

# A Relational Database for Snow Avalanches

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**Abstract.** *In order to be able to have a better overview of the avalanche history and to try and analyze the prevailing meteorological conditions at the time of an avalanche, the Snow Avalanche Division of the Icelandic Meteorological Office (IMO) set about designing an electronic database. The setup of the tables is such as to minimize entries via the keyboard and thus minimizing typing errors. The integrity of the database system allows us to set up rules such that e.g. it is not possible to enter an avalanche unless information on the track has been entered previously. And it is not possible to enter an avalanche track unless one has entered the county in which the track is located. In the future, the idea is to link the avalanche database with the IMO meteorological database, such as to include information on the prevailing meteorological conditions for individual avalanche occurrences or cycles. Conversely it would be possible to look up certain meteorological conditions (e.g. similar to the ones that are dominant at the present) and see what has happened in the past during those occasions. The Avalanche database will also be directly linked to a Geographical Information System (GIS) such that spatial analysis can be done on the meteorological conditions leading up to an avalanche or avalanche cycle. Snowpit information will also be linked to both the GIS and the database so that spatial analyses will include snow stratigraphy. It is hoped that in the future all this information will greatly aid in the avalanche forecasting, hazard analyses, zoning etc.*

## Introduction.

Historical records of avalanches in Iceland date back several centuries. In fact the oldest known avalanche record dates from the year 1118. It tells of a group of men who went to search for the body of a man who had drowned and "were they swept away by an avalanche and perished".

From the year 1609, records greatly improve and in all 500 fatalities are recorded since that year to date. In all, we have records of about 640 fatalities of which 190 occurred in the 19th century and 130 so far this century.

Although it is very impressive to flaunt such old records they are of very little scientific value even if we had meteorological records dating back that far. What about all the avalanches that occurred and did no damage?

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In order to be able to use data on avalanche occurrences, the data set must be fairly complete i.e. it must not only include so called destructive avalanches but also the ones that did no damage.

The Icelandic Meteorological Office (IMO) is responsible for recording avalanche occurrences and has a network of observers to do so and all meteorological observers for the IMO are supposed to report any avalanche activity. In addition we receive information from the highway crews as well as from private citizens.

In order to make this data easily accessible for use in analysis, the Avalanche Division set about developing an electronic database:

### **Design criteria.**

First we put down the design criteria as to how we would like this database to be.

- It had to include all the relevant information that we could possibly think of.
- The information should be available at various levels because different organizations requiring access, may each call for different information. Also we do not want all the information to be available to the public. E.g. we try to evaluate the reliability of the data and the person who supplies it to us, so we are maybe passing a judgment on a person that we may not wish for him or her to see.
- The design must be such that entry into the database can be done by "non-experts" . Hence the relevant information has to be selectable from tables.
- The data obtained from such tables must be fetched using point-and-click methods so as to minimize mistakes and errors.
- The database had to be accessible from remote entry stations, such as the sites of the various snow observers, highway maintenance crews, rescue teams etc. A site that has the possibility to look at data can also enter data if we allow that.
- The database itself must be able to ensure that "nonsense" is not entered and inform why it will not accept the attempted entry.
- We had to be able to make conditional inquiries such as whether any avalanches occurred between specific dates or times and maybe within a certain radius of a specified town.

The above led us to the conclusion that we would require a fully fledged relational database (RDB) so we could use the SQL (Structured Query Language) language to formulate queries. We decided to run it on a UNIX workstation (Digital Alpha) for reasons of speed and have runtime PC versions to supply the outstations with so they can enter and view the data.

We selected the INGRES database because of its advanced design, its versatile x-windows tools (Windows4GL) and its ability to handle distributed access.

Its ability to store pictures, handle users defined datatypes such as latitude and longitude and the ease of linking it to a geographical information system also weighed heavily in the selection process.

**Design Procedure.**

Before we go into describing the individual relations, we would like to point out that we will not go into details concerning the relational theory like normalization of the tables and the various types of relations. Basically we just show the tables and their connection to other tables.

Initially we listed all the information we thought might be relevant and then divided them into groups that would possibly later form the basis for the tables.

Headings of potential tables were put down on posters and hung up on the walls of the avalanche section office and the various ideas written onto those posters as they emerged. New headings initiated new posters.

The result was formulated into proper tables and each item was defined. For example, a character string, an integer, time, latitude and longitude, etc. Table 1 lists the various tables.

Next we set about designing the database, that is defining and normalizing tables, defining keys and rules for the various connections between tables

<b>Table 1 List of tables used in IMO avalanche database</b>
County
Zone
Avalanche Track.
Geographically Defined Avalanche Starting Zones (GSZ).
Avalanche.
Actual Avalanche Starting Zone (ASZ)
International Avalanche classification codes
Time symbols, coding the accuracy of the timing of the avalanche.
The source of information about the avalanche occurrence.

Tables 2 to 10 list the content of the individual tables and the various connections.

Figure 1 shows schematically the design of the database.

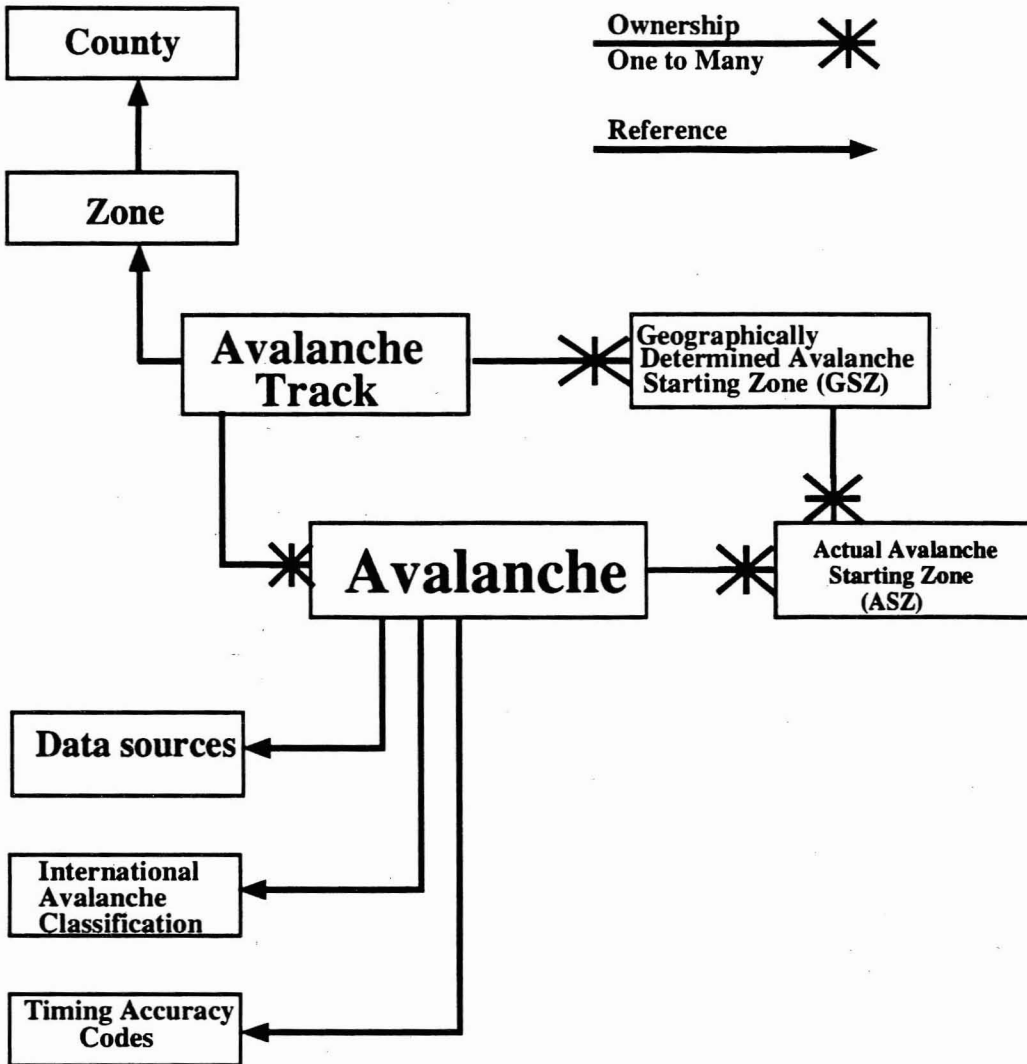


Figure 1 The schematic design of the IMO snow avalanche database

Table 2 shows the table "COUNTY". County is the jurisdiction in which the avalanche track is located. As shown, the table is referenced by the table "ZONE" via the County number.

Type of key	Item	Points to...	In table....
Primary	County number		
	County name		
	Province		
	Country region		

**Table 3 Zone, referenced by table Avalanche Track.**

Type of key	Item	Points to...	In table....
Primary	Zone		
Secondary/foreign	County number	County number	County
	Computer name		

Table 3 shows the table "ZONE". This table is ment to represent an area where conditions might be similar and similar conditions are required to inititate an avalanche. The "ZONE" table is referenced by the table "AVALANCHE TRACK" .

**Table 4 Avalanche Track**

Type of key	Item	Points to...	In table....
Primary	Avalanchetrack #		
	Avalanche track name		
Foreign	Zone	Zone	Zone
Foreign	County number	County number	Zone
	Latitude		
	Longitude		
	Type of coords.		
Foreign	Form of path	Class	Intenmatl. aval. classi- fication
	Average slope		
	Aspect		
	Special dangers.		
	Special features		
	Misc.		

Table 4 shows how the table "AVALANCHE TRACK". It describes the various geographical characteristics of the track itself. There is no information as to the actual avalanches that might come out of each individual track. The table is connected to the various tables through assorted keys as is shown in the table.

**Table 5 Geographically Defined Avalanche Starting Zone (GSZ), owned by table Avalanche Track.**

Type of key	Item	Points to...	In table....
Primary	Avalanche track #	Avalanche track #	Avalanche track
Secondary	Starting zone #		
	Avg. slope of GSZ.		
	Aspect.		
	Predominant snow loading wind dirn.		
	Description.		
	Location of track file.		
	Latitude.		
	Longitude		
	Type of co-ordinates		

Table 5 shows the geographical information and characteristics of the starting zone. Again as in the case of the table "AVALANCHE TRACK" there is no reference to the actual snow avalanche that might be coming out of the particular starting zone. The table shows the connections between the GSZ table and the various other tables.

<b>Table 6 Avalanche, owned by table Avalanche Track.</b>			
Type of key	Item	Points to...	In table....
Primary	Date and time	Date and time	A.S.Z.
Secondary	Avalanche track #	Aval. track #	Avalanche track & A.S.Z.
Foreign	Accuracy of time, code	Class	Accuracy of time, code
	Position of sliding surface	Class	Internratl. aval. classification
	Form of Motion	Class	Internratl. aval. classification
	Surface roughness of deposit.	Class	Internratl. aval. classification
	Liquid water of deposit	Class	Internratl. aval. classification
	Contami-nation of deposit.	Class	Internratl. aval. classification
	Mode of release	Class	Internratl. aval. classification
	Number of fatalities		
	Number of wounded		
	Number of persons escaped unhurt		
	Property damage		
	Other damage		
Foreign	Reference number	Reference number	Data sources
	Stopping, h.a.s.l.		
	Thickness of deposit.		
	Reliability of data source		
	Accompanying material.		
	Misc. comments		

Table 6 contains the actual avalanches. This table is of course referring back to the static information in the tables AVALANCHE and GSZ. The relationship with the table AVALANCHE TRACK is of the type one to many since there are many avalanches for each avalanche track. Here we record the characteristics of the actual snow avalanche that came down a particular track, what damage it did, how big it was etc.

Similarly table 7 shows the information relating to the actual avalanche characteristics in the starting zone. Since we have defined several avalanche starting zone's for each avalanche track, we are able to register an avalanche with as many starting zones as required. For example, height of the crown, what started the avalanche, what the sliding surface was etc.

**Table 7 Actual Avalanche Starting Zone (ASZ), owned by tables Avalanche and Geographically Defined Avalanche Starting Zone (GSZ).**

Type of key	Item	Points to...	In table....
Primary	Date and time	Date and time	Avalanche
Secondary	Avalanche track #	Avalanche track #	Avalanche & GSZ.
Secondary	Starting zone #	Starting zone #	GSZ.
	Depth of crown		
	Manner of starting	Class	Internatl. aval. classification
	Liquid water in snow at fracture	Class	Intenrnatl. aval. classification

Table 8 is a straight lookup table that contains the international avalanche classification.

<b>Table 8 International Avalanche Classification.</b> Referenced by tables Avalanche Track and Avalanche.			
Type of key	Item	Points to...	In table...
Primary	Class		
Ref: Hydrological Sciences Bulletin, XVIII,4/1973			

Table 9 contains the code for the accuracy of the timing of the avalanche. It is based on the the initial letter of the timing accuracy. For example if the accuracy is determined to be plus or minus 3 hours the code is "K3" K being the first letter in the word *klukkutími* which is Icelandic for an hour. Similarly if the accuracy is plus or minus 2 weeks the code is "V2" *vika* being the Icelandic word for week.

Note that there is a code "K0" for when the Time of the avalanche is precisely known.



**Table 9 Timing Accuracy Codes, referenced by table Avalanche.**

Code	Item
D1 to D6	Day
K0 to K12	Hours
M1 to M4	Months
V1 to V4	Weeks

Table 10 shows where the information regarding the avalanche came from and assorted information regarding the source. This table also serves as a database for the snow observers and the various individuals who have an interest in avalanches. The table can also contain references to books, newspapers and radio and TV reports.

**Table 10 Data sources, referenced by table Avalanche.**

Type of key	Item	Points to...	In table....
Primary	Reference number	Reference number	Avalanche
	I.D. #		
	Name.		
	Address		
	Zip code		
	Postal address		
	Home phone		
	Work phone		
	Cellular phone #		
	Pager #		
	Fax #		
	Computer		
	Association		
	Occupation		
	Relations		
	Training and expertise		

## Design of the User Interface.

As stated above, the user interface had to be such that the data entry would be relatively easy and the danger of mistakes minimised.

First we had to decide upon the "look" of the interface. We decided that we would have four main windows:

- Avalanches.
- Avalanche Tracks.
- Zones.
- Data Sources.

These four entry windows were all put together in the initial selection window. When the entree starts up the database that main selection windows appears. He or she will then select which entry window is required. That window will then appear.

The "zone" entry window is connected to two tables:

- The Zone table.
- The County table.

The integrity of the zone entry window is such that it is not possible to save a specific zone in the database unless a county is selected for that particular zone. This ensures that the zone information is always complete.

The "Avalanche Track" entry window is connected to four tables:

- The Avalanche Track table
- The Geographically Defined Avalanche Starting Zone (GSZ) table.
- The International Avalanche Classification table.
- The Zone table.

The integrity of the Avalanche Track entry window is such that it is not possible to store an Avalanche Track into the database, unless it has been placed in an existing zone. Also it is not possible to enter a GSZ unless it has been associated with an Avalanche Track. In the case where there is no known GSZ it can be entered as unknown. There is no limit to how many GSZ's can be associated with a particular avalanche track.

The "Avalanche" entry window is connected to six tables:

- The Avalanche table:
- The Avalanche Track table.
- The Geographically Defined Avalanche Starting Zone (GSZ).
- The Actual Avalanche Starting Zone table.
- The International Avalanche Classification table.
- The Data Source table.

Similarly, the integrity is such that it is not possible to store an ASZ unless it is associated with an Avalanche. It is however possible to define an unknown ASZ.

The Data Source entry window is only connected to the Data Source table.

The entry into the tables is mostly done by opening a table and selecting by clicking with a mouse on the desired item. E.g. when entering an Avalanche and wishing to select a track, one clicks on the track entry field and thus opens the Avalanche Track table. It is possible to enter the starting letter or letters and thus only open up the relevant part of the AT table. Also, one can select the zone or the county (or both) and open up a table with the relevant AT's. The same goes for all the entry fields.

As much as possible is selected using this method. The only things that are entered via the keyboard e.g. for an avalanche is the time it occurred, the various size factors, number of fatalities, injured and unhurt, damage.

The extent of the avalanche will be entered directly into a GIS system (ArcInfo, see below).

For an avalanche track one has only to type in the AT#, the name, the special dangers, features and whatever comments necessary. Everything else will be selected from other tables(lookup and otherwise) or derived from the GIS system (slope, aspect, co-ordinates).

Conversely it is not possible to delete an item that is referenced to by another table. For example it is not possible to delete an avalanche track that has an avalanche pointing to it nor is possible to delete an avalanche that has a ASZ pointing to it.

### **Querying the Database.**

The four above mentioned entry windows can also serve as query windows. It is possible to make limited queries by entering or selecting specific items. More complicated queries can be made by either entering a direct SQL command or using specially designed applications made with the developing tool Windows4GL. The latter is in the designing phase at the IMO.

As mentioned earlier, certain users require specific information. For example, the Civil Defence require the avalanche history of a specific community whereas the scientist who is studying what happened when a specific weather system moved across the island needs to know what happened during a specific time interval. The rescue team that is involved in a search and rescue mission in a town that has been hit by an avalanche needs to know where the avalanche tracks are located above the town.

By customising the application it is possible to easily control the access of the various users. Thus they can only see what they are meant to see and there is little chance of them altering the data.

By having access to the IMO meteorological database it is possible to run models to calculate the nearest neighbour for a particular situation and by linking the dates found with dates in the avalanche database it is possible to see

what happened for that particular situation. The IMO database is very complete and with modern computer power, it should be possible to get good results.

Also it will be easy to link and use the avalanche database with any kind of avalanche forecast models.

### **Links with Geographical Information Systems.**

The Avalanche Section of the Icelandic Meteorological Office has recently acquired the ArcInfo GIS system. The plan is to use the INGRES database as the attribute database for the GIS system. Thus it will be possible to simply click on the outlines of the avalanche and get up on the screen all the relevant data for the avalanche. Similarly we plan to plot into the GIS system the zones, the avalanche tracks and the avalanche starting zones (GSZ). The avalanche maps will thus serve as an access to the avalanche database.

With a link between the GIS system and the database, certain attributes can be determined directly such as slope, aspect, latitude and longitude etc.

The possibilities of the Geographical Information Systems seem considerable. The initial thought is to make use of the spatial capabilities of the system. It will be possible to determine possible snow loading areas and linking GIS to avalanche runout models and avalanche risk evaluation models.

### **Other Features.**

Another feature that was mentioned earlier as important was the ability of the database to store photographs. We plan to make use of this and include oblique aerial photographs in the database. We believe that when evaluating the risk involved and estimating the potential hazard it is invaluable to be able to view an actual photograph of the avalanche track.

We are also working toward linking the results of a snowpit program (Snowpro by Gasman Industries Ltd.) to the database. The resulting ascii files that are produced by Snowpro, will be transmitted over phone lines or communication networks to the IMO and entered directly into the database. The geographical location as given by the snow observer will be used to make spatial predictions of the snow stability within a zone. Also it will be possible to make direct queries as to the snowpit information available within a specified distance of an avalanche starting zone. For example, meteorological conditions may indicate a possible instability within a specified zone. Then it will be of great help in the evaluation of the potential threat of avalanches to be access all the relevant data in one place.

The Icelandic Meteorological Office publishes an avalanche annal every year. With this new database it is possible to use the report writer feature to give a simple command to produce such an annal. This is a considerable time saving compared to the old way of doing it.

Also the IMO publishes data reports on the avalanche history of the various communities in Iceland, that are threatened by avalanches. Those reports have in the past been quickly outdated but with the database it will be possible to

produce an "up to date" report on demand. And with the ArcInfo GIS system it will similarly be possible to produce "up to date" maps just as easily.

### Conclusions.

It is our feeling that in order to be able to do any kind of modern analyses on a particular phenomena, in this case avalanches it is of very great importance to organise the data in a meaningful way. We believe that our Relational Avalanche Database will greatly help in any kind of avalanche analysis being done. It must be understood however, that no matter how well designed a database is, it can never be better than the data entered. We have found that great care must be taken to ensure that the initial phase of data entering is of the highest quality. In the case of our database, the so called *zones* are the critical part followed closely by the *avalanche tracks*. Although the idea of the database is such that a non-expert should be able to enter data, certain things can only be done by an experienced avalanche professional.

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