How to Measure Trail Capacity *

This paper compares traditional methods for estimating summer and winter trail capacity. It offers rules of thumb, ratios and new research findings. As we look at trail design in Europe and North America, we notice that due to lift upgrades, lifts are faster and lift lines are disappearing. Because of this, the available skiing time has almost doubled. The technical evolution in snow grooming and snowmaking allows trails to endure much higher traffic. Thanks to the refined turning and carving equipment skiers and snowboarders are more comfortable on steeper slopes. All these positive factors contribute to increased stress on trails. Consequently, it is time to verify the trail capacities. A suspicion looms that trail densities have grown too high and the creation of new trails lags behind expectations of clients that are ready to excel. How to measure trail capacity is a topic for OITAF to consider. It may be the most vulnerable aspect of continued success of winter sports.
A review produced no recent reference on how to measure summer trail capacity. A simple method is included. It assumes that groups leaving at designated intervals expect a higher quality of the recreation experience. This approach can be used during any season and makes it easier to deliver what is being advertised.

Overview

The winter sports scene is constantly changing and a review of traditional lift and trail planning theory is in order. This serves as an introduction to upgrade lift systems particularly with regards to higher speed and capacity. Reference is made to comfortable carrying capacity and skiers-at-on-time models. Inconsistencies found in these models are pointed out.

Based on recently published research, modified trail densities are presented that reflect technological evolutions on supplier and consumer ends. To assign appropriate density by expected use, 3 different zones are explained. The need to create more diverse trails and features is addressed. To put crowding or project feasibility in perspective, seasonal peak attendance diagrams are suggested. Finally a new approach for determination of summer trail and summer site capacity is formulated.

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Introduction

"It's not your father's business anymore". It's the snow sliding industry, where everyone screams to be included who has spent dearly for new carving tools (1). Today, many ski lifts haul bikes, carts and sleds. Some lifts have even added pedestrian lanes for summer and winter.

Despite this change, the skier is still paying for most of these auxiliary activities and it is therefore most important to consider what made skiing popular. By understanding the early ski product that was so popular that it grew annually, we can begin to decipher what the more recent changes mean to the average skier.

A stagnating market may be a signal that some changes rated poorly with the skiing public. Following a suspicion, we will look for crowding of trails to be the culprit. This may be simple: at the beginning we found one trail for a single chair lift, two for a double. Then we went to three trails for a triple, four for a quad. May we have 6 trails for a 6-pack? How many for an 8-pack?

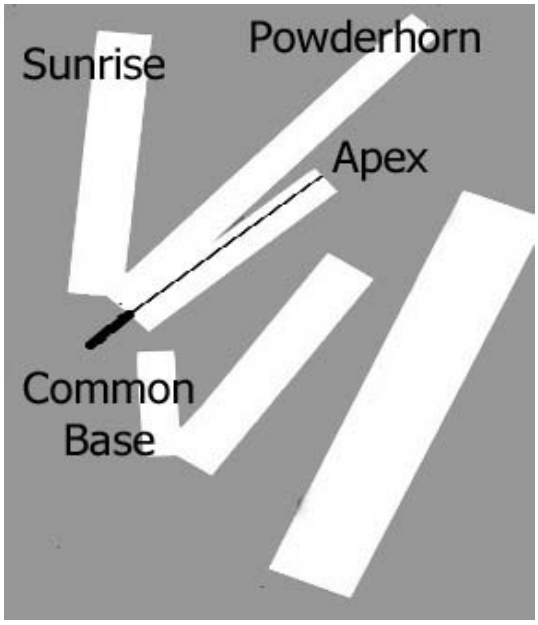
Analysis of the original ski product

1) Layout

Unprecedented French ski area development in the sixties defined a new skiing product. Among others, Jean Cattelin and staff of the French agency SEATM (Sérvice d'Etude et d'Aménagement Touristique de la Montagne) drew diagrams with lift bars drawn approximately as wide as all trails should be built. The bar represents trail width measured in units of people per hour (p/h), see Figure 1.
Under federal government policy and subsidy, the French created large high altitude ski domains. "Le plan masse" (trail master plan) and the "grenouillère" (base congregation area) determined circulation space. A sketch plan was made, where cumulative trail widths were drawn under the assumption that trails should measure 10% of the lift capacity in meters. This translates to approximately (30 m) 100 feet for every 300 p/h lift capacity. This sketch plan has sometimes been referred to as a "stick diagram" in the U.S.

Alpentech has applied a similar stick diagram to Solitude, Utah. Overlapping lift bars (Figure 1) indicate where space had to be compromised.

Figure 1: Solitude Stick Diagram
Initial lift layout (gray/ white)
Later lift modification (black)



As width of the white bars is scaled to 100 feet per 300 p/h, a double chair would typically measure 400', a triple 600' and a quad 800' across the fall line. For areas that measure less than 30% slope, up to twice as many people can be assigned to the width when trails are covered by snowmaking and are regularly groomed. Good spacing of lifts prevents overlapping of (white) bars.

At Solitude, trails congregate at the common base of three lifts (Sunrise 1750 p/h, Powderhorn 1050 p/h and Apex 1200 p/h). This occurs where an overlap of the white bars is evident. This encroachment of space was later corrected, when the Forest Service base land, located at the common base of the lift, was dedicated to skiing instead of a village. To fix the problem indicated by the overlap, the Apex lift was extended downhill thus creating a separate loading area. The modification cost approximately $80,000.

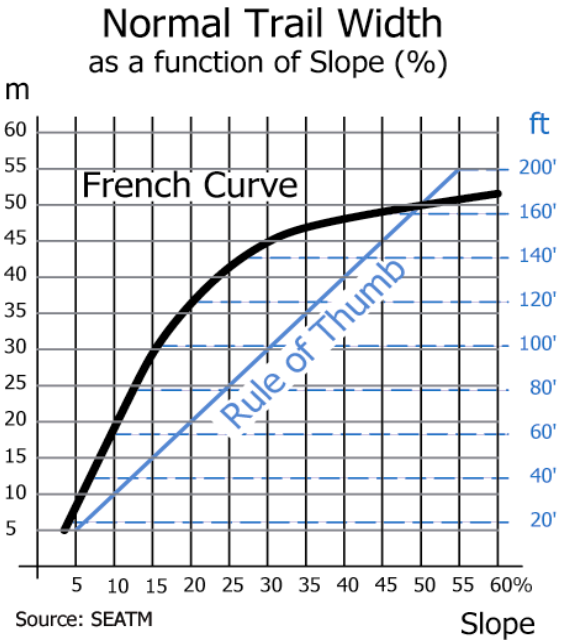
Solitude won the National Ski Areas Slope and Trail design award for well-organized mountain circulation.

2) Design

More detailed trail plans followed the fall line of the topography. To cut a specific trail, some Europeans use a straight-line Rule of Thumb where the width (measured in meters) would be no less than the percent of the fall line slope. The French defined a curved relationship between a single trail width and the slope. These two width ratios (Figure 2) were applied to all major trails. The French Curve accommodates extra space for mixed abilities on the most popular slope range (25 to 45%). During design, trail widths would meander slightly along a uniform pitch; however, widths were mostly kept uniform throughout for more effective trail grooming.

Terrain variety can be used creatively. Grading and building traverses are required to achieve even trail gradients per ability level and to better accommodate grooming.

Figure 2 Width to Slope ratios



The single most important factor in trail layout is to find the fall line and places to change trail direction for more aesthetic landscape integration. From a landscape architect's perspective (3), good mountains function as an integrated system of trails, service roads and lifts where ability levels seldom interfere.

Recent Research

During his research work at the Technical University in Vienna, Dipl. Ing. Stefan Salzmann evaluated some 5000 video recordings on strategically located test slopes to determine ability-classified space requirements. Survey participants were asked if the perceived density at the test site was acceptable. The analysis established a basis for updating a comfort zone for skiers on a modern, groomed slope. A summary of the work has been recently published (4). Following is a brief abstract relating to Figures 3 and 4 below.

1) Applied Method

Modern traffic analysis involving the behavior of pedestrian and bicycle traffic in a control space has been used to model acceptable limits for skiers. The interaction of motion and distance to each other was used to formulate a Distance Model.

This model was applied to 37 control spaces located on groomed slopes. The results were surprisingly orderly regarding the slope and the ability levels. Minimum Groomed Area has been converted into people/acre (p/ac) and the Maximum Transfer per unit trail width into people per hour per foot (p/h/ft).

Figure 3

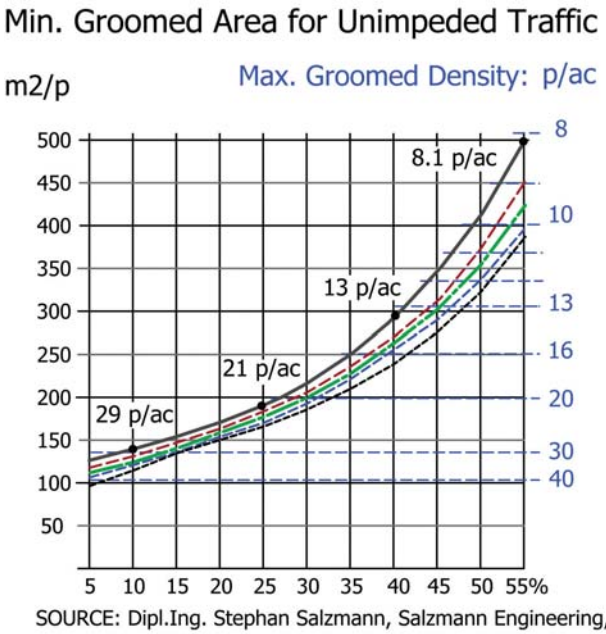
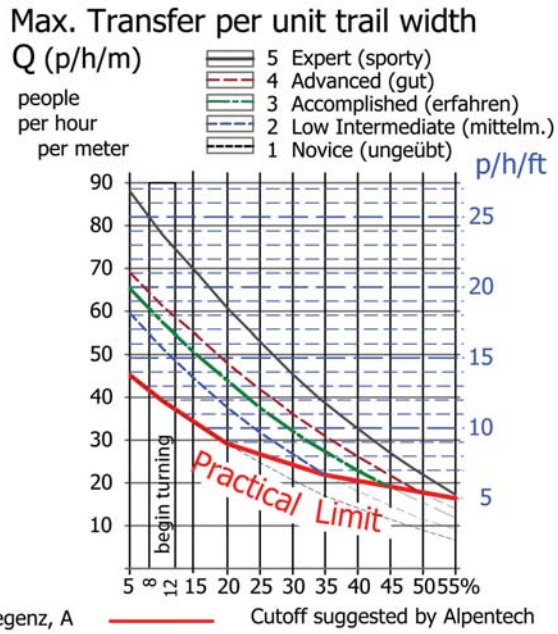


Figure 4



SOURCE: Dipl.Ing. Stephan Salzmann, Salzmann Engineering, Bregenz, A

Cutoff suggested by Alpentech

2) Definitions

A) The Minimum Groomed Area required for Unimpeded Traffic, Figure 3, shows a minimum space required per skier using a groomed trail. This is subject to many factors and is an estimate that has been arrived at with empirical means.

B) Maximum Transfer per unit trail width, (or traffic flow) Figure 4, is a derivative of Figure 3. It is intended to assist in dimensioning uphill facilities from trails.

3) Findings

Generally, Mr. Salzmann feels that the nearly unlimited capability to move people by cable has simply moved the queues from lift lines uphill to the trails. He believes that some large investments in recent lift upgrades in Austria may prove to be counter-productive, because guests are not willing to accept congestion on trails. This perception motivated his analysis.

Based on good correlation of interviews with calculations, the Salzmann study found:

- Slope is the primary influence for trail capacity.
- The combination of flatter slopes and the higher ability achieves the highest number of skiers per unit width.
- Trail width seemed less significant at uniform ability and traffic direction.
- Bad weather and visibility affect the outcome significantly; however, bad weather normally lowers traffic, while sunshine contributes to accepting highest traffic densities.
- Measurements were limited to well groomed slope sections only. When applying such measurements from tests to an entire trail, other factors limiting the capacity, such as bottlenecks, poor visibility and stopping patterns of skiers and snowboarders must be taken into consideration. Such factors may reduce the hourly transfer of a skier trail considerably.
- The technological evolution forces more frequent review of the findings.

CCC and SAOT estimates

The most noteworthy guideline for evaluating the Comfortable Carrying Capacity (CCC) and skiers-at-one-time (SAOT) estimates are Forest Service guidelines and stipulations of the Commercial Alpine Skiing Policy of British Columbia, Canada.

The United States Ski Industries Association in 1992 organized a standard definition task force; however, it failed to produce clearer terminology. This effort was abandoned.

Because ski area consultants and large ski resorts have designed their own spreadsheets or models, it is difficult to compare results. By replicating reports, the danger is that results can be consistently wrong or insignificant.

The CCC concepts are difficult to comprehend because virtual densities are used. Virtual densities cannot be directly measured because they include the SAOT densities, implying that the daily tickets sold be divided by the total trail acreage. Some reports will use a pod density, implying that all 3 components of the population in the pod, those waiting, lift riding and actually being on the trails, are divided by the trail acre of the pod. The use of the CCC concepts will hide what is happening to the guest on the trails.

As significant changes are taking place on the trails and the lift system, it is mandatory to isolate these items. Research on behavior of moving people in space (2) may better clarify what is happening on ski trails.

There is a fourth component, comprised of the inactives who are neither skiing, waiting nor lift riding. These vary greatly between reports. Already 1978 O'Connor Associates recorded inactive population at Mammoth Mountain as 28 % of all ticket holders because they were either inside buildings or in parking lots or staging areas between 11 a.m. and 2 p.m. A recent report (5) includes 12 % inactives to model SAOT.

More simply put, the maximum number of happy clients depends on the available mountain space.

Trail time is up!

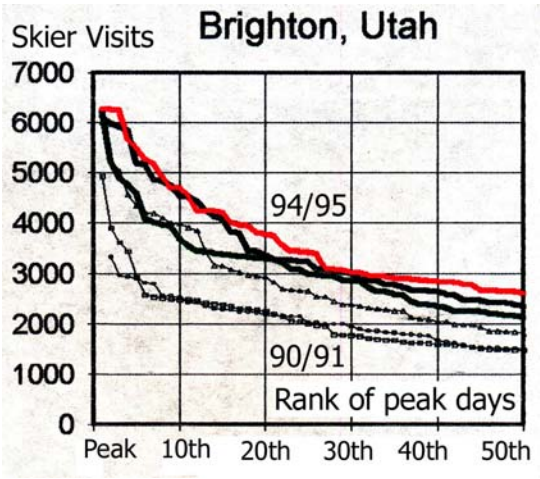
During the last 20 years of detachable lift construction in the U.S., the ratio of skiing time to ride time has increased incrementally with every such lift built. Lift upgrading (speed plus capacity) brought drastically shorter waiting lines. The increase of the trail population switching from a heavily used fixed grip to detachable grip lift pod is approximately 35 percent.

The time-split found in most ski areas is approximately 1/8 waiting, 3/8 lift riding and ½ on trails during a typical design day.

Design Day Concept

A simple graph of the peak days reveals the significance of crowding. It can also show how successful a lift system modification has been. For example, we note a very positive development at Brighton, Utah, during the years of detachable lift conversion.

Figure 5
Evolution of Peak Days



At the end, more people attended much more often. Skier visits doubled between 1990 and 1995. Besides the new lifts all other facilities were able to accept more skiers.

The striking similarity of day ski area and destination resort Peak Attendance Curves reveals this simple graph as an underestimated planning tool. Although the Forest Service sometimes noted the 11th highest peak day for the design day, the attendance curves are rarely seen in reports.

Squeezing by

Bottlenecks have been most drastically affected by lift upgrades. It is not uncommon that traffic police must manage bottlenecks that cannot be improved. Aspen Mountain and the Warm Springs arrival area at Sun Valley are two examples we have analyzed. Managed bottlenecks are not necessarily causing severe or frequent accidents but they do annoy the client. Huge grooming and snowmaking efforts have been undertaken by the industry to offer a high quality product in the basic ski area. This boosted the overall trail carrying capacity far beyond the French Curve.

On the average, most trails carry higher densities where large investments in uphill facilities have taken place.

What is the guest expecting?

Now that the consistent and improved product (guaranteed snow cover and perfect grooming) has been enjoyed for a while, has boredom set in? More variety and excitement is now expected. Hunger for additional space and adventure is fed by aggressive marketing. The first reaction of the industry has been to provide terrain parks. Guidelines helped to define terrain parks. For smaller ski areas, terrain park operation and management costs may be proportionally too high. New, natural trail creation may be more cost effective. The Big Sky tram to Lone Mountain shines as an example for getting additional market share. Natural opportunities for accessing expert and extreme terrain must be professionally evaluated.

Ski Trail Density Update

As destination resorts reach further and offer greater mobility, it becomes necessary to differentiate between 3 zones according to base proximity and guest expectations.

The Central Zone includes the base area and all major lift pods required for ingress and egress. This is an "animated" zone with highest traffic density thanks to machine groomed and well-managed trails. During drought periods, this zone equates to the snow making acreage.

The Powder Zone includes significantly lower density than the Central Zone and snowmaking is not available. In this area, accessibility may be compromised but space per person should be at least twice that available in the Central Zone.

The Perimeter Zone includes terrain accessible by hiking or by dispersal of facilities. Sometimes, it has closed sections due to lack of snow or demand. In this zone, accessibility and space compromises are acceptable. Expert or extreme skiers most often use this zone.

Ski Trail Design Density Discussion

By identifying a Central and a Powder Zone we appreciate that mountain use is constrained by site conditions. An extreme Perimeter Zone may not be an available site condition.

The important topic of diversified ski trail development is to provide more intimate contact with nature. This can translate into a noble objective of preservation.

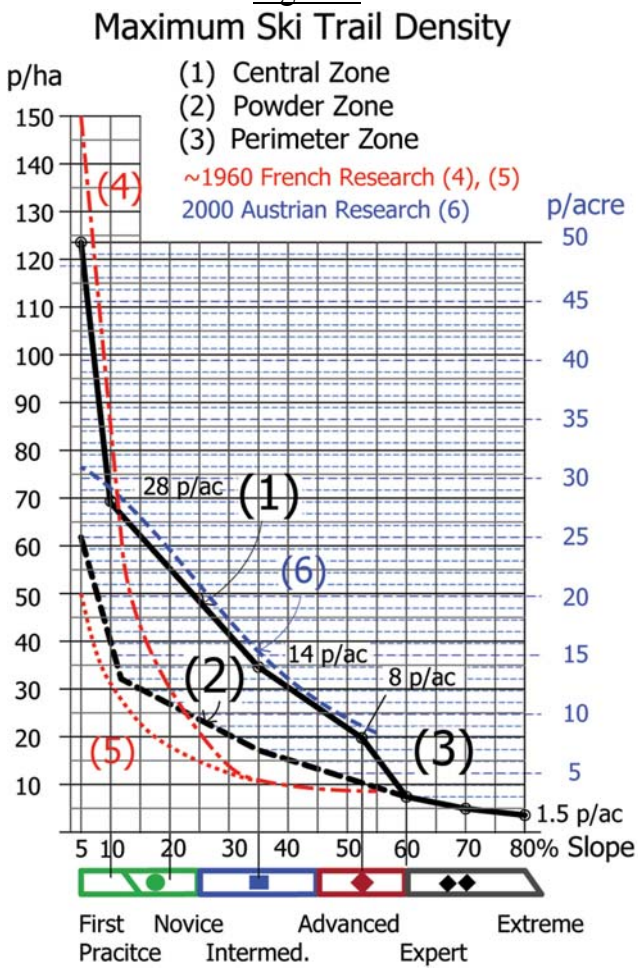
Agencies should discuss the need and the significant differences of the 3 zones when future ski terrain expansion is presented to the non-skiing public. Many non-skiers only know the Central Zone. Understated access and uses in the Powder and Perimeter Zones clash with the need for modifications satisfying high-density traffic in the Central Zone.

Letting skiers and snowboarders reach the perimeter, where help may be remote and risks high, can be an extreme business proposition. In this area where guides may be needed, an orderly group dispatch may offer a safe management option.

Understanding and managing variable density leads into a more focused discussion of ski product diversity.

A revised maximum ski trail density, shown in Figure 6, is intended to raise density within proven limits. Two noteworthy references on ski trail density are used to recommend maximum density levels for the 3 zones.

Figure 6



The French Resort development boom of the sixties produced a model for building in more elevated areas. The average skiing speed was probably high at that time when comparing the personal ski equipment. It should be noted that the average terrain in the high French ski domains was not wooded. The skis and boots used in those days may have provided the same control freeboarders have using snowboards today. Inferior control the equipment used to have may be a fine point during a comparison of snowboard versus ski control.

In Figure 6, a range is enclosed by signify a **possible (4)** and a **comfortable density (5).** This applied to initial French ski area construction and has been exceeded in the high traffic zones

Austria relies partly on Dipl. Ing. Stephan Salzmann to look at the evolution of densities. Since the initial era of ski area construction, drastic increases of ski trail traffic has been experienced also in Austria. The durability of highly managed trails is made possible by an unprecedented snowmaking, grooming and lift equipment evolution. As expected, the perception of comfortable is higher on the groomed trails today. The range of recommended densities moved significantly upwards over the entire spectrum of snow groomed terrain.

Addressing Diversity

The Terrain Park is a well-managed product thanks to uniform guidelines; however, the cost to imitate nature with terrain parks is significant. In the long run, finding the right opportunity to access natural terrain and create natural trail diversity, may be more rewarding.

The flying snowboarder and the drifting extreme skier are already on most ski area brochures. The general skiing public may soon wonder if the high maintenance and risks involved in running the new attractions affect their ticket prices. It has become difficult for marketing departments to determine if it is better to lose a family of regulars to a group of new age kids. Circulation to and from terrain parks needs analysis because the access corridors may not be supervised like the parks.

<u>The state of the art</u>

- In post Olympic Utah, half-pipes, terrain parks and aerial jump sites have taken precedence over other ski area projects. The Best Snow on Earth is being compacted to diversify its use.
- Extreme ski lifts such as the Lone Mountain tram at Big Sky and novel extreme private lifts near Silverton, Colorado and Alpine Meadows, California are raising new expectations in the extreme ski market. What can be wisely offered in this sector? Are we running out of options?
- During summer, scenic rides, hiking and mountain biking are occupying lift departments in many ski areas. Multi season operation may be the most promising direction for diversification.

Summer Trail Capacity

Many destination resorts report over 50 miles of bike trails today. Ultimately, there will be many more hikers than bikers if the increased sales of hiking boots in the U.S. is an indication of the hiking market. Many of these new hiking boots are worn abroad in a more sophisticated social context where population density has forced much more intense mountain living. Mountain resort interconnection routes and scenic crest trails, linking with cultural and natural highlights could create larger trail demand. Without planning lifts and mountain restaurants to work better for summer use, this demand will stay flat. Good signage, reliable as well as detailed maps may be a good beginning to start trail development. To offer a dusty service road off the mountain- top is undermining a positive image. Speedy summer lifts, longer summer rides to the perimeter as well as adventure and interpretive parks can bring a new appeal to summer. -- The first project may begin with building a creative lift evacuation trail.

Building a tradition for lift hiking and mountain biking is an illusion without building a good trail network off the mountain. A dusty service road hike will not suffice. Hiking trail construction by volunteers for volunteers is not uncommon. Alpentech offers an approach to measure summer trail capacity, inspired by a Swiss mountain carrying capacity guideline (6).

Summer Trail Capacity

Hourly Transfer = Direction x Groups per hour x Group size x Miles / mph.

Applicable to hiking, mountain biking or other managed trail uses such as carts, rides, slides

Where: The direction column in your spreadsheet would carry 1, 2 or 3.

(1) single track, meaning preferred one-directional traffic;
(2) bi-directional traffic requires widening of trail in suitable locations. Forest Service 52" standard trail width is recommended throughout.
(3) mixed traffic requires minimal width of 7 to 10 feet depending on expected user types and densities.

Group departures per hour can be estimated in conjunction with group size.

Group size is a most important experience value for design of a managed trail program. (How many carts to purchase, or how many guides to hire?)

One-way distance, in miles (or km). It may be useful for ability classification of trails to include vertical and horizontal measurements in separate. Segregate similarly steep sections to estimate average speed and classify the trail from comparative experience.

Miles per hour average speed in (mph) or km/h may be clocked or estimated.

Summer Mountain Capacity Estimate

Once summer trail capacity is derived from existing trail inventory estimates for a Comfortable Summer Capacity (CSC) can be made:

CSC = Hourly Transfer x open hours / avg. stay (h) x % day use / % active time

Trail users-at-one-time may include active and inactive users as well as spectators.

Example: CSC = 240 p/h x 8 h / 3h x 0.4 / 0.6 = 426 daily users

Where: Hourly transfer is calculate from the first formula, or alternatively it may be given by the lift: If a triple chair runs every 10 seconds with 2 people per chair, and the two following chairs transporting their bikes, the lift capacity is 2 persons in 30 seconds or 240 per hour. (Note that staging of events can quickly exceed normal operating capacities.)

"Open hours" is the basis for determining the trail use efficiency, e.g. 8 hours

Average stay of riders, e.g. 3 hours in the example

% day use of the capacity expected to occur during design day, e.g. 40%.

% active time of the running loop(s) consisting of, e.g. 60% of the total time span between ticket purchase and departure. The remainder of the inactive stay (thus 40 %) could be spent simply reading and signing liability waivers and/or chatting with friends, or bringing in revenue, such as renting equipment, shopping, eating, etc.

Spectators are an important additional component of mountain biking and events. The significance of summer recreation in winter sports centers is minor. Animated base areas near urban centers offer the best prospect and seem to draw local skiers who come to enjoy the mountain environment also during summer.

General Conclusions

More people enjoy the technological evolution of highly groomed ski trails today; however, we must determine at what level of use trail density becomes unacceptable. Recent research on the subject suggests that acceptable traffic flow range between 18 and 40 persons per hour per meter trail width (p/h/m). This is significantly higher than for formerly less groomed trails where overall traffic flow may averaged approximately 10 p/h/m. Well-groomed trails allow the transfer rates to be more than double that of less groomed trails.

Two relationships co-exist

1) Lift Capacity equals Trail Capacity, leading to Capital Investment
2) Space requirement translates to number of people and results in tickets sold

Group dispatch at designed intervals can offer a qualitative experience and optimal use of both summer and winter trails

More Specific Conclusions

Strategic trail grooming patterns effectively shift densities away from critical bottlenecks.

For bottlenecks and mazes, uniform traffic direction is mandatory. Detail traffic design is needed to achieve highest transfer of skiers in those areas.

A general rule of thumb applies to less managed slopes, of 10 skiers per hour per meter of trail width.

More specific assignment of the maximum transfer rate, for returning skiers per hour per unit trail width (p/h/m) can be made. It can be assumed that on the average, under favorable conditions, well-groomed trails may handle **per meter** width:

up to 40 p/h on a 5-10% slope
up to 33 p/h on a 15% slope
up to 23 p/h on a 30% slope
up to 18 p/h on a 50% slope

The above values exceed the expectation of traditional skiers, such as teaching and family skiing, as well as carving and snowboarding (free-boarding).

The creation of Powder and Perimeter Zones can diffuse trail congestion and must be available, especially during peak days, to satisfy traditional skiers and snowboarders who require more space.

Resorts offering only highest density zones may lose skiers until they create some lower density zones.

NOTE: Some ski areas face a dilemma due to difficulty to expand both their permit and trail widths. After modernizing ski lifts to satisfy new client expectations, they may find that trail congestion is no longer acceptable. In order to bring back clients by diversifying the product, such as adding features and dispersing skiing, resorts may be forced to reduce the appropriated SAOT.

The suspicion is that unless trail width can measure up to lift capacities, more traditional clientele may be lost than can be replaced by newcomers.

The spiral of higher expectations will continue to bring an evolution of the mountain sports. This will continue to challenge planners.

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