Chapter 4

Description Languages

As mentioned in the previous chapter, the configuration of the platform is achieved mainly by means of four configuration files, that describe the configuration of scenario, teams, disturbances and missions. In this chapter, the formal languages developed to express the information regarding those topics are presented in detail. First, a brief description of some implementation considerations is made and then each of the four languages is described.

4.1 Implementation

The four languages were implemented as four XML (eXtensible Markup Language)[1] dialects [W3C, 2008], and specified using XML Schema [W3C, 2004].

A markup language, such as XML, allows for structure (hierarchical mainly) to be easily represented, and, being a self-documenting format, it provides not only with the data, but also with the meta-data to describe the data. Current technological advances (mostly regarding processing and memory capabilities) make the two major disadvantages of using such formats – the larger size of the resulting files and the processing costs associated with these documents – to be only minor disadvantages, which can, some of the times, even be overlooked. XML is perhaps the most popular markup language, and since its inception, it has been adapted to a wide range of applications, in a large number of areas, including medical [Schweiger et al., 2005], [Kumar et al., 2009], multimedia [Deursen et al., 2007], corporate [ANSI/AIIM, 2009] or military [Hobbs, 2003] [Wittman Jr., 2009], among other more traditional areas for XML applications, such as the web [Silva et al., 2007a], [Silva et al., 2007b], [Georgieva & Georgiev, 2010].

The specification of the dialects also needed to be used in the various components of the platform. For that purpose, the dialect specifications, in XML Schema, were converted into C♯ classes, using the XML Schema Definition Tool [Microsoft Corporation, 2010]. This tool is capable of generating Common Language Runtime classes based on an XML Schema document (it

[1] More information available online, from `http://www.w3.org/XML/`

can also generate an XML Schema file based on either a set of classes, or an XML file, making it a very flexible tool to be used when working with XML and XML Schema and one of the several supported programming languages). This easiness of transforming a dialect specification into code is also of great usefulness when changes are made to a dialect specification – the changes to the specification are rapidly reflected into the code, which reduces the cost of changes to the language specifications in the future. There is, however, one limitation to this process – no two elements can have the same name. Even though XML Schema allows for elements to have the same name but different specification (provided that an in-line type definition is used), this would imply the creation of classes with the same name, and therefore no two elements in the four dialects have the same name (except when using the same definition).

Part of the specification process for the four dialects was done using Altova XMLSpy[2], a powerful and flexible tool for working with XML-based technology. The Visual XML Schema Editor included in this tool was also used for capturing the images used to illustrate dialect specifications in this document.

4.1.1 Physical Structure

Each of the four dialects was specified in a separate XSD file. In order to facilitate the development of these dialects, elements common to two or more of them were grouped into a file (Common.xsd) that was then imported by each of the four main dialect specification files – see Fig. 4.1.

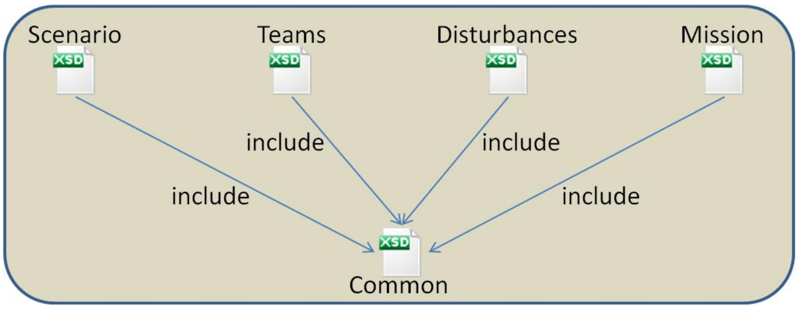


Figure 4.1: Physical Structure of XSD Files for Dialect Specification

This decision to eliminate repeatability was made as to facilitate specification and decrease the probability of introducing errors: using repeated code on more than one location increases the chances for an error to be made, especially if changes to an element need to be replicated into all definitions. This also allows for an element to be used in more than one dialect, without the need to change its name. This choice, however, also entails an increased need for attention during development – if a common element needs to be changed only in one of the dialects, but not in the other, it has to be removed from the common file and renamed. Table 4.1 shows the classification according to category and emphasis, as described above, but considering the five produced files.

[2]More information available online at `http://www.altova.com/xmlspy.html`

	Static	**Dynamic**
Scenario	SDL	DDL
	Common	
Team	TDL	MDL

Table 4.1: Language Files Classification

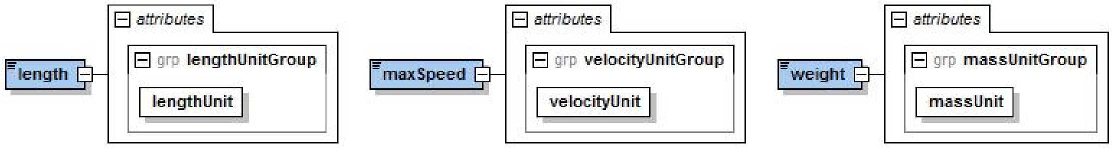
4.1.2 Additional Notes

All elements that provide a physical measure are accompanied by an attribute that defines the unit in which the value is being specified. This is done for two main reasons: first, to accommodate the different units that are commonly used to specify the same measurement type, according to context (ground vehicle speeds are usually indicated in either kilometers per hour or miles per hour, but for boats or aircraft the most widely used unit is knots); and second, to make the developed dialects compatible with users with different backgrounds (for instance, users in the UK and the US usually use different measurement units). Table 4.2 shows the units used in some measurement elements, as well as the symbols used for the representation of the unit in the Control Panel interfaces.

Type	**Unit Name**	**Interface Symbol**
Length	Meter	m
	Centimeter	cm
	Kilometer	km
	Foot	ft
	Inch	in
	Mile (Statute)	mi
	Nautical Mile	nm
Volume	Cubic Meter	m3
	Cubic Centimeter	cm3
	Cubic Kilometer	km3
	Cubic Foot	ft3
	Cubic Inch	in3
	Cubic Mile (Statute)	mi3
	Cubic Nautical Mile	nm3
	Gallon	gal
	Liter	l
Angle	Degree	Deg
	Radian	Rad
Area	Square Meter	m2
	Square Centimeter	cm2
	Square Kilometer	km2
	Square Foot	ft2
	Square Inch	in2
	Square Mile	mi2
	Square Nautical Mile	nm2
Mass	Gram	g
	Kilogram	kg
	Ounce	oz
	Pound	lb
Speed	Meters per Second	m/s
	Inches per Second	in/s
	Kilometers per Hour	kph
	Miles per Hour	mph
	Nautical Miles per Hour (Knots)	kts

Table 4.2: Measurement Units

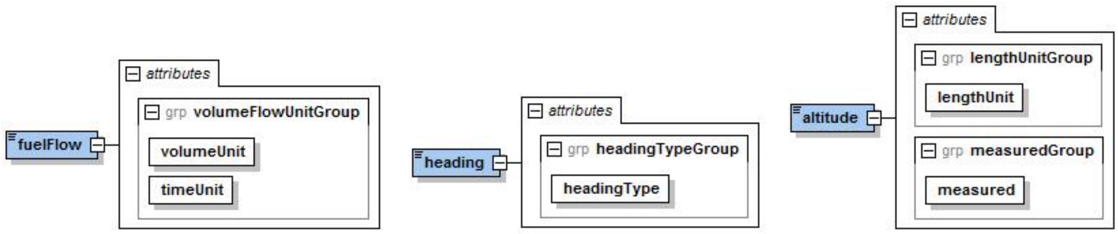
Most of these elements are located in the file that defines the common elements. Figures 4.2(a), 4.2(b) and 4.2(c) show examples of elements that use these attributes, namely the use of length, speed and mass unit attributes. Figure 4.3(a) shows an example of an element that needs two unit attributes, as it specifies the fuel consumption (volume over time).



(a) Length Element (b) Max Speed Element (c) Weight Element

Figure 4.2: Length, Maximum Speed and Weight Elements

Additionally, some elements feature some contextual choices, in a manner similar to unit choice; for instance, the altitude of a set of coordinates can be specified to be above the mean sea level (amsl) or above ground level (agl); a heading (direction) can be specified to be relative to the local Earth's magnetic field North orientation, also known as magnetic North (Mag) or relative to the Earth's geographic North, also known as true North (True). Figures 4.3(b) and 4.3(c) show two examples of elements that use these contextual choices – Fig. 4.3(c) shows an element (altitude) that combines the contextual choice attribute (how the altitude is measured) and the unit attribute (length unit).



(a) Fuel Flow Element (b) Heading Element (c) Altitude Element

Figure 4.3: Fuel Flow, Heading and Altitude Elements

4.2 Scenario Description Language

In this section, a full overview of the Scenario Description Language (SDL) is given, and each part of the scenario definition is analyzed in more detail. As previously stated, this dialect was developed in order to fully describe an operating scenario for a team (or several teams) of mobile robotic vehicles. The root element of a scenario description is named *scenario*, and it contains elements describing the unchangeable (static) part of the environment. Equation 4.1 formalizes the representation of a *scenario* element as a tuple constituted by four sets – bases of operations, controllers, agent types and no-fly areas.

$$
\begin{aligned}
&Scenario = \langle B, C, T, N \rangle \\
&B = \{BaseOfOperations\} \\
&C = \{Controller\} \\
&T = \{AgentType\} \\
&N = \{Area\}
\end{aligned}
\tag{4.1}
$$

In more detail, the scenario is defined as a tuple comprised of:

- a set of bases of operations $B = \{b_1, b_2, \cdots, b_{nb}\}$ (which may contain an airport, port and/or a ground base) that can be used by one or more of the teams
- a set of controllers $C = \{c_1, c_2, \cdots, c_{nc}\}$, that control traffic on a well defined area of space
- a set of agent types $T = \{t_1, t_2, \cdots, t_{nt}\}$, that define the available vehicles types and their characteristics
- a set of no-fly areas $N = \{n_1, n_2, \cdots, n_{nn}\}$, that define the areas that no team can navigate through

Figure 4.4 shows the graphical representation of the *scenario* element.

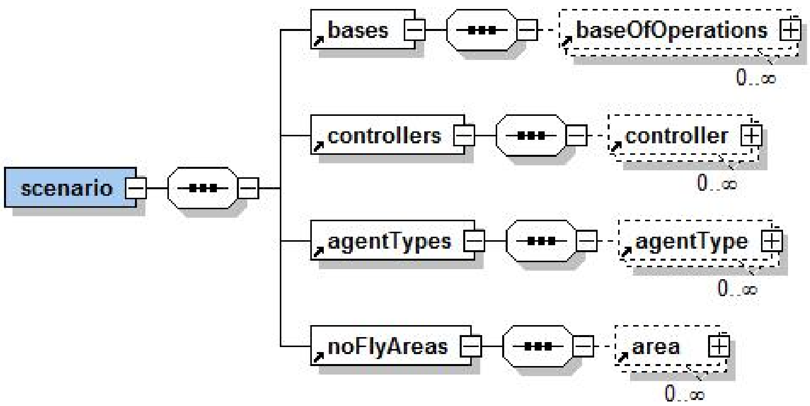


Figure 4.4: Root Scenario Elements

Each of the four main scenario elements is described in more detail in the following four sections – for presentation simplification, the *area* element (no-fly areas) is presented before the *controller* element.

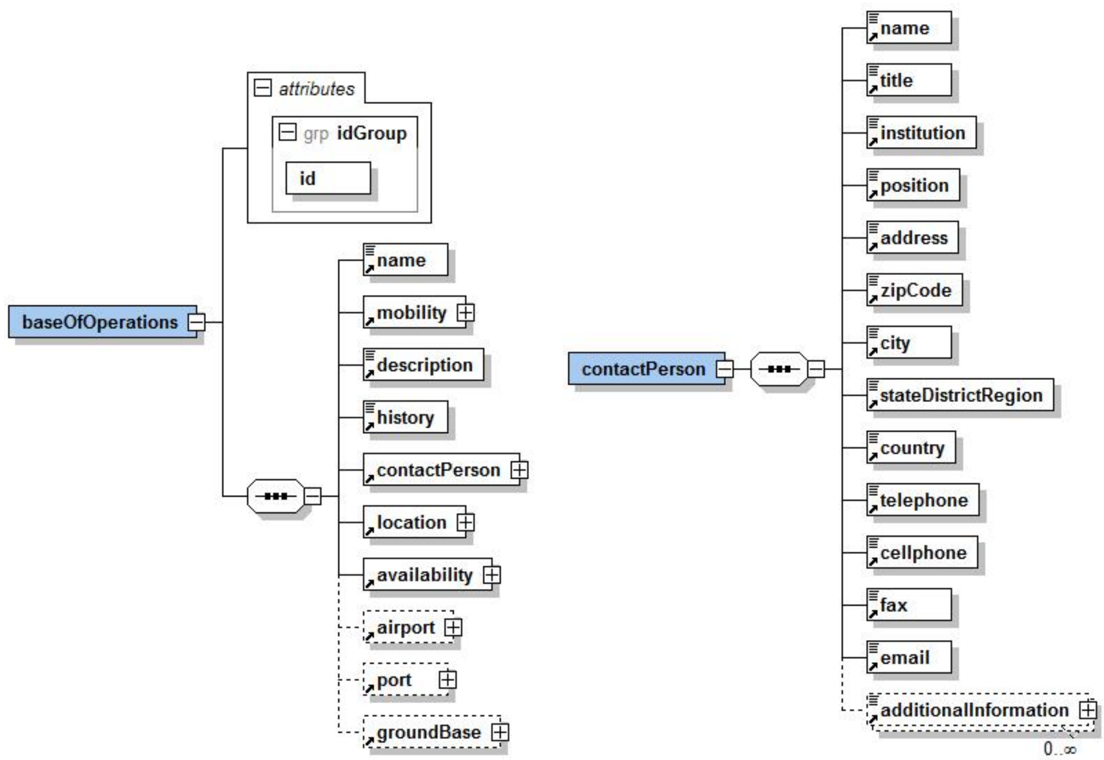
4.2.1 Bases of Operations

This section of the SDL file contains a list of available bases of operations. The concept of base of operations is derived from traditional military bases, which are well-defined regions (sometimes even physically delimited) that contain structures and other resources that allow for services to be rendered to personnel, vehicles or other equipment.

Each base of operations has a unique identifier, which will later be referenced by the TDL file – see section 4.3. For each base of operations, a number of information details are provided (Fig. 4.5(a) shows the information contained within the *baseOfOperations* element in a graphical notation):

- **name**. The name by which the base of operations is known. If the base contains only an airport (or only a port, or only a ground base), the name of the base is usually coincident with its name.

- **mobility**. This element includes four boolean attributes (air, land, water and underwater), which indicate the type of vehicles the base provides support for – see Fig. 4.6(a). Also, these attributes define the existence of the optional elements *airport*, *port* and *groundBase* (described below).



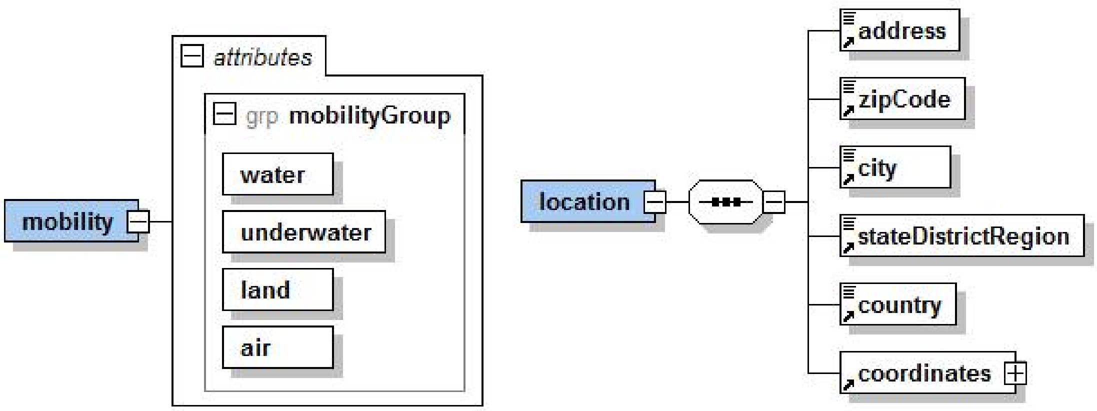
(a) *BaseOfOperations* Element Definition (b) Contact Person

Figure 4.5: Base of Operations and Contact Person Elements

- **description**. A brief textual description of the base of operations, that may include a listing of available services and facilities.

- **history**. This element can contain a detailed description of the base of operations, and its historical background, as well as the modifications it went through over time.

- **contactPerson**. This element contains detailed information about the person to contact regarding the base of operations. It includes name and title of the person of contact; the institution he works for and his position within that institution; address for physical correspondence (address, zip code, city, state and country) and other contacts (e-mail, telephone, cell phone and fax); and the possibility to add any additional information items, such as preferred contact hours or alternative contacts. Figure 4.5(b) shows the definition of this element.
- **location**. Provides information regarding the location of the base of operations. It is comprised by a physical address (which may or may not coincide with the address of the person of contact) and the coordinates for the location of the base (usually either the coordinates for the center of the base, or those of the office where the contact person can be reached) – see Fig. 4.6(b).



(a) Mobility Element (b) Location

Figure 4.6: Mobility and Location Elements

- **availability**. This element describes the temporal availability of the base for operations (for instance, one base of operations b_1 may only be available during daytime, but not for night operations, while another base b_2 may only be available during weekdays, but not during the weekend). If the base is not always available for operations, at least one availability slot must be indicated; each availability slot contains the start and end date and time of the period during which the base is available; also, if the specified availability slot occurs periodically, the rate of recurrence can be specified, as well as the initial and final dates during which the recurrence is valid. Figure 4.7 shows the definition of the availability element and listing 4.1 shows an example of an availability element – in this example, the base would be available every day from January 1 to December 31, 2010, from 9AM to 5PM.

Listing 4.1: Availability Element Example

```
...
<availability available="periodic">
   <timeSlot repeat="Day" every="1">
```

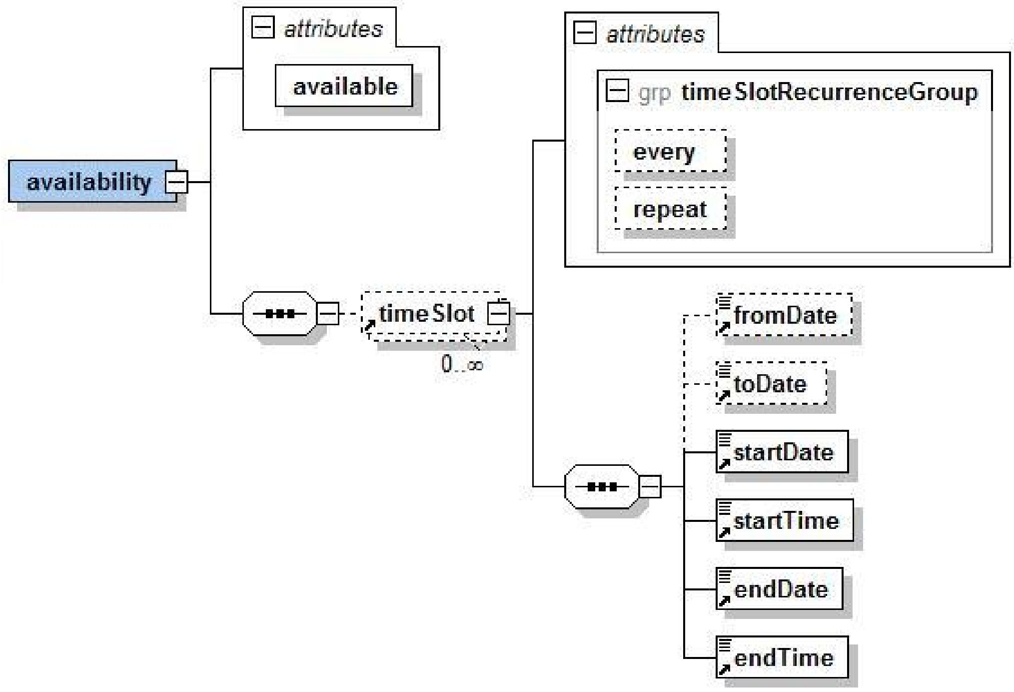


Figure 4.7: Availability Element Definition

```
        <fromDate>2010-01-01</fromDate>
        <toDate>2010-12-31</toDate>
        <startDate>2010-01-01</startDate>
        <startTime>09:00:00</startTime>
        <endDate>2010-01-01</endDate>
        <endTime>17:00:00</endTime>
    </timeSlot>
</availability>
...
```

- **airport**. This optional element contains a detailed description of the airport within the base of operations, its structure and the services it provides (this element is described in more detail below). The presence of this item is determined by the value of the *air* attribute of the *mobility* element.
- **port**. This optional element contains a detailed description of the port within the base of operations, its structure and the services it provides to boats and/or submarines. The presence of this item is determined by the values of the *water* and *underwater* attributes of the *mobility* element.
- **groundBase**. This optional element contains a detailed description of the ground base within the base of operations, its structure and the services it provides. The presence of this item is determined by the value of the *land* attribute of the *mobility* element.

Given the complexity of the *airport*, *port* and *groundBase* elements, they are described in detail in the following three sections.

4.2.2 Airport

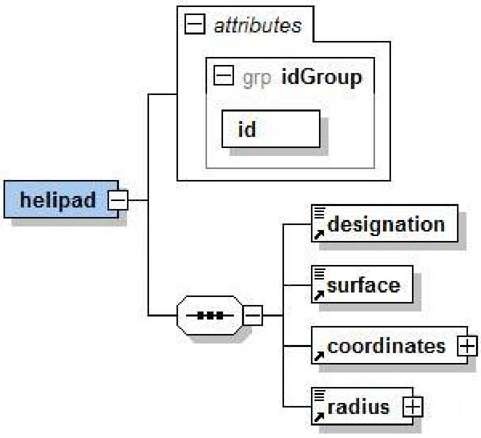
In order to provide a description of airports closer to what is used in the real world, some applications that make use of an airport description were analyzed, as seen in section 2.3. Considering the different formats and information included in the analyzed simulators, it was decided to include a stripped down version of the airport description found in FSX, focusing on the important aspects, such as positioning, dimensions, and intersections of possible paths, leaving out the information regarding visual details, such as lights or signs.

Equation 4.2 shows the contents of the *airport* element, which are explained in more detail below.

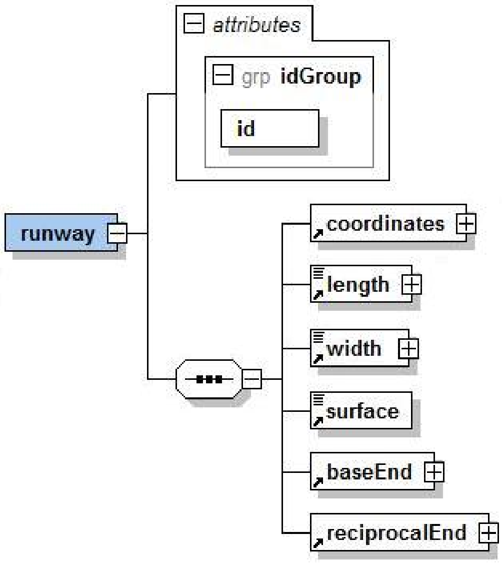
$$\begin{aligned}
Airport &= \langle name, description, contactPerson, location, \\
&\qquad IATA, ICAO, magVar, H, R, T, P, G, U \rangle \\
H &= \{Helipad\} \\
R &= \{Runway\} \\
T &= \{Taxiway\} \\
P &= \{Parking\} \\
G &= \{Hangar\} \\
U &= \{Utility\}
\end{aligned} \tag{4.2}$$

- **name**. The name by which the airport is known.
- **description**. Textual description of the airport and the services it provides.
- **contactPerson**. Information regarding the person of contact for the airport; its definition is the same as for the base of operations.
- **location**. Information regarding the location of the airport; its definition is the same as presented above for the base of operations.
- **IATA**. The IATA (International Air Transport Association) code of the airport; this code is comprised of three letters, and widely used for major airports, namely in baggage tags.
- **ICAO**. The ICAO (International Civil Aviation Organization) code of the airport; this code is comprised of four alphanumeric characters, and provides a unique code for each airport worldwide.
- **magVar**. The magnetic variation (difference, given in degrees, between true North and magnetic North) at the airport location.
- **helipad**. Helipads are relatively small, round or square regions of the airport used by helicopters for vertical takeoff and landing; the helipad element is comprised of four items, as can be seen in Fig. 4.8(a):

- **designation**. The name by which the helipad is known.
- **surface**. Material the surface of the helipad is made of.
- **coordinates**. Coordinates for the center of the helipad.
- **radius**. Radius of the helipad.



(a) Helipad Element



(b) Runway Element

Figure 4.8: Helipad and Runway Elements

- **runway**. Runways are the straight, flat and long strips of terrain used by aircraft for takeoff and landing; the runway element is comprised by several items, as represented graphically in Fig. 4.8(b):
  - **coordinates**. Coordinates for the center of the runway.
  - **length**. Length of the runway.
  - **width**. Width of the runway.
  - **surface**. Material the surface of the runway is made of.
  - **baseEnd**. Contains information regarding one of the two orientations of the runway; it includes the designation of the runway (a number, from 01 to 36, corresponding to one tenth of the magnetic heading of the runway), coordinates for the start and end points of the runway and its orientation (heading).
  - **reciprocalEnd**. Contains information regarding the other orientation of the runway; the designation should differ from the designation of the baseEnd by 18, and the orientation by 180°; the start and end points may match the end and start points of the baseEnd, respectively, but in some cases that may not be the case.

- **taxiway**. Taxiways are used for ground operations (either by aircraft or by other vehicles operating on the airport), connecting runways with other areas of the airport, such as parking spaces, fuel facilities, hangars or helipads; this element is comprised by four items, as shown graphically in Fig. 4.9:
  - **designation**. The name by which the taxiway is known.
  - **surface**. Material the surface of the taxiway is made of.
  - **width**. Width of the taxiway.
  - **path**. Contains information about the shape of the taxiway; it include both initial and final points of the taxiway, as well as a variable number of middle points – where the taxiway changes direction or where it intersects with another taxiway or runway; each point contain the coordinates of its location; in case of interception, the taxiway(s) and/or runway(s) it intercepts with are also specified.

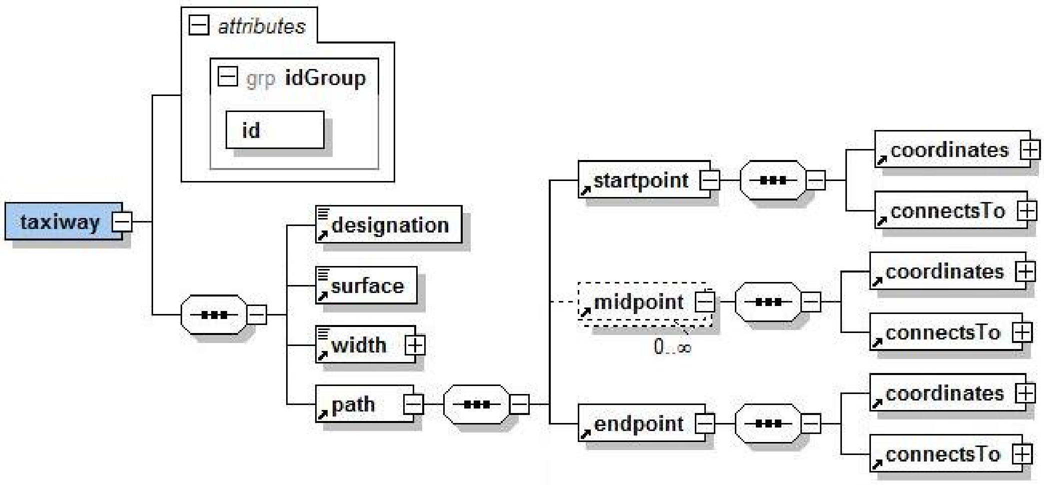


Figure 4.9: Taxiway Element Specification

- **parking**. Parking spaces are specific locations within the airport, used to park aircraft, usually for a relatively short period of time; this element has several items:
  - **designation**. The designation of the parking space.
  - **description**. Description of the parking space, including purposes (whether the parking space is used mainly by commercial aircraft, cargo companies, privately owned jets, or others) and other information.
  - **airlines**. Lists which airlines have priority of use over the specific parking space.
  - **coordinates**. Coordinates of the parking space.
  - **radius**. Radius of the parking space.
  - **connection**. Indicates the taxiway (including the specific coordinates) where the parking space connects to the taxiway network.

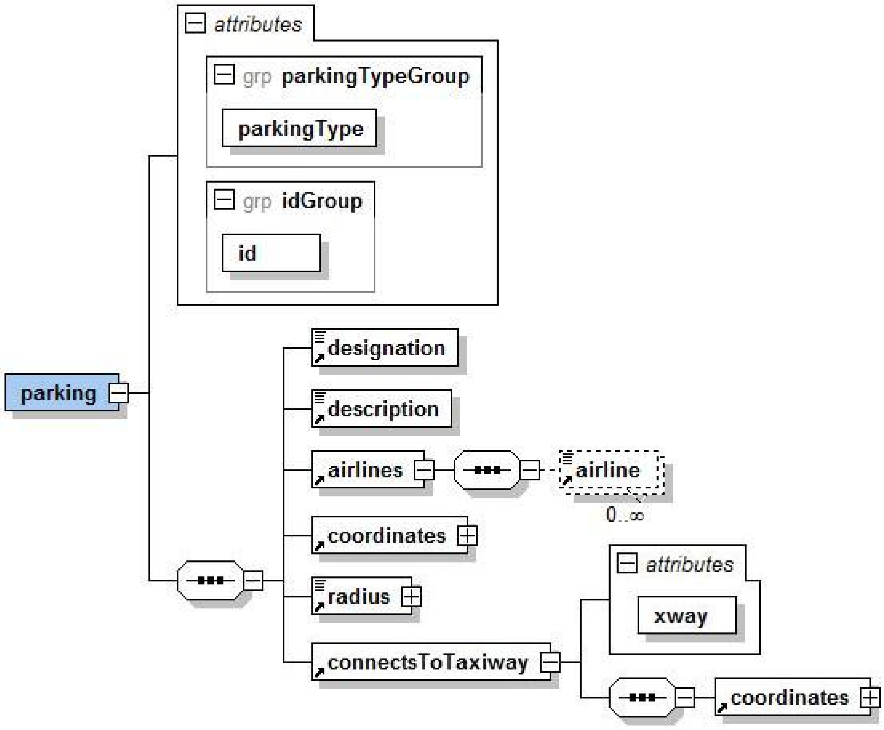


Figure 4.10: Parking Element Specification

- **hangar**. Hangars are closed structures, usually used for long-term housing of aircraft, maintenance or repair operations; this element has three items, as represented graphically in Fig. 4.11:
  - **designation**. The designation of the hangar.
  - **description**. Brief description of the hangar, especially in terms of its purposes and possible owner.
  - **shape**. Specifies the shape of the hangar (expressed as a polygon), its height, useful area and the type, location and size of the doors.

- **utility**. There are four types of utilities – Tower, Fuel Facility, Battery Facility and Water Facility – with three common elements:
  - **designation**. The designation of the utility.
  - **coordinates**. Coordinates for the center of the utility.
  - **radius**. Radius of the utility.

  In addition to these three elements, the Tower also has an element specifying its height; both Fuel and Water Facilities have the available quantity of fuel or water, respectively; and the Fuel Facility has an indication of the type of fuel it provides.

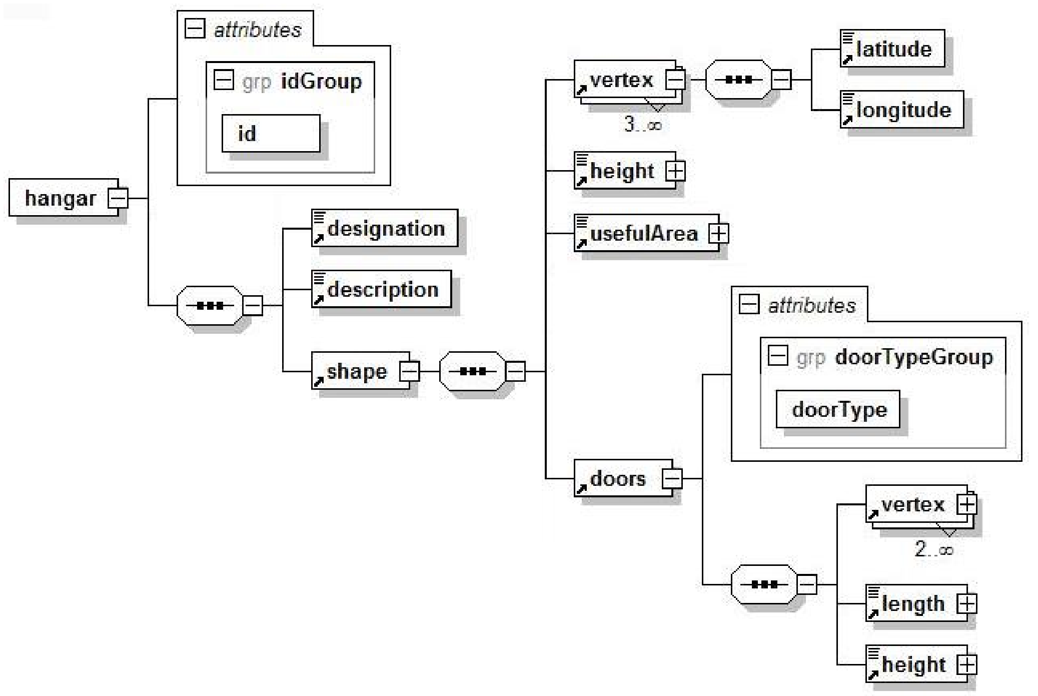


Figure 4.11: Hangar Element Specification

The information contained in these element (namely, the information retrieved from the *runways* and *taxiways* elements) is structured in a manner that facilitates its use in the construction of a graph containing the possible paths to be used by airplanes while on the ground [Sousa, 2010]. This information is of major importance so that the agents can plan their paths with maximum efficiency.

4.2.3 Port

The port has a similar structure to the airport, but adapted to meet the requirements for modeling a water facility. Figure 4.12 represents the port element graphically, and the several elements that constitute a port are enumerated below:

- **name**. The name by which the port is known
- **description**. Brief description of the port and its facilities and the services it provides
- **contactPerson**. The details for the person who should be contacted for matters regarding the port. The definition of this element is the same as the one presented above
- **location**. The location of the port (the definition of this element is the same as presented above)
- **magVar**. The magnetic variation at the location of the port