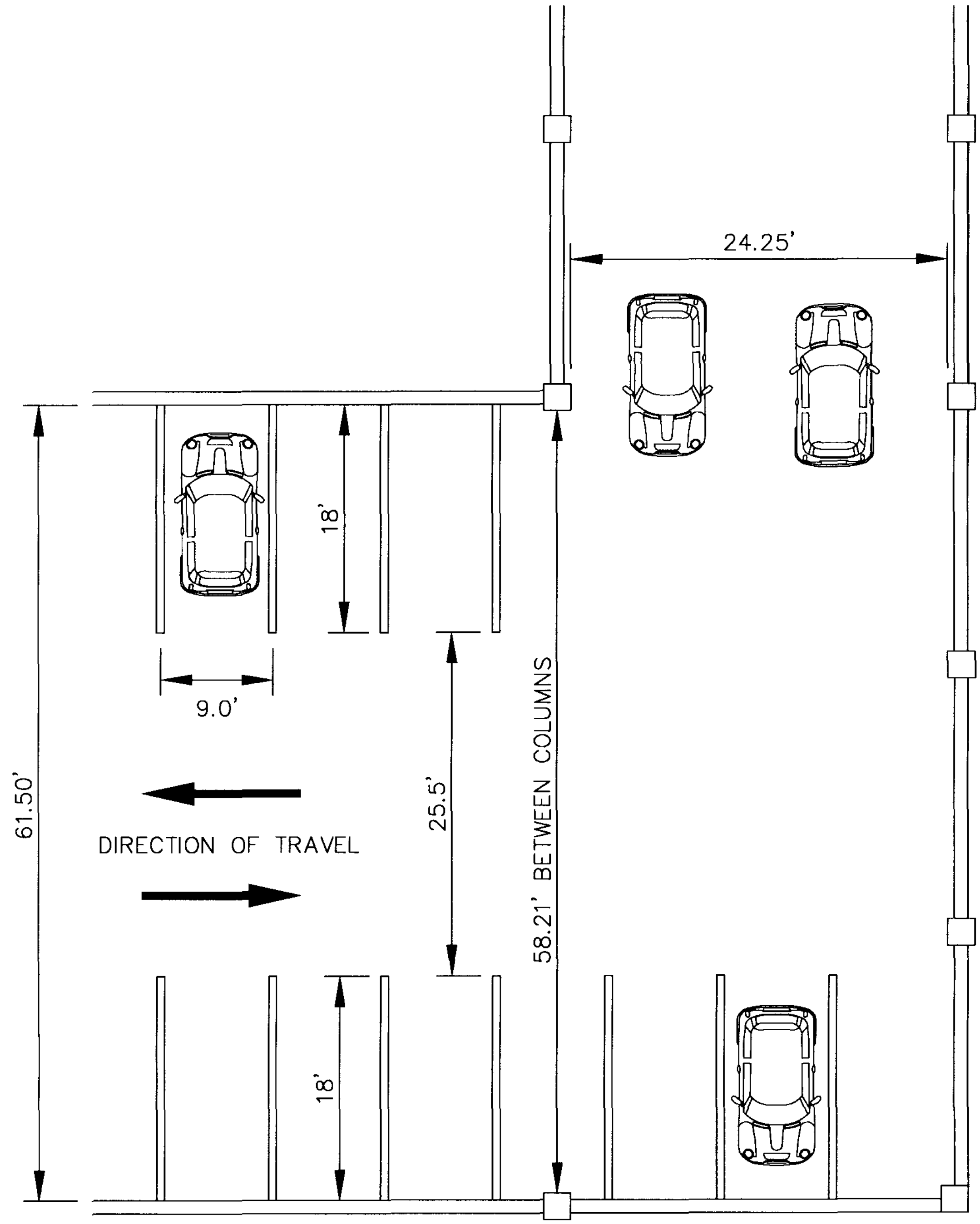
Approved as Requested: ✓

Approved as Modified: ____

Denied ______

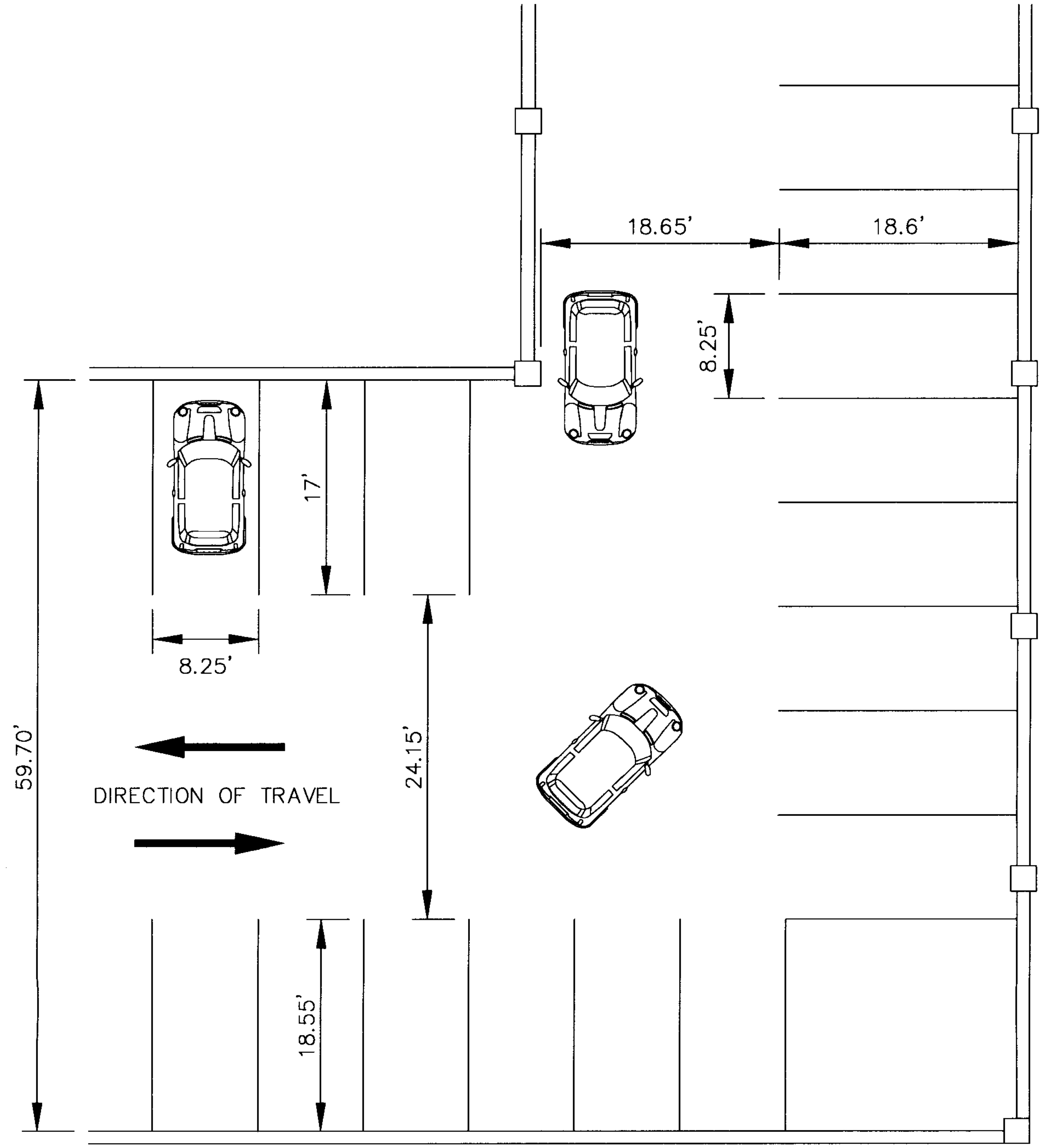
Dated: 12/14/05

\DE#33-05 Rood Ave. Parking Structure Parking Module Dimensions



ST. MARY'S PARKING STRUCTURE

DEPARTMENT OF PUBLIC WORKS AND UTILITIES ENGINEERING AND TECHNICAL SERVICES DIVISIONS CITY OF GRAND JUNCTION, COLORADO	LAYOUT DIMENSIONS	APPROVED: MC DATE: NOV. 2005 DRAWN: CM	PAGE 1



CITY / COUNTY PARKING STRUCTURE

DEPARTMENT OF PUBLIC WORKS AND UTILITIES ENGINEERING AND TECHNICAL SERVICES DIVISIONS CITY OF GRAND JUNCTION, COLORADO	LAYOUT DIMENSIONS	APPROVED: MC DATE: NOV. 2005 DRAWN: CM	PAGE 1

CITY OF
Grand Junction
COLORADO

PUBLIC WORKS
& UTILITIES

PROPOSED EXCEPTION TO TEDS

To: Tim Moore, Public Works Manager

From: Mike Curtis, Project Engineer

Copy to: Mike McDill, City Engineer

Date: December 6, 2005

RE: Parking Module Dimensions for Proposed Rood Avenue Parking Structure

PROPOSED EXCEPTION

On April 20, 2005 the City Council authorized the City Manager to sign a Memorandum of Agreement between the City of Grand Junction and the Downtown Development Authority to build a parking structure. The parking structure is to be built on the south side of Rood Avenue between Four and Fifth Streets. The parking structure will occupy the middle section (300 feet long) while the "ends" of the block (50 feet) at both Fourth and Fifth Streets will be left vacant for other development purposes.

Blythe Design + co. is designing the parking structure with Walker Parking Consultants and The Lawrence Group. Walker Parking Consultants has reviewed the parking dimensional requirements contained in Chapter 4 of the City of Grand Junction's Transportation Engineering Design Standards (TEDS) and found that they are overly generous compared to National Parking Standards published by the Institute of Transportation Engineers, the Parking Consultants Council of the National Parking Association, the Eno Foundation for Transportation, and the Urban Land Institute. The parking dimensional tables from publications of those organizations are attached to this memorandum. Also, attached is a table of parking dimensions from the book ***Parking Structures; Planning, Design, Construction, Maintenance and Repair.*** Walker has also included the parking dimensional table from the City of Denver and City of Salt Lake City which have similar vehicle size characteristics as Grand Junction. On behalf of Walker Parking Consultants and Blythe Design + co., I am requesting exceptions to the parking module dimensions in Chapter 4 of the TEDS manual. Walker recommends a stall width of 8'6" for all day employee parking and 9'0" for visitor parking. Walker requests the City of Grand Junction allow a 52'4" parking module for 60-degree angle parking, a 57'0" parking module for 75-degree angle parking, and a 60-foot parking module for 90-degree parking for this project. These parking module dimensions would apply to stall widths of 8'6" and 9"0".

ALTERNATIVES CONSIDERED

Walker Parking Consultants has reviewed nine different parking layouts. Because of site constraints (property is only 125 feet deep), the longest parking module can only be 60'9" in length. Reviewing the Parking Stall Dimensions and Layout Table in Chapter 4 of TEDS, the site can only accommodate 60-degree angle parking and meet the City parking module dimensions. Options being considered by Walker include 60, 75, and 90-degree parking. With angle parking there is an opportunity to narrow the garage which could avoid relocating two significant electrical transformers on the property and allow for a landscape buffer along Rood Avenue.

PROPOSED DESIGN

The schematic parking layouts have been narrowed from nine to three. The three alternatives that are being considered are a 60-degree one-way traffic layout, a 75-degree one-way traffic layout, and a 90-degree two-way traffic layout. A design review meeting is scheduled for December 12, 2005 to discuss these three layouts. The preferred alternative selection will be made after this meeting.

IMPACTS OF CHANGE

1. **Will the exception compromise safety?**
   This exception will not impact safety. This exception will meet National Parking Standards as referenced in Walker Parking Consultants letter of November 15, 2005.

2. **Have other alternatives been considered that would meet the standard?**
   The parking design layout would be limited to 60-degree angle parking. No other alternatives could be considered if the exception is not allowed.

3. **Has the proposed design been used in other areas?**
   The City/County Parking Garage and St. Mary's Hospital Parking Structure parking modules dimensions don't meet Chapter 4 of TEDS. Field measurements of the parking modules were taken and are attached. The Rood Avenue Parking Structure proposed parking module dimensions are more generous than either of the two existing parking structures.

4. **Will the exception require CDOT or FHWA coordination?**
   No

5. **Is this a one-time exception or a manual revision?**
   I am asking for a one-time exception.

WALKER
PARKING CONSULTANTS

Walker Parking Consultants
5350 S. Roslyn Street, Suite 220
Greenwood Village, CO 80111

Voice: 303.694.6622
Fax: 303.694.6667
www.walkerparking.com

November 15, 2005

Mike Curtis, P.E.
Project Engineer
City of Grand Junction
Public Works Department/Engineering
250 North 5th Street
Grand Junction, CO 81501

Re: Parking Dimensions
Rood Avenue Parking Structure
Grand Junction, CO

Dear Mike,

Walker Parking Consultants has reviewed the parking dimensional requirements contained in Chapter 4 of the City of Grand Junction's Transportation Engineering Design Standards (TEDS) and find that they are overly generous compared to National Parking Standards published by the Institute of Transportation Engineers, the Parking Consultants Council of the National Parking Association, the Eno Foundation for Transportation, and the Urban Land Institute. The parking dimensional tables from publications of those organizations are attached. Also, attached is a table of parking dimensions from the book "PARKING STRUCTURES; PLANNING, DESIGN, CONSTRUCTION, MAINTENANCE AND REPAIR. Further, we have included the parking dimensional tables from the City of Denver and City of Salt Lake City which have similar vehicle size characteristics as Grand Junction. The purpose of this letter is to provide justification for a deviation of the parking module dimension for the referenced parking structure from the City of Grand Junction Transportation Engineering Design Standards (TEDS) and/or suggest a revision to those standards.

The TEDS parking dimensional table is attached. Parking module dimensions vary depending on the stall width (a parking module consists of two rows of parking with a drive aisle between). The stall width can be 8.5 ft, 9.0 ft or 9.5 ft. Walker recommends a stall width of 8'6" for all day employee parking and 9'0" for visitor parking.

Generally, the wider the stall, the narrower the drive aisle may be. This relationship is accounted for in the Grand Junction parking dimensions, however, the aisle dimensions are over-sized compared to national parking standards resulting in over-sized parking modules as illustrated in the following table.

Parking Module National Standards

Stall width = 8'6"

Angle of Park	NPA/PCC[1]	ITE[2]	ULI[3]	ENO[4]	Walker[5]	Average	Grand Junction
60 degrees	51.5	54	52.5	52.41	51	52.28	60.20
65 degrees	53		53.75		52.25	53.00	
70 degrees	54		55		53.5	54.17	
75 degrees	55	59	56	60.07	54.5	56.91	64.00
90 degrees	59	61	60	60.88	58.5	59.88	65.00

Notes:

1 Guidelines for Parking Geometrics, April 2002 by the Parking Consultants Council of the National Parking Association

2 Guideline for Parking Facility Location and Design, May 1990, by the Institute for Transportation Engineers, Washington, DC

3 The Dimensions of Parking, Fourth Edition, November 2000, by the Urban Land Institute, Washington, DC.

4 PARKING, by Robert A Weant and Herbert S. Levenson, ENO Foundation for Transportation
ENO Foundation for Transportation, 1990

5 PARKING STRUCTURES: PLANNING, DESIGN,CONSTRUCTION, MAINTENANCE & REPAIR, Third Edition, by Chrest, et al, Kluwer Academic Publishers, Norwell, MA, 2001

For 8'6" wide stalls at a 90-degree angle of park, a 65'0" parking module is required by the City of Grand Junction compared to approximately 60 feet according to the above national parking standards. For 60-degree parking, a 60.2-foot parking module is required by the City of Grand Junction compared to an average of 52'4" according to the above national parking standards. For 75-degree parking, a 64-foot parking module is required by the City of Grand Junction compared to an average of approximately 57 feet according to the above national parking standards.

Walker Parking Consultants is a multi-disciplined engineering firm specialized in the design of multi-level parking structures. We have 13 offices across the United States and approximately 300 employees. We have designed over 3000 parking structures in our 40-year history. Walker has tracked vehicle sales and dimensions annually since the early 80's. Each year we calculate the 85th percentile "Design Vehicle" and base our recommended parking dimensions on that vehicle size. This calculation includes SUV's, minivans and light trucks. Enclosed is a recent magazine article that summarizes our analysis of vehicle sizes for the past year. The design vehicle based upon 2003 vehicle sales is 6'8" by 17'2", or the size of the Lincoln Navigator SUV.

Walker Parking Consultants is presently considering both 90-degree and angle parking options for the referenced project. The site is not deep enough to accommodate a parking module over

60'9". A narrower garage could avoid relocating two significant electrical transformers at the alley on this property.

The city of Grand Junction parking modules are not consistent with the national parking standards particularly for angle parking. We have found many times that city planners calculate the parking module incorrectly. The parking module is calculated by multiplying the vehicle projection from the bumper wall by two for the two rows of parking, and then adding the required drive aisle width. When the vehicle is parked at an angle, the vehicle projection is larger than the length of the vehicle. The maximum vehicle projection is the length of the diagonal of the rectangle representing the size of the design vehicle, which is 18'5" for the Lincoln Navigator. Oftentimes the rectangle representing the parking stall length and width is used incorrectly to calculate the vehicle projection. Since the stall is larger than the vehicle, this calculation results in a vehicle projection that is too large. For a 75 degree angle of park, the calculated vehicle projection is 18'4" for the Lincoln Navigator. The recommended drive aisle width in accordance with the previous references for a 75-degree parking angle ranges from 16'10" (NPA) to 22' (ITE). Therefore, the calculated parking module for a 75-degree parking angle, in accordance with published national standards, then ranges from 53'6" to 58'8".

Walker respectfully requests that the city of Grand Junction allow a 52'4" parking module for 60-degree angle parking, a 57'0" parking module for 75-degree angle parking, or a 60-foot parking module for 90-degree parking for this project.

If you have further questions, please contact us.

Sincerely,

WALKER PARKING CONSULTANTS

Donald R. Monahan. PE
Vice President

Enclosure

cc: Roy Blythe
Josh Comfort
Rich Keller

APPENDIX A

the parking area and to ensure that the vehicle overhang does not obstruct sidewalks or other pedestrian walking areas.

Parking stalls may be oriented at 0°, 30,°45°, 60°, 75° or 90° to the parking aisle. Both stall and aisle dimensions and layout will vary depending on the stall orientation. The use of parking stalls oriented 90° to the building face with two-way aisles is generally preferred as this permits the most direct route between the parking stall and the building and minimizes auto/pedestrian conflicts adjacent to buildings.

Where larger vehicles may be frequent users of the parking facilities, it is appropriate to increase the parking stall dimensions according to the dimensions and turning characteristics of the vehicle.

Parking aisles shall be designed to accommodate the turning characteristics of the vehicles that will most commonly use the parking facilities. Dead-end parking aisles are prohibited without provision of an adequate turn around. Aisles should not exceed 300-350 feet in length without a break in circulation.

Parking Stall Dimensions and Layout

Parking Angle	A Stall Width in Feet	B Stall Length in Feet	C Aisle Width in Feet
0°	22.0	9.0	12.0
	22.0	9.5	12.0
	22.0	10.0	12.0
30°	9.0	18.0	11.0
	9.5	18.0	11.0
	10.0	20.0	11.0
45°	8.5	21.0	13.0
	9.0	21.0	12.0
	9.5	21.0	11.0
60°	8.5	21.1	18.0
	9.0	21.0	16.0
	9.5	21.0	15.0
75°	8.5	19.5	25.0
	9.0	19.5	23.0
	9.5	19.5	22.0
90°	8.5	18.5	28.0
	9.0	18.5	25.0
	9.5	18.5	24.0

APPENDIX B

PARKING

ROBERT A. WEANT
AND
HERBERT S. LEVINSON

ENO FOUNDATION for TRANSPORTATION Inc.

Eno Foundation for Transportation

P.O. Box 2055
Westport, Connecticut 06880
Tel. 203-227-4852

Eno Foundation was established by William Phelps Eno in 1921. Its purpose is to help to improve transportation in all its aspects through the conduct and encouragement of appropriate research and educational activities, and through the publication and distribution of information pertaining to transportation planning, design, operation, and regulation.

One of the objectives of the Eno Foundation is to encourage the dissemination of ideas, opinions, and facts relating to the field of transportation. The facts, opinions and conclusions set forth herein are those of the authors. They do not necessarily represent the views or opinions of the Eno Foundation nor can the Foundation assume any responsibility for the accuracy or validity of any of the information contained therein.

This publication is intended to provide accurate and authoritative information about automobile parking. It is sold with the understanding that the publisher is not engaged in rendering a professional service. If advice or other expert assistance is required, the services of a competent professional should be sought.

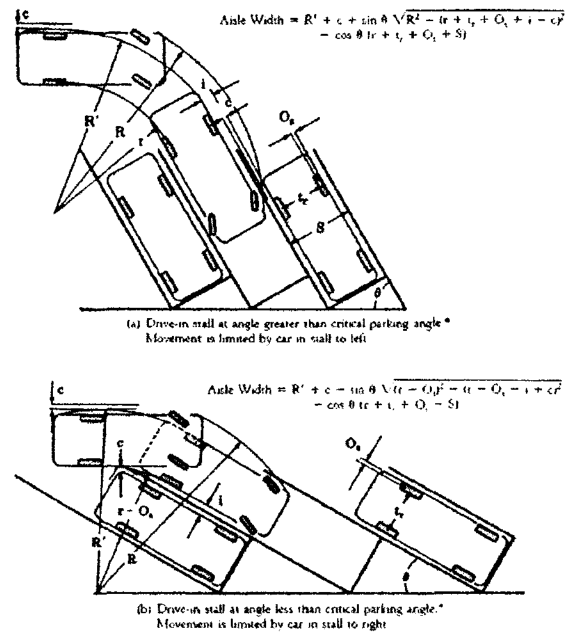
Library of Congress Catalog Number 85-82020. Printed in the United States of America.

occur when the parking angle is relatively flat (less than 60 degrees) or when pedestrian traffic is anticipated to be quite high. In such instances aisle width may have to be expanded beyond what would suffice for the sole consideration of vehicle maneuvering space. Other factors such as zoning requirements and emergency or maintenance vehicle access may influence aisle width choice.

While the determination of an appropriate aisle width will rely more on judgement than on analytical calculations, analytical equations have been used to derive aisle width. Equations, however, are no substitute for experience and judgement. In part, this is because they are unable to accurately account for varying driver behavior and ability.

Aisle width design equations are predicated on a driver proceeding along the driving aisle, coming to a full stop, turning the vehicle's wheels for as tight of a turn as possible, and then proceeding into the parking space. In practice, the driving path is conditioned by continuous vehicle movement along a spiraling turn, as opposed to a straight line path of tangency, connecting a constant radius turn into the stall. This inability of equations to simulate driver behavior is most apparent with 90-degree stall layouts. Equation-derived aisle widths for 90-degree parking usually exceed the minimum aisle width actually required by the design vehicle operated with average driver ability. For relatively flat angles of parking, equation-calculated aisle widths may more accurately reflect the minimum width needed for vehicle maneuvering, but the width may not be adequate to provide for other influences on aisle width, such as safe pedestrian movement or emergency vehicle access.

Aisle width equations do have some value. They can be used to help gauge the adequacy of selected designs, if the correct assumptions are made in respect to design vehicle dimensions and performance characteristics, and if the equations' limitations are realized. Thus, aisle width equations can be a tool for parking design. Equations (shown in Figure 8.3) are, perhaps, the most widely known and used formulas for calculating aisle width. These equations were used to derive the values shown in Table 8-3, using the large and small car design vehicle dimensions shown in Table 8-1 for an 8'6"-wide large car stall and a 7'6" wide small car stall at four different parking



* Critical parking angle is the angle at which the aisle width required for parking-unparking car to clear the car in the stall on the left is equal to aisle width required to clear car in stall on right. This angle is given by the expression

$$\theta' = \cot^{-1}\frac{\sqrt{R^2 - (r + t_r + O_s + i - c)^2} + \sqrt{(r - O_s)^2 - (r - O_s - i + c)^2}}{2S}$$

Figure 8.3. Formulas derived for the aisle width required to maneuver into or out of a parking stall in one pass

Source: Edmund R. Ricker, *Traffic Design of Parking Garages* (Westport, CT: Eno Foundation, 1957).

angles. Aisle widths shown in the table for parking at 90 degrees have been adjusted (calculated values reduced by 15 percent) to better reflect actual driving practice. Calculated aisle widths of less than 11 feet for large cars and 10 feet for small car design are not shown, since these are the more commonly recommended minimum widths for one-way traffic aisles. Generally small car spaces should only be used in 90-degree configurations.

Parking Module Width

The parking module is the clear width provided for the parking of vehicles, including access aisle width. In most cases, the module contains two rows of parking with an aisle between. The parking module (dimensions W shown in Figure 8.4) is computed by adding the stall depths, derived

Grand Junction
Downtown Parking Structure

City of Grand Junction
Downtown Development Authority

DDA
DOWNTOWN DEVELOPMENT AUTHORITY

BLYTHE DESIGN co.
The Art & Science of Construction
- Architecture
- Engineering
- Project Management
- Interiors

WALKER
PARKING CONSULTANTS

THE LAWRENCE GROUP
ARCHITECTS

12/12/2005

Grand Junction Downtown Parking Structure

Schematic Design Narrative

December 12, 2005

Architectural Narrative:

The Rood Avenue exterior elevation of this building is its most important Architectural element. The design will attempt to make the parking garage exterior compatible with the existing varied fabric of downtown Grand Junction. Per the attached conceptual elevation, it is anticipated the façade will be constructed of downtown building materials to include brick, pre-cast concrete, stucco, stone tile, simulated stone detailing, metal window framing, and pre-finished metals. Street-level planters along portions of this façade are being considered. Signage identifying entry and exit points will present unique opportunities for a splash of color and/or public art. All of these elements will be combined as illustrated with minor modifications as dictated by budget constraints.

The ends of the 300 foot long parking structure, along 4th and 5th Streets, will be identified by pedestrian vertical circulation (stairs and elevator(s)) to provide both relief to the overall block face and clear pedestrian access points for easy use. The vehicular entry will be emphasized with Architectural features such as entry canopies, stepped-out building façade, and strategic artwork/landscaping.

The roof itself will be hidden by a minimum 18" high parapet at the façade of the structure, with the possible raised ramp along the alley being covered by a simple parapet/roof which is not visible from the immediate environs.

The rear elevation of the garage will be largely open air, to satisfy "open garage" Building Code requirements. Guardrails and vehicular bumper stops will be incorporated to relieve the façade, which will be essentially concrete to address maintenance, low visibility, and economy concerns. Delivery, loading space and/or parking may be accommodated along the rear of the garage in the alley, depending on the selected parking option.

Both the east and west ends of the structure will be solid split face colored concrete block, for near-term aesthetic concerns and providing blank walls for future end-cap development.

The streetscape has potential to be improved by delineating drop-off/pick-up areas, landscaped areas between sidewalk and street, street trees, decorative paving materials, street lighting, and art/seating areas. The extent of these improvements will be largely dictated by City design objectives and available budget.

It is currently anticipated that the existing pedestrian circulation will not be modified, utilizing existing crosswalks and sidewalks. A future "breezeway" access across the alley to Main Street is being considered.

Structural Narrative:

Foundation:

Based on the geotechnical report received, a deep foundation system consisting of either drilled caissons or auger pressure grouted piles is anticipated. The soils report mentions the need for casing and dewatering of drilled caissons, which would make this system more difficult to install. The auger cast pile system would be faster to install and less objectionable to neighbors, however, probably more expensive.

A deep foundation system will support cast-in-place concrete grade beams that will be used to support the superstructure of the parking facility. The design will incorporate requirements for retaining soil as required for below grade spaces, with consideration given to maintaining access through the alleyway south of the project. The design will also include foundation elements necessary for the lateral support system of the structure.

Structure:

Options for structure for the new parking garage is being evaluated. It is anticipated that either a cast in place post tension concrete or a precast concrete system will be utilized.

Mechanical and Electrical Narrative:

Mechanical Systems

The mechanical systems for the parking garage will consist of a small split system air conditioning unit for the elevator equipment room. This unit will likely be a one ton unit with the condensing unit mounted inside the garage in a protected area. The structure will not be staffed and thus there are no plans for toilets in the facility.

Plumbing Systems

The plumbing system for the garage will consist of a waste system to handle the rain/snow that falls on/ in the parking garage as well as moisture that falls from the cars entering the garage. This system will include cast iron waste piping from area drains in the garage and routed in specific areas of the garage so as to not impede traffic in the area. This waste will be routed to a sand/oil interceptor prior to entering the city utility system. The parking structure is not anticipated to be staffed and thus it is not planned for toilets in the facility.

Fire Protection Systems

The structure will be protected with a series of dry standpipes with 2-1/2" fire department hose connections. The building will have a fire department connection located in a convenient location where a pumper truck can connect and pressurize the standpipe system with water. Please note that due to the classification and construction of the building a dry sprinkler system is not required.

Electrical Systems

The Electrical service will require a 600 Amp, 208 volt, 3 phase service. The service will be placed in a secure location and serve the lighting, elevator, security and miscellaneous systems. The service will be routed from an existing transformer location. This transformer will be evaluated by the project design team and Xcel Energy as to the feasibility of reusing existing. If the transformer location needs to be relocated, the new service will feed from the new transformer located near the alley.

The lighting will be a combination of HID lighting and service lighting as needed to provide a minimum necessary foot candle value for safety and security in the parking garage area. Power for the building will be limited to minimal service power as well as elevator power. Security systems will be provided with control power and conduit. This conduit will provide a routing for sales and/or security systems in the space. These security and sales systems will be provided by vendors selected by the owner.

Grand Junction Downtown Parking Structure

Building Code Review:

2000 International Building Code

Type of Construction: S-2; (2 hour firewall between S-2 and B occupancies)

Special Occupancy Requirements: 8'-2" minimum clear height at Level 1 for ADA compliance; 7' minimum clearance at other areas.

Proposed Building Data: Basement- NA
Level 1- 35,241 GSF
Level 2- 35,241 GSF
Level 3- 25,241 GSF
Top Level- 6,684 GSG

City Development Code Data: B-2 Zoning
Front Yard Setback- 15'- (Will Require Director Approval for 0' setback)
Maximum Height- 65'

Type of Construction: Type II B

Fire Resistance Rating Requirements: Structural Frame- 0 Hr
Bearing Walls Interior & Exterior- 0 Hr
Non- Bearing Walls- Interior & Exterior- 1 Hr
Floor & Roof3 Construction- 0 Hr

Allowable Stories: 8 Stiers

Allowable Area: 50,000 s.f./ Floor

Allowable Area: 400,000 s.f. Total

Allowable Height Increase for Sprinklers: 20' (Not Required)

Allowable Story Increase for Sprinklers: 1 Story (Not Required)

Mezzanines: NA

Allowable Area Increase for Frontage: Area increases allowed if 50% open vs. 20% open (Not Required)

Incidental Use Areas: NA (Not planned for other uses to be in the project)

Means of Egress Requirements: 35,241 s.f. / level= 171 occupants/ level
171 occupants/ level= 51.3 inches / 2 exits = 25.7 inches / exit

Dead End Corridors: 2.5 X Corridor Width= 60'

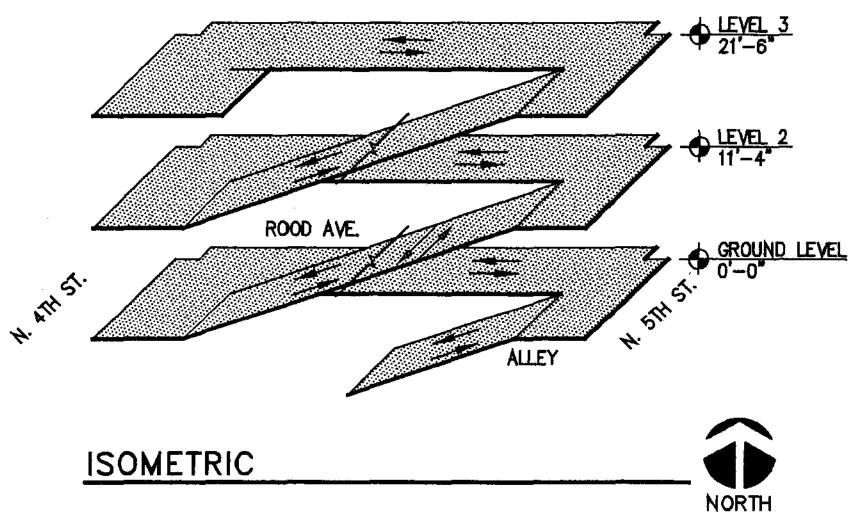
OPTION 4C – SINGLE THREAD

Pros

- Simple functionality – Easy for people to become familiar with garage and find their way
- Flat façade facing street – A straight façade is easier to design Architectural treatment and more pleasing to the human eye
- All stalls are on the parkers search path to the top
- Lowest building height at alley side
- Entry/Exit centered along Rood Ave.
- Option to do flat roof over entire structure
- User groups can be separated at any point

Cons

- Dead end parking at the top (if parked) and below grade portion (can be used for reserved)
- Underground portion = not as desirable spaces & higher construction cost
- Pedestrian walkway required to be at east or west end of building
- Sloped ramp will be challenging to add a roof
- Structure consumes entire width of site
- Longer vehicular travel path to exit
- Structure needs to be notched for transformer access



OPTION 5C & 5D – CAMELBACK HELIX

Pros

- Entry/Exit centered along Rood Ave.
- Flat façade facing street – A straight façade is easier to design Architectural treatment and more pleasing to the human eye
- Pedestrian walkway is located at the center of the building
- Option to do partial roof at the Rood Ave. side to keep entire structure height down at the alley
- Fewer traffic conflicts with angled parking
- Possible occupied space at the alley side under the elevated ramp
- No notch in the structure is necessary for the transformer access

Cons

- Higher structure height at the alley by 8'-4"
- Sloped ramp will be challenging to add a roof
- Backwards lane configuration for traffic flow at the center ramp
- Speed ramp at center – lack of comfort for users
- User groups separation is limited to per floor

OPTION 5C – 60 DEGREE

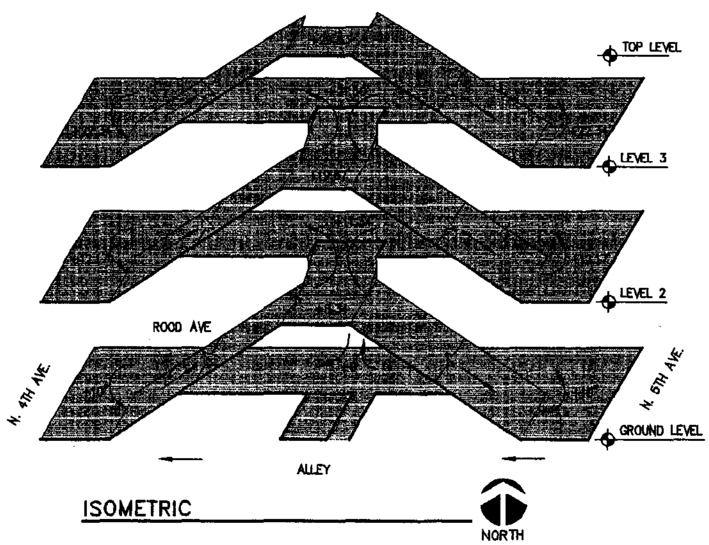
Cons

- Alley would need to be designated as 'One-Way'
- Opportunity for 21 additional angled stalls along the alley
- Most inefficient structure

OPTION 5D – 75 DEGREE

Pros

- The site is maximized with the number of stalls
- Opportunity for 12 additional parallel stalls along the alley



ISOMETRIC

ROOD AVE. PARKING GARAGE

GRAND JUNCTION, COLORADO

GARAGE OPTIONS - PROS AND CONS

WALKER PARKING CONSULTANTS

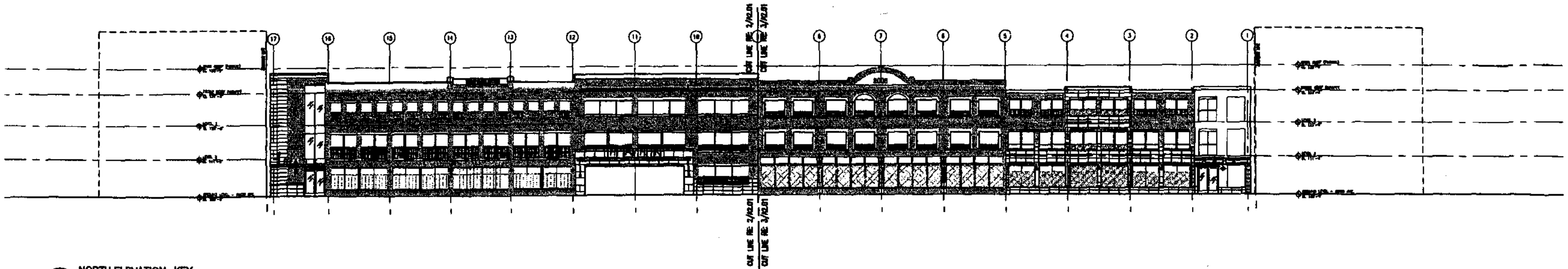
DECEMBER 12, 2005 — 23-7013.00

PARKING DATA SUMMARY
WALKER'S RECOMMENDEND STALL & PARKING MODULE SIZE
OPTION 4C, 5C & 5D

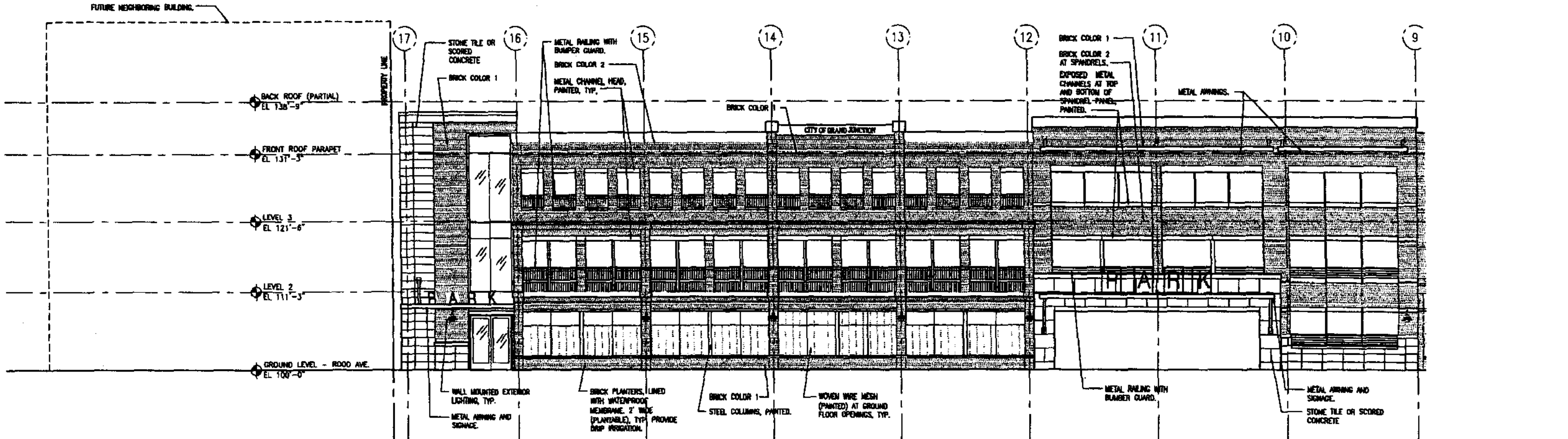
Preferred

12-13-05

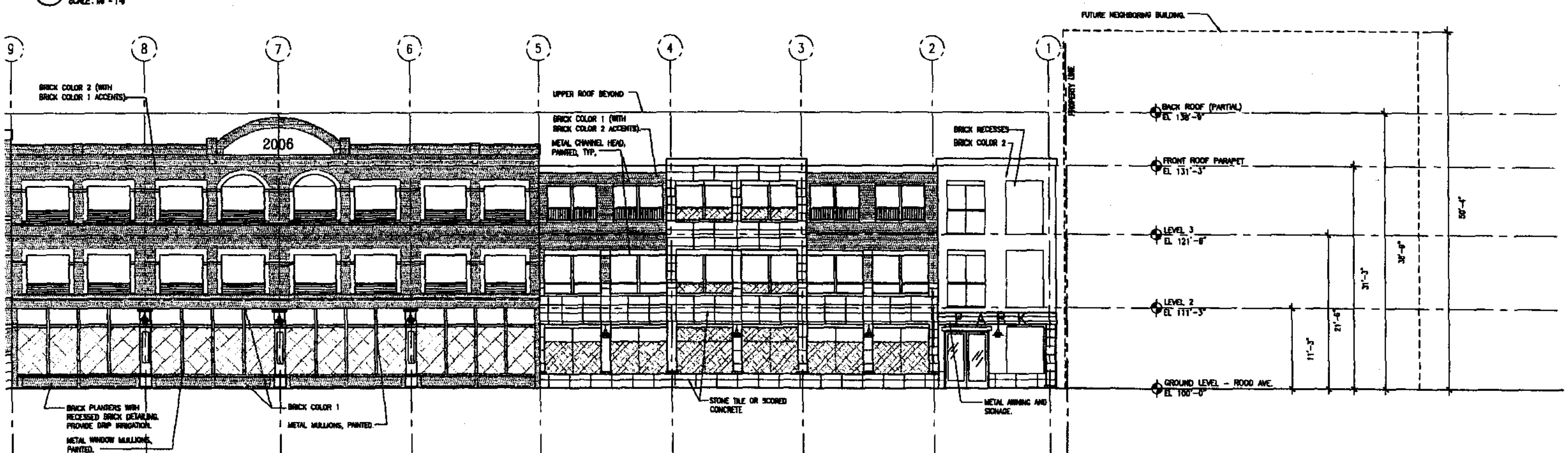
	Single Thread	Camelback Helix		
	Option 4c - 90º	Option 5c - 60º	Option 5d – 75º	
No. of Stalls	319	276	317	ONE WAY
S.F.	103,484	96,816	105,046	
Efficiency	324 s.f./stall	351 s.f./stall	331 s.f./stall	
No. of Stalls in Alley	0	21	12	
Total No. of stalls on site	319	297	329	
Efficiency w/Alley Stalls	324 s.f./stall	326 s.f./stall	319 s.f./stall	TEDS
Stall Size	9'-0"	8'-6"	8'-9"	8'-6"
Stall Projection	18'-0"	18'-9"	18'-10"	19'6"
Drive Aisle	24'-0"	14'-6"	→ 18'-10"	25' - TWO WAY
Module Size	60'-0"	52'-0"	56'-6"	62' TWO WAY
# of Bays	2	2	2	
# of 180° Turns to Top	4	5	5	
Ramp Capacity	420	980	980	
Flat façade (Rood)	Yes	Yes	Yes	
Flat façade (Alley)	No	No	No	
T.O. Parapet - Rood	25.17'	25.17'	25.17'	
Alley	25.17'	33.50'	33.50'	
Ped. Walkway	Yes (East)	Yes (Center)	Yes (Center)	
Below Grade Prkg	Yes	No	No	
# of stalls covered by a Flat Roof (no roof on sloped ramps)	79 of 115	44 of 93	51 of 107	



1 NORTH ELEVATION - KEY
SCALE: 1/16" = 1'-0"



2 NORTH ELEVATION - PARTIAL
SCALE: 1/8" = 1'-0"



3 NORTH ELEVATION - PARTIAL
SCALE: 1/8" = 1'-0"

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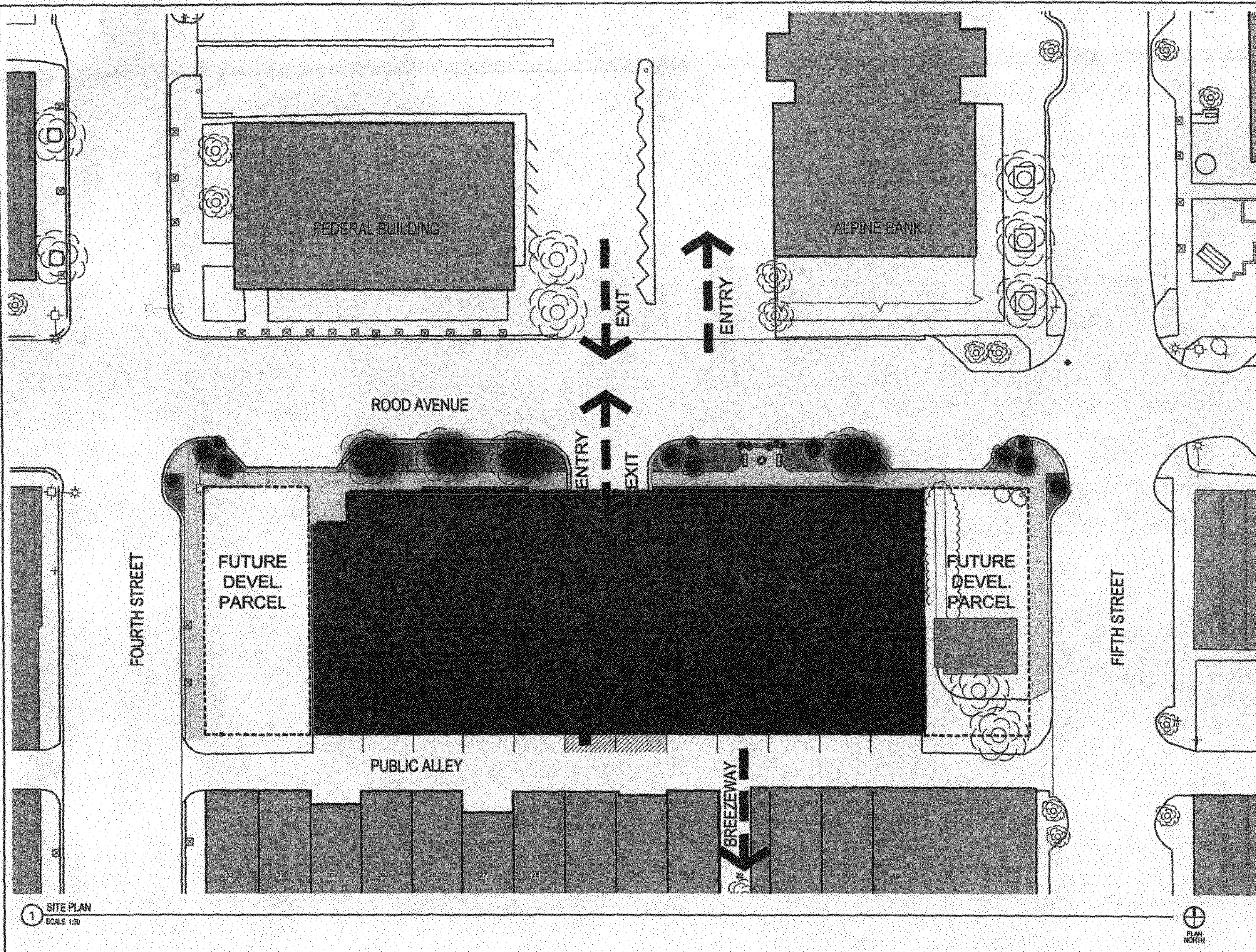
Project Title:

GRAND JUNCTION DOWNTOWN PARKING STRUCTURE
GRAND JUNCTION COLORADO

No.	Revision Description	Date
	Pricing Set (Schematic Design)	12.08.05

Sheet Title:

Project Number: 05411.001
Sheet Number:
Drawn By:
Issue Date: 12.08.05



1 SITE PLAN
SCALE 1:20

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Project Title:

ROOD AVENUE PARKING STRUCTURE

GRAND JUNCTION COLORADO

No.	Revision Description	Date
	Pricing Set (Schematic Design)	12.12.05

Sheet Title:

Project Number: 05411.001
Sheet Number:
Drawn By:
Issue Date: 12.12.05

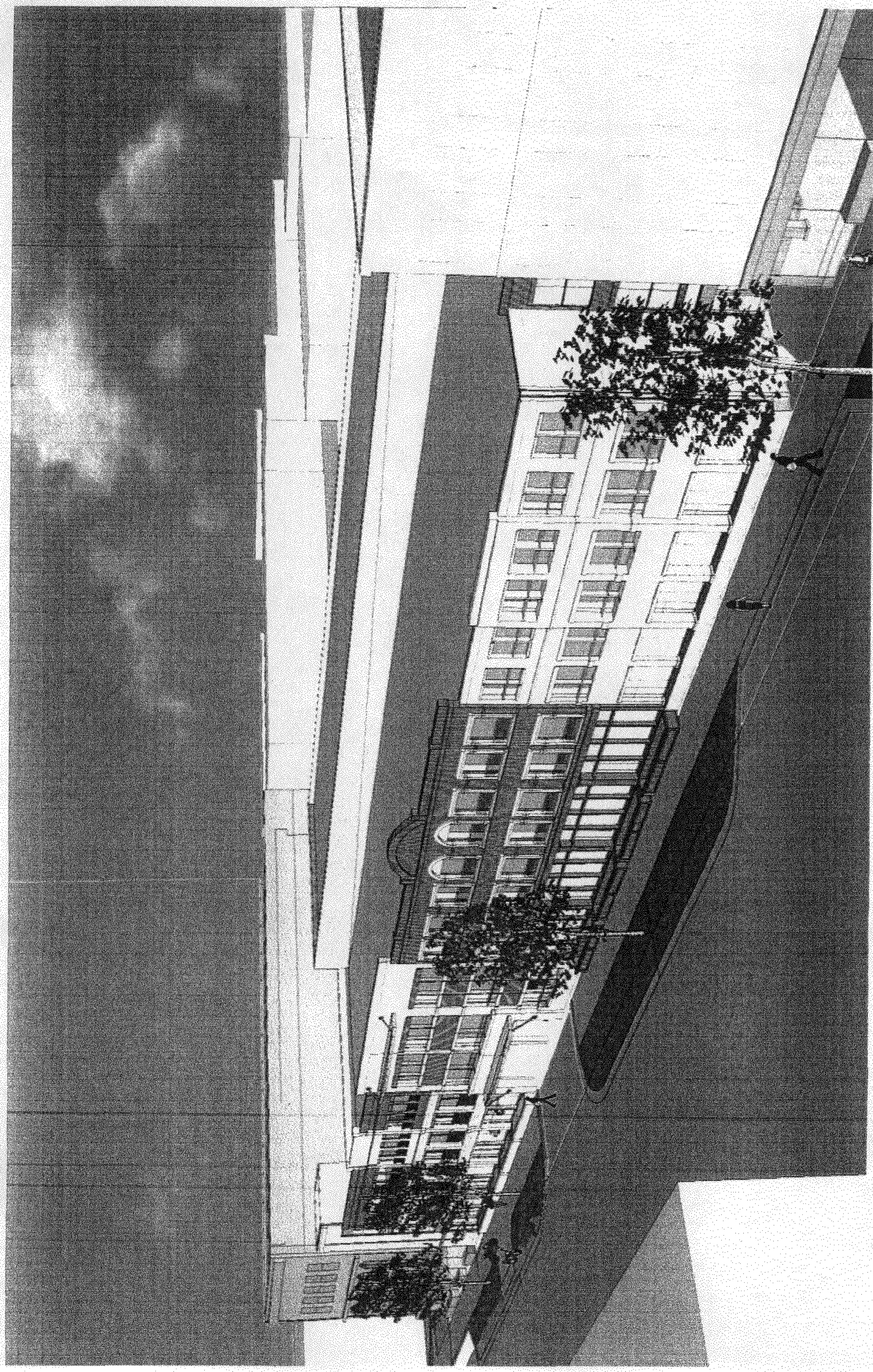

Table 8-3. **Calculated Parking Dimensions**
(Based on Ricker formula)

Parking Angle and Projected Vehicle Length		*Stall Widths*		*Aisle Widths*	*Module Widths*				*Clearances*	
		Sw	*WP*	*AW*	W_1	W_2	W_3	W_4	*c*	*i*
Large-car Design Vehicle (77" by 215")										
90°	VP_w = 18.42' VP_i = 18.42'	8'6"	8.50'	24.04'	42.46'	60.88'	60.88'	60.88'	1.5'	2.0'
75°	VP_w = 19.45' VP_i = 18.62'	8'6"	8.80'	21.17'	40.62'	60.07'	59.24'	58.41'	1.5'	2.0'
60°	VP_w = 19.16' VP_i = 17.55'	8'6"	9.82'	14.09'	33.25'	52.41'	50.80'	49.19'	1.5'	2.0'
45°	VP_w = 17.21' VP_i = 14.94'	8'6"	12.02'	11.0'	28.21'	45.42'	43.15'	40.88'	1.5'	2.0'
Small-car Design Vehichle (66" by 175")[a]										
90°	VP_w = 15.08' VP_i = 15.08'	7'6"	7.50'	22.27'	37.35'	52.43'	52.43'	52.43'	1.5'	2.0'
75°	VP_w = 15.99' VP_i = 15.28'	7'6"	7.76'	20.14'	36.13'	52.12'	51.41'	50.70'	1.5'	2.0'
60°	VP_w = 15.38' VP_i = 14.00'	7'6"	8.66'	13.9'	29.28'	44.66'	43.28'	41.90'	1.5'	2.0'
45°	VP_w = 14.20' VP_i = 12.26'	7'6"	10.61'	10.0'	24.20'	38.40'	36.46'	34.52'	1.5'	2.0'

a. Small car spaces normally are considered only for 90-degree layouts.

Note: See Figure 8.4 for definition of terms.

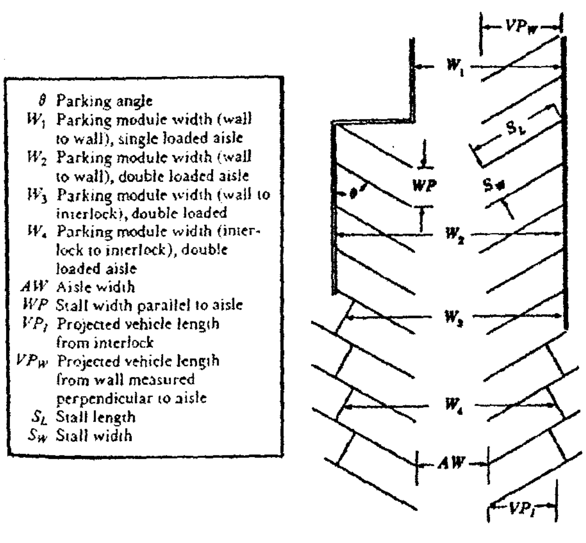

Figure 8.4. Dimensional elements of possible parking layouts

from the projected design vehicle length and bumper clearance, to the aisle width for the given parking angle. Projected design vehicle length has the same dimensional value as stall depth.

For angles of parking less than 90 degrees, the module width may be reduced by one interlock dimension for each row of stalls in a module that is interlocked with a row in an adjacent module. Calculated bumper-to-bumper interlock reduction dimensions vary depending on parking angle. Suggested bumper-to-bumper interlock reduction dimensions for various parking angles are: 90-degree angle, 0.00 interlock reduction (feet); 75-degree, 1.00; 60-degree, 1.67; and 45-degree, 2.33. Interpolation of values for other angles between 45 and 75 degrees will yield a reasonable result.

Typical ranges in parking module widths for different parking angles are shown in Table 8-4. The most appropriate module width for a given parking angle depends on (1) type of parking op-

APPENDIX C

Don Monahan

A Proposed Recommended Practice

Guidelines for Parking Facility Location and Design

Prepared by Technical Council Committee 5D-8, chaired by Paul C. Box, P.E., President of Paul C. Box and Associates, Skokie, Illinois

May 1990

ite

3 Surface Parking Design

Most of the basic principles of parking layout can be illustrated by a review of surface lot design. Stall and aisle dimensions and arrangements, horizontal circulation patterns, reservoir needs, and entry-exit revenue controls are similar for lots and garages. The special elements introduced by garages (columns, ramps, vertical circulation patterns, daytime lighting, and ventilation) are covered separately in the "Parking Structure Design" chapter.

3.01 Relationship between Design and Operation

The operation of a parking facility is greatly influenced by its design. The design elements and their associated operational features may be identified in successive steps as follows:

1. Vehicular access from the street system (entry driveway);
2. Search for a parking stall (circulation and/or access aisles);
3. Maneuver space to enter the stall (access aisle);
4. Sufficient stall size to accommodate the vehicle's length and width plus space to open car doors wide enough to enter and exit vehicle;
5. Pedestrian access to and from the facility boundary (usually via the aisles);
6. Maneuver space to exit from the parking stall (access aisles);
7. Routing to leave the facility (access and circulation aisles); and
8. Vehicular egress to the street system (exit driveway).

The simplest form of off-street parking is the single stall at a home. Assuming a straight driveway, steps 1 and 8 use the same lane and curb cut. Steps 2 and 7 are rudimentary. Thus, a driveway serving a one-car parking stall or garage cannot be considered as representing a second parking space if such parking would block continuous access to the basic stall. Step 6 usually involves backing out into the public street or alley, as part of 7 and 8. Herein lies the essential difference between low-volume parking and what generally should be practiced in facilities designed to handle more than two or three cars. Except along alleys, the larger lots should have all parking and unparking maneuvers contained off-street. Frequent backing of cars across sidewalks and into public streets increases congestion and creates hazards.

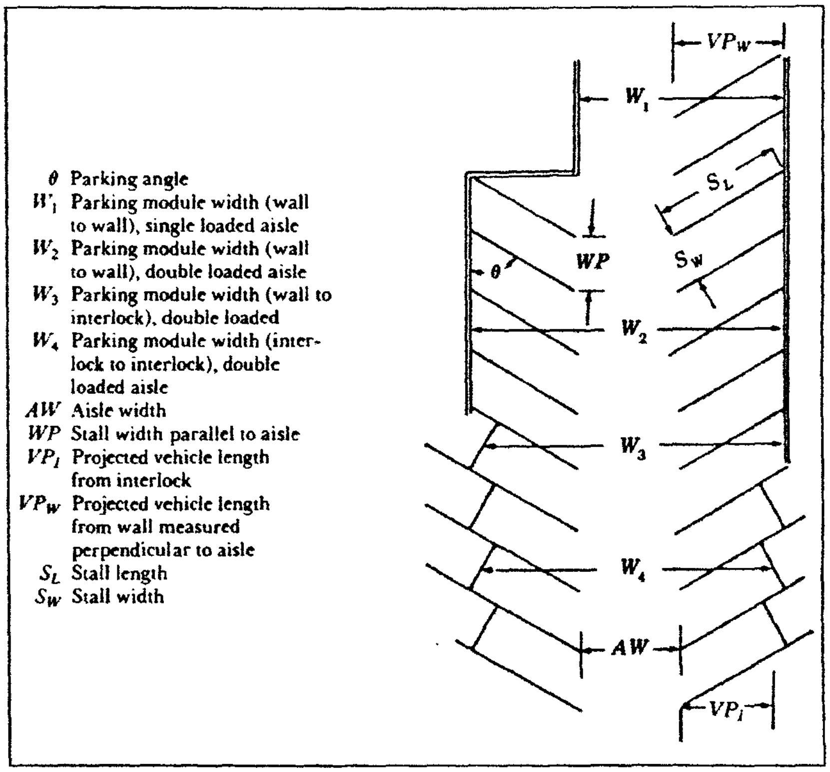

Figure 3. Dimensional elements of parking layouts. (Source: Adapted from cited reference 11, Figure 4.)

3.02 Stall and Aisle Dimensions—Large Cars

In developing the design of a parking facility, it is customary to work with stalls, aisles, and combinations called "modules".

A complete module is one access aisle servicing a row of parking on each side of the aisle (see Figure 3). In some cases, partial modules are used where the aisle serves only a single one-side row of parking. This arrangement is inefficient and should be avoided.

The minimum practical stall width varies principally with turnover (frequency of stall use), experience of the parker, and vehicle size. Commercial parking attendants can park large cars in stalls less than 8.0 feet wide. With self-parking, stall widths that will accommodate most passenger cars and light trucks range between 8.3 feet and 8.8 feet, depending on anticipated parking activity. Site-specific circum-

Table 1. Stall Width Classification

Class	Width (ft)[a]	Typical Turnover Low	Typical Turnover Medium	Typical Turnover High	Typical Uses
A	9.00			X	Retail customers, banks, fast foods, other very high turnover
B	8.75		X	X	Retail customers, visitors
C	8.50	X	X		Visitors, office employees, residential, airport, hospitals
D	8.25	X			Industrial, commuter, university

[a]Large-size vehicle, measured at right angles to stall

Figure 4. Example of guardrail to protect building wall if parker drives over wheel stops. (Source: Paul C. Box and Associates, Inc., Skokie, Ill.)

stances will influence determinations of the most appropriate stall width dimension. For example, a generous stall width is suggested by conditions of high parking turnover or limited module width in which to develop the access aisle. Where parking turnover is expected to be low, as for all-day employee parking, narrower stall widths are usually acceptable.

Other use considerations may also influence stall width selection. In order to allow for shopping cart movement between parked vehicles, food supermarket parking is often designed with a wider stall dimension than used for other types of parking having similar turnover characteristics. Generous parking stalls also may be appropriate for special events where parking maneuvers must be performed as rapidly as possible.

One approach to the range of stall width needs is to consider a stall *class*. This might be roughly equated to the level of service concept, whereby parking delay and ease of access and egress varies with expected activity and type of user. Table 1 identifies typical stall widths associated with turnover/user characteristics.

The long-term trend in American automobile design toward increased width has currently been reversed. However, more efficient engines and increased use of light-weight materials may in the future allow some "regrowth" of vehicle size. The practical limits needed for door opening space between cars and driver or passenger access to the vehicles combine to produce an "optimum" stall width of about 8.5 feet for most applications today, unless vehicles are segregated by general size. This is based upon a large-size design vehicle that is 6 feet wide and 17 to 18 feet long.

Stall widths exceeding 9 feet are not recommended (except for handicapped stalls) because of inefficiency—wasted land and pavement area, unnecessary added maintenance (cleaning, lighting), decreased capacity for a given site, increased storm water runoff, and increased walking distances for users. It is important to note that stall widths are measured crosswise to the vehicle. If the stall is placed at an angle of less than 90 degrees, the width parallel to the aisle must be increased proportionately.

The length of the stall should be appropriate to the overall length of most cars expected to use the space. A length of 18.5 feet has served this purpose in past years, but a value of 17.5 feet is now recommended on the basis of decreased average automobile sizes.

These lengths refer to the effective longitudinal dimension of the stall (but not necessarily the length of the stall line marking—see the "Construction Elements" section of this chapter). When rotated to angles of less than 90 degrees, the stall depth perpendicular to the aisle increases up to one foot more and then decreases.

Most parking aisles serve for both circulation and access to stalls. Exceptions concern crosswise or "end-loop" aisles. The access aisle width required to allow single-pass parking and unparking maneuvers varies principally with the angle of parking and secondarily with the stall width. It obviously is also related to the stall length. When dealing with large facilities, most parking designers work directly with the combinations of stall depth plus aisle width, or modules.

For 90-degree parking, the aisle width can also be related to the practice of pull-in versus back-in parking. Typically, a driver backing into a stall requires about 4 feet less aisle width. Unfortunately, the majority of drivers (both male and female) are reluctant to back into parking stalls. For this reason, pull-in design is the norm for practically all facilities.

The total dimensions required for a parking module are produced by adding together the aisle width plus the stall depths (perpendicular to the aisle) on both sides. However, the effective stall depth depends on the boundary conditions of the module. If car bumpers contact a wall or fence on both sides, the maximum total module requirement is developed. If there is no boundary barrier of bumper height, but tires of parked cars contact wheel stops or curbing, the vehicle overhang must be considered. The curb must be set back. For 90-degree pull-in parking, the setback to the inner face (wheel side) of the curb should be about 2.5 feet. For back-in operation, a 4.0- to 4.5-foot setback of curbing is needed because of the greater rear overhang of typical automobiles.

These setback dimensions are not adequate to furnish complete protection to any fences or decorative walls located on the perimeter. Unusual overhangs may be found, and it is also possible for tires to ride up on or over the blocks or curbing. When positive limitation is required, a bumper contact barrier, such as a structural wall or highway guardrail, should be used at the end of the stall (Figure 4).

For parking at angles of less than 90 degrees, front bumper overhangs are reduced in proportion to the angle and, for example, reach about 2 feet at a 45-

Table 2. Large Size Parking Layout Dimension Guidelines[a]

Parking Class[b]	S_w Basic Stall Width[c] (ft)	*WP* Stall Width Parallel to Aisle (ft)	VP_w Stall Depth to Wall (ft)	VP_i Stall Depth to Interlock[d] (ft)	*AW* Aisle Width[c,f] (ft)	Modules: W_2 Wall to Wall[f] (ft)	Modules: W_4 Interlock to Interlock[d,f] (ft)
	Two-Way Aisle—90 Degrees						
A	9.00	9.00					
B	8.75	8.75	17.5	17.5	26.0	61.0	61.0
C	8.50	8.50					
D	8.25	8.25					
	Two-Way Aisle—60 Degrees						
A	9.00	10.4					
B	8.75	10.1	18.0	16.5	26.0	62.0	59.0
C	8.50	9.8					
D	8.25	9.5					
	One-Way Aisle—75 Degrees						
A	9.00	9.3					
B	8.75	9.0	18.5	17.5	22.0	59.0	57.0
C	8.50	8.8					
D	8.25	8.5					
	One-Way Aisle—60 Degrees						
A	9.00	10.4					
B	8.75	10.1	18.0	16.5	18.0	54.0	51.0
C	8.50	9.8					
D	8.25	9.5					
	One-Way Aisle—45 Degrees						
A	9.00	12.7					
B	8.75	12.4	16.5	14.5	15.0	48.0	44.0
C	8.50	12.0					
D	8.25	11.7					

NOTES: These dimensions are subject to slight reductions by local agencies under high-cost conditions (such as garages) or slight increases in areas subject to special needs (such as extensive snowfall).

[a]See Figure 3 for description of elements.

[b]See Table 1 for typical uses (A for high turnover, B and C for medium turnover, and C and D for low turnover).

[c]Measured at right angles to stall line.

[d]May also apply to boundary curb where bumper overhang is allowed.

[e]To vehicle corner.

[f]Rounded to nearest foot.

degree angle.

Another type of module, the interlock, is possible at angles less than 90 degrees. There are two types of interlocks. The more common and preferred is the bumper-to-bumper arrangement shown in Figure 3. The other is the "nested" interlock; it can be used only at 45 degrees and is produced by adjacent aisles having one-way movements in the same direction. This arrangement requires the bumper of one car to face the fender of another car. Wheel stops are necessary for each stall, and, even with their use, the probability of vehicular damage is much greater than for other parking arrangements. Therefore, this type of parking layout is not recommended, unless the vehicle rows are separated by a curbed median.

Table 2 lists suggested basic design dimension guidelines for large-size cars for typical parking angles, stall widths, and modules. In practice, a faster parking operation will be achieved if the dimensions are increased. Slight reductions are also feasible, as given in the table notes.

Narrowed stall width in each class for parking angles of less than 90 degrees is not desirable. There is a relation between stall width and aisle width, as shown in Table 2, but the stall width needs are basically determined by door-opening clearances. Only at very flat angles of less than 35 degrees will doors open ahead or behind the cars in adjacent stalls, and even then there can be little reduction in basic stall width.

3.03 Small-Car Dimensions

Special dimensions for small-car parking have increased application in North America. The percentage of such cars varies by year and also somewhat by geographical location. It is currently about 40 to 50 percent in the United States.

A suitable stall length for small cars is 15 feet. Stall widths of 7.5 feet are appropriate for typical uses and widths of 8.0 feet for higher turnover conditions. These dimensions are based on a small-size design vehicle about 5 feet

APPENDIX D

Jc.N Monahan

Parking Consultants Council
National Parking Association

Guidelines for Parking Geometrics

April 2002

NPA/PCC *Guidelines for Parking Geometrics* Committee

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in a range of stall widths of 8'3" to 9'1". Due to the inconvenience of the latter dimension, and the common acceptance of 9'0" as a comfortable stall width, we limit our upper end recommendation to 9'0". Figure 2 presents guidelines for appropriate stall width.

Figure 2: Recommended Stall Widths

Typical Parking Characteristics	Recommended Parking Stall Width
Low turnover for employees, students, etc	8'3" to 8'6"
Low to moderate turnover visitor stalls (office visitor parking, long term parking at airports, etc.)	8'6" to 8'9"
Moderate to higher turnover visitor parking: retail, medical visitors; short term parking at airports, etc.	8'9" to 9'0"

The turnover or type of user does not affect the length of the stall. Many drivers, in fact, do not generally fully pull into a stall. Where a restraint on parking module such as a wall exists, the average clear dimension from the front of the vehicle to the restraint is generally about 0'9". Combining this dimension with design vehicle length results in a stall length of 18'0".

It has been recommended for years by experienced parking and traffic consultants that stall and aisle geometry for parking facilities should be based on rotation of the design vehicle to the desired angle rather than rotation of the stall dimensions. In practical terms, the aisle is that space left when two vehicles are parked directly opposite each other. The real controlling factor on the aisle, and consequently on the comfort of the design, is the dimension between curbs, walls or other parking stall guides.

The rotation of a stall to a particular angle is a theoretical exercise with no practical embodiment in the field. Some have argued that rotating the stall indicates the length of stripe required. A study by the British equivalent of the Transportation Research Board[4] clearly demonstrated that stopping the stripe short of the driver's side rear corner of the vehicle encourages the parker to pull further into the stall than if the stripe extends out to the far side corner of the rotated stall.

Aisle and Module Dimensions

Parking designers use the term "module" for the combined dimension of two parked vehicles and the aisle between. In the design condition employed to determine recommended modules, the two opposing vehicles are both design vehicles (85th percentile). The recommended size of the design aisle is then predicated on the turning movement of a third design vehicle into the first stall beyond the design vehicle on the right hand side, as the right hand turn is slightly more difficult due to visibility of potential obstructions. Trial and error originally determined parking modules. However, Edmund Ricker developed a series of equations, which modeled the movement of a vehicle into a parking stall[5]. Over the years these equations have been modified to better simulate the aisle/stall relationship.[6] Even so, field observations indicate that these equations are conservative, but they do help in determining relative aisle sizes for a similar level of comfort at various angles. The combination of these equations and practical experience have resulted in the development of a set of module dimensions that provide an acceptable minimum levels of comfort for the turning movement. Figure 3 presents recommended minimum parking modules.

Figure 3: Recommended Minimum Modules

Design Vehicle: Angle of Parking (degrees)	6'7" x 17'3" Module (width)
45	47'0"
50	48'6"
55	50'0"
60	51'6"
65	53'0"
70	54'0"
75	55'0"
90	59'0"

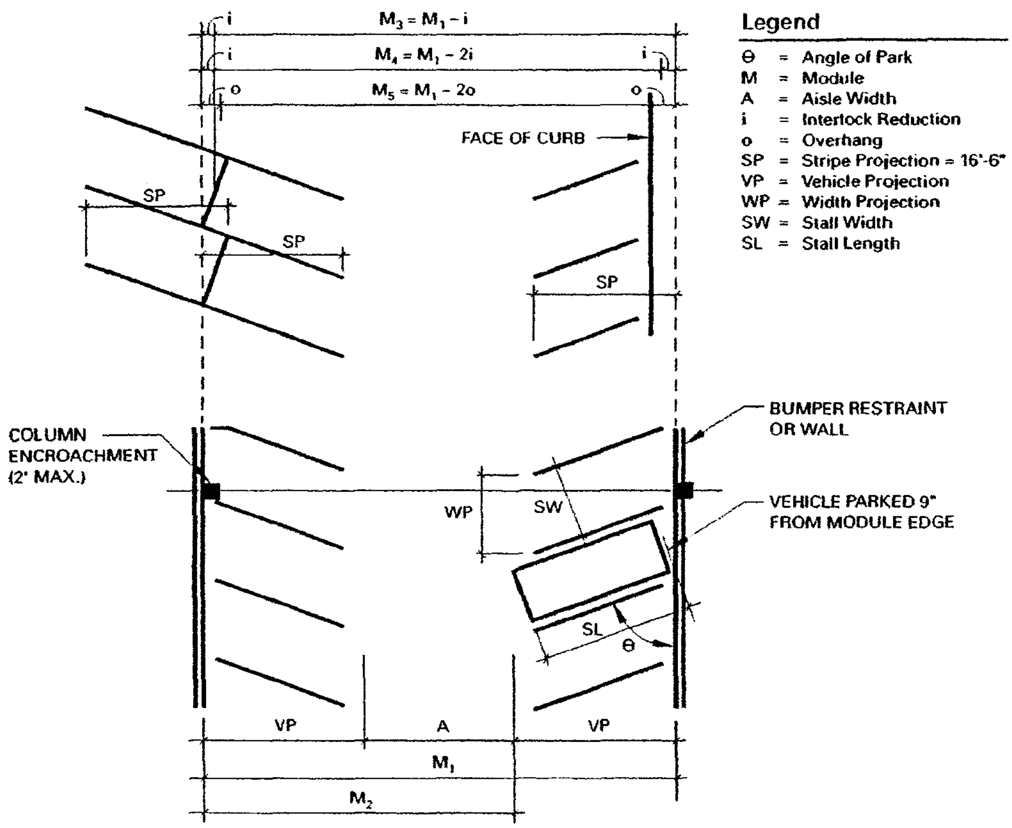
These "minimum" modules would be provided in very urban settings, with low turnover parking and where users are accustomed to minimum geometrics. Up to three feet can be added to aisle widths to achieve more comfortable geometrics. Adding more than three feet results in excessive aisle widths that are not utilized by parkers, thus resulting in wasted space.

The modules recommended in Figure 3 assume parking lot conditions without physical restrictions. When a positive vehicle restraint is not provided, such as in a shopping center parking lot, vehicles occasionally pull into the stall too far, impacting the aisle width in the adjacent module. This can be a particular problem in the "snowbelt" when stall markings are sometimes obscured. Therefore, when a curb, wall or other physical guide/restraint is provided at most if not all stalls, the aisle width (and therefore the resulting module) can be reduced by one foot.

As noted previously, there is a relationship between the stall and module such that a wider stall width can have a tighter module for the same comfort of turn into stalls. A common rule of thumb is that for each additional inch of stall width, the module can be reduced three inches to maintain a similar level of comfort of turn into the stall.[7] Generally speaking, we prefer to keep modules as small as possible and hold stall (including door opening clearance) widths wider, because the public is more appreciative of a comfortable stall width with a modest decrease in maneuverability into the stall module as compared to a wider aisle and narrower stall. Also, comfortable stall widths moderate the impact of small incremental changes in vehicle sizes in the shorter term. The PCC does recommend that while the smaller module/larger stall width relationship be used to hold *equal* comfort for different stall widths, designers and localities should be afforded the freedom to choose a combination of minimum stall width/minimum modules or more comfortable stall widths and modules to meet the needs of any given circumstance.

The basic module presented in Figure 3, is a "wall-to-wall" or "out-to-out" dimension. However a variety of other conditions may exist. Figure 4 presents common terminology and dimensional relationships for parking layout while Figure 5 provides additional dimensions commonly needed in parking design.

Figure 4: Parking Layout Considerations



Angles between 75 and 90 degrees are generally not recommended because the aisle becomes wide enough that a vehicle can back out and go the wrong way in a one-way design. The movement is tighter than that in these recommendations, but is achievable, particularly by smaller vehicles. Moreover, with the trigonometry of the rotated design vehicle, the overall module is nearly the same as required for 90 degree parking. If a site is appropriate for that module, it is usually better to just employ 90 degree parking with two-way traffic rather than 80 or 85 degree parking. Angles of less than 60 degrees are rarely used because they result in very inefficient parking, ie, significantly more overall sq ft of parking area per space is required for the same number of stalls. Figure 5, however, does include angles down to 30 degrees.

Figure 5: Common Parking Dimensions

Angle (deg)	Base Module	Veh Proj	Aisle Width	Single Loaded Module	Wall to Intlck (8'6")	Intlck to Intlck (8'6")	Curb To Curb	Over-hang	8'3" stalls Width Proj	8'3" stalls Intlck	8'6" stalls Width Proj	8'6" stalls Intlck	8'9" stalls Width Proj	8'9" stalls Intlck	9'0" stalls Width Proj	9'0" stalls Intlck
	M_1	VP	A	M_2	M_3	M_4	M_5	o	WP	i	WP	i	WP	i	WP	i
30	41'2"	15'1"	11'0"	26'1"	37'6"	33'10"	38'8"	1'3"	16'6"	3'7"	17'0"	3'8"	17'6"	3'9"	18'0"	3'11"
35	43'0"	16'0"	11'0"	27'0'	39'6"	36'0"	40'2"	1'5"	13'5"	3'5"	14'10"	3'6"	15'3"	3'7"	15'8"	3'8"
40	44'10"	16'11"	11'0"	27'11"	41'7"	38'4"	41'8"	1'7"	12'10"	3'2"	13'3"	3'3"	13'8"	3'4"	14'0"	3'5"
45	47'0"	17'7"	11'10"	29'5"	44'0"	41'0"	43'6"	1'9"	11'8"	2'11"	12'0"	3'0"	12'4"	3'1"	12'9"	3'2"
50	48'6"	18'2"	12'2"	30'4"	45'9"	43'0"	44'8"	1'11"	10'9"	2'8"	11'1"	2'9"	11'5"	2'10"	11'9"	2'11"
55	50'0"	18'8"	12'8"	31'4"	47'7"	45'2"	45'10"	2'1"	10'1"	2'4"	10'5"	2'5"	10'8"	2'6"	11'0"	2'7"
60	51'6"	19'0"	13'6"	32'6"	49'4"	47'2"	47'2"	2'2"	9'6"	2'1"	9'10"	2'2"	10'1"	2'2"	10'5"	2'3"
65	53'0"	19'2"	14'8"	33'10"	51'2"	49'4"	48'6"	2'3"	9'1"	1'9"	9'5"	1'10"	9'8"	1'10"	9'11"	1'11"
70	54'0"	19'3"	15'6"	34'9"	52'7"	51'2"	49'4"	2'4"	8'9"	1'5"	9'1"	1'5"	9'4"	1'6"	9'7"	1'6"
75	55'0"	19'1"	16'10"	35'11"	53'11"	52'10"	50'2"	2'5"	8'6"	1'1"	8'10"	1'1"	9'1"	1'2"	9'4"	1'2"
90	59'0"	18'0"	23'0"	41'0"	59'0"	59'0"	54'0"	2'6"	8'3"	0'0"	8'6"	0'0"	8'9"	0'0"	9'0"	0'0"

[1] Deduct 1 ft from aisle, and corresponding module, for parking in structures or where guides or curbs are provided at least 30% of the stalls.

[2] Add min 10" to stall width where adjacent to walls, columns and other obstructions to door opening and/or turning movement.

[3] Add min 10" to stall width for stalls next to curbs and islands to reduce trip hazard.

[4] Up to 3 ft of aisle width may be added to provide a higher level of comfort.

[5] Light poles and columns may protrude into a parking module a maximum of 2 ft combined as long as they do not impact more than 30% of the stalls. For example, either a 1 ft encroachment on both sides of the aisle, or a 2 ft encroachment on one side only, is acceptable.

[6] Interlock reductions cannot be taken where there is encroachment by columns, light poles or other obstructions at more than 30% of the stalls in the bay.

[7] Aisles and corresponding modules are for two-way traffic flow for 90 degree parking and one- way traffic flow for angled parking between 30 and 75 degrees.

[8] For an equal level of comfort of turn into the stall, 3" can be deducted from the module for each 1" additional stall width (maximum of 9'0" stall width.)

[9] Parallel parking stall length is 21'0".

[10] All dimensions rounded to the nearest inch.

APPENDIX E

Don Monahan

THE DIMENSIONS OF PARKING

FOURTH EDITION

ULI Urban Land Institute

NATIONAL PARKING ASSOCIATION
NPA
LEADERSHIP · PROFESSIONALISM · SERVICE

About ULI—the Urban Land Institute

ULI–the Urban Land Institute is a nonprofit education and research institute that is supported and directed by its members. Its mission is to provide responsible leadership in the use of land in order to enhance the total environment.

ULI sponsors education programs and forums to encourage an open international exchange of ideas and sharing of experiences; initiates research that anticipates emerging land use trends and issues and proposes creative solutions based on that research; provides advisory services; and publishes a wide variety of materials to disseminate information on land use and development. Established in 1936, the Institute today has more than 15,000 members and associates from more than 50 countries representing the entire spectrum of the land use and development disciplines.

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About NPA–the National Parking Association

The National Parking Association (NPA), founded in 1951, is an international network of more than 1,100 parking professionals from across the United States and around the world —the trade association for the parking industry. Members include private commercial parking operators; suppliers of equipment or services to the industry; parking administrators for colleges and universities, hospitals, municipalities, airports, and public authorities; engineers and architects; and developers. The Parking Consultants Council is a special professional group within the NPA, composed primarily of engineers and architects who produce a broad range of technical publications on the design, construction, and layout of parking facilities as well as recommended guidelines for zoning ordinances, use of handicapped spaces, lighting, and other issues of importance to traffic engineers, state and municipal officials, and parking professionals. The NPA acts as a clearinghouse for parking industry information, provides special services for its members, tracks federal legislation of interest to parking, sponsors an annual international convention and trade exposition, and publishes a magazine ten times a year.

Martin L. Stein
Executive Director

Recommended bibliographic listing:
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There is a growing disparity between the size of passenger vehicles and light trucks.

FIGURE 8-4

RECOMMENDED MINIMUM MODULE DIMENSIONS*

Parking Module Width for One-Way Traffic and Double-Loaded Aisles

Parking Angle (in degrees)	Module	Vehicle Projection	Aisle
45	48'0"	17'8"	12'8"
50	49'9"	18'3"	13'3"
55	51'0"	18'8"	13'8"
60	52'6"	19'0"	14'6"
65	53'9"	19'2"	15'5"
70	55'0"	19'3"	16'6"
75	56'0"	19'1"	17'10"
90	60'0"	18'0"	24'0"

*Design vehicle = 6'7" x 17'0".

Determining Parking Space Dimensions

A parking space that is wide enough for comfortable door opening clearance will be acceptable for vehicle maneuvering if the associated aisle is properly sized. As a result, parking space widths have generally been based on required door opening clearances (the distance between vehicles). Door opening clearances should range from 20 inches for vehicles in low-turnover facilities to 24 to 27 inches for vehicles in high-turnover facilities.[3] Combining these dimensions with the width of the composite design vehicle results in parking space widths that range from 8 feet, 3 inches to nine feet. Figure 8-3 presents recommendations for adjusting stall widths based on turnover. In summary, the ease of maneuverability into and out of spaces and the degree of comfort afforded the motorist and passengers should be related to the local environment.

The turnover rate or user type does not affect the length of the parking space. The average distance between vehicles and a restraint, such as a curb stop, is generally about nine inches. Combining this dimension with design vehicle length results in a recommended parking space length of 18 feet. It should also be noted that experienced parking and traffic consultants have long recommended that parking space and aisle geometry for parking facilities should be based on rotation of the design vehicle to the desired angle rather than on rotation of the parking space dimensions. The available drive aisle is the width left between two vehicles parked directly opposite each other. The controlling factors for design of the drive aisle are determined by the design criteria for curbs, walls, or other parking space constraints that protrude into spaces and/or the drive aisle.

FIGURE 8-5

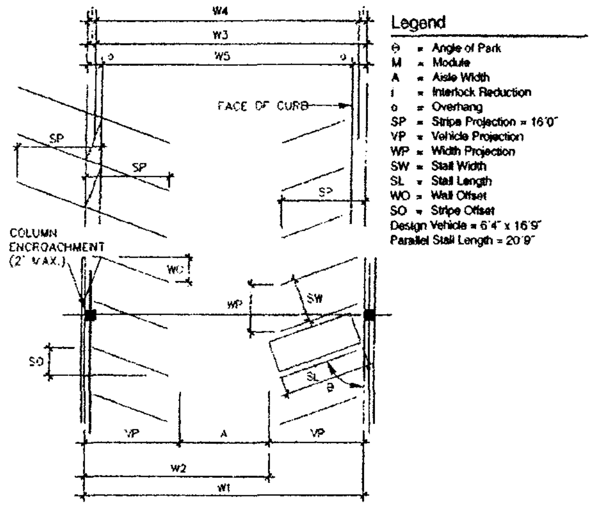
COMMON PARKING DIMENSIONS FOR 8'6" STALLS

Angle	Base Module W1	Single Loaded W2	Wall to Interlock W3	Interlock to Interlock W4	Curb to Curb W5	Overhang o	Interlock i	Stall Width Projection WP
45	48'0"	30'4"	45'0"	42'0"	44'6"	1'9"	3'0"	12'0"
50	49'9"	31'6"	47'0"	44'3"	45'11"	1'11"	2'9"	11'1"
55	51'0"	32'4"	48'7"	46'2"	46'10"	2'1"	2'5"	10'5"
60	52'6"	33'6"	50'4"	48'2"	48'2"	2'2"	2'2"	9'10"
65	53'9"	34'7"	51'11"	50'1"	49'3"	2'3"	1'10"	9'5"
70	55'0"	35'9"	53'7"	52'2"	50'4"	2'4"	1'5"	9'1"
75	56'0"	36'11"	54'11"	53'10"	51'2"	2'5"	1'1"	8'10"
90	60'0"	42'0"	60'0"	60'0"	55'0"	2'6"	0'0"	8'6"

Dimensions have been rounded to nearest inch.
*Design vehicle = 6'7" x 17'0".

FIGURE 8-6

COMMON PARKING DIMENSIONS



Determining Aisle and Module Dimensions

Parking designers use the term module for the combined dimension of two parked vehicles and the aisle between. Trial and error originally determined parking modules. However, Edmund Ricker, an early pioneer in the field of parking design geometrics, developed a series of equations that modeled the movement of a vehicle into a parking space. Over the years, the equations have undergone refinement and now better simulate the aisle/parking space relationship. The combination of these equations and practical experience has resulted in the development of a set of module dimensions that provide an acceptable minimum level of comfort for the turning movement as seen in Figure 8-4.

When designing basic parking space geometry for a particular parking facility (surface lot or structured parking), the designer should account for fundamental parking criteria, some of which include site location, site dimensions, site constraints (trees, power poles, buildings, and so forth), surrounding streets, traffic flow, parking demand generators, local zoning and landscaping mandates, surface conditions, and parking user categories. Each criterion can be unique to each parking location, thereby creating circumstances where the parking geometry must be carefully considered and adjusted on a case-by-case basis to allow for the location's maximized potential.

Most of these criteria are "givens," allowing for little flexibility. However, user characteristics may mandate some flexibility in parking space geometry to maximize the efficiencies of the parking facility. We have previously discussed recommended stall widths for low-turnover, medium-turnover, and high-turnover parking. By holding to the above modules and adjusting the stall width, the designer can ensure comfortable parking dimensions.

It is important to note that the dimensions provided in this chapter list recommended minimums. It may be appropriate and prudent to provide wider spaces in accordance with the location-based criteria discussed above. Consultants have found that increasing stall width and decreasing aisle width is a preferred method of maintaining an overall minimum level of comfort while maximizing user acceptance. An adjustment of three inches less per module for each one inch in additional stall width is recommended.[4]

Figure 8-5 presents some additional dimensions that are useful for laying out parking facilities for the minimum module dimensions shown in Figure 8-6. It is important to note that the interlock dimension and stall width projection (parallel to the aisle) are calculated for an 8-foot, 6-inch stall.

The recommended minimum dimensions assume parking lot conditions without physical restrictions. When a curb stop is not provided, such as in a shopping center parking lot, vehicles occasionally pull into the parking space too far, thereby reducing the aisle width of the adjacent module. This can be a particular problem in the Snow Belt, where space markings are sometimes obscured. Therefore, when a curb, wall, or other physical restraint is provided at each parking space, the aisle width (and therefore the resulting module) can be reduced by one foot.

It is common in parking structures for columns to extend beyond the face of the bumper wall or vehicle restraint and therefore into the module. Encroachments also occur in parking lots at light poles. It is recommended that columns, light poles, or other appurtenances be allowed to encroach into the module and affect up to 30 percent of parking spaces. The encroachment should be limited to

- a maximum combined reduction of two feet (i.e., six inches into parking spaces on one side of the aisle and 1 foot, 6 inches on the other side) below the module widths recommended in Figure 8-2; or
- one foot below the module if the one-foot credit is taken for vehicle restraints at every parking space.

Column encroachments into the width of a parking space are occasionally used in short-span designs on the theory that if the column is clear of the door swing zone, the parking space width is maintained. However, the turning movement into the parking space is constrained by the column; the clear space for turning into a typical parking space between two design vehicles in the two adjacent parking spaces is the parking space width plus at least 20 inches. To maintain the same clear space for turning movement into each parking space, the parking spaces adjacent to walls, columns, or other obstructions must be widened by at least ten inches.

APPENDIX F

PARKING STRUCTURES

PLANNING, DESIGN, CONSTRUCTION, MAINTENANCE AND REPAIR

Third Edition

Anthony P. Chrest
Mary S. Smith
Sam Bhuyan
Mohammad Iqbal
Donald R. Monahan

Kluwer Academic Publishers
Boston/Dordrecht/London

3.4.1.3 Recommended US Parking Dimensions

With the surge in vehicle width through 1999, we have recently added 3 in. to our recommended stall widths while adjusting the modules for the turning impact and the vehicle projection of a wider, slightly longer car. See Table 3-6 for our recommended dimensions for stall widths and modules (the wall- to- wall dimension of two rows of parked vehicles and the aisle between.)

The level-of-service approach provides assistance in tailoring a design for the users of the specific project. In parking design, there are virtually infinite combinations of stall width and module.

Table 3-6. Recommended Stall Width Dimensions

North America	LOS D	LOS C	LOS B	LOS A
Stall Width	8'-3"	8'-6"	8'-9"	9'-0"
Angle of Park	Module (ft.)			
40	46.50	47.50	48.50	49.50
50	48.25	49.25	50.25	51.25
55	49.50	50.50	51.50	52.50
60	51.00	52.00	53.00	54.00
65	52.25	53.25	54.25	55.25
70	53.50	54.50	55.50	56.50
75	54.50	55.50	56.50	57.50
90	58.50	59.50	60.50	61.50

LOS A dimensions are the most generous and are often employed in high turnover situations, including shopping centers, airport short-term lots and hospital visitor and patient parking. LOS B might be employed for the same uses in very urban settings where tighter dimensions are accepted; LOS B is also employed for other visitor situations with less turnover, such as longer term parking at airports and visitor parking at office buildings. LOS C parking is often employed for employee parking and/or student parking at universities, although we sometimes move up to LOS B for these uses if a higher level of comfort is desired. LOS D is only employed in the most urban of settings such as downtown New York City, where people are happy just to find a parking space.

As before, no recommendations are provided for LOS E and F designs, because they simply are not recommended. For reference purposes, LOS F designs result in extremely tight conditions where some parkers have to make several attempts to get into the stall. Encroachment into adjacent stalls may leave them unusable.

APPENDIX G

CITY OF DENVER

CHART 1
OFF-STREET PARKING

For other than 90-degree parking, the minimum aisle width for two-way trafic shall be twenty (20) feet.

If a public alley is used as the aisle or access to adjoining parking spaces, the spaces or projection must be lengthened as necessary to provide a total alley or aisle width of twenty (20) feet for 0-degree through 75-degree angle parking and twenty-three (23) feet for 90-degree angle parking. This requirement shall apply to all new uses and developments except single unit dwellings and duplexes.

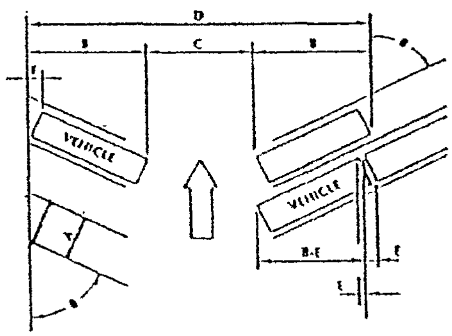
Parking angles between 0 and 30 degrees or between 75 and 90 degrees are not allowed. Other angles between 30 and 75 degrees are allowed and the dimensions for those angles shall be determined through interpolation.

PART A: Parking Lot Dimensions—Universal sized stall (8.5′ x 17.5′)

Parking Angle	*Stall Width* (A)	*Projection* (B)	*Aisle* (C)	*Module* (D)	*Interlock Reduction* (E)	*Overhang Allowance* (F)	Interlock - Interlock Module
0°	8.5′	8.5′	10.0′	27.0′	—	—	
30°	8.5′	15.0′	11.0′	41.0′	2.0′	1.5′	37'0"
45°	8.5′	17.0′	13.0′	47.0′	2.0′	2.0′	43'0"
60°	8.5′	18.0′	16.0′	52.0′	1.5′	2.0′	49'0"
75°	8.5′	18.5′	18.0′	55.0′	1.0′	2.5′	53'0"
90°	8.5′	17.5′	23.0′	58.0′	—	2.5′	58'0"

65°: 50'4"
70°: 51'8"

65° MODULE (D):
(55'-52') 5/15 + 52 = 53'0"
70° MODULE (D):
(55-52) 10/15 + 52 = 54'0"



PART B: Parking Lot Dimensions—Separately Designated Small Car (SC), 7.5′ x 15.5′, and Large Car (LC) Stalls, 8.5′ x 19.0′

The dimensions from this chart shall be used only in controlled situations as approved by the zoning administrator—where the owner/manager can determine which employees/residents shall park in specific parking spaces.

Small car stalls shall not exceed forty (40) per cent of the total stalls provided.

Parking Angle	*Stall Type*	*Stall Width* (A)	*Vehicle Projection* (B)	*Aisle* (C)	*Typical Module* (D)	*Interlock Reduction* (E)	*Overhang* (F)
0°	SC	7.5′	7.0′	10.0′	24.0′	—	2.0′
	LC	8.5′	8.0′	11.0′	27.0′	—	3.0′
30°	SC	7.5′	14.0′	11.0′	39.0′	1.8′	1.3′
	LC	8.5′	16.7′	12.0′	45.4′	2.5′	2.0′
45°	SC	7.5′	15.2′	12.0′	42.4′	1.5′	1.5′
	LC	8.5′	18.3′	13.0′	49.6′	2.3′	2.3′
60°	SC	7.5′	16.3′	13.5′	46.1′	1.3′	1.7′
	LC	8.5′	20.0′	16.0′	56.0′	1.8′	2.5′
75°	SC	7.5′	16.5′	17.3′	50.3′	0.8′	1.8′
	LC	8.5′	20.2′	19.0′	59.4′	1.3′	2.8′
90°	SC	7.5′	15.5′	19.0′	50.0′	—	2.0′
	LC	8.5′	19.0′	23.0′	61.0′	—	3.0′

(Ord. No. 1-88, eff. 1-15-88)

90° SC + 90° LC = 15.5′ + 23.0′ + 19.0′ = 57.5′
90° SC + 60° LC = 15.5′ + 19.0′ + 18.0′ = 52.5′ (50.7′ w/ Interlock)
90° SC + 75° LC = 15.5′ + 19.0′ + 18.5′ = 53.0′ (51.7′ w/ Interlock)
75° SC + 60° LC = 16.5′ + 17.3′ + 18.0′ = 51.8′ (49.2′ w/ Interlock)
75° SC + 75° LC = 16.5′ + 18.0′ + 18.5′ = 53.0′ (50.9′ w/ Interlock)

APPENDIX H

POLICY
of the Division of Transportation
Salt Lake City Public Works Dept.

Section F1.c2

Timothy P. Harpst, PE - Transportation Engineer — Date: 11 MAR 91

OFF-STREET PARKING

All off-street parking designs shall conform to the accompanying Standard Detail dimensions chart and be approved by the Transportation Engineer or his/her designee.

Parking angles between 0° and 45° or between 75° and 90° are not allowed. Other angles between 45° and 75° are allowed and the dimensions for those angles not shown shall be determined through interpolation.

Use of a public alley as aisle access to individual parking spaces is prohibited in residential zones and where zoning requires landscaped rear or buffer yards. Approval of the Planning and Zoning Division is required in all other areas. If a public alley is used as the aisle or access to adjoining parking spaces, the spaces or projection must be lengthened as necessary to provide a total alley or aisle width of 20 feet for 0° (parallel) through 75° angle parking and 23 feet for 90° angle parking. This requirement shall apply to all new uses and developments except single unit dwellings and duplexes.

Handicap stalls shall be a minimum of 13 feet wide. The minimum number of handicap stalls required is determined in ordinance 21.84.050, Handicapped Parking Spaces.

Maneuverability around the end of the aisles (aisle cross-overs) is dependent on the minimum acceptable turning radii of the vehicle. For one-way traffic, the minimum inside radius is 12 feet and the minimum outside radius is 25 feet. For two-way traffic, the minimum inside radius is 12 feet and the minimum outside radius is 36 feet. If perimeter parking is provided, then the cross-over aisle dimension shall be the greater of that required for access to the stall or that required for turning.

Parking stalls adjacent to columns or side walls shall be one foot wider than the standard dimensions to accomodate door opening clearance and vehicle maneuverability.

Stalls shall be striped to 80% of the vehicle projection to encourage pulling further into the stall.

One foot of aisle width shall be added to lots without curb stops.

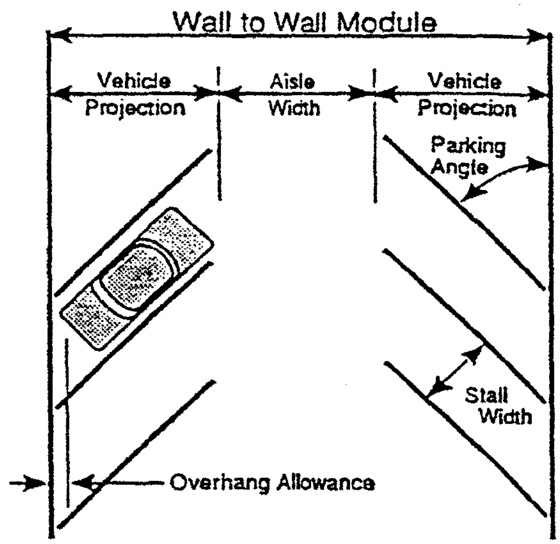
Substandard stalls shall not be allowed in new uses or developments even when they are not needed to meet parking requirements. Designated compact car stalls shall not be allowed. The dimensions given in the policy are for a 'one size fits all' design.

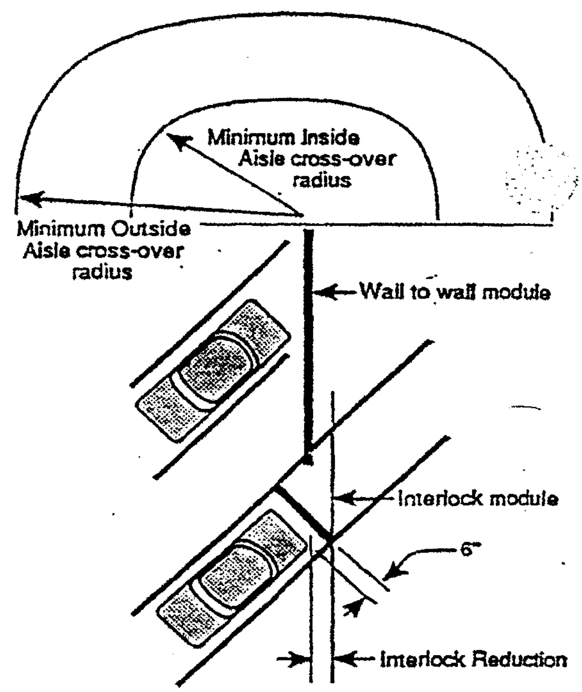
Parking lots should make provisions for the secure parking of bicycles.

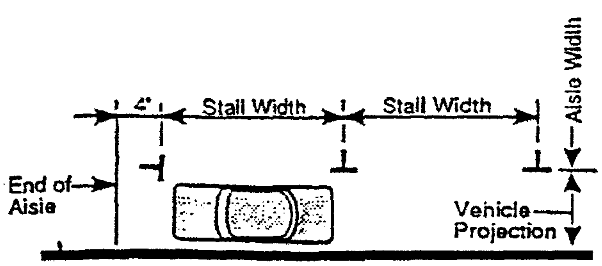
Driveway widths shall meet the criteria of the city zoning ordinance and city site development ordinance. The Transportation Division will review and approve the number and location of driveways. In general, the number of driveways shall be kept to a minimum and the distance from adjacent intersections maximized.

STANDARD DETAIL - FOR PARKING STALLS

Parking Angle	Stall Width	Vehicle Projection	Aisle Width	Wall to Wall Module Width	Interlock Reduction	Overhang Allowance
0	22'0"	8'03"	12'08"	29'02"	0'00"	2'00"
45	8'03"	16'10"	14'11"	48'07"	2'03"	2'00"
50	8'03"	17'05"	15'06"	50'04"	2'00"	2'00"
55	8'03"	17'11"	16'02"	52'00"	1'10"	2'01"
60	8'03"	18'03"	16'10"	53'04"	1'07"	2'02"
65	8'03"	18'06"	17'09"	54'09"	1'04"	2'03"
70	8'03"	18'07"	18'07"	55'09"	1'01"	2'04"
75	8'03"	18'06"	20'01"	57'01"	0'10"	2'05"
90	8'03"	17'06"	24'10"	59'10"	0'00"	2'06"
0	22'00"	8'06"	11'11"	28'11"	0'00"	2'00"
45	8'06"	16'10"	14'02"	47'10"	2'03"	2'00"
50	8'06"	17'05"	14'09"	49'07"	2'00"	2'00"
55	8'06"	17'11"	15'05"	51'03"	1'10"	2'01"
60	8'06"	18'03"	16'01"	52'07"	1'07"	2'02"
65	8'06"	18'06"	17'00"	54'00"	1'04"	2'03"
70	8'06"	18'07"	17'10"	55'00	1'01"	2'04"
75	8'06"	18'06"	19'04"	56'04"	0'10"	2'05"
90	8'06"	17'06"	24'01"	59'01"	0'00"	2'06"
0	22'00"	8'09"	10'08"	28'02"	0'00"	2'00"
45	8'09"	16'10"	13'05"	47'01"	2'03"	2'00"
50	8'09"	17'05"	14'00"	48'10"	2'00"	2'00"
55	8'09"	17'11"	14'08"	50'06"	1'10"	2'01"
60	8'09"	18'03"	15'04"	51'10"	1'07"	2'02"
65	8'09"	18'06"	16'03"	53'03"	1'04"	2'03"
70	8'09"	18'07"	17'01"	54'03"	1'01"	2'04"
75	8'09"	18'06"	18'07"	55'07"	0'10"	2'05"
90	8'09"	17'06"	23'04"	58'04"	0'00"	2'06"
0	22'00"	9'00"	9'05"	27'05"	0'00"	2'00"
45	9'00"	16'10"	12'06"	46'04"	2'03"	2'00"
50	9'00"	17'05"	13'03"	48'01"	2'00"	2'00"
55	9'00"	17'11"	13'11"	49'09"	1'10"	2'01"
60	9'00"	18'03"	14'07"	51'01"	1'07"	2'02"
65	9'00"	18'06"	15'06"	52'06"	1'04"	2'03"
70	9'00"	18'07"	16'04"	53'06"	1'01"	2'04"
75	9'00"	18'06"	17'10"	54'10"	0'10"	2'05"
90	9'00"	17'06"	22'07"	57'07"	0'00"	2'06"







Date	Revisions
3/11/91	changed layout

APPENDIX I

20 Years of Vehicle Size Trends:

Have We Reached Another Turn in the Road?

By Mary S. Smith

The History

Following the "crisis" resulting from the Arab Oil Embargo of 1973, the size of the average car in the United States reduced substantially. At first, very small vehicles were offered for sale to balance the very large vehicles then in production; some projected that 80 percent of cars would be classified as small[1] by 1990. (See Figure 1.) The manufacturers then began "downsizing" large cars.

Walker Parking Consultants (WPC) began monitoring vehicle sizes in 1984. In the first year, WPC evaluated the size of all cars "on the road" in the United States (per R. L. Polk's database of vehicle registrations). Thereafter, we evaluated the sales of cars in each calendar year as reported by *Automotive News*. One focus initially was on the percent of small vehicles, because it was then "in vogue" to provide small car-only

Note: This article is another in a series on the impact of changing car sizes on recommended parking geometrics, but it is an especially significant one because 2005 is the 20th anniversary of not only the first article in this series, but the first article contributed to *PARKING* (and indeed any parking magazine) by Mary Smith, a senior vice president with Walker Parking Consultants. In honor of this occasion, we will briefly review trends since the publication of the original article, "Parking Standards," published in the July/August 1985 *PARKING*, before discussing 2004 sales and their impact on parking geometrics.

Figure 1. Small Car Sales

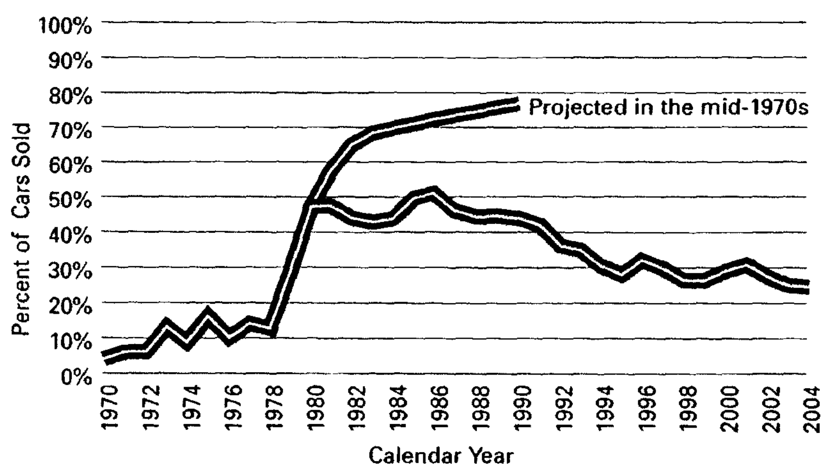
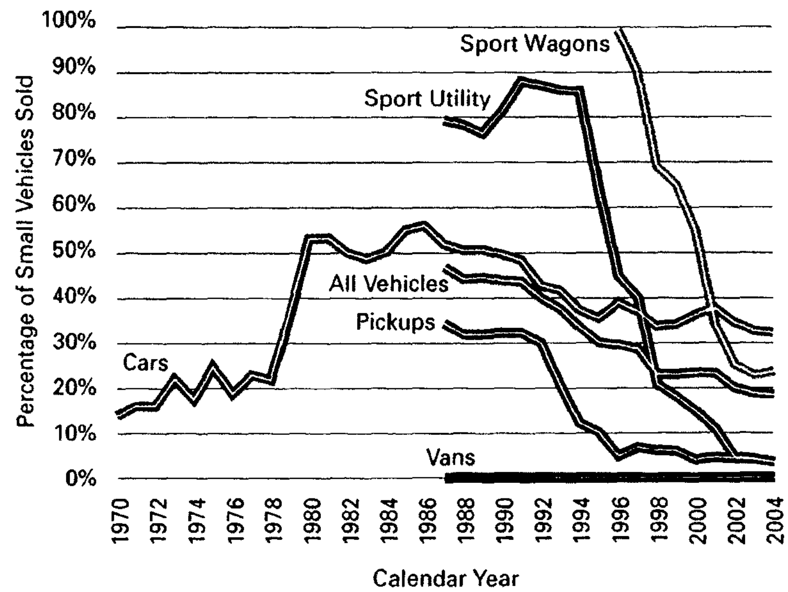


Figure 3. Sales of Small Vehicles by Type

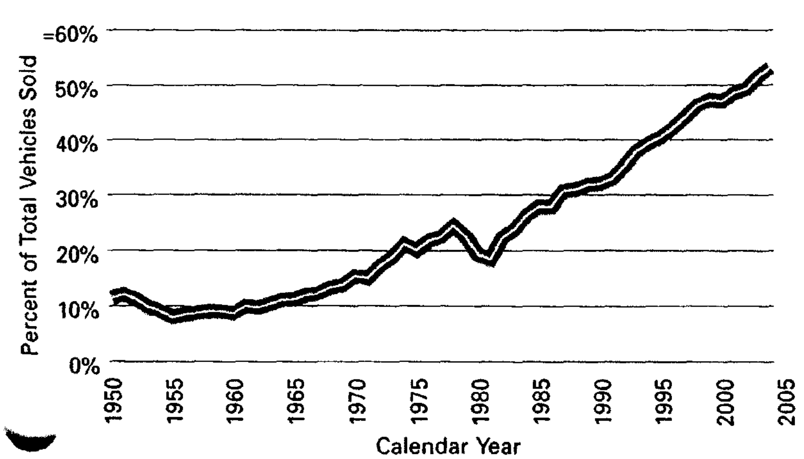


stalls, and we needed to understand their sizes and presence in the vehicle mix to respond to this issue. However, at about the time we started monitoring car sizes, the sales of small cars began a slow, steady decline that has continued to this day. This was because the auto industry quickly figured out how to improve aerodynamics and fuel efficiency, and both small and large cars began to get larger again.[2] Then, the significant trend of the 1990s was the increasing use of what the auto industry and federal government call "light trucks" (pickup trucks, sport utility vehicles and vans) for personal transportation. (See Figure 2.)

WPC began evaluating the impact of light trucks on parking dimensions in 1988, using the same definition of vehicle sizes (ie, a small SUV is comparably sized to a small car.) The size of all light trucks has been increasing in parallel with the size of cars and the overall percentage of small vehicles used for personal transportation has continued to decline. (See Figure 3.)

Since 1996, however, the most significant trend in vehicles has been the development of the sport wagon, a cross between a car and an SUV.[3] This has moderated the impact on parking dimensions of the continuing, steady increase (2 percent per year since 2000) in market share of light trucks, because sport wagons, on average, are smaller than SUVs.

Figure 2. Light Trucks Market Share (Pickups, Vans, SUVs, and Sport Wagons)

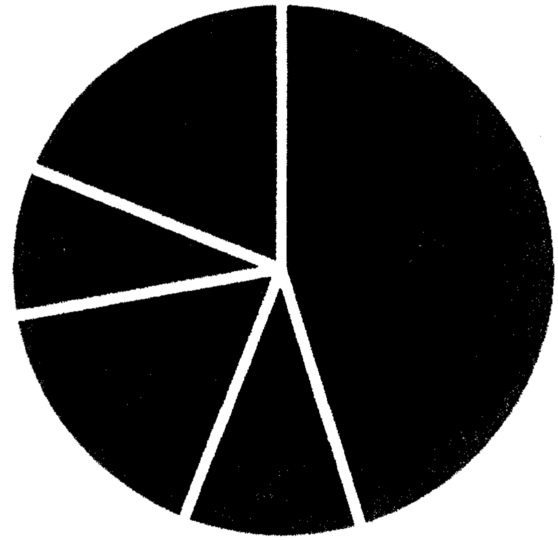


2004 Sales

We have completed our analysis of 2004 (calendar year) vehicle sales. The following summarizes a few key trends:

- Overall, car and light truck sales increased 1.5 percent from 2003.
- Cars dropped from 47 percent of sales in 2003 to 45.4 percent in 2004, apparently due to increasing sales of sport wagons.
- The percent of cars that qualify as small inched down from 32.7 percent

Figure 4. Proportion of Vehicles by Type (CY 2004)



in 2003 to 32.6 percent in 2004.

- The percent of small light trucks inched up, from 7.1 percent to 7.5 percent, due to sales of small sport wagons.
- Overall, the percent of small vehicles still declined, from 19.2 percent to 18.9 percent.
- Annual sales of SUVs are down just a tad (1 percent).
- Annual sport wagon sales have increased from 66,000 in 1996 to 500,000 in 2000 to 1.75 million in 2004. From 2003 to 2004, they increased 17.6 percent.
- Annual sales of vans have declined from 1.8 million in 2000 to less than 1.5 million in 2002-2004, suggesting that minivan drivers have switched to sport wagons. However, van sales were up 4.7 percent in 2004, the first increase since 2000.
- Overall, the percent of vehicles in classes 10 and 11 (the largest vehicles) went up 24.2 percent and 9.3 percent, respectively. Since 2002, class 10 vehicles have increased from 14.3 percent to 16.4 percent of vehicle sales and class 11 went from 9.3 percent to 10.8 percent.

Figure 4 presents the proportion of vehicles by type in 2004 calendar year sales. Together cars, sport utility vehicles and sport wagons represent almost three-fourths of the market. We believe that our analysis using all light trucks sold in a calendar year is conservative for determination of parking geometrics, because a significant number of pickups and vans (especially the largest of the large, such as extended vans that can carry up to 15 people), are used for commercial purposes and are not likely to be present in parking lots in the same proportion as they comprise in vehicle sales. That is, while class 11 comprises 10.8 percent of sales, we would expect less than 10 percent of the vehicles parked in most parking facilities at any one time to be class 11 vehicles.

It is interesting to note that higher gas prices in the spring/summer of 2004 did not significantly affect the size of vehicles sold overall for the entire year. While some have noted significant declines in the annual sales of certain very large SUVs (Expedition and Suburban sales down 12 percent in 2004 from 2003, Ford Excursion sales down 24 percent and the Hummer H1 down 39 percent), those declines were countered by significantly increased sales of the GMC Yukon XL (up 85 percent) and the Cadillac Escalade (up 21 percent.) Overall, class 11 sales (the largest of the large) of SUVs increased 5.2 percent from 2003 to 2004. In the same period, sales of Class 10 sport utility vehicles went up by almost one-third (32.6 percent).

However, it is believed that this increase in large SUV sales was driven to at least some extent by the expiration of certain federal tax breaks last year. For many years, there was a tax break that allowed small business owners (intended for farmers and construction companies) to deduct as a business expense as much as $100,000 of the cost when they bought "trucks" over 6,000 pounds. Savvy accountants were quietly recommending that clients take advantage of it and buy large SUVs, which according to the federal government are "trucks." For example, as noted in a January 2003 news report[4] by KOMO (a TV station in Seattle), a new Land Rover with a sticker price of $72,000 at that time cost only $50,000 after the tax break. When Congress realized what was going on, it placed a ceiling on the amount of the deduction to $25,000 for SUVs, effective October 1 last year. An additional tax break providing a first year bonus depreciation of 50 percent for new vehicles used for business also expired on December 31 of last year. The press reported the changes, and people ran out to buy big vehicles before the credits disappeared. Some bought a vehicle they otherwise wouldn't have bought at that time, others bought a much larger vehicle than they would otherwise have bought.

According to *Automotive News*[5], 13,546 Land Rovers were sold last year, a 12.1 percent increase over the prior year, and 14.1 percent of the annual sales occurred in December. It is believed that the credit particularly drove sales of the luxury SUVs, such as the Cadillac Escalade, GMC Yukon XL, and Range Rover, and probably "propped up" sales for Expeditions and Suburbans as well as large pickups. It also ; likely that some who intended to buy large vehicles in 2005 accelerated the purchase to late 2004.

Trends in First Quarter, 2005

Given the high gas prices again this spring and summer, we evaluated some (but not all) of our metrics for the latest data available from *Automotive News* for the same periods in 2004 and 2005 to see if the trends are significantly different than described above.

Cars vs. Trucks: Car sales through August were up 3.5 percent, while light trucks were up 4.6 percent. Light trucks represented 53.8 percent of the market, as compared to 53.6 percent in the same period last year, and 54.6 percent overall last year. In the month of August, however, there was a distinct upsurge in car sales, with car sales up 10.1 percent and light trucks down 1.6 percent. The percentage of light trucks sold in August dropped from 54 percent in 2004 to 51.2 percent in 2005. Because summer sales have been heavily influenced by the "employee discount" promotion of the Big 3 American manufacturers, it is difficult to know whether the trend to light trucks, as represented by the curve in Figure 2, may have simply leveled out (per the year-to-date data) or will actually turn downwards after for the first time since 1982. The impact of fuel shortages and escalating gas prices due to the hurricane Katrina disaster on vehicle sales is also not yet known.

Light Truck Sales by Class: In the spring and early summer, many newspapers have been commenting on the impact of high gas prices on vehicle sales, with an obvious bias against big vehicles. They report declines in sales of some big vehicles without mentioning sales of others are increasing. They also don't mention other factors, such as the expiration of the tax breaks on large vehicles. To determine what

Table 1: Changes in Sales by Class, YTD July 2005 vs. YTD July 2004

	6 & 7	8 & 9	10 & 11	Overall
Pickups	+0.4%	+1.0%	+14.9%	+11.6%
Vans		–3.6%	+11.2%	+3.0%
Sport Utility	–21.3%	–3.6%	–7.8%	–5.9%
Sport Wagons	+25.0%	+17.0%	+18.6%	+19.1%
All Light Trucks	+11.5%	+2.4%	+8.8%	+5.4%

the actual trend is, we did a simplified analysis of light truck sales in three size categories: "small" (classes 6 and 7), medium (classes 8 and 9) and large (classes 10 and 11) for pickups, vans, sport utility vehicles and sport wagons. This analysis compares sales in the first seven months (through July) of 2005 with those in the same period of 2004. Looking at sales in broader categories reduces the impact of incentives that can and do drive vehicle sales to different models in shorter time frames. We did not evaluate car sales.

As seen in Table 1, there clearly is a continued shift of sales from sport utility vehicles to sport wagons, and more importantly, sport wagon sales appear to be shifting to smaller classes. Conversely, pickups and vans appear to be getting larger as sales increase overall. Some of the decline in large SUV sales may simply be due to accelerated purchases in 2004, due to the expired tax break previously mentioned. However the declines in small and midsize SUV sales clearly indicate that buyers are moving to sport wagons. The increment in "larger" vans is driven by increased sales of the Chrysler Town and Country (up 48 percent), the Chevy Express (up 21 percent) and the Honda Odyssey (up 15 percent). The smaller minivan market clearly has been affected by sport wagons. Overall "small" light trucks have increased 5.4 percent over the same quarter last year.

It is interesting that despite the clear trends in SUV sales, General Motor's CEO Rick Wagoner has continued to argue that high gasoline prices are not going to hurt big SUVs and pickups all that much. In the April 18, 2005 issue of *Automotive News*, Jason Stein quotes Wagoner as saying that buyers of full-sized SUVs are "less income-sensitive." Wagoner blames the age of its large SUV models, which are scheduled to be replaced next January, as the primary reason its large SUV sales are down. In the aforementioned article on Range Rover sales, the vice president for marketing of Range Rover, Sally Eastwood, made the same argument (that gas sales aren't going to affect sales of their larger vehicles), saying that the "break point" on the Range Rover is $5 per gallon. Land Rover officials do expect a short-term decline of sales compared to last year due to reduction in the tax break. A new Range Rover debuted this spring with an emphasis on high-performance luxury, including a supercharged version that the company expects to account for 25 to 30 percent of sales of the Range Rover. That combined with Dodge's continued promotion of a "macho" image, including its Hemmi engines, indicates that the manufacturers believe that performance (i.e., power over fuel efficiency) sells.

At the same time last spring, Ford's public relations spin was that high gas prices clearly were affecting light truck sales, which is not totally supported by the overall increase in light truck sales. But that was perhaps self-serving, since Ford already updated its large SUVs for the 2004 model year and declared 2005 "the year of the car" with several updated or new car models.

Meanwhile, GM delayed some mid-sized car programs in order to get its new full-size SUVs and pickups to market this January. Stein noted in a more recent article "a change of tone" in GM's public com-

One of the clear strategies of the "Big Three" is to move towards hybrids for its larger gas-guzzling vehicles. Hybrids have gas engines supplemented by electric motors recharged by otherwise wasted energy, from activities such as braking.

ments; GM now says that at $3 a gallon there is some impact but GM's spokesman said they don't think gas prices will be at or above $3 by January. For GM stockholders' sake, one hopes not: with gas prices at $3.49 per gallon, it will cost $130.88 to fill the tank of a Chevrolet Suburban, more than double what it cost last January.[6]

However the manufacturers try to spin it, the sales of all light trucks are up 5.4 percent, but larger SUV sales are down almost 8 percent and even GM's spokesman now admits they don't expect large SUV sales to return to peak levels,. Therefore, potential buyers of GM's "old" SUVs aren't turning to other models in the same class, but rather shifting to sport wagons and cars that are not only smaller generally but lighter and more fuel efficient than a comparably sized SUV.

Moreover, the federal government very recently published proposed guidelines for fuel efficiency of light trucks. These standards break the vehicles into groups by size, and then seek to force the fuel efficiency of vehicles in each group up, about only 4-5 mpg by 2001. That is in increase of about 20 percent, and the smallest vehicles in the light truck category (entry level sport wagons such as the Chevy Equinox) would have to achieve 28.4 mpg, more than the standard for all cars (27.5, which won't change.). Given the manufacturers' past ability to get maximum performance and vehicle size at the mandated levels of fuel efficiency, I personally doubt that these new standards will significantly affect vehicle dimensions, other than to keep them from getting any larger!

One of the clear strategies of the "Big Three" is to move towards hybrids for its larger gas-guzzling vehicles. Hybrids have gas engines supplemented by electric motors recharged by otherwise wasted energy, from activities such as braking.

Hybrids: Toyota's hybrid Prius sales more than doubled last year, but the total sold last year was still less than 54,000 vehicles. Interestingly, the 2005 Prius is one inch wider and five inches longer than earlier models. As of this writing, Toyota is on track to sell more than 100,000 Priuses in 2005, again doubling over the prior year. According to the Associated Press[7], the three hybrids on the market last year (Prius, a version of the Honda Civic and the Ford Escape) accounted for 83,000 vehicles in 2004, an 81 percent increase over the prior year, but they remain less than 1 percent of light vehicles sold. As reported by *Automotive News* on August 8, 2005, Toyota expects 25 percent of its sales in the United States to be hybrid by the end of the decade…up from 6.7 percent today—in just four years.

Major manufacturers are planning to introduce a dozen new hybrids in the next three years. For SUVs, the Lexus RX 400h, Mercury Mariner and Toyota Highlander Hybrid are now available. GM's new "hybrid" Silverado and Sierra pickup trucks only use the electric motor for starting the engine and accessories like air conditioning and the radio; the "propulsion" system is not hybrid. The new Dodge Ram hybrid combines diesel and electric power for propulsion. Dodge also plans to introduce a hybrid version of its Sprinter van this year.

However, for those contemplating buying a hybrid primarily to get better gas mileage, beware! Reportedly, the EPA standards for calculating fuel efficiency woefully overestimate the mileage. *Consumer Reports* found that hybrids like the Prius and Civic performed at only 60 percent of the estimated mileage for city driving. For highway driving, expect 75 to 85 percent of the EPA estimate. Because hybrids cost more, Edmonds.com estimates that gas would have to cost $5.60/gallon for hybrid drivers to break even at the end of five years, if they drive 15,000 miles a year.

Moreover, the SUV hybrids tend to use the concept to obtain more performance with only slightly improved fuel efficiency. There is a significant reduction in emissions, which helps the environment in the areas of greenhouse gases and global warming.

What's Next: The next big change is fuel cell vehicles, prototypes of which are already available for fleet use (so limited because a special refueling setup can be provided at the home base of the vehicles.) "Gas tanks" will be replaced by tanks of liquid or gaseous hydrogen. The reaction of hydrogen and oxygen creates the energy to power the vehicle, and the only emission is water vapor. Others are looking at methane rather than hydrogen for fuel cells, because gasoline stations can easily be converted to methane stations and methane comes from natural gas rather than foreign oil. The equipment on the vehicle turns methane into hydrogen for the same reaction.

Some argue that since the most likely source of mass-produced and distributed hydrogen is from carbon-based fossil fuels such as natural gas and gasoline, there will be no significant reduction, overall, in life cycle greenhouse gas emissions, and energy efficiency.[8] (The polluting emissions will simply shift to the plants converting gasoline or natural gas to hydrogen.) MIT, in fact, concluded that hybrid gas/electric and particularly diesel/electric vehicles offer more potential reduction in energy use and greenhouse gasses, at least in the next 15 to 20 years. Those pinning their environmental dreams on hydrogen fuel cells hope that eventually somebody will figure out how to convert water or some other non-carbon source to hydrogen (for example, by solar power at retrofitted gas stations) and then the car turns it back to water while driving...a perfectly non-polluting, endlessly renewable loop.

In the meantime, the industry is working on perfecting the fuel cells themselves. There are many difficulties in the ultimate acceptance of fuel cell vehicles, not the least of which is the likely cost of the vehicles, the bulk of the equipment (leaving only two usable seats in a mini-van), the limited range (100 miles or so between fill-ups) and the cost of providing a hydrogen-distribution system. GM's vision is that the automobile will be completely redesigned around fuel cells, with mechanical systems (like steering and braking) replaced by electronic ones. In fact, GM's "AUTOnomy"[9] concept vehicle would have a single chassis and hydrogen-fuel cell powered engine and power train. Passenger compartments would be replaceable, allowing a growing family to switch from car to a minivan to a sport utility vehicle over the 20-year life of the power train and chassis. That would make the vehicle far more affordable over the life cycle.

Design Vehicles

In order to respond to the trends in vehicle size over time, WPC sought a rational way to determine the appropriate parking dimensions as vehicle sizes change. Early references employed a "design vehicle" that was selected to be "among the larger vehicles" or "above average" on the road at the time. In 1985, WPC adopted the 85th percentile vehicle in the range from smallest to largest vehicle sold as our design vehicle.

WPC essentially assumes that all vehicles parked opposite and on either side of a vacant stall are design vehicles, and yet another design vehicle arrives to park in the stall. Cars larger than the 85th percentile vehicle can still be accommodated in spaces designed using this approach; they simply have less convenience in maneuvering if larger vehicles happen to be parked in the vicinity. The statistical probability, however, is that most of the vehicles parked in the area will be smaller. Table 2 summarizes design vehicles for each type of vehicle (cars, pickups, SUVs, sport wagons and vans) and a "composite design vehicle" representing the 85th percentile vehicle among all vehicle sales at three key points in time.

Table 2: Design Vehicles

	1983 registrations	1998 sales	2004 Sales
Cars	6'3" x 17'2"	6'2" x 16'8"	6'1" x 16'6" Buick LaCrosse
Pickups		6'8" x 18'8"	6'8" x 18'10" Ford F250
Vans		6'8" x 18'3"	6'7" x 18'8" Chevy Express
Sport Utility		6'7" x 17'1"	6'7" x 17'2" Ford Expedition
Sport Wagon		NA	6'5" x 15'9" Acura MDX
Composite Design Vehicle		6'7" x 17'1"	6'7" x 17'4" Ford F 150

Source: Evaluation of Calendar Year Vehicle Sales per Automotive News.

It should be remembered that our analysis is based on new vehicle sales (with the exception of the first year of our research.[10]) It generally takes a few years for the mix of vehicles on the road to approach the mix of sales.

In 1983, the design vehicle among cars seen on the road was one inch longer but four inches narrower than the composite design vehicle in 1998. As we originally only studied cars, the car design vehicle was also the composite design vehicle. In 1983, this design vehicle was already significantly smaller than that of the early 1970s. The design vehicle in at least one reference (Eno Foundation, 1976) was 6'8" x 18'9"; an older reference (Eno Foundation, 1957) recommended a design vehicle of 6'6" by 18'0". Overall, the design vehicle in 1983 was 4 inches narrower and 2 inches shorter than the composite design vehicle today, but you will note that the design vehicle today among cars is even smaller than it was in either 1983 or 1998.

A significant change occurred in 1998 sales: the composite design vehicle changed from a Mercedes-Benz that was 6'3" x 17'1" to the Ford Expedition, which was the same length but four inches wider. Therefore, in 1999, WPC added three inches to our recommended stall widths and added one foot to the recommended modules. (The parking module is the out-to-out dimension of two rows of parked vehicle and the aisle between.) The design vehicle

Table 3: Recommended Dimensions for US Parking

	LOS D	LOS C	LOS B	LOS A
Stall Width:	8'3"	8'6"	8'9"	9'0"
Angle of Park		**Module (ft)**		
45°	46.50	47.50	48.50	49.50
50°	48.25	49.25	50.25	51.25
55°	49.50	50.50	51.50	52.50
60°	51.00	52.00	53.00	54.00
65°	52.25	53.25	54.25	55.25
70°	53.50	54.50	55.50	56.50
75°	54.50	55.50	56.50	57.50
90°	58.50	59.50	60.50	61.50

in 1999 was also the Ford Expedition; from 2000 through 2003, the design vehicle was the Expedition's sister vehicle, the Lincoln Navigator, which was one inch wider and one inch longer than the Expedition. This did not merit a further change in our standards. However, among calendar year 2004 sales, the design vehicle is a base model Ford F150 pickup truck (6'7" x 17'4"). This change occurred because the Navigator's width was increased another two inches for the 2004 model year, causing it to have a larger footprint and "leap-frog" to the other side of the Ford 150 in the range of smallest to largest. The Ford F150 is three inches longer than the Expedition of 1998, and thus one might consider increasing the modules. However we have decided not to do so for several reasons:

- The Expedition, Navigator and Ford F150 are all built on the same platform and have the same wheelbase; the differences in dimensions are fundamentally differences in trim (bumper shape, wheel wells, etc).
- The 85th percentile is reached just across the border between the Ford F150 and the next smaller vehicle, not well into the Ford F150 sales.
- Our analysis is conservative because it includes all pickups and vans sold, even though many of the largest vehicles are used solely for commercial purposes and are less likely to be in the mix of vehicles in most parking lots than sales would indicate.
- We believe the still-increasing sales of sport wagons and extended high prices of gasoline could cause the design vehicle to become smaller in the next year or two, as previously discussed. The new fuel efficiency standards for light trucks will also tend to hold vehicle sizes constant.

Recommended Geometrics

Walker employs a Level of Service (LOS) approach to parking design, allowing for customizing the design to the needs of the user and the owner. LOS A dimensions are the most generous, and are often employed in high turnover situations, including shopping centers, airport short-term lots and hospital visitor and patient parking. LOS B might be employed for the same uses in very urban settings where tighter; LOS B is also employed for other visitor situations with less turnover, such as longer-term parking at airports. LOS C parking is often employed for employee parking and/or student parking at universities, although we sometimes move up to LOS B for these uses if a higher level of comfort is desired. LOS D is only employed for valet parking or for longer-term parking in the most urban of settings such as downtown New York City, where people are happy just to find a parking space.

We continue to recommend against small-car-only stalls, except in remnants of space. In no event should there be more than about 15 percent of the parking capacity provided as small car-only stalls (7'9" by 16').

Although the design vehicle did get three inches longer among 2004 sales, we suspect that it may not stay that way very long.

Conclusion

While the size of vehicles did "bottom out" in the 1980s, the evaluation of design vehicles concludes that the vehicles of today remain smaller than those of the early 1970s, before downsizing began. The slow but steady increase in vehicle sizes since 1995 has clearly leveled out as of this writing and if the trends of light truck sales in the first seven months of 2005 (not to mention the sales trends in the month of August) hold through year end, a number of indices regarding vehicle size would turn downwards, including the size of sport wagons, SUVs and pickup trucks. And the overall percent of small vehicles might rise. So we may very well be at another turning point in the road, relative to vehicle sizes.

However, it should be remembered that press reports in summer 2004 when gas prices were high indicated that there was significant impact on large vehicle sales. After gas prices declined, that trend reversed, and overall, sales of large vehicles outpaced smaller ones for the year. Some large SUV and pickup sales may have been driven by late-year incentives by the U.S. manufacturers who were trying to maintain market share, and others may have been driven by the tax break on vehicles over 6000 pounds. Whatever the market forces, the fact is vehicles did get marginally larger last year overall, despite high gas prices in the spring and summer.

But even if the indices we monitor do turn down, vehicle sizes may not get that much smaller. Manufacturers are clearly working hard to improve fuel efficiency overall with hybrids in the short term so as to avoid a significant decline in market share of their (most profitable) larger vehicles. And they clearly seem to feel that performance is more important to the American driver than fuel efficiency. In the longer term, the industry sees fuel cells as the ultimate solution to both pollution and energy conservation but the development of a non-fossil fuel source of hydrogen that can be easily and widely distributed is the key to widespread conversion to fuel cell technology.

In summary, although the design vehicle did get three inches longer among 2004 sales, we suspect that it may not stay that way very long. Therefore, we are not modifying our recommend parking dimensions, which were last adjusted in 1999.

Notes

[1] For the purposes of parking design, the Parking Consultants Council employs a classification of vehicles based on footprint (length times width); classes 5-7 are considered "small"; classes 8-11 are considered large.

[2] According to *Automotive News*, the EPA determined that average horsepower and weight were at their "best," ie, lowest, point in 1981.

[3] WPC employs the *Automotive News* classifications for all vehicles, including the definition of "sport wagons."

[4] *http://www.komotv.com/news/story.asp?ID=22303*

[5] Rick Kranz, "End of big SUV tax break could hurt Range Rover," *Automotive News*, May 2, 2005

[6] Jason Stein, "Fuel costs raise doubts about GM SUVs," *Automotive News*, September 5,2005.

[7] Dee-Ann Durbin, Associated Press, *Indianapolis Star*, Monday April 25,2005

[8] Weiss et al, "Comparative Assessment of Fuel Cell Cars," Massachusetts Institute of Technology Laboratory for Energy and the Environment, Publication LFEE 2003-001 RP

[9] *http://www.gm.com/company/gmability/adv_tech/600_tt/650_future/autonomy_050103.html*

[10] WPC used RL Polk data on vehicle registration nationwide for the initial base line of vehicle sizes then on the road. ℗