

2.3. DEVELOPMENT OF DESIGN

2.3.1. Surveying

Surveying is the technique and science of accurately determining the terrestrial or 3D space position of points and the distances and angles between them. These points are usually, but not exclusively, associated with positions on the surface of the Earth, and are often used to establish land maps and boundaries for ownership or governmental purposes. In order to accomplish their objective, **surveyors** use elements of geometry of engineering, mathematics, physics, and law.

Surveying has been an essential element in the development of the human environment since the beginning of recorded history (ca. 5000 years ago) and it is a requirement in the planning and execution of nearly every form of construction. Its most familiar modern uses are in the fields of transport, building and construction, communications, mapping, and the definition of legal boundaries for land ownership.

Method

Historically, angles and distances were measured using a variety of means, such as chains with links of a known length, for instance a Gunter's Chain, or measuring tapes made of steel or invar. In order to measure horizontal distances, these chains or tapes would be pulled taut, to reduce sagging and slack. Additionally, attempts to hold the measuring instrument level would be made. In instances of measuring up a slope, the surveyor might have to "break" the measurement- that is, raise the rear part of the tape upward, plumb from where the last measurement ended.

Historically, horizontal angles were measured using a compass, which would provide a magnetic bearing, from which deflections could be measured. This type of instrument was later improved upon, through more carefully scribed discs providing better angular resolution, as well as through mounting telescopes with reticles for more precise sighting atop the disc. Additionally, levels and calibrated circles allowing measurement of vertical angles were added, along with verniers for measurement down to a fraction of a degree- such as a turn-of-the-century Transit (surveying).

The simplest method for measuring height is with an altimeter — basically a barometer — using air pressure as an indication of height. But for surveying more precision is needed. Toward this end, a variety of means, such as precise levels have been developed, which are

calibrated to provide a precise plane from which differentials in height between the instrument and the point in question, typically through the use of a vertical measuring rod.

As late as the 1990's the basic tools used in planar surveying were a tape measure for determining shorter distances, a level for determine height or elevation differences, and a theodolite, set on a tripod, with which one can measure angles (horizontal and vertical), combined with triangulation. Starting from a benchmark, a position with known location and elevation, the distance and angles to the unknown point are measured. A more modern instrument is a total station, which is basically a theodolite with an electronic distance measurement device (EDM) and can also be used for leveling when set to the horizontal plane. Since their introduction, total stations have made the technological shift from being optical-mechanical devices to being fully electronic with an onboard computer and software. Modern top-of-the-line total stations no longer require a reflector or prism (used to return the laser used for distancing) to return distance measurements, are fully robotic, and can even e-mail point data to the office computer and connect to satellite positioning systems, such as a Global Positioning System (GPS). Though GPS systems have increased the speed of surveying, they are still only accurate to about 20 mm. As well GPS systems do not work in areas with dense tree cover. It is because of this that EDMs have not been completely phased out. Robotics allows surveyors to gather precise measurements without extra workers to look through and turn the telescope or record data. A faster way to measure (no obstacles) is with a helicopter with laser echolocation, combined with GPS to determine the height of the helicopter. To increase precision, beacons are placed on the ground (about 20 km apart). This method reaches a precision of about 5 cm.

With the triangulation method, first, one needs to know the horizontal distance to the object. If this is not known or cannot be measured directly, it is determined as explained in the triangulation article. Then the height of an object can be determined by measuring the angle between the horizontal plane and the line through that point at a known distance and the top of the object. In order to determine the height of a mountain, one should do this from sea level (the plane of reference), but here the distances can be too great and the mountain may not be visible. So it is done in steps, first determining the position of one point, then moving to that point and doing a relative measurement, and so on until the mountaintop is reached.

Types of surveys

- *ALTA/ACSM survey*: a surveying standard that incorporates elements of the boundary survey, mortgage survey, and topographic survey. ALTA/ACSM surveys, frequently shortened to *ALTA surveys*, are often required for real estate transactions.
- *Boundary survey*: the actual physical extent of property ownership, typically witnessed by monuments or markers, such as (typically iron rods, pipes or concrete monuments in the ground, but also tacks or blazes in trees, piled stone corners or other types of monuments) are measured, and a map, or plat, is drawn from the data.
- *Deformation survey*: a survey to determine if a structure or object is changing shape or moving. The three-dimensional positions of specific points on an object are determined, a period of time is allowed to pass, these positions are then re-measured and calculated, and a comparison between the two sets of positions is made.
- *Draw lot*: one lot from a plat is drawn, with any easements and setbacks that may be on it.
- *Foundation survey*: the position of the house is measured before it is finished being built.
- *Mortgage survey*: a simple survey that generally determines land boundaries and building locations. Mortgage surveys are required by title companies and lending institutions when they provide financing to show that there are no structures encroaching on the property and that the position of structures is generally within zoning and building code requirements. Some jurisdictions allow mortgage surveys to be done to a lesser standard, however most modern U.S. state minimum standards require the same standard of care for mortgage surveys as any other survey. The resulting higher price for mortgage surveys has led some lending institutions to accept "Mortgage Inspections" not signed or sealed by a surveyor.
- *Physical survey*: the finished house and driveway are measured, and all markers on the boundary are indicated. This is recorded when the lot is sold.
- *Plot plan*: a proposal for a house or other building and driveway or parking lot are added to a draw lot.
- *Subdivision plat*: a plot or map based on a survey of a parcel of land. Lines are drawn inside it, indicating the location of roads and lots. Plats are usually discussed back and

forth between the developer and the surveyor until they are agreed upon, at which point pins are driven into the ground to mark the lot corners and curve ends, and the plat is recorded in the cadastre (USA, elsewhere) or land registry (UK). In some jurisdictions, the recording or filing of a subdivision plat is highly regulated. The final map or plat becomes, in effect, a contract between the developer and the city or county, determining what can be built on the property and under what conditions.

- *Topographic survey*: a survey that measures the elevation of points on a particular piece of land, and presents them as contours on a plot.
- *Hydrographic survey*: a survey conducted with the purpose of mapping the seabed for navigation, engineering, or resource management purposes. Products of such surveys are nautical charts.
- *Construction surveying (otherwise "lay-out" or "setting-out")*: the process of establishing and marking the position and detailed layout of new structures such as roads or buildings for subsequent construction. In this sense, surveying may be regarded as a sub-discipline of civil engineering.
- *Archaeological survey*: used to accurately assess the relationship of archaeological sites in a landscape or to accurately record finds on an archaeological site.