The Shade Availability Index
A new quantitative scale to support the design of shaded sidewalks and walking paths

Or Aleksandrowicz, Naama Shapira, Michelle C. Levenson, Shachar Zur and David Pearlmutter

TECHNION Israel Institute of Technology | Faculty of Architecture and Town Planning

BDAR Big Data in Architectural Research Lab

SAMUEL Neaman Institute FOR NATIONAL POLICY RESEARCH

אוניברסיטת בן-גוריון בנגב Ben-Gurion University of the Negev

11 July 2025, ICUC12

Habima Square, Tel Aviv-Yafo
Designer: Dani Karavan

Shade is a design feature

Lack of shade is a design failure

Shade Index (SI): describes on a scale of 0 to 1 the ratio between maximum incoming insolation and blocked insolation for a specific point or area

$$SI_p = 1 - \left(\frac{Insolation_p}{Insolation_r} \right)$$

Aleksandrowicz, Or, Shachar Zur, Yonatan Lebendiger, and Yoav Lerman. "Shade Maps for Prioritizing Municipal Microclimatic Action in Hot Climates: Learning from Tel Aviv-Yafo." Sustainable Cities and Society 53 (February 1, 2020): 101931.

Spring/Summer Shade Index

Color	Range
	0.00 - 0.02
	0.03 - 0.04
	0.05 - 0.06
	0.07 - 0.08
	0.09 - 0.11
	0.12 - 0.14
	0.15 - 0.17
	0.18 - 0.21
	0.22 - 0.26
	0.27 - 0.31
	0.32 - 0.38
	0.39 - 0.46
	0.47 - 0.58
	0.59 - 0.81
	0.82 - 1.00

Spring/Summer Shade Index

■	0.00 - 0.02
■	0.03 - 0.04
■	0.05 - 0.06
■	0.07 - 0.08
■	0.09 - 0.11
■	0.12 - 0.14
■	0.15 - 0.17
■	0.18 - 0.21
■	0.22 - 0.26
■	0.27 - 0.31
■	0.32 - 0.38
■	0.39 - 0.46
■	0.47 - 0.58
■	0.59 - 0.81
■	0.82 - 1.00

Petah Tikva
Part of a
spring/summer
shade map

Mapping:
Morel Weisthal and Or
Aleksandrowicz

Guidelines for Applying Quantitative Shade Indicators in Urban Planning in Israel

Or Aleksandrowicz, Naama Shapira, Michelle Clark Levenson, Shachar Zur and David Pearlmutter
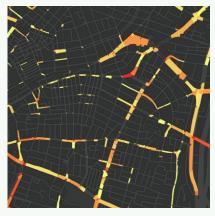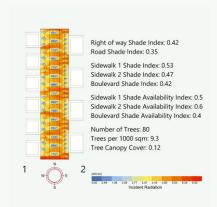
| June 2025

MAP the urban shade hierarchy by using shade maps

PRIORITIZE intervention sites for shade intensification or shade preservation

Right of way Shade Index: 0.42
Road Shade Index: 0.35

Sidewalk 1 Shade Index: 0.53
Sidewalk 2 Shade Index: 0.47
Boulevard Shade Index: 0.42

Sidewalk 1 Shade Availability Index: 0.5
Sidewalk 2 Shade Availability Index: 0.6
Boulevard Shade Availability Index: 0.4

Number of Trees: 80
Trees per 1000 sqm: 9.3
Tree Canopy Cover: 0.12

DESIGN shading according to the Shade Availability Index

Shade quantification: what should we consider?

- Reference Space
  (What is the spatial unit of reference?)

  ➡️ A sidewalk

- Reference Time
  (What is the time span during which shade matters the most?)

  ➡️ 6 August=6 May, 08:00-17:00 (DST)

- Reference surface
  (Which surface should be shaded?)

  ➡️ The sidewalk's surface

Thermal Comfort of Shade?

Rabin Square, Tel Aviv, 14.7.2020

14:37

Air temperature: 29.16 °C
Relative Humidity: 67%
Wind Speed: 1.63 m/s
Global Solar Radiation: 64 W/m^2
MRT: 37.30 °C
Feels like (PET): 31.01 °C
Feels like (UTCI): 32.33 °C

14:22

Air temperature: 29.40 °C
Relative Humidity: 66%
Wind Speed: 2.41 m/s
Global Solar Radiation: 832 W/m^2
MRT: 62.25 °C
Feels like (PET): 40.02 °C
Feels like (UTCI): 37.56 °C

14:52

Air temperature: 29.49 °C
Relative Humidity: 66%
Wind Speed: 1.18 m/s
Global Solar Radiation: 63 W/m^2
MRT: 35.61 °C
Feels like (PET): 31.15 °C
Feels like (UTCI): 32.57 °C

15:03

Air temperature: 29.26 °C
Relative Humidity: 67%
Wind Speed: 1.75 m/s
Global Solar Radiation: 832 W/m^2
MRT: 58.06 °C
Feels like (PET): 39.48 °C
Feels like (UTCI): 37.27 °C
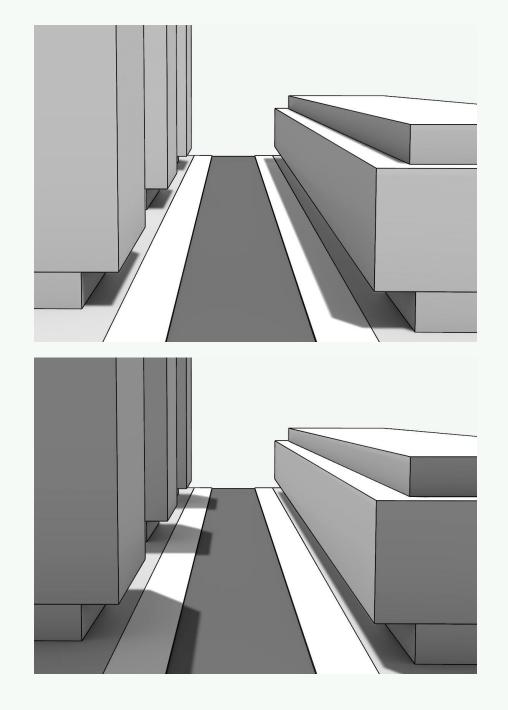
Aleksandrowicz, Or, and David Pearlmutter. "The Significance of Shade Provision in Reducing Street-Level Summer Heat Stress in a Hot Mediterranean Climate." Landscape and Urban Planning 229 (January 2023): 104588.
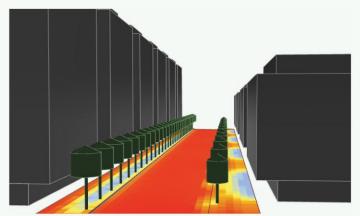
How to quantify shade in detailed design?

The Shade Availability Index (SAI) describes, on a scale of 0 to 1, the ratio of daytime hours during a reference date (for example, 08:00-17:00 on 6 August) when a sidewalk is in a sufficient state of shading.

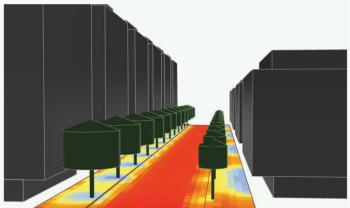A sidewalk is in a sufficient state of shading when at least half of its area at a given moment is shaded.

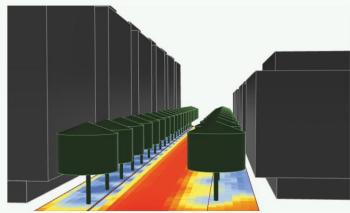# Shading levels rated according to the Shade Availability Index (SAI)

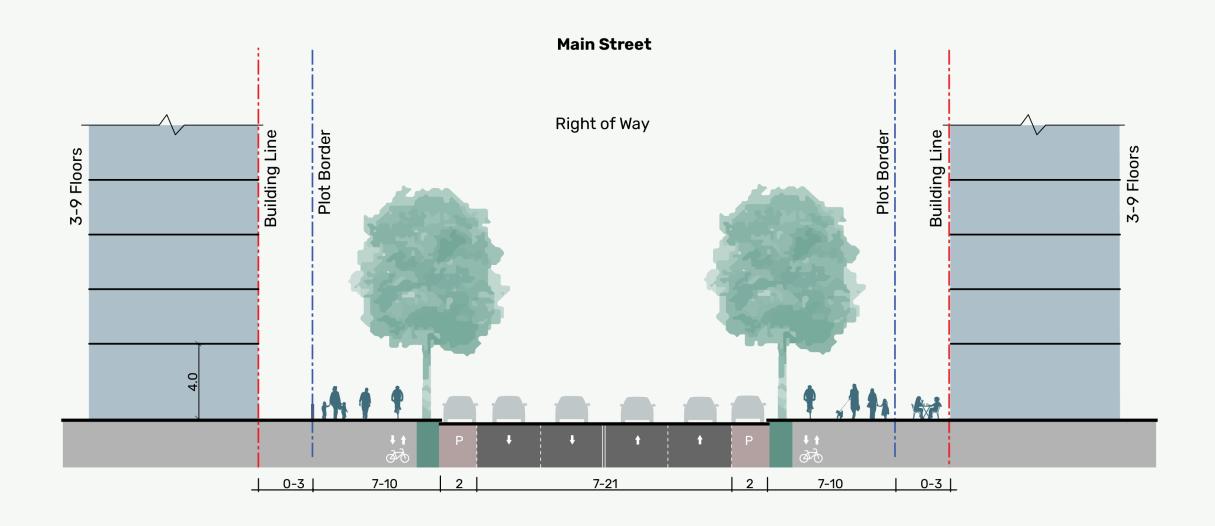**Acceptable shading**

SAI ≥ 0.5

Very good shading

SAI ≥ 0.7

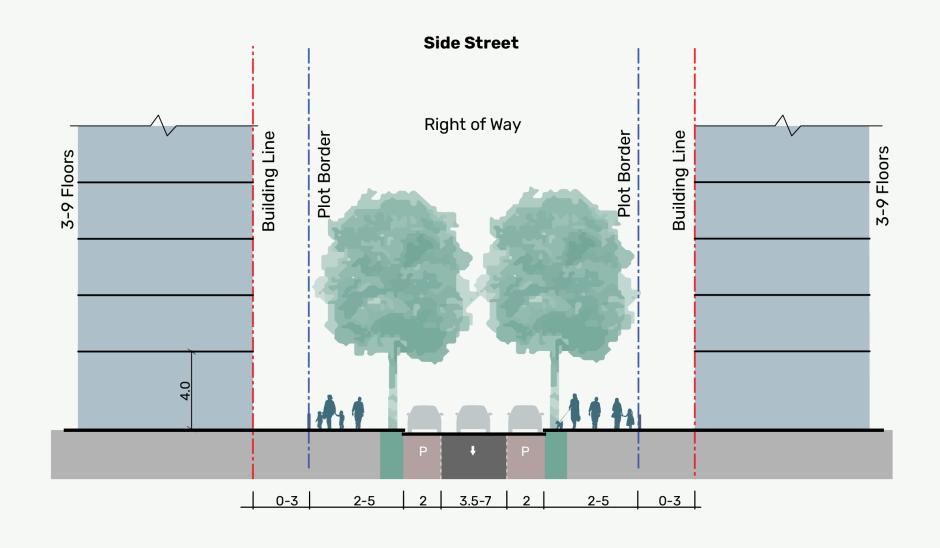**Excellent shading**

SAI ≥ 0.9

Parametric evaluation of the Shade Availability Index

Main Street

Right of Way

3-9 Floors

Building Line

Plot Border

Plot Border

Building Line

3-9 Floors

4.0

P

P

0-3 | 7-10 | 2 | 7-21 | 2 | 7-10 | 0-3

Parametric evaluation of the Shade Availability Index

Side Street

Right of Way

3-9 Floors

Building Line

Plot Border

Plot Border

Building Line

3-9 Floors

4.0

| 0-3 | 2-5 | 2 | 3.5-7 | 2 | 2-5 | 0-3 |

Kikayon 1.6: Grasshopper code for parametric outdoor shade calculation
Or Aleksandrowicz, Ezra Ozery

Side 1 Trees

First row — Add trees? True

Tree type: Tree Type D

Tree trunk setback from curb [m]: 1.0

Number of trees: 8

Resulting distance between tree trunks [m]: 25

Side 2 Trees

First row — Add trees? True

Tree type: Tree Type A

Tree trunk setback from curb [m]: 0.6

Number of trees: 16

Resulting distance between tree trunks [m]: 12.5

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Kikayon 1.6: Grasshopper code for parametric outdoor shade calculation
Or Aleksandrowicz, Ezra Ozery

Radiation Analysis Properties

True=Turn analysis on — True

Analysis resolution [m] — 1

Start month number — 8

End month number — 8

Start date number — 6

End date number — 6
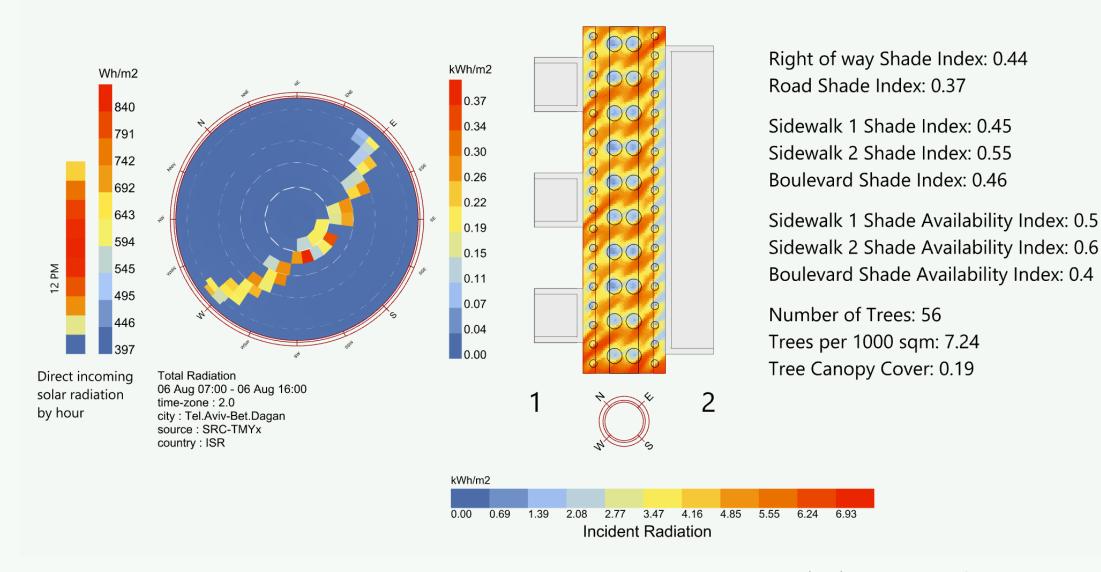
Start hour — 8

End hour — 16

Sadeghipour Roudsari, M., Pak, M.: Ladybug: a parametric environmental plugin for Grasshopper to help designers create an environmentally-conscious design. In: BS2013: 13th International IBPSA Conference. , Chambéry, France (2013).

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Aleksandrowicz, O., & Ozery, E. (2023). A Parametric Tool for Outdoor Shade Design: Harnessing Quantitative Indices and Visual Feedback for Effective and Efficient Climatic Design of Streets. In M. Turrin et al.(Eds.), Computer-Aided Architectural Design (pp. 302–316). Springer Nature Switzerland.

Kikayon 1.6: Grasshopper code for parametric outdoor shade calculation
Or Aleksandrowicz, Ezra Ozery

Wh/m2

840	
791	
742	
692	
643	
594	
545	
495	
446	
397	

12 PM

Direct incoming solar radiation by hour

Total Radiation
06 Aug 07:00 - 06 Aug 16:00
time-zone : 2.0
city : Tel.Aviv-Bet.Dagan
source : SRC-TMYx
country : ISR

kWh/m2

0.37
0.34
0.30
0.26
0.22
0.19
0.15
0.11
0.07
0.04
0.00

Right of way Shade Index: 0.44
Road Shade Index: 0.37

Sidewalk 1 Shade Index: 0.45
Sidewalk 2 Shade Index: 0.55
Boulevard Shade Index: 0.46

Sidewalk 1 Shade Availability Index: 0.5
Sidewalk 2 Shade Availability Index: 0.6
Boulevard Shade Availability Index: 0.4

Number of Trees: 56
Trees per 1000 sqm: 7.24
Tree Canopy Cover: 0.19

1   2

kWh/m2

| 0.00 | 0.69 | 1.39 | 2.08 | 2.77 | 3.47 | 4.16 | 4.85 | 5.55 | 6.24 | 6.93 |

Incident Radiation

Aleksandrowicz, O., & Ozery, E. (2023). A Parametric Tool for Outdoor Shade Design: Harnessing Quantitative Indices and Visual Feedback for Effective and Efficient Climatic Design of Streets. In M. Turrin et al.(Eds.), Computer-Aided Architectural Design (pp. 302–316). Springer Nature Switzerland.

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Rate of compliance with shading targets: Main streets

North-South Orientation

Design scenario (main street)	Planting distance between trees	Percentage of cases in which acceptable shading is achieved (shade availability index: 0.5)		Percentage of cases in which very good shading is achieved (shade availability index: 0.7)		Percentage of cases in which excellent shading is achieved (shade availability index: 0.9)	
		Western sidewalk	Eastern sidewalk	Western sidewalk	Eastern sidewalk	Western sidewalk	Eastern sidewalk
Buildings only		55	56	7	7	0	0
Buildings and *Celtis bungeana* trees after 5 years of growth	10 m	66	65	14	13	0	0
Buildings and *Delonix regia* trees after 5 years of growth		70	68	19	18	0	0
Buildings and shade trees (*C. bungeana/D. regia*) trees after 10 years of growth		100	99	98	97	69	72
Buildings and *C. bungeana* trees after 5 years of growth	5 m	78	83	44	53	9	7
Buildings and *D. regia* trees after 5 years of growth		100	97	89	84	33	32
Buildings and shade trees (*C. bungeana/D. regia*) trees after 10 years of growth		100	100	100	100	99	95

Northeast-Southwest Orientation

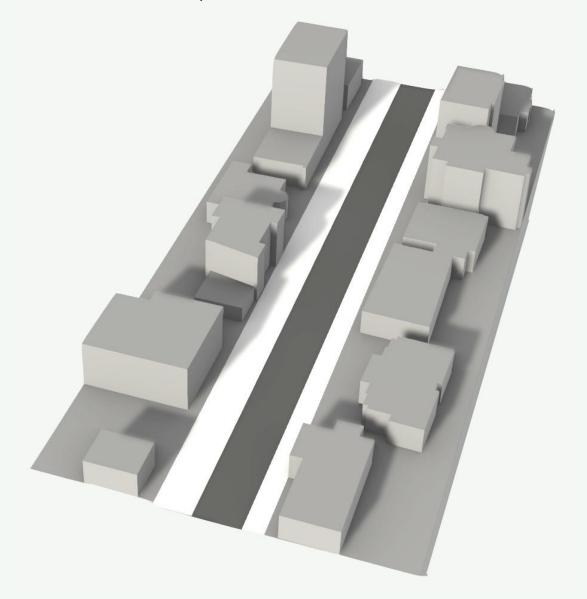| Design scenario (main street)	Planting distance between trees	Percentage of cases in which acceptable shading is achieved (shade availability index: 0.5)		Percentage of cases in which very good shading is achieved (shade availability index: 0.7)		Percentage of cases in which excellent shading is achieved (shade availability index: 0.9)	
		South-western sidewalk	North-eastern sidewalk	South-western sidewalk	North-eastern sidewalk	South-western sidewalk	North-eastern sidewalk
Buildings only		10	59	0	7	0	0
Buildings and *Celtis bungeana* trees after 5 years of growth	10 m	25	69	2	15	0	0
Buildings and *Delonix regia* trees after 5 years of growth		34	73	3	19	0	0
Buildings and shade trees (*C. bungeana /D. regia*) trees after 10 years of growth		100	100	100	97	82	84
Buildings and *C. bungeana* trees after 5 years of growth	5 m	82	92	28	71	0	22
Buildings and *D. regia* trees after 5 years of growth		100	96	76	80	40	43
Buildings and shade trees (*C. bungeana /D. regia*) trees after 10 years of growth		100	100	100	95	99	96

East-West Orientation

Design scenario (main street)	Planting distance between trees	Percentage of cases in which acceptable shading is achieved (shade availability index: 0.5)		Percentage of cases in which very good shading is achieved (shade availability index: 0.7)		Percentage of cases in which excellent shading is achieved (shade availability index: 0.9)	
		Northern sidewalk	Southern sidewalk	Northern sidewalk	Southern sidewalk	Northern sidewalk	Southern sidewalk
Buildings only		0	31	0	7	0	0
Buildings and *Celtis bungeana* trees after 5 years of growth	10 m	0	44	0	32	0	4
Buildings and *Delonix regia* trees after 5 years of growth		0	51	0	41	0	16
Buildings and shade trees (*C. bungeana/D. regia*) trees after 10 years of growth		100	86	100	82	97	79
Buildings and *C. bungeana* trees after 5 years of growth	5 m	22	60	19	52	0	28
Buildings and *D. regia* trees after 5 years of growth		51	70	46	64	25	44
Buildings and shade trees (*C. bungeana/D. regia*) trees after 10 years of growth		100	94	100	93	97	88

Rate of compliance with shading targets: Side streets

North-South Orientation

Design scenario (side street)	Planting distance between trees	Percentage of cases in which acceptable shading is achieved (shade availability index: 0.5)		Percentage of cases in which very good shading is achieved (shade availability index: 0.7)		Percentage of cases in which excellent shading is achieved (shade availability index: 0.9)	
		Western sidewalk	Eastern sidewalk	Western sidewalk	Eastern sidewalk	Eastern sidewalk	Western sidewalk
Buildings only		89	92	53	59	0	10
Buildings and *Celtis bungeana* trees after 5 years of growth	10 m	98	94	70	77	16	25
Buildings and *Delonix regia* trees after 5 years of growth		99	95	73	82	19	41
Buildings and shade trees (*C. bungeana/D. regia*) trees after 10 years of growth		100	100	100	100	100	100
Buildings and *C. bungeana* trees after 5 years of growth	5 m	100	100	99	98	80	85
Buildings and *D. regia* trees after 5 years of growth		100	100	100	100	98	96
Buildings and shade trees (*C. bungeana/D. regia*) trees after 10 years of growth		100	100	100	100	100	100

Northeast-Southwest Orientation

Design scenario (side street)	Planting distance between trees	Percentage of cases in which acceptable shading is achieved (shade availability index: 0.5)		Percentage of cases in which very good shading is achieved (shade availability index: 0.7)		Percentage of cases in which excellent shading is achieved (shade availability index: 0.9)	
		South-western sidewalk	North-eastern sidewalk	South-western sidewalk	North-eastern sidewalk	South-western sidewalk	North-eastern sidewalk
Buildings only		70	93	30	65	0	9
Buildings and *Celtis bungeana* trees after 5 years of growth	10 m	81	96	47	77	0	24
Buildings and *Delonix regia* trees after 5 years of growth		89	100	66	95	23	73
Buildings and shade trees (*C. bungeana/D. regia*) trees after 10 years of growth		100	100	100	100	100	100
Buildings and *C. bungeana* trees after 5 years of growth	5 m	100	100	100	100	84	93
Buildings and *D. regia* trees after 5 years of growth		100	100	100	100	98	99
Buildings and shade trees (*C. bungeana/ D. regia*) trees after 10 years of growth		100	100	100	100	100	100

East-West Orientation
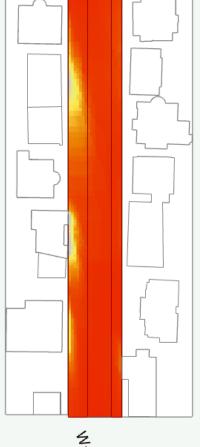
Design scenario (side street)	Planting distance between trees	Percentage of cases in which acceptable shading is achieved (shade availability index: 0.5)		Percentage of cases in which very good shading is achieved (shade availability index: 0.7)		Percentage of cases in which excellent shading is achieved (shade availability index: 0.9)	
		Northern sidewalk	Southern sidewalk	Northern sidewalk	Southern sidewalk	Northern sidewalk	Southern sidewalk
Buildings only		0	71	0	46	0	0
Buildings and *Celtis bungeana* trees after 5 years of growth	10 m	71	86	5	84	0	75
Buildings and *Delonix regia* trees after 5 years of growth		96	90	75	88	2	80
Buildings and shade trees (*C. bungeana/D. regia*) trees after 10 years of growth		100	100	100	100	100	99
Buildings and *C. bungeana* trees after 5 years of growth	5 m	100	93	100	92	100	84
Buildings and *D. regia* trees after 5 years of growth		100	98	100	96	100	94
Buildings and shade trees (*C. bungeana/D. regia*) trees after 10 years of growth		100	100	100	100	100	100

How to design shade with the SAI?
A real-life example

Ben Ami Street, Acre

Source: Survey of Israel

Ben Ami Street, Acre

Right-of-way Shade Index: 0.09
Road Shade Index: 0.04

Sidewalk 1 Shade Index: 0.18
Sidewalk 2 Shade Index: 0.06

Sidewalk 1 Shade Availability Index: 0.1
Sidewalk 2 Shade Availability Index: 0.0

Number of trees: 0
Trees per 1000 sqm: 0
Tree canopy cover ratio: 0

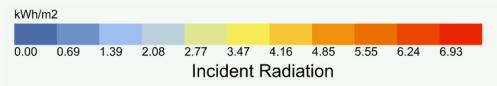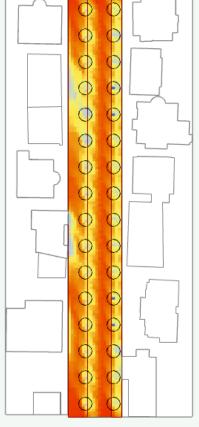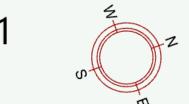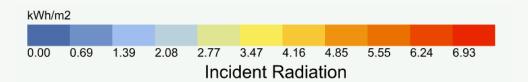Baseline, no trees

Width of the southern sidewalk (1): 7.2 m

Width of the northern sidewalk (2): 3.9 m

Right-of-way width: 20.1 m

Street segment length: 160 m

kWh/m2

0.00 0.69 1.39 2.08 2.77 3.47 4.16 4.85 5.55 6.24 6.93

Incident Radiation

Ben Ami Street, Acre

Right-of-way Shade Index: 0.34
Road Shade Index: 0.28

Sidewalk 1 Shade Index: 0.34
Sidewalk 2 Shade Index: 0.49

Sidewalk 1 Shade Availability Index: 0.3
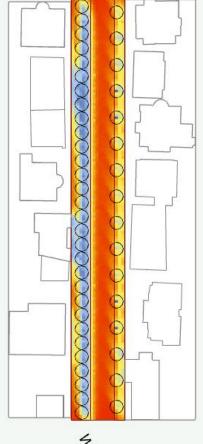Sidewalk 2 Shade Availability Index: 0.6
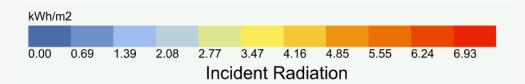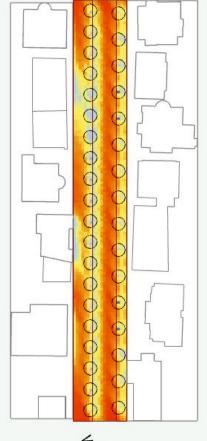
Number of trees: 32
Trees per 1000 sqm: 10.08
Tree canopy cover ratio: 0.20

Adding 16 Delonix regia trees (10 m tree intervals), shading conditions after 5 years.

1   2

kWh/m2

| 0.00 | 0.69 | 1.39 | 2.08 | 2.77 | 3.47 | 4.16 | 4.85 | 5.55 | 6.24 | 6.93 |

Incident Radiation

Ben Ami Street, Acre

Right-of-way Shade Index: 0.37
Road Shade Index: 0.32

Sidewalk 1 Shade Index: 0.38
Sidewalk 2 Shade Index: 0.49
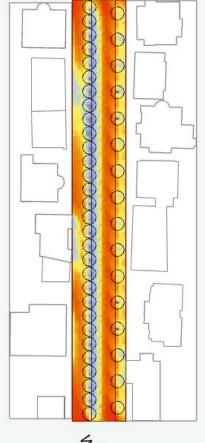
Sidewalk 1 Shade Availability Index: 0.4
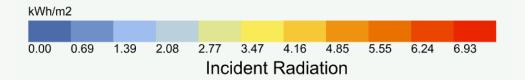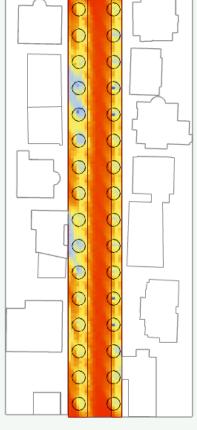Sidewalk 2 Shade Availability Index: 0.6

Number of trees: 36
Trees per 1000 sqm: 11.34
Tree canopy cover ratio: 0.22

Adding two additional Delonix regia trees to the southern sidewalk, shading conditions after 5 years.

1   2

kWh/m2

| 0.00 | 0.69 | 1.39 | 2.08 | 2.77 | 3.47 | 4.16 | 4.85 | 5.55 | 6.24 | 6.93 |

Incident Radiation

Ben Ami Street, Acre

Right-of-way Shade Index: 0.43
Road Shade Index: 0.40

Sidewalk 1 Shade Index: 0.45
Sidewalk 2 Shade Index: 0.49

Sidewalk 1 Shade Availability Index: 0.4
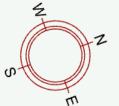Sidewalk 2 Shade Availability Index: 0.6
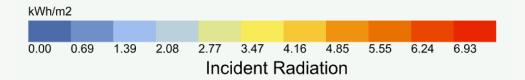
Number of trees: 46
Trees per 1000 sqm: 14.48
Tree canopy cover ratio: 0.28

Increasing the number of Delonix regia trees on the southern sidewalk to 30 (5 m tree intervals), shading conditions after 5 years.

1   2

kWh/m2

0.00   0.69   1.39   2.08   2.77   3.47   4.16   4.85   5.55   6.24   6.93

Incident Radiation

Ben Ami Street, Acre

Right-of-way Shade Index: 0.41
Road Shade Index: 0.21

Sidewalk 1 Shade Index: 0.64
Sidewalk 2 Shade Index: 0.49

Sidewalk 1 Shade Availability Index: 1.0
Sidewalk 2 Shade Availability Index: 0.6
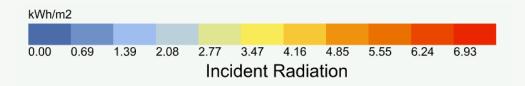
Number of trees: 46
Trees per 1000 sqm: 14.48
Tree canopy cover ratio: 0.28

Moving the Delonix regia trees on the southern sidewalk 3.2 m from the curb, allowing for the integration of a bike lane, shading conditions after 5 years.

1   2

kWh/m2

0.00   0.69   1.39   2.08   2.77   3.47   4.16   4.85   5.55   6.24   6.93

Incident Radiation

Ben Ami Street, Acre

Right-of-way Shade Index: 0.32
Road Shade Index: 0.17

Sidewalk 1 Shade Index: 0.46
Sidewalk 2 Shade Index: 0.49

Sidewalk 1 Shade Availability Index: 0.4
Sidewalk 2 Shade Availability Index: 0.6

Number of trees: 32
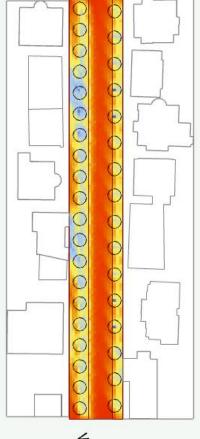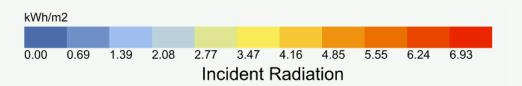Trees per 1000 sqm: 10.08
Tree canopy cover ratio: 0.20

After moving the Delonix regia trees on the southern sidewalk 3.2 m from the curb, re-examine the shading conditions using only 16 trees, shading conditions after 5 years.

kWh/m2

0.00 0.69 1.39 2.08 2.77 3.47 4.16 4.85 5.55 6.24 6.93

Incident Radiation

Ben Ami Street, Acre

Right-of-way Shade Index: 0.34
Road Shade Index: 0.17

Sidewalk 1 Shade Index: 0.49
Sidewalk 2 Shade Index: 0.49
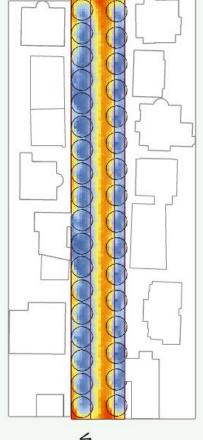
Sidewalk 1 Shade Availability Index: 0.5
Sidewalk 2 Shade Availability Index: 0.6

Number of trees: 34
Trees per 1000 sqm: 10.71
Tree canopy cover ratio: 0.21

Adding two additional trees on the southern sidewalk (18 in total) to achieve the minimum threshold on both sidewalks, shading conditions after 5 years.

kWh/m2

| 0.00 | 0.69 | 1.39 | 2.08 | 2.77 | 3.47 | 4.16 | 4.85 | 5.55 | 6.24 | 6.93 |

Incident Radiation

1   2

Ben Ami Street, Acre

Right-of-way Shade Index: 0.65
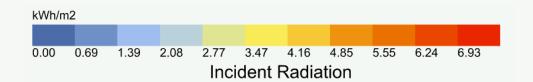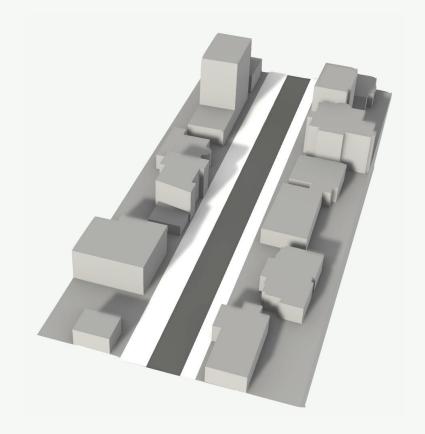Road Shade Index: 0.48

Sidewalk 1 Shade Index: 0.79
Sidewalk 2 Shade Index: 0.84

Sidewalk 1 Shade Availability Index: 1.0
Sidewalk 2 Shade Availability Index: 1.0
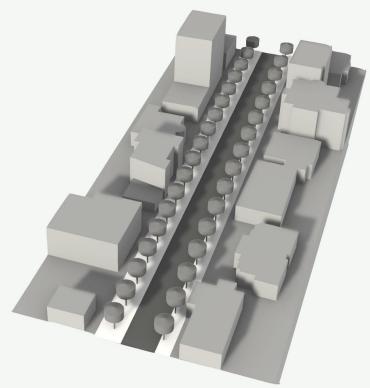
Number of trees: 34
Trees per 1000 sqm: 10.71
Tree canopy cover ratio: 0.21

Calculating shading conditions after 10 years.

kWh/m2

| 0.00 | 0.69 | 1.39 | 2.08 | 2.77 | 3.47 | 4.16 | 4.85 | 5.55 | 6.24 | 6.93 |

Incident Radiation

Ben Ami Street, Acre
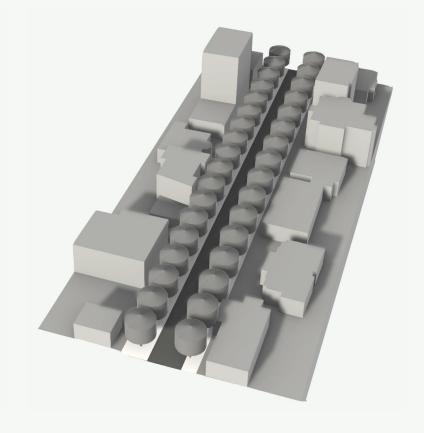
Baseline: Remotely under the minimum shading threshold

After 5 years: Achieving acceptable shading on both sidewalks using 34 trees

After 10 years: Achieving the highest level of shading on both sidewalks without additional trees

Keep Cool!

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