

Optimization of Ski Resort Layouts

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Trail Map of Ski Resort

Zermatt, Switzerland

www.ski-zermatt.com



What is a Chairlift?



Waiting in Line to Board a Chairlift



Objective

- ▶ Analyze how to equally disperse skiers across a mountain on ski slopes and chairlifts to reduce lift lines and crowding
- ▶ Given a mountain layout, determine what type of lifts optimize the resort to minimize wait time and reduce cost

Use Case Diagram



Requirements

► Resort Requirements

- Combining the lifts, slopes, and outside walking areas, the resort has a maximum capacity before crowds make it uncomfortable and unsafe.
- The flow of the system follows the basic equation: $\text{Lift capacity} = \text{Slope capacity} + \text{Waiting capacity}$
- All lifts have vehicles and motors suitable to support riders of any human size, weight, and possible handicap

► Lift Requirements

- Lift lines should have a set maximum wait period before boarding (percentage of flow).
- Each lift has a maximum capacity depending on number of vehicles (chairs), distance between riders, and capacity per vehicle.

► Slope Requirements

- The maximum capacity of each slope is estimated at a point before safety is jeopardized (assuming slope capacity is much greater than lift capacity).
- The resort must contain slopes of various difficulty levels to accommodate skiers of all abilities.
- Lesser skilled skiers must be able to reach the entrance/exit of the resort via slopes of their ability.

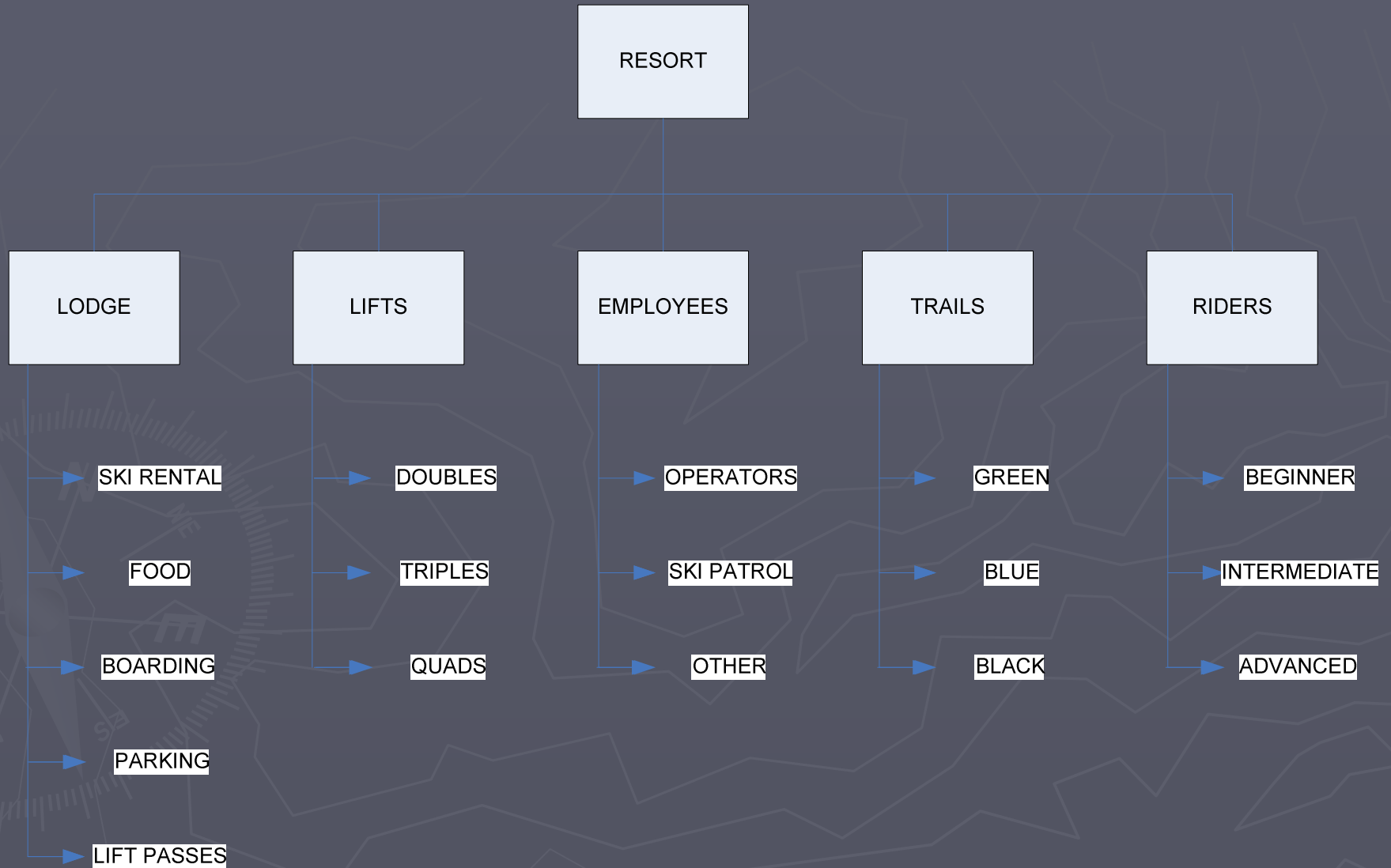
► Business Requirements

- Determine the maximum desired wait period to board a lift (based on maximum capacity of the resort)
- Determine the maximum capacity on the slopes based on the maximum capacity of the lifts
- Determine the total capacity in the resort
- Determine the impact to the resort if one lift is not operating (bottlenecks, overcrowding, ability to remain open)

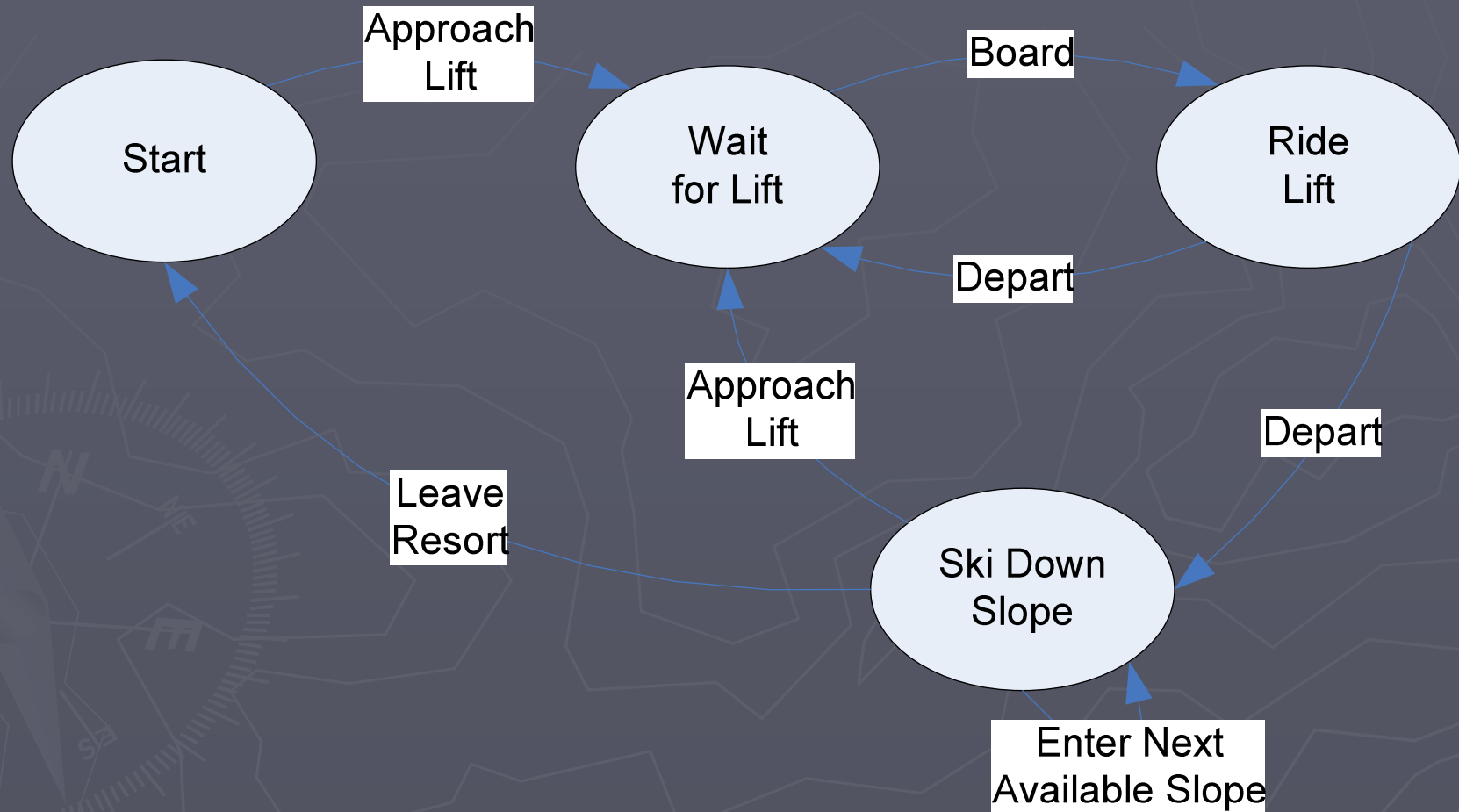
Behavior and Assumptions

- ▶ The simulated ski resort is below the tree line. There are no bowls or open areas, only distinct paths from top to bottom and bottom to top of the mountain.
- ▶ Other factors that spread people around mountain are IGNORED:
 - Falling and stopping (flow is based on average, which takes into account more falls on beginner slopes)
 - Location of a lodge (eating, bathroom, taking a break, meeting people, etc)
 - Weather and snowmaking
 - Races (open/closed slopes)
 - Terrain (moguls, grooming, ice, powder, etc are criteria for rating the difficulty of a slope)
- ▶ The capacity of each lift varies with length, number of seats per chair, and distance between chairs.
- ▶ Weather, whatever it may be, is the same across the entire mountain.
- ▶ Cost is not in dollars, but in terms of a cost factor

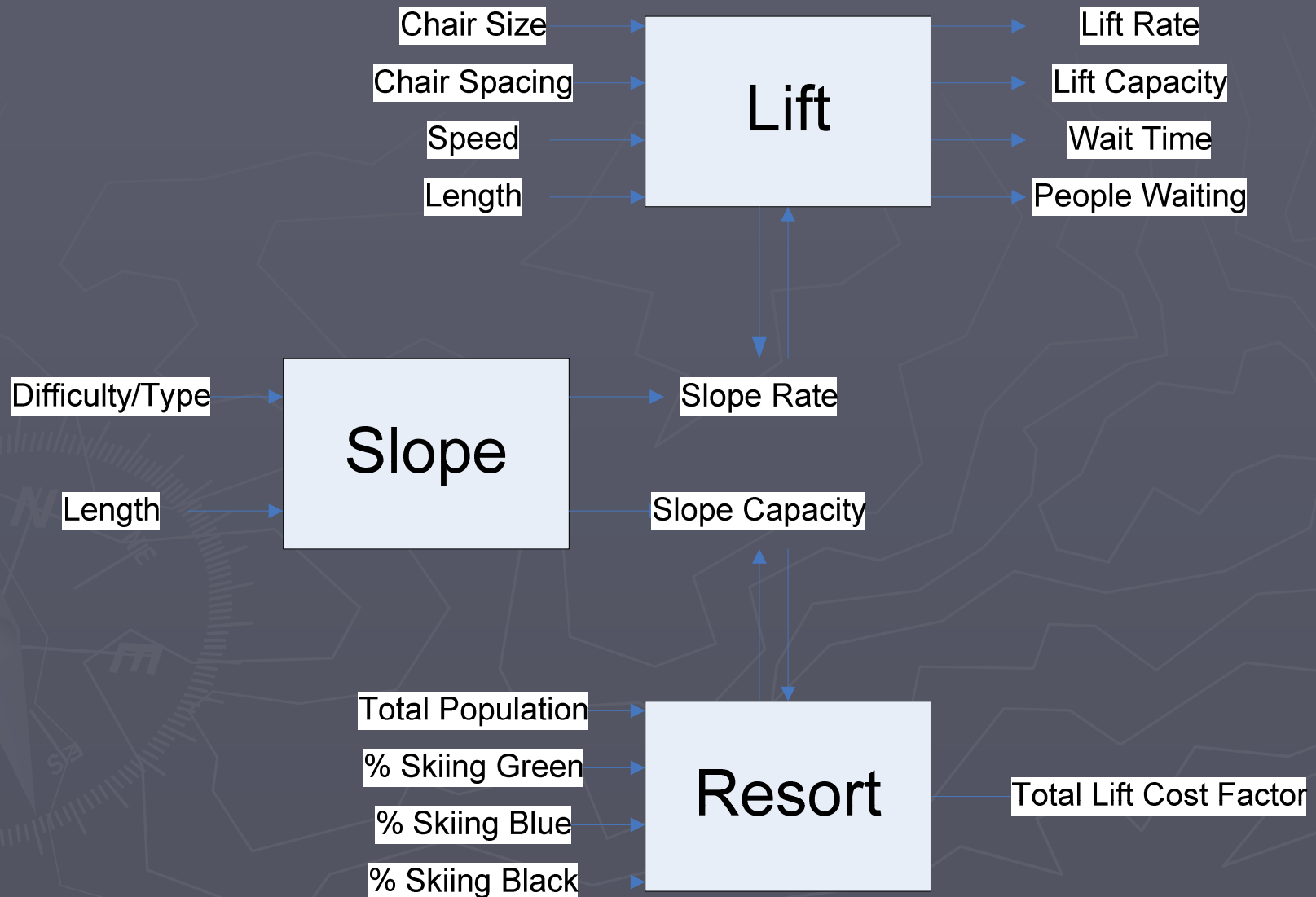
Structure Diagram



State Diagram



Input/Output



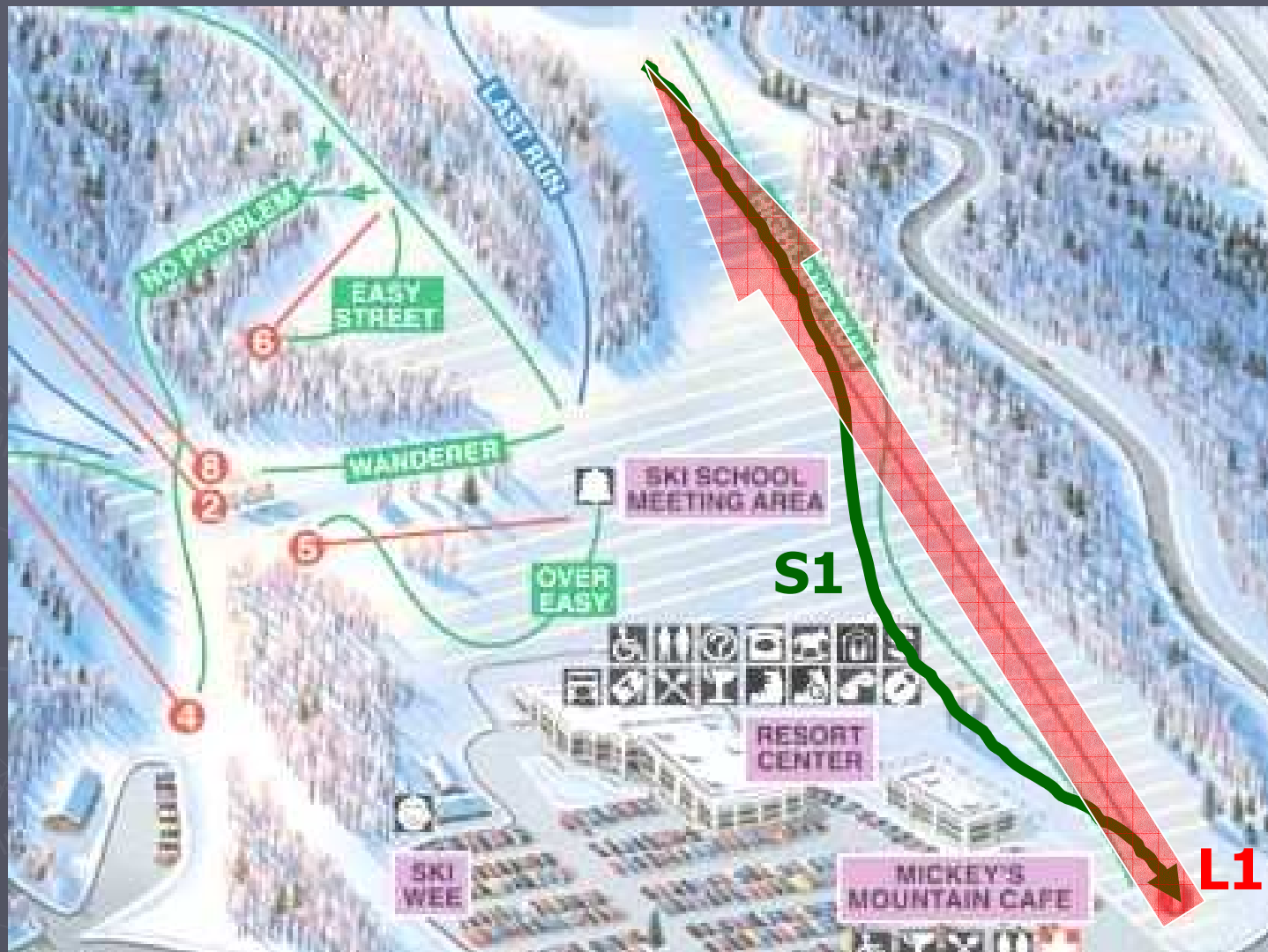
The Model

- ▶ Flow going up mountain = Flow going down mountain + Wait period to board lift
- ▶ Flow = Capacity/Length
- ▶ Wait period has a capacity
- ▶ Total population in resort (Input)
- ▶ Lift info (size, speed, etc.) (Input)
- ▶ Types of slopes (Input)
- ▶ Outputs: Wait time and Cost factor

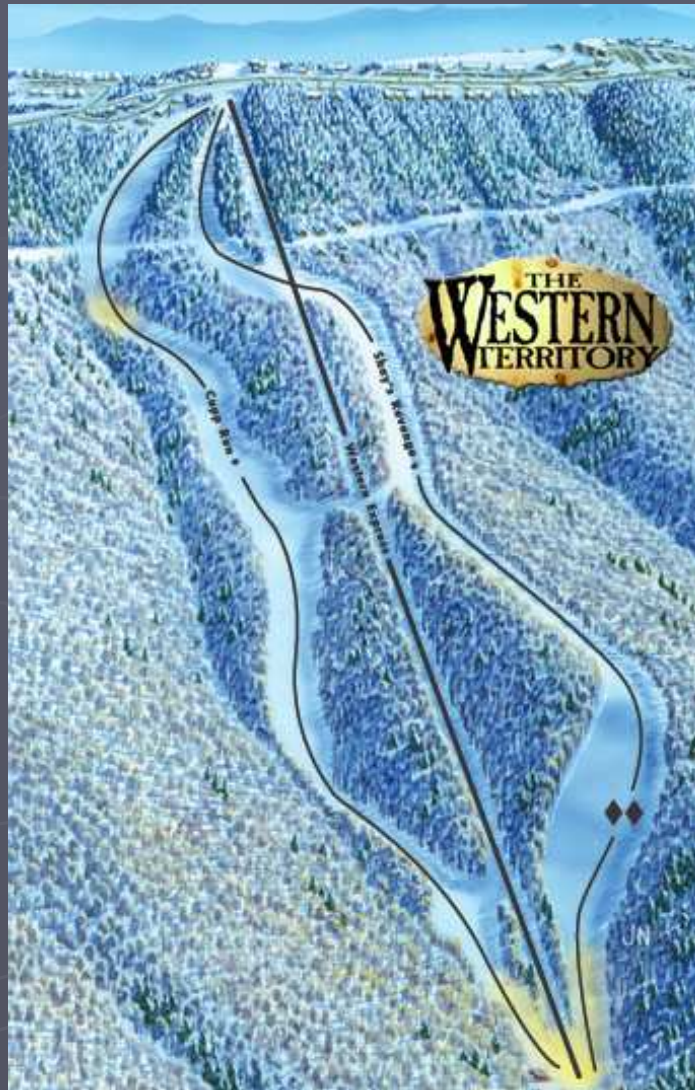
Winterplace, WV



1 Lift, 1 Slope



Snowshoe, WV



1 Lift, 2 Slopes



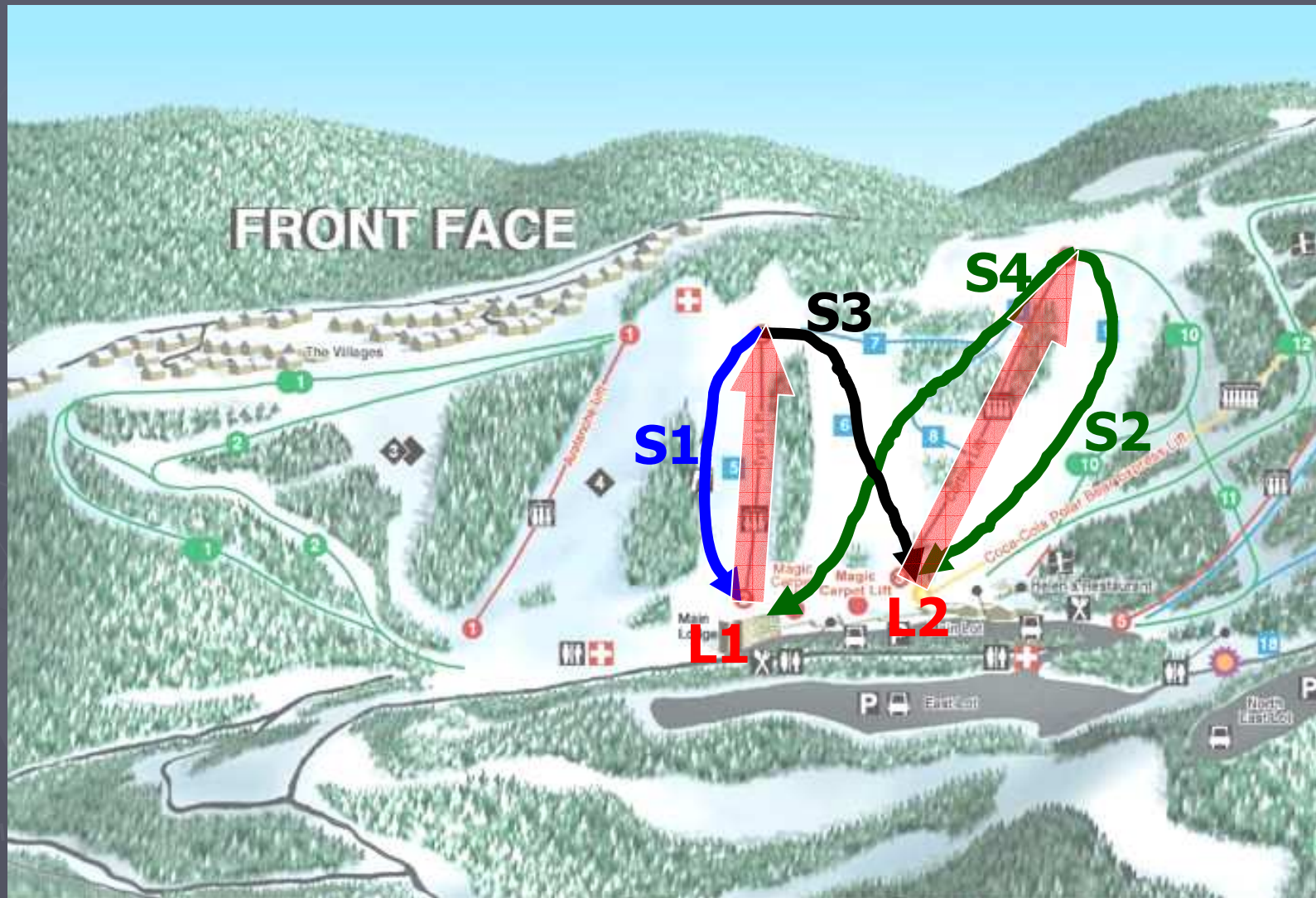
1 Lift, 2 Slopes

Lift 1 Data			Slope 1 Data			Resort Data			
Specification	Quantity	Units	Specification	Quantity	Units	Specification	Quantity	Units	
Lift Chair Size =	2	seats	Type of Slope =	Blue		Total Resort Population =	700	people	
Lift Chair Spacing =	60	ft	Average Skier Speed =	20	mph	% Green =	0%		
Lift Speed =	1100	ft/min	Converted Skier Speed =	105600	ft/hr	People Skiing Green =	0	people	
Converted Lift Speed =	66000	ft/hr	Slope Length =	9600	ft	% Blue =	70%		
Lift Length =	7200	ft	Slope Capacity =	140	people	People Skiing Blue =	490	people	
Number of Chairs =	120	chairs	Slope Rate =	3520	people/hr	% Black =	30%		
Lift Rate =	2200	people/hr				People Skiing Black =	210	people	
Lift Capacity =	240	seats							
Time Between Chairs =	3.27273	seconds				Lookup Table	mph	%	Total
Total People Waiting =	285	people	Slope 2 Data			Black	30	30%	1
Wait Time =	7.77	minutes	Specification	Quantity	Units	Blue	20	70%	1
Lift Cost Factor =	1388		Type of Slope =	Black		Green	10	0%	0
			Average Skier Speed =	30	mph	Chair Size Lookup Table	Factor		
			Converted Skier Speed =	158400	ft/hr	1	1		
			Slope Length =	8400	ft	2	1.2		
			Slope Capacity =	35	people	3	1.4		
			Slope Rate =	5280	people/hr	4	1.6		

Seven Springs, PA



2 Lifts in Parallel, 4 Slopes



2 Lifts in Parallel, 4 Slopes

Lift 1 Data			Slope 1 Data			Resort Data			
Specification	Quantity	Units	Specification	Quantity	Units	Specification	Quantity	Units	
Lift Chair Size =	4	seats	Type of Slope =	Blue		Total Resort Population =	1000	people	
Lift Chair Spacing =	60	ft	Average Skier Speed =	20	mph	% Green =	70%		
Lift Speed =	450	ft/min	Converted Skier Speed =	105600	ft/hr	People Skiing Green =	700	people	
Converted Lift Speed =	27000	ft/hr	Slope Length =	4200	ft	% Blue =	20%		
Lift Length =	3600	ft	Slope Capacity =	14	people	People Skiing Blue =	200	people	
Number of Chairs =	60	chairs	Slope Rate =	1408	people/hr	% Black =	10%		
Lift Rate =	1800	people/hr	Slope 2 Data			People Skiing Black =	100	people	
Lift Capacity =	240	seats	Specification	Quantity	Units	Total Slope Capacity =	146	people	
Time Between Chairs =	8	seconds	Type of Slope =	Black		Total Slope Rate =	4928	people/hr	
Total People Waiting =	265	people	Average Skier Speed =	30	mph	Total Lift Capacity =	360	people	
Wait Time =	8.82	minutes	Converted Skier Speed =	158400	ft/hr	Total Lift Rate =	3600	people/hr	
Lift Cost Factor =	834		Slope Length =	2400	ft	Total Lifts =	2	lifts	
Lift 2 Data			Slope Capacity =	3	people	Total People Waiting =	494	people	
Specification	Quantity	Units	Slope Rate =	1056	people/hr	Average Wait Time =	8.23	minutes	
Lift Chair Size =	4	seats	Slope 3 Data			Total Lift Cost Factor =	1476		
Lift Chair Spacing =	60	ft	Specification	Quantity	Units	Lookup Table			
Lift Speed =	450	ft/min	Type of Slope =	Green			mph	%	Total
Converted Lift Speed =	27000	ft/hr	Average Skier Speed =	10	mph	Black	30	10%	1
Lift Length =	1800	ft	Converted Skier Speed =	52800	ft/hr	Blue	20	20%	1
Number of Chairs =	30	chairs	Slope Length =	4800	ft	Green	10	70%	2
Lift Rate =	1800	people/hr	Slope Capacity =	57	people	Chair Size Lookup Table			
Lift Capacity =	120	seats	Slope Rate =	1232	people/hr		Factor		
Time Between Chairs =	8	seconds	Slope 4 Data			1	1		
Total People Waiting =	229	people	Specification	Quantity	Units	2	1.2		
Wait Time =	7.65	minutes	Type of Slope =	Green		3	1.4		
Lift Cost Factor =	642		Average Skier Speed =	10	mph	4	1.6		
			Converted Skier Speed =	52800	ft/hr				
			Slope Length =	6000	ft				
			Slope Capacity =	72	people				
			Slope Rate =	1232	people/hr				

Liberty, PA



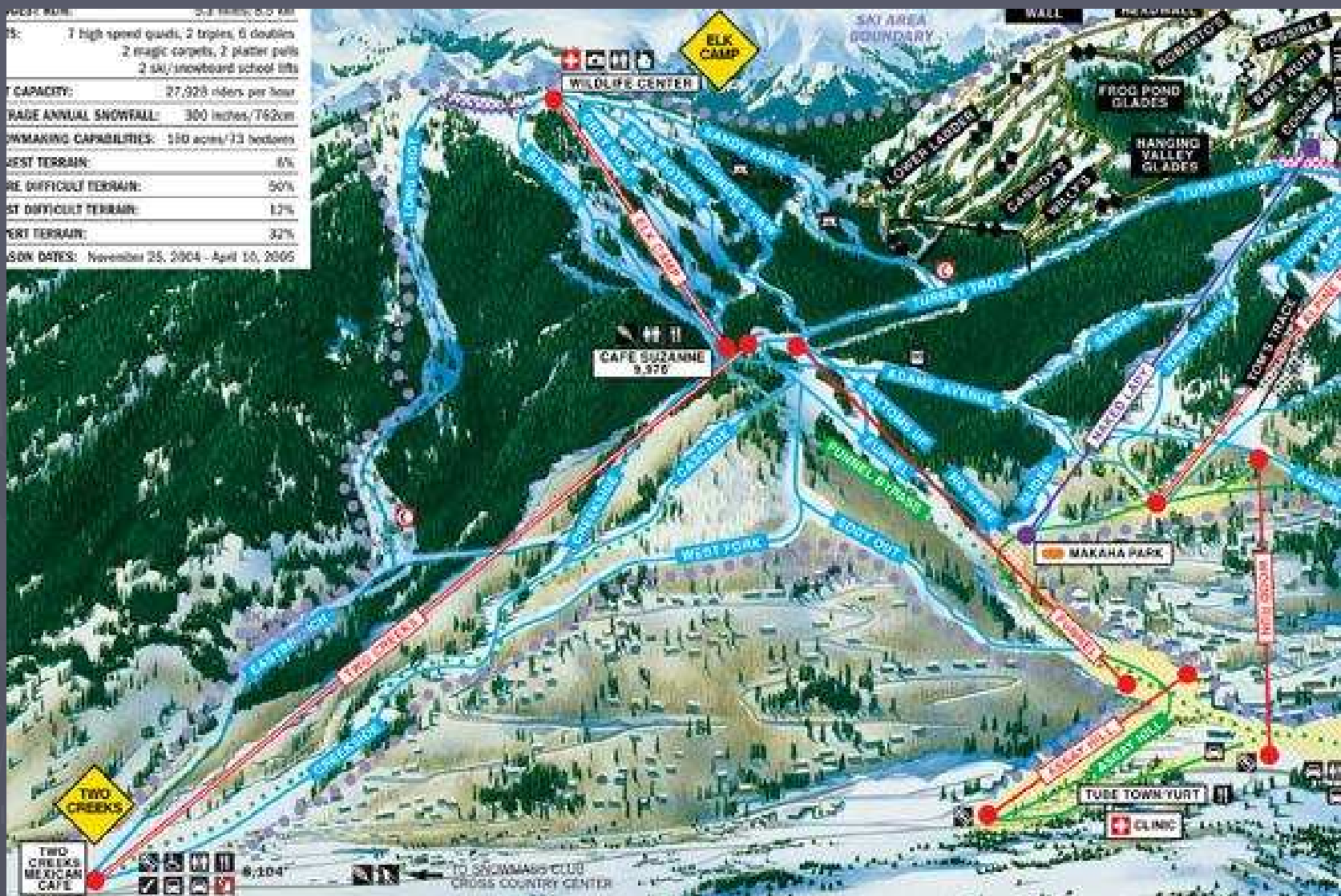
2 Lifts Converging, 2 Slopes



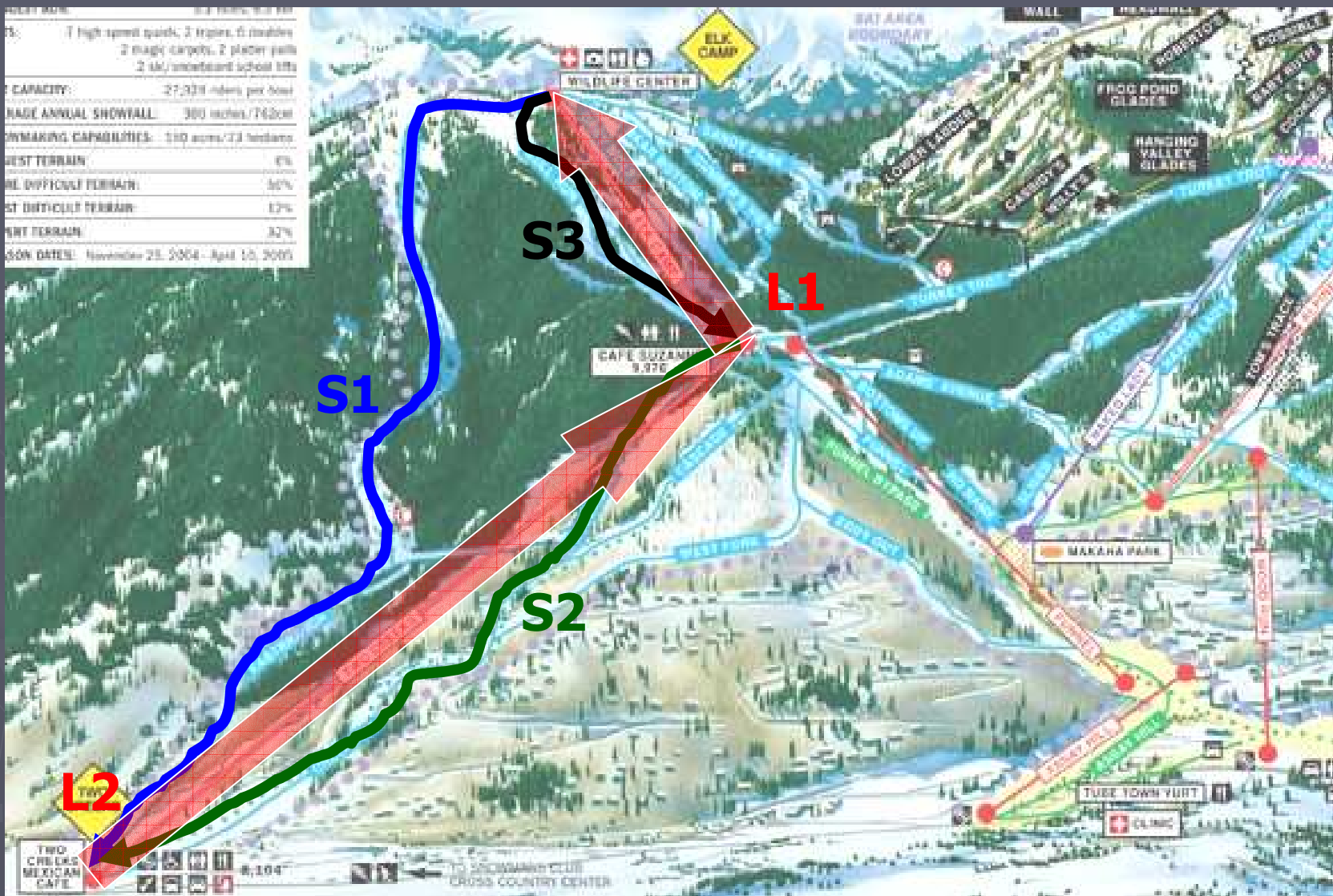
2 Lifts Converging, 2 Slopes

Lift 1 Data			Slope 1 Data			Resort Data		
Specification	Quantity	Units	Specification	Quantity	Units	Specification	Quantity	Units
Lift Chair Size =	3	seats	Type of Slope =	Black		Total Resort Population =	1000	people
Lift Chair Spacing =	60	ft	Average Skier Speed =	30	mph	% Green =	0%	
Lift Speed =	450	ft/min	Converted Skier Speed =	158400	ft/hr	People Skiing Green =	0	people
Converted Lift Speed =	27000	ft/hr	Slope Length =	3200	ft	% Blue =	70%	
Lift Length =	2400	ft	Slope Capacity =	28	people	People Skiing Blue =	700	people
Number of Chairs =	40	chairs	Slope Rate =	2376	people/hr	% Black =	30%	
Lift Rate =	1350	people/hr	Slope 2 Data			People Skiing Black =	300	people
Lift Capacity =	120	seats	Specification	Quantity	Units	Total Slope Capacity =	176	people
Time Between Chairs =	8	seconds	Type of Slope =	Blue		Total Slope Rate =	6072	people/hr
Total People Waiting =	205	people	Average Skier Speed =	20	mph	Total Lift Capacity =	300	people
Wait Time =	9.11	minutes	Converted Skier Speed =	105600	ft/hr	Total Lift Rate =	4650	people/hr
Lift Cost Factor =	618		Slope Length =	4800	ft	Total Lifts =	2	lifts
Lift 2 Data			Slope Capacity =	148	people	Total People Waiting =	524	people
Specification	Quantity	Units	Slope Rate =	3696	people/hr	Average Wait Time =	7.45	minutes
Lift Chair Size =	3	seats				Total Lift Cost Factor =	1970	
Lift Chair Spacing =	60	ft						
Lift Speed =	1100	ft/min				Lookup Table	mph	%
Converted Lift Speed =	66000	ft/hr				Black	30	30%
Lift Length =	3600	ft				Blue	20	70%
Number of Chairs =	60	chairs				Green	10	0%
Lift Rate =	3300	people/hr						
Lift Capacity =	180	seats				Chair Size Lookup Table	Factor	
Time Between Chairs =	3.27273	seconds				1	1	
Total People Waiting =	319	people				2	1.2	
Wait Time =	5.80	minutes				3	1.4	
Lift Cost Factor =	1352					4	1.6	

Snowmass, CO



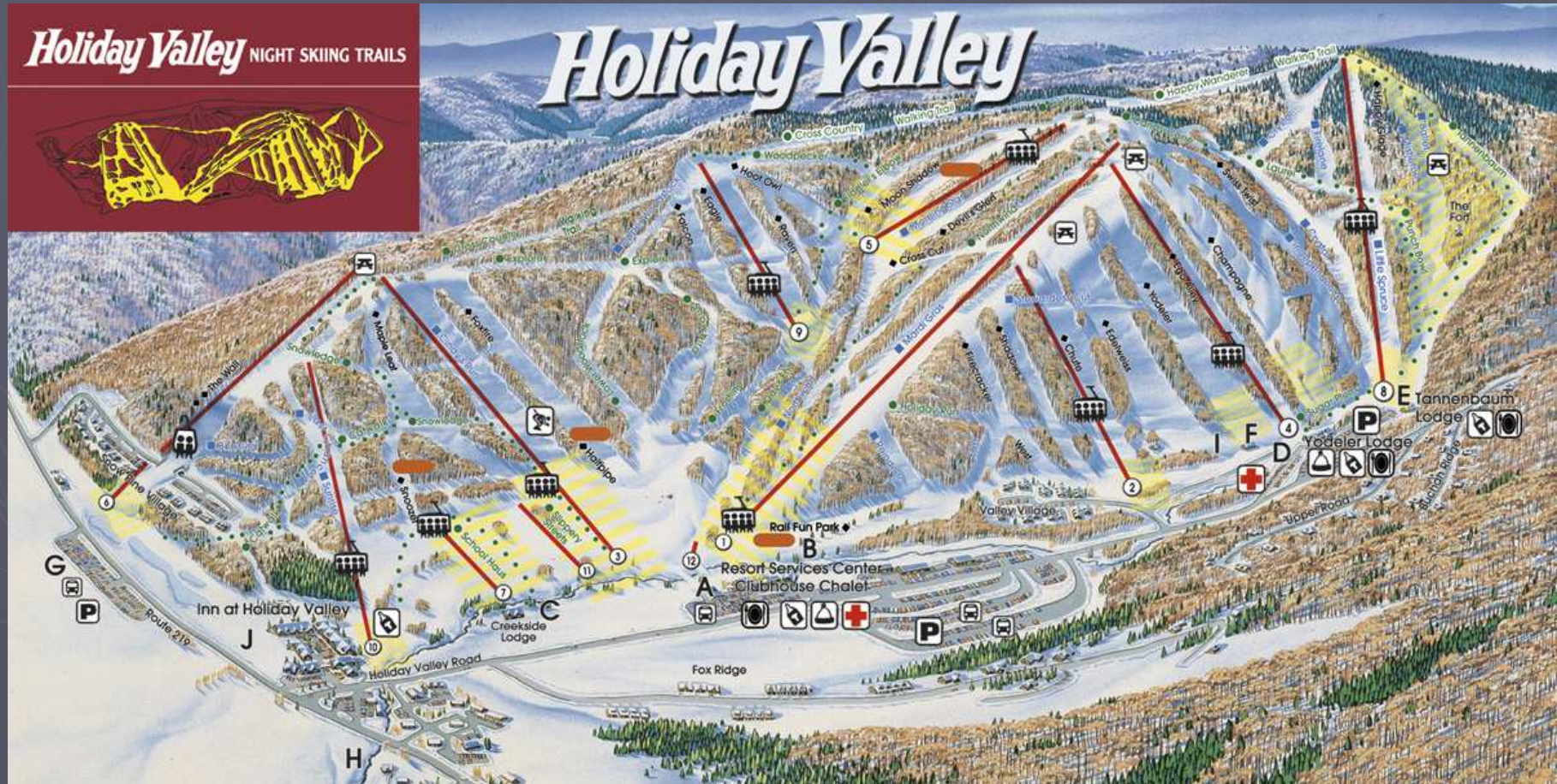
2 Lifts in Series, 3 Slopes



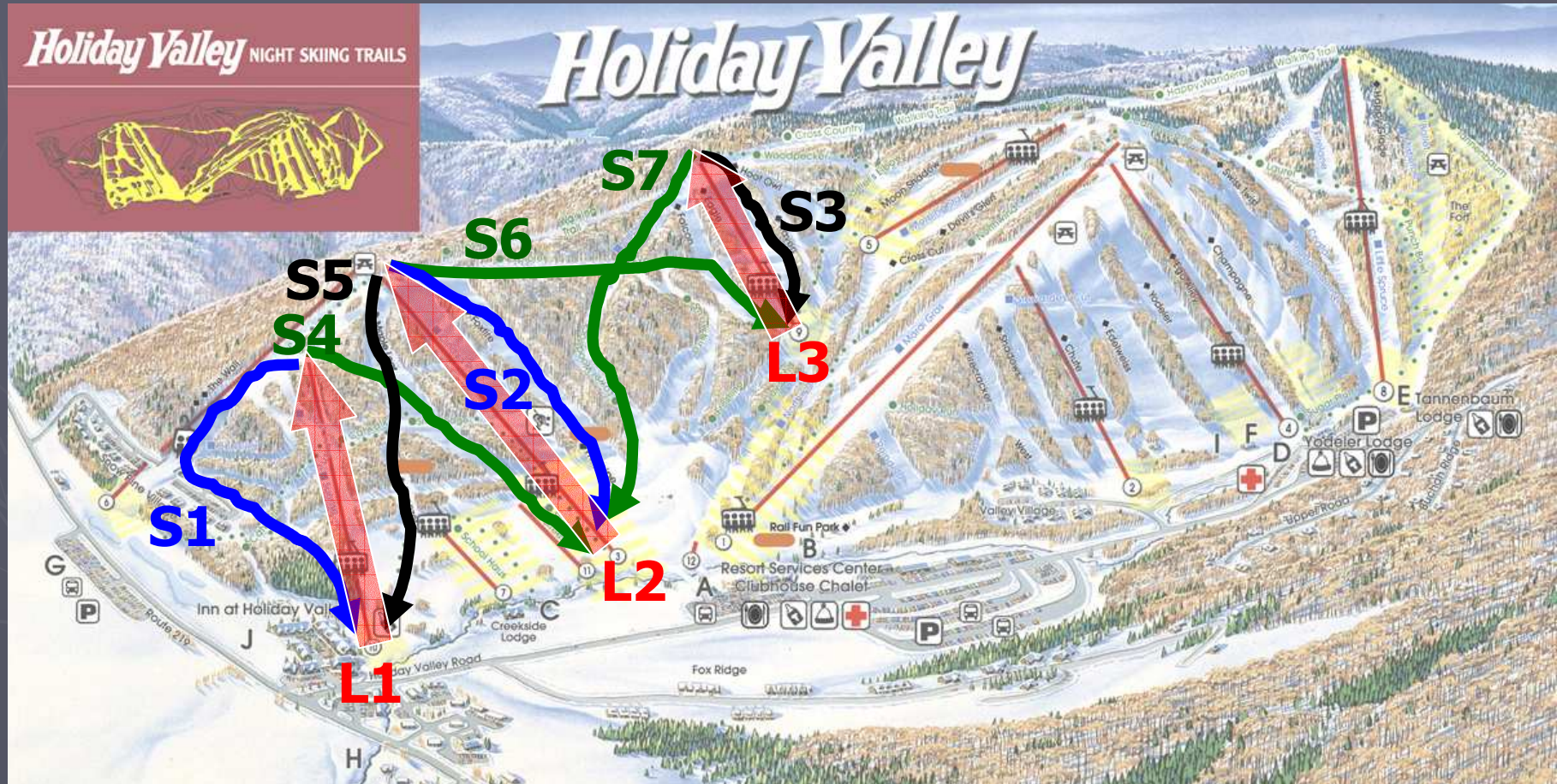
2 Lifts in Series, 3 Slopes

Lift 1 Data			Slope 1 Data			Resort Data		
Specification	Quantity	Units	Specification	Quantity	Units	Specification	Quantity	Units
Lift Chair Size =	3	seats	Type of Slope =	Blue		Total Resort Population =	1500	people
Lift Chair Spacing =	60	ft	Average Skier Speed =	20	mph	% Green =	56%	
Lift Speed =	1100	ft/min	Converted Skier Speed =	105600	ft/hr	People Skiing Green =	840	people
Converted Lift Speed =	66000	ft/hr	Slope Length =	9600	ft	% Blue =	12%	
Lift Length =	3600	ft	Slope Capacity =	36	people	People Skiing Blue =	180	people
Number of Chairs =	60	chairs	Slope Rate =	634	people/hr	% Black =	32%	
Lift Rate =	3300	people/hr	Slope 2 Data			People Skiing Black =	480	people
Lift Capacity =	180	seats	Specification	Quantity	Units	Total Slope Capacity =	164	people
Time Between Chairs =	3.27273	seconds	Type of Slope =	Green		Total Slope Rate =	5139	people/hr
Total People Waiting =	215	people	Average Skier Speed =	10	mph	Total Lift Capacity =	900	people
Wait Time =	3.91	minutes	Converted Skier Speed =	52800	ft/hr	Total Lift Rate =	7700	people/hr
Lift Cost Factor =	1352		Slope Length =	2400	ft	Total Lifts =	2	lifts
Lift 2 Data			Slope Capacity =	112	people	Total People Waiting =	436	people
Specification	Quantity	Units	Slope Rate =	1971	people/hr	Average Wait Time =	3.46	minutes
Lift Chair Size =	4	seats	Slope 3 Data			Total Lift Cost Factor =	3604	
Lift Chair Spacing =	60	ft	Specification	Quantity	Units	Lookup Table		
Lift Speed =	1100	ft/min	Type of Slope =	Black			mph	%
Converted Lift Speed =	66000	ft/hr	Average Skier Speed =	30	mph	Black	30	32%
Lift Length =	10800	ft	Converted Skier Speed =	158400	ft/hr	Blue	20	12%
Number of Chairs =	180	chairs	Slope Length =	2400	ft	Green	10	56%
Lift Rate =	4400	people/hr	Slope Capacity =	16	people	Chair Size Lookup Table		
Lift Capacity =	720	seats	Slope Rate =	2534	people/hr		Factor	
Time Between Chairs =	3.27273	seconds				1	1	
Total People Waiting =	221	people				2	1.2	
Wait Time =	3.01	minutes				3	1.4	
Lift Cost Factor =	2252					4	1.6	

Holiday Valley, NY



3 Lifts, 7 Slopes



3 Lifts, 7 Slopes

Lift 1 Data			Slope 1 Data			Resort Data		
Specification	Quantity	Units	Specification	Quantity	Units	Specification	Quantity	Units
Lift Chair Size =	3	seats	Type of Slope =	Blue		Total Resort Population =	1500	people
Lift Chair Spacing =	60	ft	Average Skier Speed =	20	mph	% Green =	60%	
Lift Speed =	450	ft/min	Converted Skier Speed =	105600	ft/hr	People Skiing Green =	900	people
Converted Lift Speed =	27000	ft/hr	Slope Length =	6400	ft	% Blue =	30%	
Lift Length =	4800	ft	Slope Capacity =	12	people	People Skiing Blue =	450	people
Number of Chairs =	80	chairs	Slope Rate =	792	people/hr	% Black =	10%	
Lift Rate =	1350	people/hr	Slope 2 Data			People Skiing Black =	150	people
Lift Capacity =	240	seats	Specification	Quantity	Units	Total Slope Capacity =	320	people
Time Between Chairs =	8	seconds	Type of Slope =	Blue		Total Slope Rate =	4224	people/hr
Total People Waiting =	106	people	Average Skier Speed =	20	mph	Total Lift Capacity =	840	people
Wait Time =	4.72	minutes	Converted Skier Speed =	105600	ft/hr	Total Lift Rate =	6650	people/hr
Lift Cost Factor =	786		Slope Length =	9600	ft	Total Lifts =	3	lifts
Lift 2 Data			Slope Capacity =	60	people	Total People Waiting =	340	people
Specification	Quantity	Units	Slope Rate =	1056	people/hr	Average Wait Time =	4.01	minutes
Lift Chair Size =	4	seats	Slope 3 Data			Total Lift Cost Factor =	3248	
Lift Chair Spacing =	60	ft	Specification	Quantity	Units	Lookup Table		
Lift Speed =	1100	ft/min	Type of Slope =	Black			mph	%
Converted Lift Speed =	66000	ft/hr	Average Skier Speed =	30	mph	Black	30	10%
Lift Length =	7200	ft	Converted Skier Speed =	158400	ft/hr	Blue	20	30%
Number of Chairs =	120	chairs	Slope Length =	3600	ft	Green	10	60%
Lift Rate =	4400	people/hr	Slope Capacity =	1	people	Chair Size Lookup Table		
Lift Capacity =	480	seats	Slope Rate =	264	people/hr		Factor	
Time Between Chairs =	3.27273	seconds	Slope 4 Data			1	1	
Total People Waiting =	156	people	Specification	Quantity	Units	2	1.2	
Wait Time =	2.12	minutes	Type of Slope =	Green		3	1.4	
Lift Cost Factor =	1868		Average Skier Speed =	10	mph	4	1.6	
Lift 3 Data			Converted Skier Speed =	52800	ft/hr			
Specification	Quantity	Units	Slope Length =	7200	ft			
Lift Chair Size =	2	seats	Slope Capacity =	37	people			
Lift Chair Spacing =	60	ft	Slope Rate =	528	people/hr			
Lift Speed =	450	ft/min	Slope 5 Data					
Converted Lift Speed =	27000	ft/hr	Specification	Quantity	Units			
Lift Length =	3600	ft	Type of Slope =	Black				
Number of Chairs =	60	chairs	Average Skier Speed =	30	mph			
Lift Rate =	900	people/hr	Converted Skier Speed =	158400	ft/hr			
Lift Capacity =	120	seats	Slope Length =	9600	ft			
Time Between Chairs =	8	seconds	Slope Capacity =	13	people			
Total People Waiting =	78	people	Slope Rate =	528	people/hr			
Wait Time =	5.19	minutes	Slope 6 Data					
Lift Cost Factor =	594		Specification	Quantity	Units			
			Type of Slope =	Green				
			Average Skier Speed =	10	mph			
			Converted Skier Speed =	52800	ft/hr			
			Slope Length =	9600	ft			
			Slope Capacity =	160	people			
			Slope Rate =	704	people/hr			
			Slope 7 Data					
			Specification	Quantity	Units			
			Type of Slope =	Green				
			Average Skier Speed =	10	mph			
			Converted Skier Speed =	52800	ft/hr			
			Slope Length =	10800	ft			
			Slope Capacity =	37	people			
			Slope Rate =	352	people/hr			

Summary of Models

Layout	Resort Population	Average Wait Time	Total People Waiting	Total Lift Cost Factor
1 Lift, 1 Slope	200 people	8.62 min	129 people	498
1 Lift, 2 Slopes	700 people	7.77 min	285 people	1388
2 Lifts Parallel, 4 Slopes	1000 people	8.23 min	494 people	1476
2 Lifts Converging, 2 Slopes	1000 people	7.45 min	524 people	1970
2 Lifts Series, 3 Slopes	1500 people	3.46 min	436 people	3604
3 Lifts Parallel, 7 Slopes	1500 people	4.01 min	340 people	3248

Variation of Input Within a Model

► 1 Lift, 2 Slopes: Input Variables

■ Slope

- Difficulty/Type of Slope
- Length of Slope

■ Lift

- Chair Size
- Chair Spacing
- Lift Speed
- Lift Length

■ Resort

- Total Population
- Percentage of People Skiing Various Types of Slopes

1 Lift, 2 Slopes Variation

	Input												Output		
	Slope 1		Slope 2		Lift				Resort				Wait Time	# People Waiting	Total Lift Cost Factor
	Type	Length	Type	Length	Size	Spacing	Speed	Length	Population	% Green	% Blue	% Black			
Base	Blue	9600	Black	8400	2	60	450	7200	700	0%	70%	30%	25.89	388	738
Type/ % Skiing Type	Green	9600	Green	8400	2	60	450	7200	700	100%	0%	0%	20.44	307	738
	Green	9600	Black	8400	2	60	450	7200	700	50%	0%	50%	23.62	354	738
	Black	9600	Green	8400	2	60	450	7200	700	50%	0%	50%	24.08	361	738
	Blue	9600	Blue	8400	2	60	450	7200	700	0%	100%	0%	25.55	383	738
Slope Length	Blue	12000	Black	8400	2	60	450	7200	700	0%	70%	30%	24.94	374	738
	Blue	9600	Black	12000	2	60	450	7200	700	0%	70%	30%	25.48	382	738
	Blue	9600	Black	7200	2	60	450	7200	700	0%	70%	30%	26.03	390	738
	Blue	7200	Black	8400	2	60	450	7200	700	0%	70%	30%	26.85	403	738
Chair Size	Blue	9600	Black	8400	3	60	450	7200	700	0%	70%	30%	10.34	233	954
	Blue	9600	Black	8400	4	60	450	7200	700	0%	70%	30%	2.56	77	1218
Spacing	Blue	9600	Black	8400	2	50	450	7200	700	0%	70%	30%	18.12	326	795.6
	Blue	9600	Black	8400	2	80	450	7200	700	0%	70%	30%	41.45	466	666
Lift Speed	Blue	9600	Black	8400	2	60	1100	7200	700	0%	70%	30%	7.77	285	1388
Lift Length	Blue	9600	Black	8400	2	60	450	4000	700	0%	70%	30%	33.01	495	610
	Blue	9600	Black	8400	2	60	450	6000	700	0%	70%	30%	28.56	428	690
	Blue	9600	Black	8400	2	60	450	8000	700	0%	70%	30%	24.12	362	770
Population	Blue	9600	Black	8400	2	60	450	7200	300	0%	70%	30%	-0.77	-12	738
	Blue	9600	Black	8400	2	60	450	7200	400	0%	70%	30%	5.89	88	738
	Blue	9600	Black	8400	2	60	450	7200	600	0%	70%	30%	19.23	288	738
	Blue	9600	Black	8400	2	60	450	7200	800	0%	70%	30%	32.56	488	738

Variation of Input Summary

- ▶ All Variations of input compare to the base
- ▶ Wait Time, People Waiting decrease when:
 - Slope Type is slower (Green is slowest)
 - Total Slope Length is greater
 - Chair Size is greater
 - Chair Spacing is closer
 - Lift Speed is faster
 - Lift Length is longer
 - Total Population is fewer

Variation of Input Summary

► Lift Cost Factor decreases when:

- Chair Size is smaller
- Chair Spacing is farther apart
- Lift Speed is slower
- Lift Length is shorter

► Factors of significant impact:

- Chair Size, Chair Spacing, Lift Speed, and Resort Population affect Wait Time the most
- Chair Size, Chair Spacing, and Lift Speed affect Total Lift Cost Factor the most

Conclusions

► Our model:

- Designed for when skiers create lines at the base of the lifts
- Input values can be modified to make comparisons of different configurations of lifts
- With more precise cost info, alternative lift configurations can be economically compared

Trade-Offs

- ▶ Make slopes as long as possible to keep skiers on slopes and out of lift lines
 - Trade-off: covers more land which costs more money
- ▶ Use more beginner slopes because they keep skiers on the slope longer
 - Trade-off: advanced skiers get bored of easy terrain
- ▶ Use many longer lifts to keep people out of lift lines
 - Trade-off: fewer and shorter lifts conserve cost
- ▶ Attract many skiers to maximize profit
 - Trade-off: skiers desire shorter lines and minimal congestion

Potential Future Work

- ▶ Create a “building-block” approach in order to combine the configurations we’ve already created/simulated to analyze an entire trail map from a resort
- ▶ Expand to include info on time spend at the lodge, restaurants, or other activities at the resort

Thanks!

