A geocoding information system for Greenland

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Summary

Currently, addressing practices in Greenland do not fully support geocoding. Addressing points on a map by geographic coordinates is vital for emergency services such as police and ambulance for improving efficiency and avoiding ambiguities in incident handling. Therefore, it is necessary to investigate the current addressing practices in Greenland. Asiaq is a public organization of the Government of Greenland which holds three data sets regarding addressing and place references:

- locality names (towns and settlements),
- technical base maps (road center lines and buildings),
- the NIN registry (The Land Use Register of Greenland - information on the land allotments and buildings in Greenland).

The main problem is that these data sets are not interconnected, thus making it impossible to address a point in a map with geographic coordinates in a standardised way. The possible solutions suffer from the fact that Greenland has a scattered habitation pattern which makes it inflexible towards generalisation of the addressing model.
The aim is to propose an information system for the addressing system in Greenland which would support geocoding. Part of this research is dedicated to the investigation of current addressing practices in Greenland and user requirement engineering. This facilitates the design of a conceptual database model which is derived from the user requirements. Furthermore, this research includes a background survey on other addressing and geocoding systems, resemblance findings

in Danish and Greenland's addressing practices, a data dictionary for establishing a Greenland addressing system's ontology and enhanced entity relationship diagram.
The development of the Greenland addressing system using a geographic information system (GIS) and database technology would ease the work and improve the quality of public services such as: postal delivery, emergency response, customer/business relationship management, administration of land, utility planning, maintenance and public statistical data analysis, urban and regional planning, and support other decision makers.

Resumé

De nuværende adresserings fremgangsmåder i Grønland understøtter i øjeblikket ikke geocoding fuldstændigt. Det er essentielt for beredskabstjenester såsom politi og ambulancer, at kunne anvende addresse punkter på et landkort ud fra geografiske koordinater, for at forbedre effektiviteten og undgå tvetydigheder ved udryking. Derfor er det nødvendigt at undersøge nuværende adresserings metoder i Grønland.
Asiaq er en offentlig organisation nedsat af den grønlandske regering, som holder tre datasæt vedrørende adressering- og stedreferencer:

- lokaliteters navne (byer og bygder/bosættelser),
- tekniske grundkort (Vejlinjer og bygninger),
- NIN registret (Grønlands Arealregister - indeholder informationer omkring arealtildelinger og bygninger i Grønland).

Det væsentligste problem er at disse datasæt ikke er sammenkoblede, hvilket gør det umuligt at adressere et punkt på et kort med geografiske koordinater på en standardiseret måde. De mulige løsninger lider under det faktum at Grønland har et meget spredt beboelses mønster, hvilket gør det ufleksibelt i forhold til den generaliserede adresserings model.
Målet er at foreslå et adresserings informationssystem i Grønland, som vil kunne understøtte geocoding. En del af denne forskning er dedikeret til at undersøge de nuværende adresseringsmetoder i Grønland, samt undersøge brugerkrav. Dette forenkler designet af en konceptuel database model, som stammer fra

brugerkravs undersøgelsen. Derudover inkluderer denne research også en undersøgelse af andre adressering- og geocoding systemer, ligheder fundet mellem de danske og de grøndlandske adresseringsmetoder, en dataordbog til etablering af et grønlandsk addresserings systems ontologi, samt et forbedret Entitets Relation diagram.
Udviklingen af det grønlandske adresserings system ved brug af et geografisk information system (GIS) og database teknologi vil lette arbejdet og forbedre kvaliteten af offentlige tjenester, såsom: postomdeling, nødudrykning, kunde-/forretningsforbindelser, landfordeling, planlægning, vedligeholdelse af offentlige statistiske data analyser, land- og byplanlægning, og understøtte andre beslutningstagere

Preface

This thesis is was prepared at Informatics Mathematical Modelling (IMM), the Technical University of Denmark (DTU) in accordance with the requirements for obtaining a master degree in Computer Science and Engineering. The work has been conducted under the supervision of François Anton from DTU IMM and Darka Mioc from DTU Space.

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Chapter 1

Introduction

1.1 Motivation

Currently, in Greenland it is not easy to communicate the precise location of an incident to the emergency services, e.g., police [1]. There have been cases when the police department had received a report about an incident but, due to ambiguity referencing their location, these cases had not been handled properly. When the police officer received the reporting call, he was requiring for the address where the incident had happened. The officer had information about who called, and what was the building address alias [2]. Recently, several incidents have been reported in building's neighbourhood, thus, the police assumed that they knew the place. When police officers came to the named place, they encountered that there was no accident. It later turned out that the alias for the building name was the same and the reporter was located in a different town. In order to be clear and unambiguous for future incident handling an improvement has to be introduced to minimize the risks of ambiguities.

1.2 Overview of addressing systems

Addresses are the most commonly used way of referencing a location in the world. Countries have various addressing schemas and their differences have mostly evolved due to historical and cultural reasons, e.g., in Europe most of addressing schemas are similar and reference a road network, while addressing systems in Asia, (e.g., Japan) comprise hierarchy of administrative areas without referencing road names [3]. To name a few purposes for addressing systems, they are used for postal delivery, emergency service response, land administration, utility planning and maintenance and public statistical surveying.
Addresses can be utilized in different scales depending on purposes. A geographical overview of addresses can be used in land administration. In customer analysis, street names could be irrelevant where specifying place names would reveal sufficient information [3]. For mail delivery and emergency service handling a precise reference point is needed, specifically identifying an individual recipient point or place of incident. To communicate the address unambiguously there are specific rules to follow and formatting rules to obey for rendering and recognition of the address label. The ratio of delivered and mis-delivered letters and packages shows the effectiveness of communicating address information from one party to another, i.e., sender to postal service and postal service to recipient. In case of emergency services this ratio would show the proportion of address points which are found and not found or found with a certain delay.

In the other parts of the world there could be found similar inhabitation pattern to Greenland, i.e., Canada, Sweden, Australia, Saudi Arabia, etc., where settlements are 10 and more kilometres away from each other. Relatively hot or cold climate and the problematic access to goods and services are usually discouraging people to move to these locations and due to is this reason these territories are not densely populated. Addressing systems usually are adjusted to this type of inhabitance pattern, thus they are similar. For example, in Canada for the federal territory of Nunavut (furthest Northern part) the density of population is only 0.02 inhabitants/km^2 [4]. Generally, postal addresses in Canada have identifiers which resemble modes of delivery, e.g., "PO" - Post office, "RR" - Rural Route delivery, etc. [5]. Almost all of the addresses for Nunavut's region have a delivery identifier "LB" which stands for lock boxes. Lock box is also called post office box and is a delivery to a specific box in a post office. There were 8741 out of 8897 addresses with the lock box delivery type in Nunavut by February 2012 [6]. Rural area address examples in Sweden could be found in Norrbotten County [7] where population density is 2.51 inhabitants/km^2. Common addressing system is described in Section 2.2.1 whereas in rural areas the mail distribution points are used [8]. In these cases "Box" followed with a postal box number in a mail distribution point is used. When necessary this identifier replaces more commonly used street number/address place designator

line in the postal address label. In Australia, the population density in average is 2.8 inhabitants/km^2 and in the state of South Australia it is around 1.67 inhabitants/km^2 [9]. By June of 2012, South Australia would be finished with rural address standard change which now would include a distance-based road number, road name, locality and postcode [10]. It is similar to Sweden's rural road addressing standard, where the distance-based road number is also part of the address label (described in Sections 2.2.1, 2.2.2). This standard also includes changes where all the address geographic coordinates are recorded in a common database implying that geocoding is also a part of this project. There are also places with rapid population growth where addressing system standards have to be introduced because the current addressing practices are not convenient, scalable or referencing is ambiguous. For these reasons in 2010 a new addressing system was introduced in Abu Dhabi (United Arab Emirates) by a company called Nordplan [11]. Later, this company won the competition to create an addressing system for Muscat Governorate in Oman [12]. It is worth to mention that one of the biggest projects in Middle East regards addressing system has been done by Saudi Postal Corporation in Saudi Arabia. The aim was to create a mailing and residential address system for the entire kingdom. Previously mentioned projects in Abu Dhabi and Muscat Governorate had been driven to create street name based addressing system, but in Saudi Arabia as from 2010 a 13-digit address is used which is unique and systematic for each location in the kingdom [13, 14].
It is necessary to investigate which of these addressing system prototypes or a combination of them could be closest in application for Greenland. Current addressing practices in Greenland are based on several data sets which are not interconnected. Usually, buildings have a house number and a B-number plates, which are instances of house number database and B-number database.

Two of the addressing references are building number and B-number (cf. Section 5.4). Example photos of the number plates on the house is shown in Figure 1.1 and Figure 1.2. A depiction of characteristics of the settlement pattern can be seen in the Figure 1.3, 1.4 and 1.5.

Most of the towns in Greenland have a similar settlement pattern. As an example, a town called Sisimiut will be described more thoroughly.
Sisimiut is the second largest town in the Greenland with population 5,571 in 2012 [18] located by the South-eastern cost of Greenland. In the center of Sisimiut, streets have been given names but numerous smaller streets do not have a name as a reference. One of the central Sisimut streets is shown in Figure 1.6 and an example of a street name sign in is visible in Figure 1.7. Similar street naming practice is in all of the Greenland's towns.

In towns with the highest population like Sisimiut mail is distributed to the recipient mailboxes. One of them is shown in Figure 1.8.

Figure 1.1: House number plate on the museum of art (Kunstmuseum) in Greenland, Nuuk [15]

Figure 1.2: House number and B-number plate on the house in Greenland, Sisimut [16]

Figure 1.3: Harbour town Sisimiut in Greenland [17]

Figure 1.4: View from historical part of Sisimiut to Seamen's hotel and harbour [16]

Figure 1.5: Docks in Sisimiut [16]

Figure 1.6: Street leading to Artek center in Sisimiut [16]

Figure 1.7: Street name sign in Sisimiut [16]

Figure 1.8: A house near Artek center with number plates and mailbox in Sisimiut [16]

In order to be clear and distinctive for future incident handling, improvements have to be introduced to minimize the risks of ambiguities. Further chapter will outline the background study on geocoding and similar addressing systems in order to find applicable methods for Greenland's case.

Chapter 2

Background

2.1 Geocoding practices

Geocoding is the process of assigning geographic coordinates to a physical location on the Earth. Usually, it is performed for other well known geographical identifiers, such as addresses. In this work, the emphasis is on address information geocoding. The aim is to obtain a data model which supports both, geographic coordinates as a pair of latitude and longitude values, and address information designator for each address-holding property in Greenland.
Commonly used applications, such as navigation, parcel tracking, and route calculations also employ the reverse geocoding. This is a process for obtaining address data from the geographical coordinates linked to it.
Geocoding for addresses can be performed manually by adding coordinates to each respective address data record but this might not be feasible for large data sets. Therefore, a technique called address interpolation is employed. The prerequisite for this method is that there should be available spatial data which has been referenced to a coordinate system. Depending on the available data it is possible to geocode by street address, postal code and other administrative divisions [19].
For the last two methods, i.e., by postal code and administrative divisions the geocoded location for all address points in the area would be the centroid of the polygon representing the position of the polygon with respect to chosen refer-

ence system. Usually, a digitised road network is used because it gives the yield in highest achievable accuracy [19]. The digitised road network should have the following characteristics.

- Roads should be digitised as line objects for interpolation function to be applicable.
- Every road should be segmented and have an attribute of range of possible address numbers. There could be roads with one segment but to achieve the necessary precision of interpolation function's outcome, greater segmentation could be necessary.
- Roads should have a distinctive starting point. Starting point would indicate how the numbers should be distributed along the road and the segments of it.

Currently, any address interpolation method could not be directly applied in Greenland's case. First, not all of the Greenland's roads are digitised. Second, for the roads which have been digitised, the road object names or identifiers are bound to coordinate system as points rather than lines. Third, they are not segmented. Moreover, this method usually is applicable in cities with district planning because of interpolation function properties. It's outcome is more precise if the housings are aligned next to each other which is not the case Greenland's towns. Figure 2.1 is a representation of inaccuracies that could occur when interpolation distributes street numbers evenly along the street segment.

Most importantly, the requirements of Greenland geocoded addressing system include its usage for emergency case handling. Recent studies show that interpolation results are far from being reliable for this type of application. One of the biggest data sets employing the interpolation method is U.S. Census TIGER (Topologically Integrated Geographic Encoding and Referencing) [21]. It has been debated that nearly 50% of the geocoded address coordinates are offset in different property parcels [22]. Other research has confirmed that TIGER data is not sufficient for emergency handling implementations but rather non-critical applications. Their study claims that the imprecision in interpolation methods leads to 40% loss in competence for derived statistical analysis [23].
A more suitable geocoding method for Greenland's case would be an individual localisation of each separate address. The requirement of sufficient precision for emergency handling could be satisfied with this method and utilized in high precision requiring applications. The reason being that it would be possible to locate which building and, if required, address is assigned to the specific entrance door. Data could be visualized on maps in detailed scale level, up to 1:500 [24]. There are several other benefits of using this methodology over the interpolation which is based on the road network.

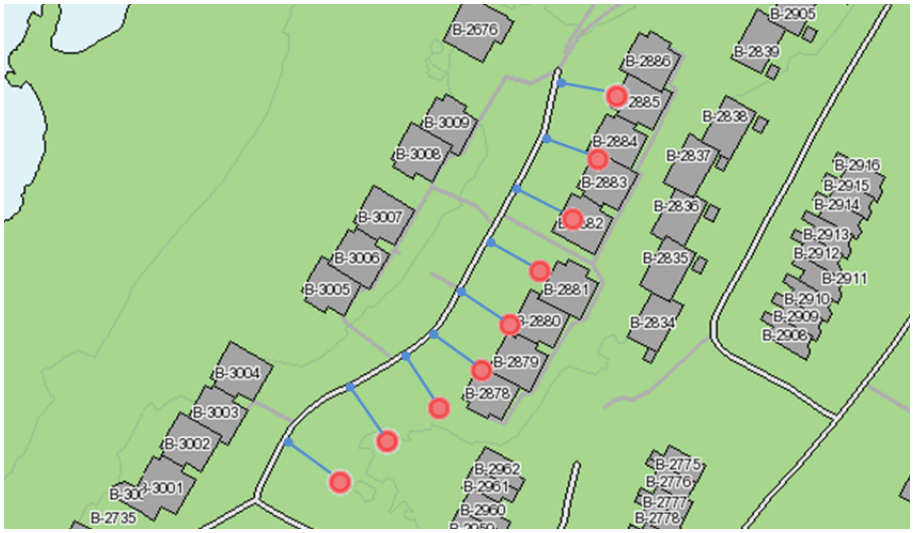


Figure 2.1: Representation of interpolation method's outcome where address points are evenly distributed along the street (background map from [20])

- As mentioned Greenland's inhabitation pattern is rather sparse. This method would precisely locate address point with minimum deviation from the address physical location, e.g., Nuukullak 3 and Nuukullak 3A - addresses in different parts of the building complex.
- Accuracy would enable possibility for detailed queries, e.g., closest neighbour find.
- Dependency of the road network would lowered, thus it would be possible to geocode sparse housings.
- Possibility to geocode addresses where the road has not been built.

However, there are caveats as well.

- Addresses would be marked as points on the map which in some of the cases could be ambiguous physical location representation, e.g., industrial building complex with one address assigned to it. This should rather be a polygon which has a centroid for address point.
- A digitised and segmented road network needs to be in place because together with start and destination points linked to it, route creating functions can estimate the desired route.

Figure 2.2: Representation of individual localisation points for building entrances linked with edges to the assigned street (background map from [20])

- No approximation point given for address which is not in the data set. Search is dependant on selection function's result in a set of address records.

Figure 2.2 represents individual localisation points for several housings in Nuuk as an example.

Similar efforts were made in Denmark's addressing system by 2001 [25]. One of the first examples published using the geocoded addressing system was Denmark's public transportation route planner [24, 26]. Followed by Denmark's emergency center incident handling system reorganization in order to improve service quality with the help of new addressing system [24]. Back when project was started it was concluded that Denmark's addressing practices were not sufficient for proceeding to geocoding immediately. There was a need for address harmonisation which involved all the municipality collaborative effort. There were issued as a collection of guidelines with examples in address and street name assignment [27, 28] and launched dedicated address data information website targeting citizens, IT companies and municipalities [24, 29]. Denmark's legislation was changed in order to support the new addressing practices. There were made rules which regulate how owners must put a number sign on the approved address properties. Statutory order on unambiguousness of street names was put in place in 2009 and the Law on Postal services was renewed to regulate post code system management [24].
Considering aspects discussed above, individual point geocoding should be implemented, but current addressing practices in Greenland would not be sufficient to support the method due to inconsistent address identifiers used. Moreover,

the legislation aspects should be considered to support the change.
In order to proceed with geocoding methods, there is a need for conceptual design for address data and the next section will discuss example practices in other parts of the world which will help to find applicable concepts.

2.2 Some of addressing and geocoding systems in world

There are several places in the world, which by the inhabitation pattern, are similar to Greenland. As mentioned in the introduction, one of the major aspects which influences the development of postal and residential addressing system is the density of the population. Therefore, it is necessary to investigate postal practices in parts of the world where the population density is similar to Greenland's. As the example practices will be investigated postal and residential addressing systems in Sweden, Canada, Australia and partly Denmark. Most of the emphasis will be put on the practices used in the rural areas and geocoding.

It is also worth to look at the practices where addressing systems are introduced in large scale, e.g., for the whole city or a country. Main reason for this is to elaborate on standardisation and implementation aspects. This case will be explained by the example of Australia, where in one of the regions there is introduced a new rural residential addressing system and Saudi Arabia which has been recently introduced residential and postal addressing system for its whole kingdom.

2.2.1 Sweden

The first example is addressing system in Sweden. Sweden is divided in counties and they are further divided in municipalities. There are 20 counties and 290 municipalities in Sweden [30]. The most sparse population is in the Northern part of Sweden, i.e., Västerbotten, Norrbotten and Jämtlands counties where the lowest density of population is in Arjeplog municipality with 0.2 inhabitants/km^2 [31]. In general, for the most of the Swedish municipalities two type of addresses are used. One of them serves for residential - the other for postal purposes. The following table describes main components of the address.

Table 2.1: Sweden's address components [32]

Component name	**Example in locational addresses**	**Example in postal addresses**	**Description**
Area of the valid standard	Sweden	SE-Sweden	Country code followed by country name
Municipality (Appendix A)	Stockholm Uppsala	*Not included*	Name of the municipality
District (part of municipality) (Appendix A)	Kungsholmen Gottsunda Rasbo	112 31 Stockholm 756 55 Uppsala 747 94 Alunda	Postal code followed by postal town. Municipal borders do not necessary coincide the postal districts. First three digits represent from which town mail would distribute further, and the last two represent type of delivery or distribution area/route
Address-area/ Street Address-areas/village, farmstead, group of buildings (Appendix A)	Bergsgatan Gottsundavågen Baggbol	Bergsgatan Gottsundavågen Baggbol	Thoroughfare name or village name/settlement name sometimes including house/farm name
Address place designation (Appendix A)	56 17B 12	56 17B 12	Street number/address place designation
Apartment/ Dwelling designation (Appendix A)	F 267 1101	F 267 1101	Designation for apartment and dwelling number
Alias/ Registered common place name (Appendix A)	Polishuset Gottsunda gård Eriksro	Polishuset Gottsunda gård Eriksro	Extra name which is not used in the register of valid postal addresses, thus unnecessary. Usually written after the address but before the addressee.

Example addresses formed from elements in Table 2.1 can be seen below:

Figure 2.3: Rural road referencing convention in Sweden (background map from [20])

Bergsgatan 56 F267 112 31 Stockholm SE-Sweden	Gottsundavågen 17B 1101 756 55 Uppsala SE-Sweden	Baggbol 12 747 94 Alunda SE-Sweden

Most of the municipalities in Sweden use street/road numbers. Around fifteen municipalities use road names with distance-based numbering. For example, address designator 451-21 would contain the following information: the referenced place is situated 4510 metres along the named road and on the left hand side and approx. 210 metres beside it on the left side of a smaller road or drive. Road side for the place can be determined by even and odd number principle. If the address number is even, housing/utility could be found on the right side of the road, if odd - it is on the left side. To show that the place it immediately adjacent to the road, number would be 452-0. Hyphen is a delimiter and mandatory character if distance-based reference is used. Visual representation of this practice is shown in Figure 2.3. Intersection P_1 marks the beginning of this road. If one would drive along this road in the direction of the arrow, d_1 would be the 4510 metres distance and d_2 the 210 metres distance. Point P_2 is the intersection where one should turn left because 451 is an odd number. Example designator 452-0 would imply that object is located on the right of the point P_2 with respect to the driving direction.

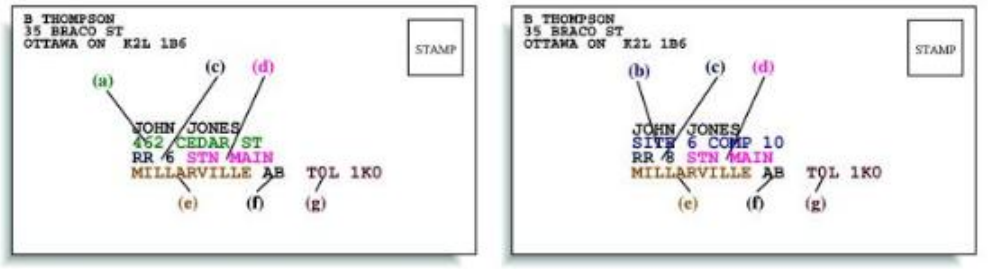


Figure 2.4: Rural area addresses in Canada [33]

Standard in Sweden [32] describes that all addresses should contain an address place designation, nevertheless this is not the situation in all the cases. There are more than 100 000 registered addresses in rural areas which do not contain a number. Exceptional cases are possible because the address area contains only one housing/utility, which means that name for it is an unique reference in the district.

2.2.2 Canada

The second example is Canada where there are many rural regions in the Northern part of the country. Most scarce population is in federal territory of Nunavut where the density of population is 0.02 inhabitants/km^2 [4]. Rural area addresses in Canada usually are comprised of components depicted in Figure 2.4.

(a) Street name (Appendix A) would most often used with its respective number, but not always there is this reference available. [33]

(b) Additional address information is required for delivery where street names could not be used as a reference. In some cases it is customer name, in other it is a SITE and/or COMP (compartment) with respective numbers.

(c) Many locations hold the rural route (RR) designator. RR is designed for postman to distinguish between city and rural areas. Designator is followed by number referencing certain route. It also tells about the delivery mode which will be explained later.

(d) Station information is included for directing mail to the proper postal office. Importance of this lies in fact that there could be more than one postal office in the same municipality. Abbreviations STN or RPO are used. STN stands for station and RPO for retail postal outlet, both followed by the name of the installation.

(e) Municipality name (Appendix A) is included using official name issued by the Canada Post.

(f) Province/federal territory name is always included using a special two-letter abbreviation issued by governmental land administration unit.

(g) The postal code (Appendix A) component is used and it has to follow a specific pattern, i.e., should be written in uppercase and placed two spaces to the right of the province with one space between the first three and last three characters.

There are several identifiers used in Canada post for showing the delivery modes. A delivery mode is an abbreviation which consist of two letters and tells the postman how to deliver the mailing. Some of the available types are [5]:

- RR (Rural Route) - delivery along or near well-defined roads in a reasonably well-settled area
- LC (Letter Carrier) - delivery by a letter carrier
- LB (Lock Box, also called post office box) - delivery to an individual customer box in a post office
- GD (General Delivery) - delivery to customers not renting a lock box, customers having no fixed address, members of the travelling public, or anyone who can not receive mail from a letter carrier or rural route contractor
- DR (Direct) - delivery for regular customers who receive bagged and/or bundled mail in high volumes
- SS (Suburban Services) - delivery to group mailboxes located in perimeters of urban areas

The whole country of Canada has been divided in 10 provinces and 3 federal territories [34]. They are further divided into postal sortation areas according to the population pattern (grater number of areas if the population is dense). The first letter in the postal code defines in which one of these major geographical area is referred. Figure 2.5 represents the sortation division.

Mentioned example of Nunavut shares the area code with Northwest Territories which is "X". Most of the deliveries in this area are made by the lock box delivery type. Recipients are supposed to do the check of their lock boxes which are installed in post offices over the area. Overall this method of delivery is 98% of all deliveries done in Nunavut by February 2012 [6].

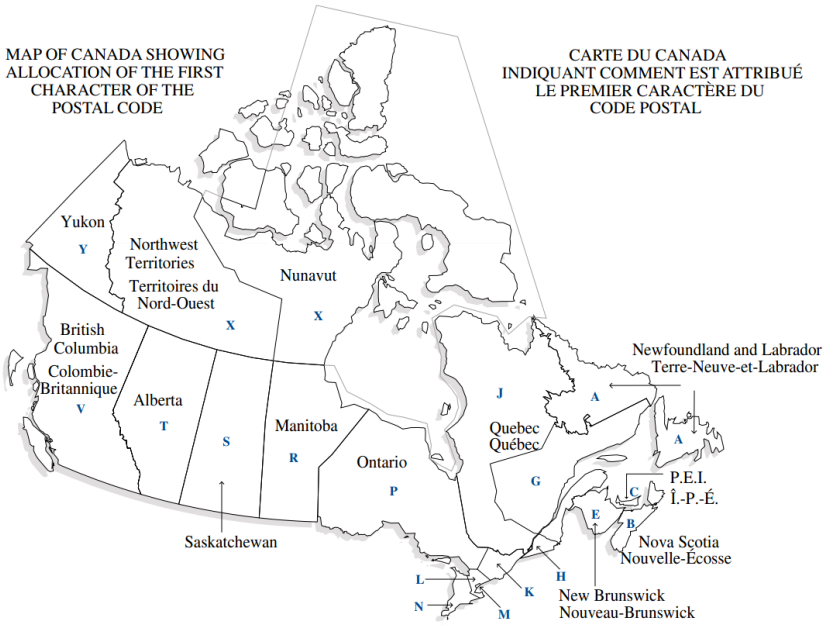


Figure 2.5: Sortation area letter designators for postal code in Canada [35]

2.2.3 Australia

Similarly as in Greenland, there was a need for change in South Australia addressing system. In particular, necessity was in rural areas where the density of population is the lowest (1.67 inhabitants/km^2 [9]). For this matter in 2006 the Rural and Urban Addressing Standard (AS/NZS 4819:2003) published by Standards Australia was put under the revision [36, 37]. The proposals from the Government of South Australian [38, 39] were aligned to be compliant with the revised standard and served for addressing rural residencies, properties and businesses with a numbered property address. Previously, many of the properties in rural areas of South Australia were referenced by some natural reference points and finding them relied on local inhabitant knowledge about the area. Thus, the objectives of making addresses consistent with the standard were: assisting emergency services to locate the properties, safety improvement in rural areas, delivery service and infrastructure improvement, nationally recognized standard providing certainty of a location. The change affected approximately 55000 properties [39] which now hold an address according to the new standard. The new rural addresses consist of four components:

- a distance based road number,

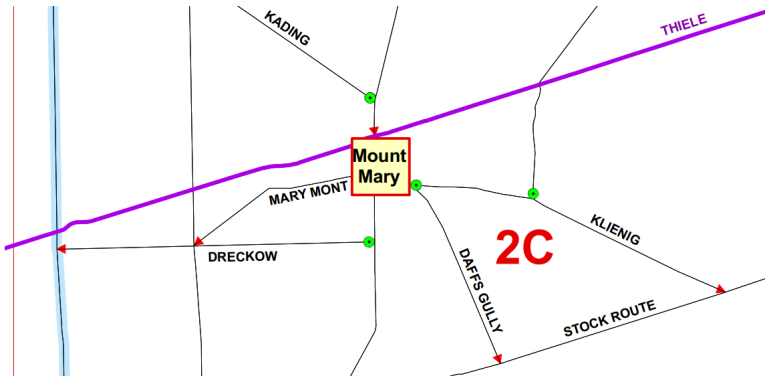


Figure 2.6: Part of rural road map in the district council of Mid Murray (North section, 2C subdivision) [40]

- road name,
- locality,
- postcode.

Change to the new addressing system was done via local councils which were responsible to allocate address and inform the property owners about the change and do infrastructural change, e.g., signposting.
The address numbering is distance based with similar approach as explained in Sweden's case (cf. Section 2.2.1). The difference is that rural road address number in Australia is one number, whereas in Sweden it is combination of two numbers concatenated with "-" after which the secondary distance is captured. To support distance based address system in South Australia, there have been developed rural road maps for each district where road starting points are distinguishable [40, 39]. Figure 2.6 represents a part of Mid Murray's district rural road maps. Roads in this figure are shown as directional edges with circle mark in the start and arrow in the end of the road. Rectangle with "Mount Mary" label represents a town in the district. From the map one can tell that it is a starting point for the roads named Daffs Gully and Klienig. Similar survey should be performed in Greenland to make sure that all the roads are mapped. In South Australia maps had been produced using areal imagery and GPS (Global Positioning System) with accuracy within 10 to 15 metres [39]. The principles for locating the address by address number system are:

- to the right of the road - even numbers, to the left - odd numbers,
- address number multiplied by 10 equals the distance in meters from the nominated road starting point to the entrance of the property.

For example, property with address "23 Daffs Guily" would be located 230 metres from Mount Mary town on the left side of the road going in the direction

to meet Stock Route.

2.2.4 Saudi Arabia

Example of Saudi Arabia would show what needs to be considered when addressing system is introduced in a large scale and what design decisions take place in cases where it is build from scratch. The governmental institution Saudi Postal Cooperation is a postal service operator in Saudi Arabia which decided to align the addressing standards according to the global standards in project initiated in 2006 [13, 14, 41]. Main objective for this was to re-create a common residential and postal addressing system for the country. In Saudi Arabia the street and dwelling address registry did not exist. Generally, deliveries were picked up by the recipients in the local post offices, because there was no systematic way of delivering them to the recipient. Moreover, the mail sorting was done manually [42]. The goal was accomplished by creating a postal code and addressing number system for the whole country comprising it in country's SDI (Spatial Data Infrastructure). The new addressing system supports automatic mail sorting. The sorting machinery is connected to geodatabases to direct mailing by verifying the recipients address and that available in the database. Machines can read postal codes and coordinates of the referenced dwelling, and later forward it to the designated mail distribution point. By the help of GIS, users can generate distribution plan and delivery routes for each mailing. Moreover, deliveries are registered in database of postal tracking. New implementation of sorting also supports the old addressing system's postcodes [42, 43]. For the project implementation, team had chosen ArcGIS server, ArcGIS Desktop and Microsoft SQL server as core supporting technologies. GIS links geodatabase to other Saudi Post's services such as mail dispatching and customer relationship management systems [13, 14].
The address locating system can allocate homes and commercial addresses by a unique 13-digit numeric code which is designated for each square metre of Saudi Arabia. With this code any building in Saudi Arabia can be uniquely referenced on the map. The subdivision of address code is represented in Figure 2.7 [44, 45].
The process of establishing the address system was divided in four sequential steps. Firstly, it was necessary to obtain high resolution satellite imageries (i.e., from QuickBird [46]. The second step was to set up the infrastructure for storing and analysing the data (e.g., ArcGIS Server 9.3, Microsoft SQL server 2008 [47]). Thirdly, there were performed field surveys to obtain the information of the land use type, building type, number of floors in each building, names of the streets etc. At last, it was necessary to implement the address for each building. The uniform of a building's address is a 5 digit postcode, 4 digit number which is the building number and 4 digit additional number [48].

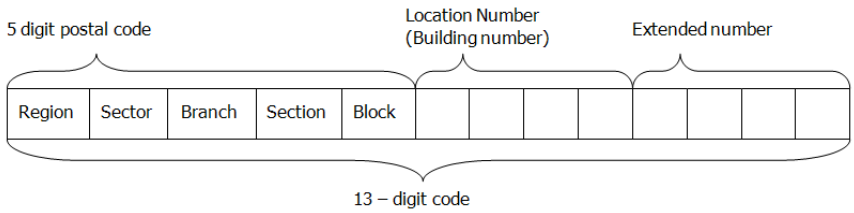


Figure 2.7: 13-digit code as a reference for any address in Saudi Arabia [44, 45]

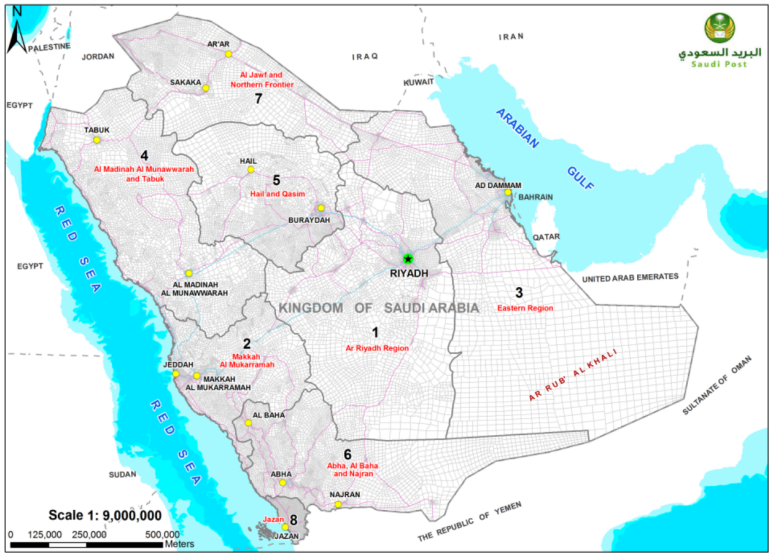


Figure 2.8: Border lines of all postcodes in Saudi Arabia within 8 postal regions [48]

Postcode's 5 digits represent subdivision of Saudi Arabia into smaller areal parcels. The first digit represents one of the 8 postal regions of the country. Second digit shows the sector which is the subdivision of the region. Each sector has branches as the third division and each branch is further divided into divisions shown as the forth digit. The last digit is for quarters which completes the 5 digit combination sequence for the postcode. Figure 2.8 shows the grid lines of all postal codes in 8 postal regions of Saudi Arabia [44, 48]. South Western regions are populated more densely, thus the finer parcelling of the regions in postcodes.
Within a postcode area, postal address is further created on basis of specification which states regulations as general policy for numbering [44, 48]. To create unified numbering system Saudi Post has made a local coordinate system which

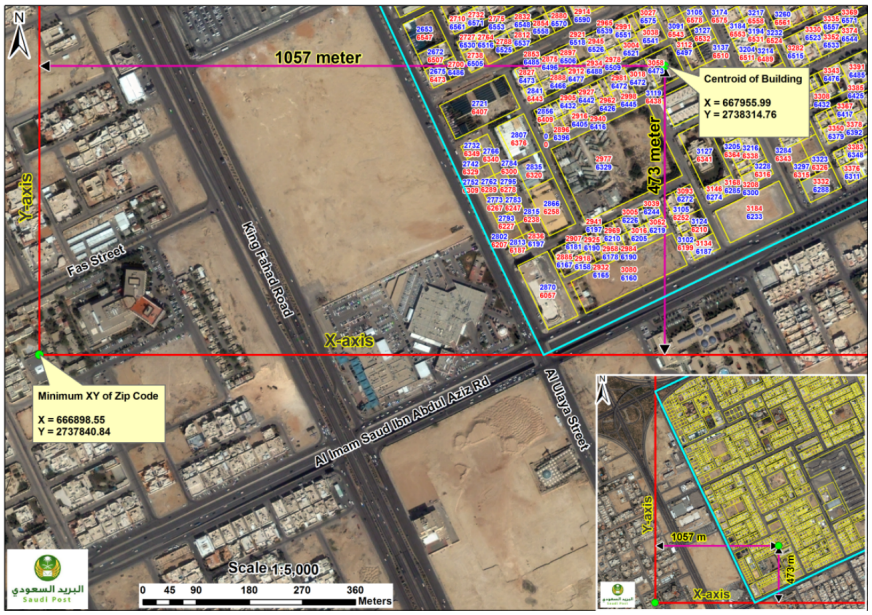


Figure 2.9: Assignment of X and Y coordinates for buildings in Saudi Arabia [48]

is based on UTM (Universal Transverse Mercator) projection. In this projection within a postcode area, each building can be referred as pair of X (value between 2000 and 5999) and Y coordinates (value between 6000 and 9999). X coordinate is the 4 digit building number and Y coordinate is the additional 4 digit number for all the buildings facing East/West direction. For North/South direction it is vice versa - Y coordinate represents the building number and X coordinate stands for the additional number. Also building numbers are odd if they are on the right side of the road which is in the South to North and West to East directions. Even numbers are assigned to buildings on the left side of the road in previously mentioned directions [44, 48].
An example in Figure 2.9 represents the methodology of X and Y coordinate assignment for the buildings. The maximum length and width of the postcode area should not exceed 4 km. There are marked two points in Figure 2.9 - Minimum XY of postcode (Zip code) and centroid of the building. Minimum XY coordinates are the minimum values of postcode coordinates in the given projection. Centroid of the building is the example building for it is needed to find the building and additional number [13, 14, 44, 48].
X value of the building = (Centroid X of building - Minimum X of Zip code) + 2000
Y value of the building = (Centroid Y of building - Minimum Y of Zip code) + 6000
In this way, absolute values of X will be in between 2000 and 5999, and values of

Y - between 6000 and 9999. The coordinate difference for the example building with respect to the minimum XY point is 1057 m along X axis and 437 m along Y axis resulting in building number 3058 and additional number 6473. It is 3058 because the building is located on the left side of the road and 3058 is the closest next even number.
The policy for building number assignment states a set of conditions which are used to support this uniformed standard [44]. It comprises mechanisms for the postcode creation, rules for parcel numbering, classification of buildings and residential units in the building. Similar set of rules would be necessary for Greenland's addressing system.

2.3 International Standards

There have been established several international standards in order to enable the sharing of environmental spatial information among organisations and use the best practice for facilitating this information. The most well known are the Infrastructure for Spatial Information in Europe (INSPIRE) and National Spatial Data Infrastructure (NSDI) in the United States. Due to the fact that Greenland has strong economical bound and special relation agreement with EU, its SDI should be made interoperable with INSPIRE which would allow to share spatial information with other European countries via INSPIRE framework. However, there have been discussions on what would be the costs and benefits for this [49, 50]. Due to dispute, INSPIRE interoperability questions are left out of the scope of this project.

2.4 Addressing practices in Greenland

In order to make any decisions towards any of the methodologies it is necessary to instigate the current addressing practices in Greenland. This include elaboration on the governance of the address, commonly used attributes for addressing a geographic place and scenarios on this data is used.

2.4.1 Address governance and cooperation

The parties involved in address info management are represented in Figure 2.10.

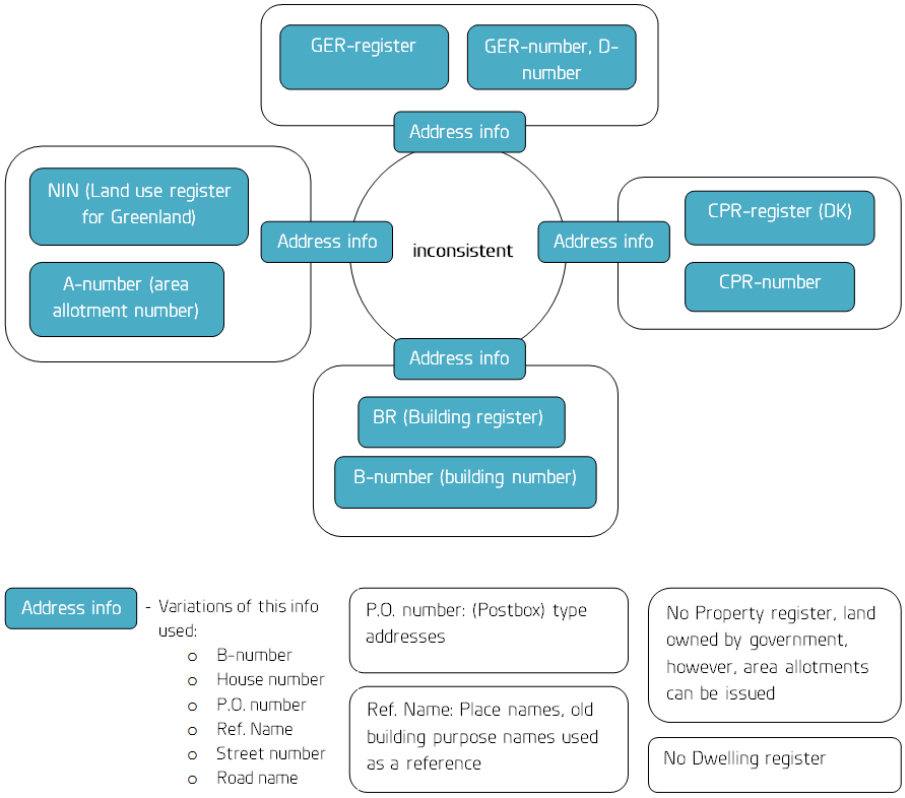


Figure 2.10: Overview of address governance in Greenland

This also illustrates the problem of attribute like address concept perception between different registers. In order to avoid the inconsistencies, the address information should be rather implemented as an entity [24].

2.4.1.1 Important authorities and tasks

Municipality Municipalities are the main responsible for the address management within their borders. After the inquiry for change of the address or request for issuing a new address has been received, municipalities start the process of change. When the issue process has been completed, responsible persons report changes to Denmark's Civil (CPR) and Business (GER) registers.

Greenland's land register The Land Use Register of Greenland (NIN) holds information on the land allotments and buildings in Greenland. In the 1st of October 2009 NIN was published as part of NunaGIS - web based geographic information system for Self Government and municipalities of Greenland. NunaGIS can therefore be used by authorities to process the land ownership application. After the application process NIN can issue the an area allotment certificate.
Every area allotment has assigned a unique A-number identifier issued by NIN. This identifier together with information, e.g., total area, has a geographical description, i.e., address where it is located.

Business registry Also known as GER (Det Grønlandske Erhvervsregister) [51] and is operating under the Taxation agency of Greenland (Skattestyrelsen [52]). Organization collects basic data of all the companies in Greenland and makes it available for public and private users.
There are two type of identifiers used in GER register. First is GER-number which corresponds to the company number and second is D-number which identifies operational units (Driftsenheder) in reliance with a certain company number. GER's responsibilities are to issue GER-numbers and D-numbers, maintain the registry, and administrate the GER register. Both of the identifiers are linked to address information, thus it is GER's responsibility to confirm that the assigned address is valid for the registered company.

CPR and CVR registers Civil register (Det Centrale Personregister) is managed by Danish Governmental institution (CPR-Kontoret) located in Denmark. All the residents of Denmark and Greenland have a record in this register with a link to an address of their residence. Similarly, it is for company register, i.e., all the companies in Denmark and Greenland are registered in Central business register (CVR - Det centrale virksomhedsregister). Depending on purposed, data from all applicants is sent to either CPR or CVR register as well processed and given a GER number in the case of an application of company registration.

Asiaq services Asiaq services and develops the NunaGIS system and secures the data of NIN. Asiaq consultants can be hired for support and training for NIN authority officers and other professionals.

Greenlandic post (TELE-POST) Organization responsible for mail distribution in Greenland. There are addresses in Greenland which are referred by the "P.O." or similar abbreviations which stand for postbox. Greenlandic post

holds a publicly available database where anyone can look up the recipient by the postbox number if the recipient has applied for one [53].

2.4.2 Defining current Greenland's addressing practices

Currently, there is no common address system established in Greenland. Addressing point on a map by geographic coordinates is vital for emergency services as police and ambulance for avoiding ambiguities in finding incidents. Therefore, it is necessary to investigate the current addressing system in Greenland to reason about possible improvements.
Asiaq is a public organization of the Government of Greenland which holds three separate databases regards addressing and place references:

- locality names (towns, villages, farmsteads, past/closed villages),
- technical base maps (including road centerlines not connected with names, and buildings),
- the NIN registry (holds information on the land allotments and buildings in Greenland).

The problem is that these data sets are not interconnected, thus making it impossible to address a point in a map with geographic coordinates in a standardised way.
Moreover, the CPR, which is managed by the Danish Governmental institution called CPR-Kontoret, seems to be the single party holding address information in a formalised way. But no geocoding is available from CPR, and all addresses seem to be grouped into the new municipalities (represented in Figure 2.11), which makes it hard to distinguish between similar street names within a municipality across different towns.

Generally, there are no roads between towns, because population is sparse and economically it is not feasible to build them, thus air and water transportation is used. Road names in towns are given only for the biggest roads, not all of the streets have been named.
The Land Use Register of Greenland identifiers are used as a reference for addressing buildings in a certain land parcel (also known as B-number). One or a group of buildings are associated with an area number, as illustrated in 2.12 NIN was introduced to support land users for producing an area allotment certificate.

In the remote locations there are cabins and lodges which people use for a seasonal and hunting stay. These houses (also cabins) usually are referred not

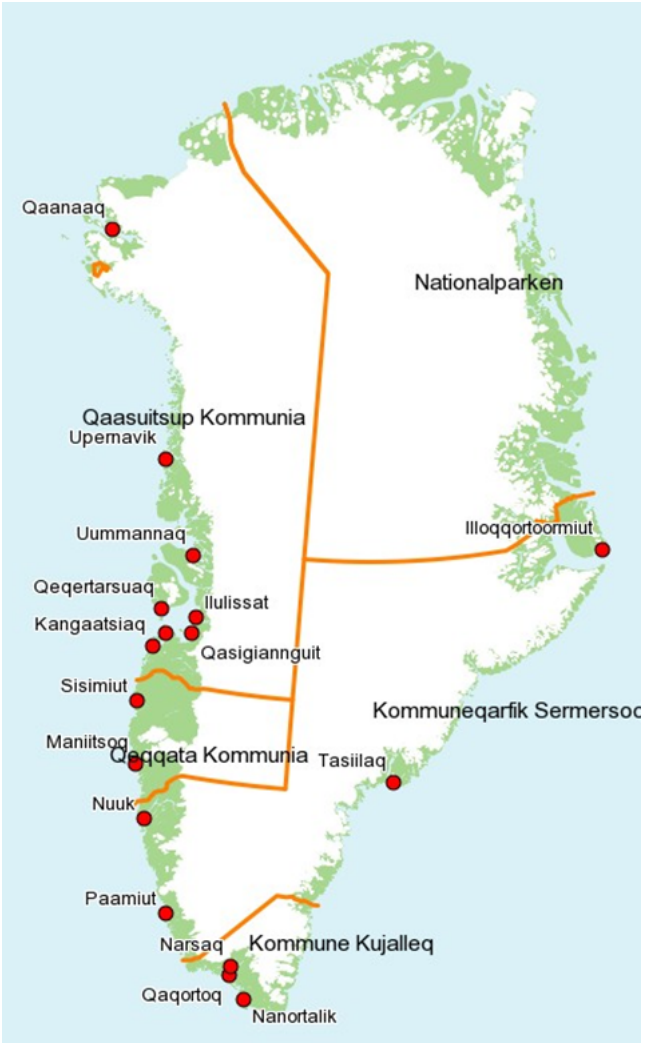


Figure 2.11: Greenland is split into four municipalities [20]

Figure 2.12: Sample of a Map for the largest city of Greenland - Nuuk in NIN [20]

individually but by covering larger area with a place name, e.g., islands, villages. It is too inefficient for the postal service to distribute the mail to these remote places. Usually, addressees themselves are going to the postal office to receive their goods. In the cases where the postal office is not established, postal officers use distribution points in often visited places, e.g., convenient stores.

2.4.2.1 Description of address components

The address components used in the for current Greenland's addressing practices are shown in table 2.2.

Table 2.2: Greenland's address components

Component name	Description	Uniform	Example
Person name (Appendix A)	Recipient name and surname	In form <Name Surname>, could also be in form <Surname Name>	Søren Jensen

Continued on next page

Table 2.2 – *Continued from previous page*

Component name	Description	Uniform	Example
Street name (Appendix A)	May also be referred as a road name	<Street name>	Nuussuaq
House number (Appendix A	Number which enumerates house as object referring	up to 3 digit <Number>	22
"B" number	Number which used for administration and city planning.	"B-" followed by 4 digits	B-2245
Building alias (Appendix A	Alias for a certain building	<Building alias>	Block 7
Apartment number (Appendix A	Number which enumerates apartment	up to 3 digit <Number>	6
Postal code (Appendix A	Postal code of the municipality	<Postal code>	2034
City name	Name of the city	<City name> or <Village name>	Sisimiut
P.O. box number	Post box number	P.O. Box <Number>	P.O. Box 234

All these components are not unique, only various combinations of them create a unique set for addressing certain reality. Ambiguities arise when the combination of the components does not reflect a unique reality, in other words, there could be more than one recipient addressed by the postal address.

2.4.3 Example scenarios

Scenarios are distinguished by cases in different locations, i.e., city, village and rural area. These cases have been given in purpose to show the difference in concepts sets that are currently used to create a valid postal address label.

City (e.g., Nuuk) Address schema would contain the following components:

- Person name

- Street name
- House number
- Apartment number
- Postal code
- City name

In some of the cases there the street names are not mentioned and in other there is a given alias for the building or utility, e.g., "Block 7". Other components are included.

Village (e.g., Atammik)

- Person name
- Street name
- "B" number
- Apartment number
- Postal code
- City name

Rural areas (e.g., hunting lodges) There are no post boxes for the recipients. Mail is taken by recipients form the local store where the postal deliveries are placed in commonly known places, e.g., "pigeon boxes".

- Person name
- "B" number
- Village name
- Postal code (for the city which is located closest to the village)

There are also some exceptions, e.g., military stations, national park, where address is usually described by recipient person name and alias of the utility or station name. Seasonal housing such as hunting cabins is referred by GPS coordinates, but usually there is no mail delivered there.

Emergency services There is currently no dedicated address database storing records of addresses linked to geographic locations. Subsequently, there is no lookup system to find address point for individual housing by inhabitant person name. When an emergency service receives an incident call, they usually require person name, house number, "B" number and road name. For example, Greenland's police use paper maps or customized Google Earth to lookup the geographic location [2].

2.5 Resemblance with Danish address system

Greenland is an autonomous country in the Kingdom of Denmark since 1953 [54] and in 2008 Greenland voted for increased self-government [55]. Nevertheless, a common governing in some of the public service infrastructures is still present. All the citizens of Greenland are registered in Denmark's personal identification number database (CPR register). This register hods personal information including the address where the person has registered as an inhabitant. The addressing system in Denmark has gone through major changes over the past few years [56]. Thus, some of the practices could be seen as potentially useful for improving Greenland's addressing system. Further sections will give an insight of Danish addressing system and reason about some of the structural elements transferred to Greenland's addressing system. Furthermore, if it is found that resemblance is close then address data which is available from CPR for Greenland could be retrieved and treated similarly as Denmark's address data.

2.5.1 Danish address system

Figure 2.13 represents a high level description of the structure of the Danish address system [25]. This system is defined in the Act on Building and Dwelling Registration and in the Statutory Order on Road names And Addresses [57]. The model consists of several components and relationships between them represented as the entity relationship diagram (ERD).

Danish addressing system's logical model entity definitions are described below and comments are given regards Greenland's practices.

- **Postcode** (Appendix A)– Denmark post codes are defined by four digit code and the name of the city or district. "Post Danmark" supports the postal delivery by maintaining and developing postal codes in Denmark.

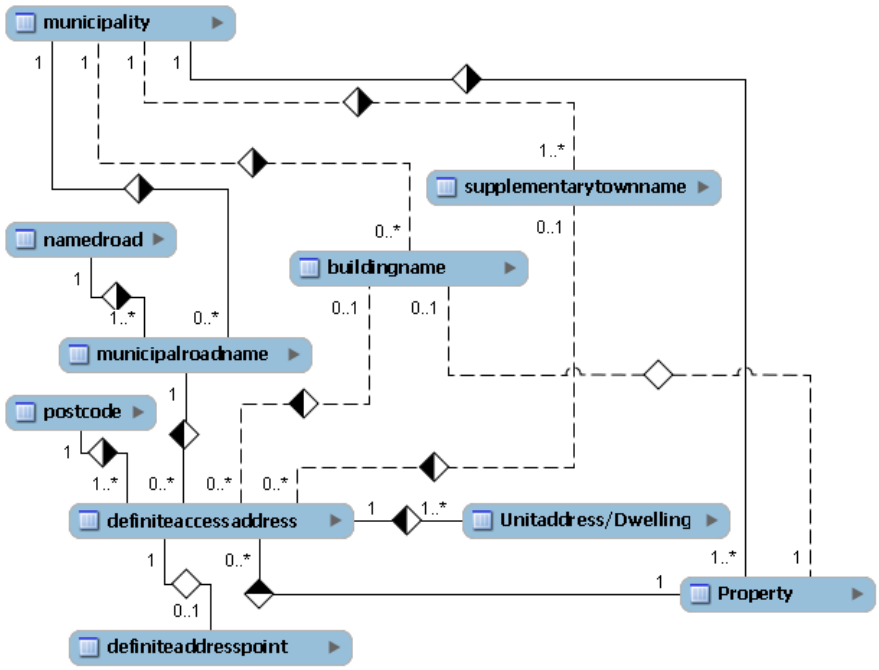


Figure 2.13: Danish address reference system high level logical model [25]. Diagram has been modified to use UML notation and additional entity *Property* has been introduced.

In Denmark, there are approximately 1200 postcodes. The definite access address (see description below) has an identifying relationship with postcode and thus the postcode should always be included in the address label.

- **Municipality** (Appendix A)– there are 5 regions and 98 municipalities in Denmark. Similarly, in Greenland there are 4 municipalities and no distinct division in regions. In Denmark, each municipality is identified by a unique name and a four digit code. Region names are not included as a components of the address. As in other Northern countries, e.g., Sweden [32], the postal code borders do not necessary coincide with municipality borders.

- **Municipal road name** (Appendix A)– In general, the road names are given by the municipal council of the municipality where the road is located in. An approval of Road Directorate is needed for the major road names to be recorded. Names have four digit code and can be composed of up to 40 characters. Overall there are approximately 108.000 municipal road names.

- **Named road**– in the cases where the road passes through several municipalities, the term "named road" is introduced. A named road has a location type which is used to concatenate municipal parts of this road into one entity. If the road is present only in one municipality the cardinality with municipal road name is 1 to 1. Similar to the municipal road name, named road has four digit code and could be defined with up to 40 characters.

- **Supplementary town name**– a name which can be assigned by the municipal council for a set of addresses in an area where additional information would ease referencing in small villages or larger postal areas. This is an optional component and, thus has a non-identifying relationship with other components. There are exception cases (approximately 0.9%) [25] where supplementary town name is necessary as part of textual address label where there are several roads with the same name within the postal code region. If the municipal council has agreed and recorded the supplementary town name, it is then a part of official textual address labels.

- **Building name ("location name")** (Appendix A)– a name which is assigned by the municipal council for a single or few addresses on a property. This is mostly due to historical reasons, e.g., farms and small settling. In Greenland, this is a common convention and proportionally there are more addresses with location names (also referred as alias) than in Denmark. However, the location name in Denmark's textual address label is optional, but in Greenland there are addresses where it is a requirement.

- **Definite access address**– an identifier which is assigned by the municipal council to reference a certain access (e.g., entrance door, gate) from a recorded road to a building or property which is ascent to this road. This term was introduced to distinguish between approved addresses and small number (2-4%) [25] of addresses which are not registered or approved by municipal council Definite access address is composed of 1-3 digits (1-999), and additionally could have a supplementary character (A-Z). There are approximately 2.3 million access addresses in Denmark. This is an identifying component and it is present in Greenland's current addressing system with a similar set of attributes.

- **Unit address**– an identifier which is assigned by the municipal council to reference a certain entrance door to a dwelling or business unit inside a building. The definite access address is a composition of unit address and defines unit address entity. Each unit address itself has a multiple field identifier composed of floor identifier and door identifier. If the unit address is equal to the definite access address its partial key has no value.

- **Definite address point**– identifier which is assigned by the municipal council and represents geographic coordinates of a definite access address. Regulations for assignment are stated in a statutory order [57]. This identifier allows to depict the specific entrance for a building on a referenced digital map. In the Danish addressing system, 99% of the definite access addresses are linked to this identifier. In Greenland, however, this is not the case. There has not been introduced an identifier for defining the physical location of certain addresses.

- **Property**– identifier which represents land, building and any subset of them that has been legally defined in the land or building ownership administration unit of Denmark.

Chapter 3

Objectives

In this project a general objective is to propose a design for an addressing system which would be more suitable for Greenland's various public services emphasising the importance of its use in emergency services. The system should unambiguously make clear which building is addressed with respect to the adjacent road. Address should be georeferenced and it should be possible to employ reverse-geocoding. The created system would be a part of Greenland's spatial data infrastructure which later could be made interoperable with larger SDI's, i.e., INSPIRE and UNSDI (initiative of the United Nations Geographic Information Working Group (UNGIWG)).

To fulfil mentioned objective there have been set several tasks. The following of them have been identified and described in the previous sections.

1. Research existing addressing practices and relevant standardisation in the world
   Describing and finding which practices could be applicable for the case studied.

2. Specifying the current addressing practices in Greenland
   Outline the current components used for addressing practices and give examples of address inconsistency issue. The inconsistency is in the use of address components to form a complete address. Furthermore, there

are no regulations to describe which address components are necessary to form a complete address.

3. Finding similarities in Danish addressing system
   Explain Danish addressing system's model and find similarities with Greenland's current practices.

Considering the findings above, there have been identified successor tasks towards designing address conceptual and logical models. Further sections will cover tasks listed below.

1. Definging Model characteristics and user requirements
   Chapter including description of the model requirements and discussing requirements with respect to geocoding, route planning and address data management. It is necessary to identify characteristics of the model in order have assumptions for the design decisions.

2. Specify data sets related to the addressing domain
   There are several data sets used for addressing practices in Greenland. It is needed to identify and describe the available data for the extraction.

3. Listing address model pre-conditions
   In order to find solution for address data inconsistency problem, it is necessary to outline findings on road network characteristics to support addressing and route planing requirements. Made assumptions should serve as pre-conditions to the address data model design.

4. Proposing a conceptual model and logical model
   Design of the geocoding information system include several steps which is described in sections including data dictionary, conceptual model relations, ontology and entity relationship diagram.

5. Draw conclusions
   Describing findings and outlining the future work to meet the requirements for the model and address management.

Chapter 4

Model characteristics and user requirements

In order to understand how the address data is organized, what are its characteristics and what is the set of user requirements, the following chapter will study these subjects.

4.1 Address data model characteristics

Address data as entity

Address data should be perceived as independent data entity which would have a distinctive object class. Wherever it would be used, the address object would no longer be a property of any linked entities, e.g., dwelling registry, business registry, and person registry, rather would have associations with them as independent object.

Currently, address data is perceived as illustrated in Figure 4.1 to the left where address is additional attribute to data sets. However, this cause inconsistencies between address data stored in each of the registries.

Before similar conceptual change was introduced in Denmark, a case study showed that address records in Denmark's National Business registry corresponded to 94% with ones found in Building and Dwelling registry [24].

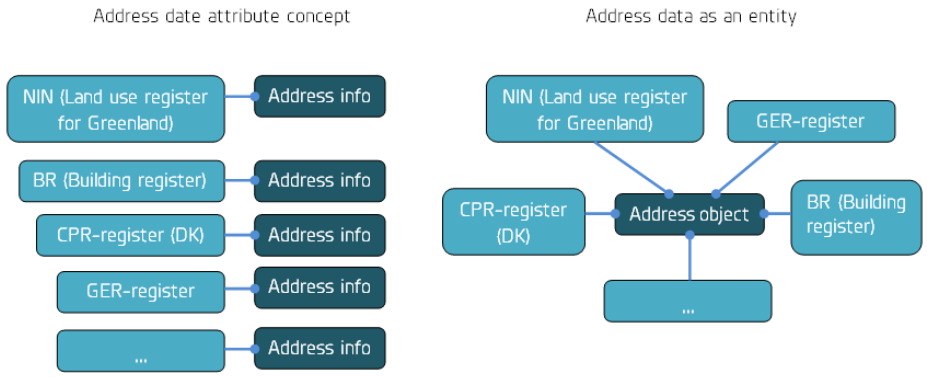


Figure 4.1: Concept for address data as an attribute and as an independent entity [24] ("..." refers to any other relevant data set)

To obtain sufficient consistency and guarantee the address data is accurate in all registries it has to be populated from an independent, up to date address data set.

Address maintenance

There should be distinguished parties responsible for address data management and maintenance. Respective legislation changes should be made to support the new addressing system.

Road naming

All of the registered roads should have unique identifiers and naming practice guidelines should be published. There should also be stated which authorities are responsible for road data maintenance.

Roads as backbone

Road names should serve as a backbone of the complete address, thus enabling to use house numbering system.

Availability

The aim should be to publish the address data for free which would have beneficial influence on public and private sectors. Address data openness is vital factor for its widespread usage. Denmark's experience approves the social benefits of this strategy [58].

4.2 User requirements

The requirements could be divided into two groups. First is with respect to addressing and geocoding, and the second is with respect to route planning. The first requirement is primary because geocoding process could be performed once addressing system is in place. As from an end user perspective, e.g., emergency service, the goal would be an address lookup service. Example of similar product is available as a public web service for address lookup in Denmark. Utilizing Building and Dwelling register (BBR), web service can locate a point on a map based on the given address and vice versa as shown in Figure 4.2.

Methodology used in this project mainly relies on relational database design [60]. Most of the data available is stored in relational database tables or files containing data lists. Object-relational or object oriented models would create an overhead in data model maintenance in comparison with relational model which could also support the requirements outlined.

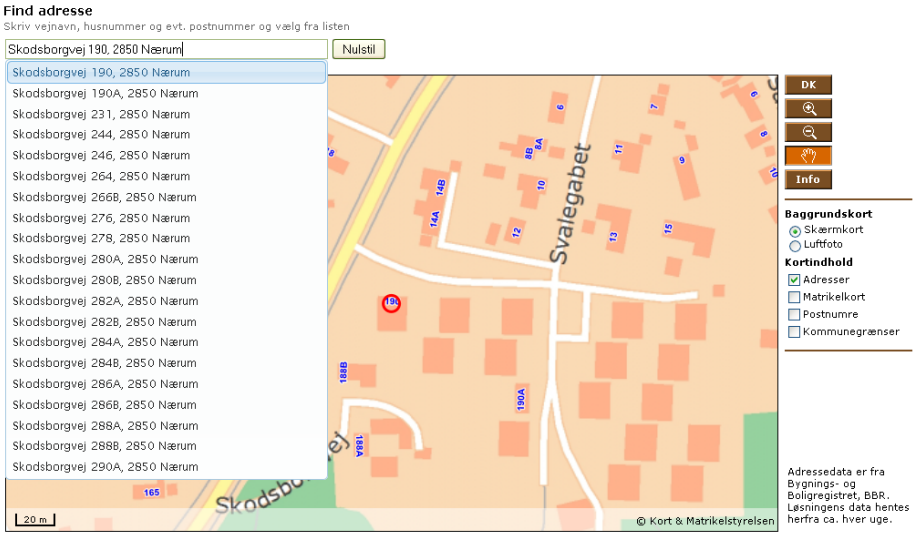
4.2.1 User characteristics

There would be three types of user roles with respect to addressing system's life-cycle.

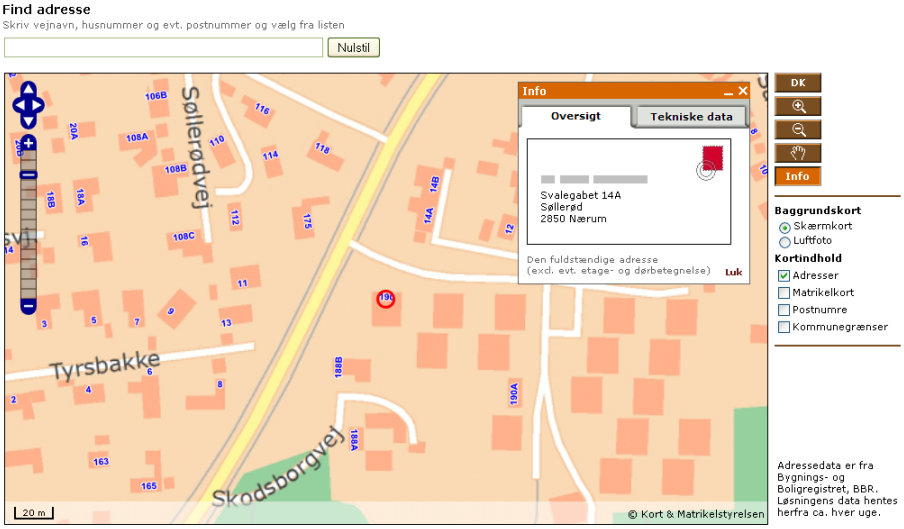
- system developers – responsible for system's design and implementation, support for data managers, maintenance of the system's software
- availability support – support for software physical deployment, performance and uptime
- data managers – updating address data, support for general users
- system's general users – companies and persons who benefit from addressing system, e.g., Government of Greenland, public health service, police, postal service.

4.2.2 Functional requirements

Decomposing functional requirements in two sections where first is related to residential address system with geocoding support and second being the route planning support for the real-time route planning systems.



(a) Finding by address data



(b) Finding by coordinates

Figure 4.2: Address lookup service for Denmark [59]

Addressing and geocoding Address data should be standardised according to a certain model which would support outlined requirements.

- The model would consist of components, their relationship, attributes and constraints described in detail.
- Model would require geographic coordinates linked to each of the address records.
- Exceptional cases for addressing remote buildings should be handled, such as hunting lodges.
- Facilities such as schools, gas stations, grocoery stores and other features like bus stations should be digitised.
- Assumption that emergency services require positioning in distance deviation of 5m from the entrance of the dwelling should be held.
- For emergency services and other context applications, reverse-geocoding would need to be supported.
- Address data should be held in one core database which would have policy for regular updates and documented API (Application Programming Interface) for the data retrieval.
- Sharing of the address information should be established across public services to support decision making, e.g., police and air ambulance.

Route planing To support the route planning there should be established road network together with journey planing engine.

- road network - road center lines together with the intersection objects with directional attributes. Road segments should have attributes to classify speed limit, pavement, mark one directional roads.
- journey planing engine - specification can be based on OGC (Open Geospatial Consortium) OpenLS Route service [61].

4.3 Towards Greenland's SDI

To establish spatial data infrastructure for Greenland requires investment which due to scale of potential usage is not economically feasible. This leads to cut

in time and resources devoted for projects related to SDI. Nevertheless there have been put effort towards sharing the spatial information with everyone in interest.
Asiaq has developed a project NunaGIS with which Asiaq has taken the leading role in moving towards SDI for Greenland. NunaGIS geoportal enables managing, producing, displaying and sharing spatial information of Greenland. Spatial data is publicly available and administrators can modify it by using available online Java applications [62, 50, 63].
Asiaq's aim has been to build a platform which would enable structuring governmental data and topographical maps, allow other public service providers to use it for sharing their data and use it for their problem solving.
The project is based on international free and open standards with goal to promote their use in further SDI development. However, project decisions do not necessary go along with INSPIRE recommendations. It is rather based on case studies which show direction for further challenge tackling [50].
These efforts are promising and can serve as a backbone of further development of SDI in Greenland. Space for improvement lies in eliminating the gap between different public administrative sectors of Greenland and collaborate towards the goal of providing better services to the society.
Considering described requirements, in the next chapter there will be proposed a design for addressing system's model using relational database methodology.

Chapter 5

Design of Greenland addressing system's information model

This chapter proposes the design of addressing system's model. It divides into sections containing available data set description, data dictionary, conceptual model and entity relationship diagram as logical model.

5.1 Addressing data set overview

NIN registry
This is a database for area allotments in Greenland. Process of application handling is done via NunaGIS. It is the responsibility of each municipality to handle their area allotment certificate assignment. Therefore, maintenance of records is done by each municipality whereas NunaGIS is supported by Asiaq.

Post registry
Postal services of Greenland (TELE-POST) has its own registry of postbox numbers. With help of online service citizens can find addressee by

choosing postcode region and postbox number [53]. This works as a verification tool rather than an address lookup service because addressee names are given only after inputting the postbox number. It is maintained by Greenland's Post and is separate from CPR register.

GER registry
Company register in Greenland which is maintained by Taxation agency of Greenland. Data is forwarded to Danish CVR registry daily.

Road registry
Most of the roads have the unique identifier, thus not all of them have been given a distinctive name. Roads are not digitised and assignment of their unique identifier is done via point rather than line. Maintenance of the road names is done by each municipality responsible persons although there are no guidelines published to improve consistency in the naming and digitising practices.

Town and settlement tables
There is available list of all the settlements and town names. This geographic information could be used to refer to a certain inhabited area.

Daily extracts from CPR registry
It contains records of addresses registered for the citizens of Greenland. It also contains GER information equivalent to CVR number in Denmark. The data, however, is provided to registers by responsible Greenland's institutions.

5.2 Currently used GIS technology at Asiaq

NunaGIS is build on Grontmij-CarlBro solution which is called CBkort. This product uses Open Source tools and languages, as MapServer for map rendering and Java Servlets on Apache Tomcat for hosting the sites. As a back-end number of spatial databases are running on PostgresSQL with the PostGIS extension [62, 63]. Data updates can be done via desktop GIS directly to PostGIS database and is managed by Perl scripts and ORG2ORG. It is also possible to eliminate the desktop GIS application by using Spatial Edit which allows to edit data sets directly from browser and is part of NunaGIS. GeoServer is configured with SDL (Styled Layer Description) and other acknowledged specifications form OGC which, e.g., allows to download data in preferred format (i.e., ESRI SHP, MapInfo TAB, GML) [62].

Figure 5.1: Available Sisimiut road network data: labels, boundries, labels

5.3 Pre-conditions for address model design

Inconsistencies in address data across different data sets could be withdrawn by help of standardised model. For this model the road network serves as a core for the addressing system which utilizes street name and the assigned number to the address. Therefore, it is necessary to improve the current practices to support the addressing and routing.
Currently, the road digitisation has been completed in biggest towns, e.g., Nuuk and Sisimiut, but not for smaller settlements. Figure 5.1 represents an extract of the digitised road network and houses in Sisimiut.

Data set includes road labels, center lines, and pavement boundaries which have been digitised using mapping software MapInfo.

Route network could be digitised as an independent network, however there could be done adjustments to the currently available digitised roads to support basic route finding.

- All commonly used streets and roads should be named. This process should comprise the identifier and a common name assignment. Segments of road center lines should have an attribute which corresponds to the name of the road through which they could be queried for the assigned address.
- Road center lines would serve as a network for routing, e.g., shortest

path algorithms to be applicable. However, algorithms can utilize network where any of the taken edges' ends is linked to a vertex. In other words, there should be introduced point objects for each intersection and road end points and linked to the road center line segments. Therefore, allowing to handle such cases as possible intersection drive directions, road lane drive directions and one way street implementations, restricted turns and similar.

- Dynamic segmentation could be employed for road pavement analysis and similar tasks.
- Guidelines for road naming and data maintenance should be created and published for all municipalities.

5.4 Data dictionary

Combining information from Asiaq [64] and knowledge about resemblance of Danish addressing system the proposed data dictionary has been developed to describe entities of Greenland's addressing system. Dictionary is subdivided in two groups, i.e., address object model and related independent objects. Address object model data dictionary is comprised of the following entities:

- **Address number** (Appendix A)– is a number which references an access from a road to a building or other property which is ascent to this road. Resembles "Definite access address" in Danish addressing system.
- **Road/Street name** (Appendix A)– name of the street or road which is assigned to the referenced address.
- **Postcode** (Appendix A)– a four digit code and delivery district name. Overall there are 29 postal codes in Greenland and they were implemented in 1967 [65]. All of them start with "39" and are part of the Danish postcode number range. Delivery district name can be up to 20 characters long.
- **Municipality** (Appendix A)– administrative division which has been updated in 2009. There are four municipalities in Greenland Kujalleq, Qaasuitsup, Qeqqata, and Sermersooq. This division is maintained by the association of Greenland's municipalities (KANUKOA) [66] and it is recorded in ISO 3166-2 section of GL [67]. This division is depicted in Figure 2.11.

- **Building alias** (Appendix A)– name which would usually reference a certain building by its physical location, nearby objects or some historical reason.
- **Floor number**– a number which represent the floor level of the building, 0 being the ground floor.
- **Door number**– an identifier which references an entrance to the dwelling inside the building. It resembles part of "Unit address" in Danish addressing system.
- **Address point**– an identifier which holds the geographic coordinates of the building descriptor.
- **Address object**– an entity which holds the complete address as an object comprising address entities from this list.

In the last administrative reform in Greenland a distinction was made between city/town (*by* in Danish) and settlement (*bygd* in Danish) [68].

- **City/Town name**– inhabited area where population exceeds 1000. In 2010 there are 13 towns where there are more than 1000 inhabitants in Greenland [68, 69].
- **Settlement name**– inhabited area where population is less than 1000. There are recorded 62 settlements where there are at least 2 persons living [68, 69].

The related independent object entities are listed below.

- **Person name/CPR** (Appendix A)- the name of the recipient from the CPR register.
- **Company name/GER** (Appendix A)- the name of the recipient business entity.
- **"B" number**– The Land Use Register of Greenland has recorded all the buildings and utilities with a representational number which is used to administrate these facilities. Number starts with "B-" continued by up to four digit code. It is worth mentioning that every facility has this number, thus it is an unique reference for addressing a certain facility.
- **"A" number**– NIN also regulates area allotments where each allotment has a given number also called the A-number.

- **Property/allotment descriptor** - identifier for generalising the concepts of ownership (assigned B-number) and allotment (assigned A-number).
- **P.O. box number**– number which is assigned to a regular mail postbox. Postbox numbers are unique within the area of town/settlements.

Table 5.1: Data dictionary of proposed Greenland addressing system's logical model

Component name	**Description**	**Uniform**	**Example**
Address number (Appendix A)	Number which enumerates house as object along the street or road	<up to 3 digit sequence>	8
Road/Street name (Appendix A)	Name of a street or road	<Street/Road name>	Qatserisut
Postcode (Appendix A)	Postal code of the delivery region	4 digit sequence where first 2 are always "39" followed by delivery district name	3900 Nuuk
Municipality (Appendix A)	Name of the municipality	<Municipality name>	Qaasuitsup
Building alias (Appendix A)	Alias for a certain building	<Building alias>	Block 7
Floor number (Appendix A)	Floor designator	<up to 2 digit sequence>	2
Door number (Appendix A)	Number which enumerates apartment	<up to 2 digit sequence>	6
City/ Town/ Settlement name	Name of the city, town or a settlement	<City name> or <City/ Town/ Settlement name>	Sisimiut
Address point	A pair of geographic coordinates	<Longitude, Latitude>	66.9167, 53.6667

Continued on next page

Table 5.1 – *Continued from previous page*

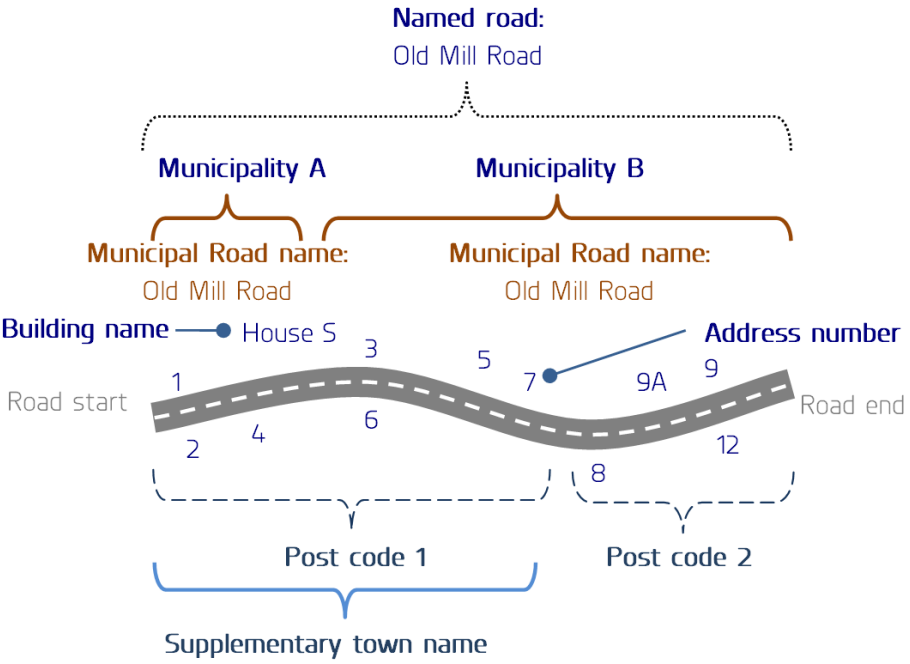
Component name	Description	Uniform	Example
Address Object	Entity for defining the complete address object	<AddressObject>	Qatserisut 8, fl. 2, ap. 6, 3900 Nuuk, Qaasuitsup

The data dictionary for related independent object entities is shown in Table 5.2.

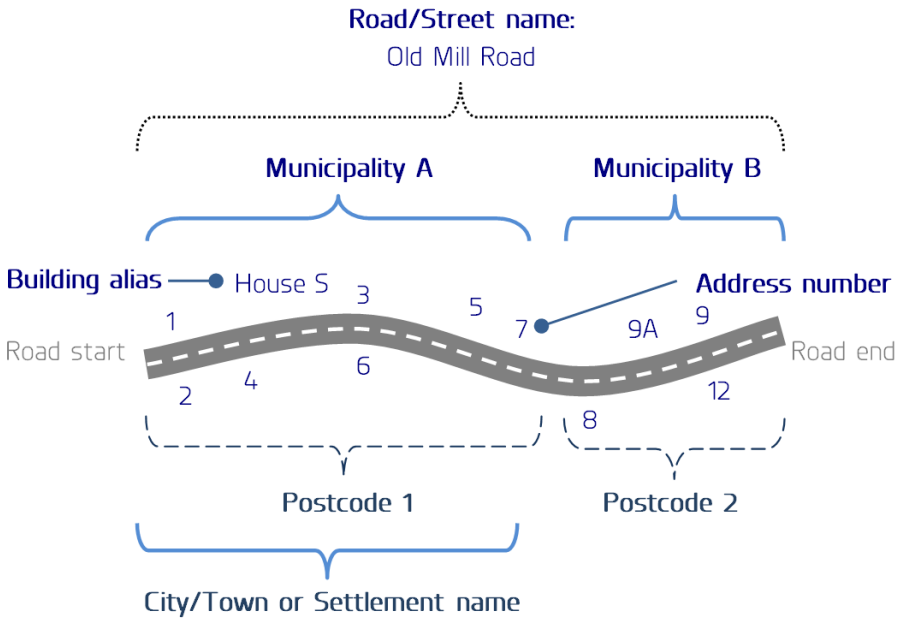
Table 5.2: Other related independent objects currently used in Greenland's addressing practices

Component name	Description	Uniform	Example
Person name (Appendix A)	Recipient name and surname	<Surname> or <Surname> <Name>	Søren Jensen
Company name (Appendix A)	Recipient company	<Company name>	Tele-Post
"B" number	Number for buildings which is used for administration and city planning.	"B-" followed by 4 digits	B-2245
P.O. box number	Post box number	P.O. Box <number>	P.O. Box 234

To represent the differences between Danish addressing model and the proposed, the Figure 5.2 shows concept naming conventions and their use for both models. Figure does not include several concepts from proposed dictionary, such as *Floor number, Door number, Address point, Address object* as well as the related independent concepts. This is done to reduce the level of details and emphasise the differences. Full mapping between corresponding concepts is represented in Table 5.3.



(a) Concepts in Danish addressing model



(b) Concepts in data dictionary proposed for Greenland's addressing model

Figure 5.2: Concepts in Danish and Greenland's addressing models. Figure modified from [25]

Table 5.3: Mapping between Greenland's and Denmark's addressing concepts

Greenland's model	**Danish model**
Address object	Definite access address
Address point	Definite address point
Address number	Part of Definite access address
Postcode	Post code
Road/Street name	Named road
Municipality	Municipality
City/Town/Settlement name	Supplementary town name
Combination of Floor and Door number	Unit address
Building alias	Building name
None corresponding	Municipal road name

An extended comparison can be found in Appendix C in Table C.1 showing the similar concept mapping from addressing systems and practices in Greenland, Denmark, Sweden, Canada, Australia and Saudi Arabia.

5.5 Conceptual model relations and ontology

In this section, will be given an explanation of a conceptual model and ontology. It will describe how ontology can be derived from conceptual model. Further, this process will be performed for concepts in proposed data dictionary in Section 5.4.

5.5.1 Conceptual model relations

Conceptual model shows the dependency within the data. In this case the model represents dependency within addressing system concepts through relation cardinality. Table 5.4 represents relationships between concepts in Table 5.1. Relationship between the first column entity and the second column entity is noted in the third column as certain cardinality, e.g., for a *Road name* there could be assigned one to many *AddressObjects*.

Table 5.4: Relations between addressing system concepts

Entity #1	**Entity #2**	**Cardinality**	**Descritption**
Road name	AddressObject	1 to 1..N	There could be one to many *AddressObject* assigned to a *Road name*
Postcode	AddressObject	1 to 1..N	There could be one to many *AddressObject* assigned to a *Postcode*
Municipality	AddressObject	1 to 1..N	There could be one to many *AddressObject* assigned to a *Municipality*
AddressNumber	AddressObject	1 to 1..N	There could be one to many *AddressObject* assigned to an *AddressNumber*
Address point	AddressObject	0..1 to 1	There could be assigned an *AddressObject* to one or to none *Address point*
City/ Town/ Settlement name	AddressObject	0..1 to 0..1	There could be assigned none or one *AddressObject* to none or one *City/ Town/ Settlement name*
Building alias	AddressObject	0..1 to 0..1	There could be assigned none or one *AddressObject* to none or one *Building alias*
AddressNumber	Floor number	1 to 1..N	There could be one to many *Floor number* assigned to a *AddressNumber*
Floor number	Door number	1 to 1..N	There could be none to many *Door number* assigned to a *Floor number*
Municipality	Road name	1 to 1..N	There could be one to many *Road name* assigned to a *Municipality*
Municipality	Postcode	1 to 1..N	There could be one to many *Postcode* assigned to a *Municipality*

Continued on next page

Table 5.4 – *Continued from previous page*

Entity #1	Entity #2	Cardinality	Descritption
Municipality	Building alias	1 to 0..N	There could be none to many *Building alias* assigned to a *Municipality*
Municipality	City/ Town/ Settlement name	1 to 0..N	There could be none to many *City/ Town/ Settlement name* assigned to a *Municipality*

5.5.2 Ontology

Ontology is cause and effect relationship definition within a set of concepts. In the database design it helps to derive logical model from conceptual model [70]. The acyclic graph [71] is used (cf. Figure 5.3) to represent data dictionary concept definition causal effects to other concepts. E.g., *Postcode* is concept (an entity) which defines *Address object* and this is represented with a directed edge. The overall graph gives information about dependencies and in combination with relation Table 5.4 can be further used to create entity relationship diagram (ERD).

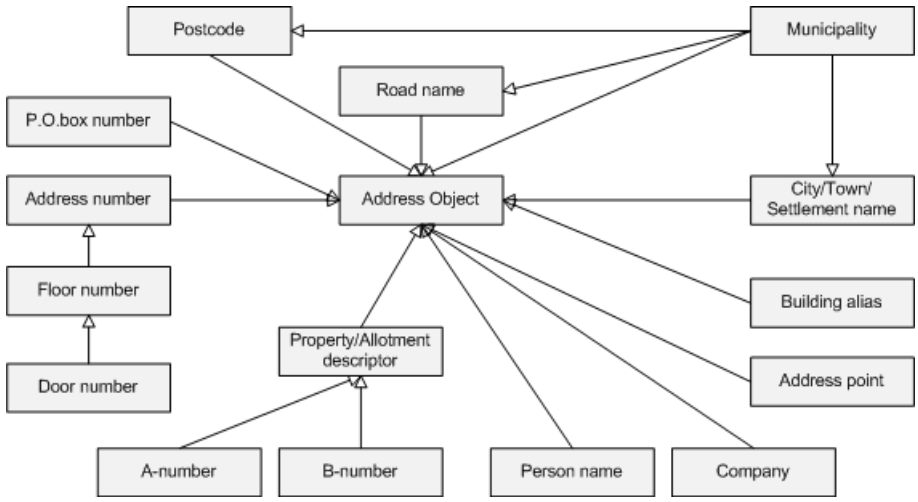


Figure 5.3: Causality of data dictionary represented as acyclic graph

5.6 Logical model - entity relationship diagram

The logical model is set of concepts put together with the relationships between them into one schema. The acyclic graph of Figure 5.3 has been transformed into ERD [60] which is represented in Figure 5.4.

Second ERD in Figure 5.5 represents the related independent object diagram. Concepts in this diagram do not affect the composition of the *Address object*, however it shows concept relations to the *Address object*. The corresponding SQL create code for models in Figure 5.4 and Figure 5.5 is listed in Appendix B.

5.7 Case studies and scenarios

Following the user requirements addressed in Section 4.2, the case studies includes description of possible benefits of proposed model introduction. There could be distinguished three cases based on common operations for public services, i.e., using addressing system with support of geocoding and second, planning the route and employing the reverse geocoding. All found important for implementation in high risk applications, e.g., address lookup and route planer for emergency services.

5.7.1 Addressing and geocoding

Proposed design of address model supports addressing and geocoding through *AddressObject*. *AddressObject* is designed to be an independent object which could be linked to other data sets, e.g., post box registry, business registry, civil register and similar. Having data stored in core address database eases the management of the data and it is consistent. Incomplete addresses are not allowed to be stored by the design of constraints, thus database engine should warn data manager about missing attributes. Employing individual point method when assigning geographic coordinates for each *AddressObject* would ensure acquired accuracy for high risk applications.
Data form the core address database could be shared via web services providing API for *AddressObject* list retrieval in form of XML (Extensible Markup Language). With set requirements for data update policy, it would be possible to ensure that after enquiry interested parties would receive up to date extract form the core address database.

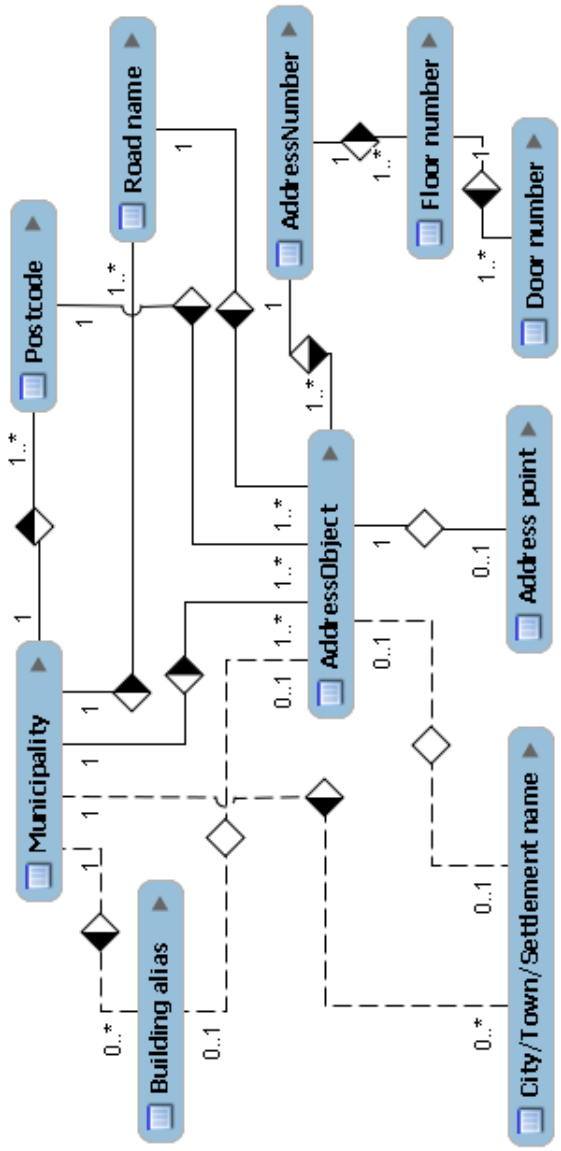


Figure 5.4: Proposed entity relationship diagram depicting *Address object* in UML notation

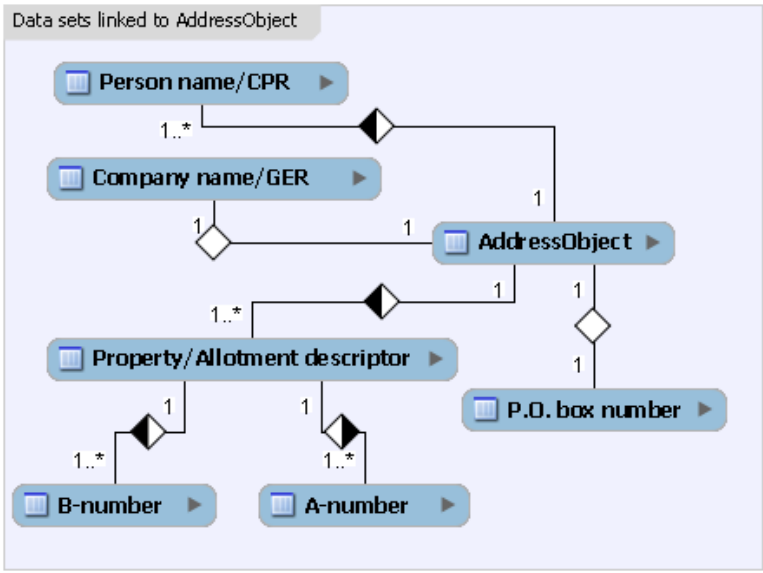


Figure 5.5: Related independent objects linked to *Address object*

5.7.2 Route finding

Currently, the only town in Greenland with support of route finding engine is Nuuk. The journey planner has been implemented via OpenStreetMap where geographical features have been digitised by a public contribution. Routes could be found with direction guidelines as shown in one of the examples in Figure 5.6.

Road network could serve as backbone for route network layer where additionally other attributes and features like intersections, restricted turns, speed limits and similar should be considered.

5.7.3 Reverse geocoding

Emergency and other services could employ similar service based on route network by reverse-gocoding when attempting to locate a place of incident. This requires a contribution from each municipality to digitise all roads and further investigations for journey planning engine choice. Designed model would support routing because geocoded addresses would be linked to a road network,

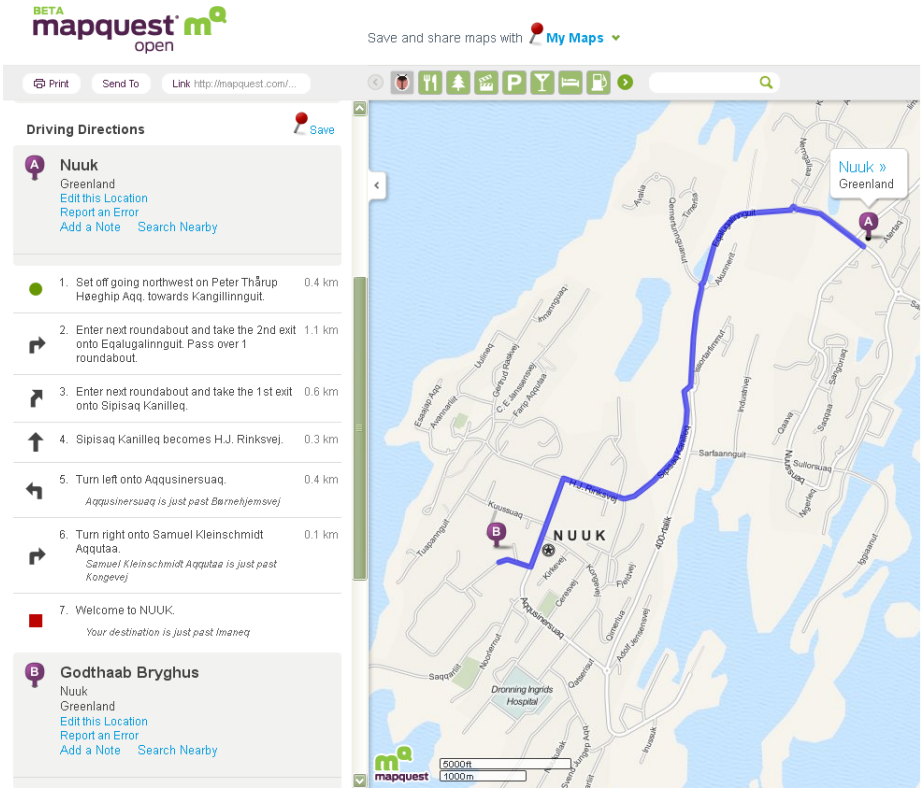


Figure 5.6: MapQuest route planner on top of OpenStreetMap shows directions for routing in Nuuk

thus allowing to find the closest point on the road with respect to geographic coordinates of the place of the incident. An example of reverse geocoding is given in Section 4.2 in Figure 4.2a.

Chapter 6

Future work

For future work it would be necessary to continue extending the proposed conceptual and logical model into a physical model. This would include adding attributes to the defined entities in data model, their data type definitions and database engine dependent modifications. Further work should include plan of road network digitisation taking into consideration the requirements of route network which would be based on it.
There should be a change in legislation to support the use of addressing standard and reached agreement to publish the address data for free for public use. This would encourage to use most recent data and avoid getting back to inconsistencies in several data sets intended to maintain the same address information. Furthermore, guidelines for road naming conventions and address system maintenance would need to be published to support address data managers.
To ensure data availability, it would be necessary to publish the data via web services ensuring certain reliability for high risk applications. Example of further use includes data retrieval for finding geographic location of an incident and showing the shortest route for getting to this location.

Chapter 7

Conclusions

The introduction of an addressing system and geocoding is a time consuming process which has been initiated in 2010 as part of Greenland's SDI plan. There is lack of work resources to fully devote to the set up milestones in the plan, therefore, research in this work could support the decision making for further actions.

The main objective was to propose a model for addressing system that will support the geocoding and take into consideration feasibility and currently used practices in Greenland. To reach this objective, there were described similar addressing systems, investigated current addressing practices in Greenland and found resemblances with Danish addressing system. Later the user requirements were set, data dictionary was created and an ontology and entity relationship diagram was produced. Proposed model introduces entities which allows to store geodata for geographic features linked to the address object.

There are several similar areas to Greenland in the world with respect to inhabitation pattern. Background study showed that there are different approaches to solve addressing issues in areas with low population density. Sweden's and Australia's approach with distance based address numbering could be applicable in Greenland once the road network is digitised. If this approach is considered as substantial, model proposed in this project also supports distance based addressing. Findings in Saudi Arabia addressing system's implementation aspects leads to conclusion that it would not be feasible from cost and benefit perspective. The enquired software and human resources necessary to apply methods

described in this project could be beyond expected expenses. Furthermore, this would discard some of the current addressing practices and conventions used Greenland, e.g., street naming, municipality areal division.
Drawbacks of using other identifiers, e.g., identifier derived from geographic coordinates as in Saudi Arabia or B-number is related with possible overhead encountered in change of convention, interoperability with other SDI. In the case of B-number use, some of the address management tasks would be more complicated and it would not be a systematic numbering with respect to adjusted road.
Resemblance with Danish addressing approaches has been studied and due to similarity of available data sets, Greenland addressing system's model relates to the model used in the Danish system. There are several other initiatives, e.g., legislation, cross-municipal project team, data availability, post-implementation address data management which could be utilized.
Road network for all Greenland should be digitised complying with described requirements. This would allow to use road network as core for the numbered addressing system and would later support the route planning.
There have been described several geocoding methods and concluded that individual point method would suite the best. Interpolation methods are less time and human resource consuming but shortcoming is unsatisfactory expected precision for purposes of high risk applications like emergency services. Individual point method would provide minimum error in distance deviation for geocoded addresses and other geographical features.
Investing for improvements in the address data consistency and introduction of geocoding would provide numerous benefits for Greenland's citizens in return. More efficient incident handling for emergency services would be the first priority, followed by other public services like postal, land administration, urban planning and tourism agencies.

Appendix A

Common terms used in the addressing domain

The following terms have been found similar in the investigated addressing practices and systems in Denmark, Greenland, Sweden, Canada, Australia and Saudi Arabia.

Alias/Registered common building or building complex - name which is commonly used and which holds an addressing value.

Apartment number/Dwelling descriptor - number given to a designated place for living or commercial usage.

Country code - international abbreviation for a country name.

Municipality - areal division usually in Nordic region to allocate the governance across different regions in the country.

Person/Company name - an addressee name which could be a company or a person name.

Postcode/District - postal service areal division for mail distribution. Worth to notice that their borders not necessarily coincide with borders of municipalities'.

Street name/Address-area - given name for a street. Due historical reasons in Europe there is a convention of street naming. Usually streets are named by, e.g., well known persons, historical events, significant geographical objects.

Street number/Address place designator - given number for a street. In Europe usually the street numbers are given in descending order along the streets in direction towards the center of the city. There are cases where the direction towards center is not obvious, thus streets are assigned a certain starting point. There are other numbering methodology and some of it has been covered in this paper, e.g., Sweden, Australia.

Appendix B

Entity relationship diagram SQL create listing

```
SET @OLD_UNIQUE_CHECKS=@@UNIQUE_CHECKS, UNIQUE_CHECKS=0;
SET @OLD_FOREIGN_KEY_CHECKS=@@FOREIGN_KEY_CHECKS,
    FOREIGN_KEY_CHECKS=0;
SET @OLD_SQL_MODE=@@SQL_MODE, SQL_MODE='TRADITIONAL';

CREATE SCHEMA IF NOT EXISTS `mydb` DEFAULT CHARACTER SET latin1
    COLLATE latin1_swedish_ci ;
USE `mydb` ;

-- -----------------------------------------------------
-- Table `mydb`.`Municipality`
-- -----------------------------------------------------
CREATE  TABLE IF NOT EXISTS `mydb`.`Municipality` (
  `idMunicipality name` INT NOT NULL ,
  PRIMARY KEY (`idMunicipality name`) )
ENGINE = InnoDB;


-- -----------------------------------------------------
-- Table `mydb`.`Road name`
-- -----------------------------------------------------
CREATE  TABLE IF NOT EXISTS `mydb`.`Road name` (
  `idRoad name` INT NOT NULL ,
  `Municipality_idMunicipality name` INT NOT NULL ,
  PRIMARY KEY (`idRoad name`, `Municipality_idMunicipality name`) ,
  INDEX `fk_Road name_Municipality1` (`Municipality_idMunicipality
      name` ASC) ,
```

```
25    CONSTRAINT `fk_Road name_Municipality1`
26      FOREIGN KEY (`Municipality_idMunicipality name` )
27      REFERENCES `mydb`.`Municipality` (`idMunicipality name` )
28      ON DELETE NO ACTION
29      ON UPDATE NO ACTION)
30  ENGINE = InnoDB;
31
32
33  -- -----------------------------------------------------
34  -- Table `mydb`.`Postcode`
35  -- -----------------------------------------------------
36  CREATE  TABLE IF NOT EXISTS `mydb`.`Postcode` (
37    `idPostcode` INT NOT NULL ,
38    `Municipality_idMunicipality name` INT NOT NULL ,
39    PRIMARY KEY (`idPostcode`, `Municipality_idMunicipality name`) ,
40    INDEX `fk_Postcode_Municipality1` (`Municipality_idMunicipality
          name` ASC) ,
41    CONSTRAINT `fk_Postcode_Municipality1`
42      FOREIGN KEY (`Municipality_idMunicipality name` )
43      REFERENCES `mydb`.`Municipality` (`idMunicipality name` )
44      ON DELETE NO ACTION
45      ON UPDATE NO ACTION)
46  ENGINE = InnoDB;
47
48
49  -- -----------------------------------------------------
50  -- Table `mydb`.`Address point`
51  -- -----------------------------------------------------
52  CREATE  TABLE IF NOT EXISTS `mydb`.`Address point` (
53    `idAddress point` INT NOT NULL ,
54    PRIMARY KEY (`idAddress point`) )
55  ENGINE = InnoDB;
56
57
58  -- -----------------------------------------------------
59  -- Table `mydb`.`Building alias`
60  -- -----------------------------------------------------
61  CREATE  TABLE IF NOT EXISTS `mydb`.`Building alias` (
62    `idBuilding alias` INT NOT NULL ,
63    `Municipality_idMunicipality name` INT NOT NULL ,
64    PRIMARY KEY (`idBuilding alias`) ,
65    INDEX `fk_Building alias_Municipality1` (`
          Municipality_idMunicipality name` ASC) ,
66    CONSTRAINT `fk_Building alias_Municipality1`
67      FOREIGN KEY (`Municipality_idMunicipality name` )
68      REFERENCES `mydb`.`Municipality` (`idMunicipality name` )
69      ON DELETE NO ACTION
70      ON UPDATE NO ACTION)
71  ENGINE = InnoDB;
72
73
74  -- -----------------------------------------------------
75  -- Table `mydb`.`City/Town/Settlement name`
76  -- -----------------------------------------------------
77  CREATE  TABLE IF NOT EXISTS `mydb`.`City/Town/Settlement name` (
```

```
78    `idCity/Town name` INT NOT NULL ,
79    `Municipality_idMunicipality name` INT NOT NULL ,
80    PRIMARY KEY (`idCity/Town name`) ,
81    INDEX `fk_City/Town name_Municipality1` (`
          Municipality_idMunicipality name` ASC) ,
82    CONSTRAINT `fk_City/Town name_Municipality1`
83      FOREIGN KEY (`Municipality_idMunicipality name` )
84      REFERENCES `mydb`.`Municipality` (`idMunicipality name` )
85      ON DELETE NO ACTION
86      ON UPDATE NO ACTION)
87  ENGINE = InnoDB;
88
89
90  -- -----------------------------------------------------
91  -- Table `mydb`.`AddressNumber`
92  -- -----------------------------------------------------
93  CREATE  TABLE IF NOT EXISTS `mydb`.`AddressNumber` (
94    `idAddressNumber` INT NOT NULL ,
95    PRIMARY KEY (`idAddressNumber`) )
96  ENGINE = InnoDB;
97
98
99  -- -----------------------------------------------------
100 -- Table `mydb`.`AddressObject`
101 -- -----------------------------------------------------
102 CREATE  TABLE IF NOT EXISTS `mydb`.`AddressObject` (
103   `idAddressNumber` INT NOT NULL ,
104   `Person name/CPR_idPerson name/CPR` INT NOT NULL ,
105   `Company name/GER_idCompany name/GER` INT NOT NULL ,
106   `P.O. box number_idP.O. box number` INT NOT NULL ,
107   PRIMARY KEY (`idAddressNumber`, `Person name/CPR_idPerson name/
          CPR`, `Company name/GER_idCompany name/GER`, `P.O. box
          number_idP.O. box number`) ,
108   INDEX `fk_AddressNumber_P.O. box number1` (`P.O. box number_idP.O
          . box number` ASC) ,
109   CONSTRAINT `fk_AddressNumber_P.O. box number1`
110     FOREIGN KEY (`P.O. box number_idP.O. box number` )
111     REFERENCES `mydb`.`P.O. box number` (`idP.O. box number` )
112     ON DELETE NO ACTION
113     ON UPDATE NO ACTION)
114 ENGINE = InnoDB;
115
116
117 -- -----------------------------------------------------
118 -- Table `mydb`.`P.O. box number`
119 -- -----------------------------------------------------
120 CREATE  TABLE IF NOT EXISTS `mydb`.`P.O. box number` (
121   `idP.O. box number` INT NOT NULL ,
122   PRIMARY KEY (`idP.O. box number`) )
123 ENGINE = InnoDB;
124
125
126 -- -----------------------------------------------------
127 -- Table `mydb`.`AddressObject`
128 -- -----------------------------------------------------
```

```
129 CREATE  TABLE IF NOT EXISTS `mydb`.`AddressObject` (
130   `idAddressNumber` INT NOT NULL ,
131   `Person name/CPR_idPerson name/CPR` INT NOT NULL ,
132   `Company name/GER_idCompany name/GER` INT NOT NULL ,
133   `P.O. box number_idP.O. box number` INT NOT NULL ,
134   PRIMARY KEY (`idAddressNumber`, `Person name/CPR_idPerson name/
          CPR`, `Company name/GER_idCompany name/GER`, `P.O. box
          number_idP.O. box number`) ,
135   INDEX `fk_AddressNumber_P.O. box number1` (`P.O. box number_idP.O
          . box number` ASC) ,
136   CONSTRAINT `fk_AddressNumber_P.O. box number1`
137     FOREIGN KEY (`P.O. box number_idP.O. box number` )
138     REFERENCES `mydb`.`P.O. box number` (`idP.O. box number` )
139     ON DELETE NO ACTION
140     ON UPDATE NO ACTION)
141 ENGINE = InnoDB;
142
143
144 -- -----------------------------------------------------
145 -- Table `mydb`.`Property/Allotment descriptor`
146 -- -----------------------------------------------------
147 CREATE  TABLE IF NOT EXISTS `mydb`.`Property/Allotment descriptor`
        (
148   `idProperty/Allotment` INT NOT NULL ,
149   `AddressNumber_idAddressNumber` INT NOT NULL ,
150   `AddressNumber_Person name/CPR_idPerson name/CPR` INT NOT NULL ,
151   `AddressNumber_Company name/GER_idCompany name/GER` INT NOT NULL
          ,
152   `AddressNumber_P.O. box number_idP.O. box number` INT NOT NULL ,
153   PRIMARY KEY (`idProperty/Allotment`, `
          AddressNumber_idAddressNumber`, `AddressNumber_Person name/
          CPR_idPerson name/CPR`, `AddressNumber_Company name/
          GER_idCompany name/GER`, `AddressNumber_P.O. box number_idP.O
          . box number`) ,
154   INDEX `fk_Property/Allotment_AddressNumber1` (`
          AddressNumber_idAddressNumber` ASC, `AddressNumber_Person
          name/CPR_idPerson name/CPR` ASC, `AddressNumber_Company name/
          GER_idCompany name/GER` ASC, `AddressNumber_P.O. box
          number_idP.O. box number` ASC) ,
155   CONSTRAINT `fk_Property/Allotment_AddressNumber1`
156     FOREIGN KEY (`AddressNumber_idAddressNumber` , `
            AddressNumber_Person name/CPR_idPerson name/CPR` , `
            AddressNumber_Company name/GER_idCompany name/GER` , `
            AddressNumber_P.O. box number_idP.O. box number` )
157     REFERENCES `mydb`.`AddressObject` (`idAddressNumber` , `Person
            name/CPR_idPerson name/CPR` , `Company name/GER_idCompany
            name/GER` , `P.O. box number_idP.O. box number` )
158     ON DELETE NO ACTION
159     ON UPDATE NO ACTION)
160 ENGINE = InnoDB;
161
162
163 -- -----------------------------------------------------
164 -- Table `mydb`.`B-number`
165 -- -----------------------------------------------------
```

```
166 CREATE  TABLE IF NOT EXISTS `mydb`.`B-number` (
167   `idB-number` INT NOT NULL ,
168   `Property/Allotment_idProperty/Allotment` INT NOT NULL ,
169   PRIMARY KEY (`idB-number`, `Property/Allotment_idProperty/
          Allotment`) ,
170   INDEX `fk_B-number_Property/Allotment1` (`Property/
          Allotment_idProperty/Allotment` ASC) ,
171   CONSTRAINT `fk_B-number_Property/Allotment1`
172     FOREIGN KEY (`Property/Allotment_idProperty/Allotment` )
173     REFERENCES `mydb`.`Property/Allotment descriptor` (`idProperty/
            Allotment` )
174     ON DELETE NO ACTION
175     ON UPDATE NO ACTION)
176 ENGINE = InnoDB;
177
178
179 -- -----------------------------------------------------
180 -- Table `mydb`.`Floor number`
181 -- -----------------------------------------------------
182 CREATE  TABLE IF NOT EXISTS `mydb`.`Floor number` (
183   `idFloor` INT NOT NULL ,
184   `AddressNumber_Building alias_idBuilding alias` INT NOT NULL ,
185   `AddressNumber_idAddressNumber` INT NOT NULL ,
186   PRIMARY KEY (`idFloor`, `AddressNumber_Building alias_idBuilding
          alias`, `AddressNumber_idAddressNumber`) ,
187   INDEX `fk_Floor number_AddressNumber1` (`
          AddressNumber_idAddressNumber` ASC) ,
188   CONSTRAINT `fk_Floor number_AddressNumber1`
189     FOREIGN KEY (`AddressNumber_idAddressNumber` )
190     REFERENCES `mydb`.`AddressNumber` (`idAddressNumber` )
191     ON DELETE NO ACTION
192     ON UPDATE NO ACTION)
193 ENGINE = InnoDB;
194
195
196 -- -----------------------------------------------------
197 -- Table `mydb`.`Door number`
198 -- -----------------------------------------------------
199 CREATE  TABLE IF NOT EXISTS `mydb`.`Door number` (
200   `idDoor` INT NOT NULL ,
201   `Floor_idFloor` INT NOT NULL ,
202   PRIMARY KEY (`idDoor`, `Floor_idFloor`) ,
203   INDEX `fk_Door_Floor1` (`Floor_idFloor` ASC) ,
204   CONSTRAINT `fk_Door_Floor1`
205     FOREIGN KEY (`Floor_idFloor` )
206     REFERENCES `mydb`.`Floor number` (`idFloor` )
207     ON DELETE NO ACTION
208     ON UPDATE NO ACTION)
209 ENGINE = InnoDB;
210
211
212 -- -----------------------------------------------------
213 -- Table `mydb`.`A-number`
214 -- -----------------------------------------------------
215 CREATE  TABLE IF NOT EXISTS `mydb`.`A-number` (
```

```
216   `idA-number` INT NOT NULL ,
217   `Property/Allotment_idProperty/Allotment` INT NOT NULL ,
218   PRIMARY KEY (`idA-number`, `Property/Allotment_idProperty/
          Allotment`) ,
219   INDEX `fk_A-number_Property/Allotment1` (`Property/
          Allotment_idProperty/Allotment` ASC) ,
220   CONSTRAINT `fk_A-number_Property/Allotment1`
221     FOREIGN KEY (`Property/Allotment_idProperty/Allotment` )
222     REFERENCES `mydb`.`Property/Allotment descriptor` (`idProperty/
          Allotment` )
223     ON DELETE NO ACTION
224     ON UPDATE NO ACTION)
225 ENGINE = InnoDB;
226
227
228 -- -----------------------------------------------------
229 -- Table `mydb`.`Person name/CPR`
230 -- -----------------------------------------------------
231 CREATE  TABLE IF NOT EXISTS `mydb`.`Person name/CPR` (
232   `idPerson name/CPR` INT NOT NULL ,
233   `AddressNumber_idAddressNumber` INT NOT NULL ,
234   `AddressNumber_Person name/CPR_idPerson name/CPR` INT NOT NULL ,
235   `AddressNumber_Company name/GER_idCompany name/GER` INT NOT NULL
          ,
236   PRIMARY KEY (`idPerson name/CPR`, `AddressNumber_idAddressNumber
          `, `AddressNumber_Person name/CPR_idPerson name/CPR`, `
          AddressNumber_Company name/GER_idCompany name/GER`) ,
237   INDEX `fk_Person name/CPR_AddressNumber1` (`
          AddressNumber_idAddressNumber` ASC, `AddressNumber_Person
          name/CPR_idPerson name/CPR` ASC, `AddressNumber_Company name/
          GER_idCompany name/GER` ASC) ,
238   CONSTRAINT `fk_Person name/CPR_AddressNumber1`
239     FOREIGN KEY (`AddressNumber_idAddressNumber` , `
            AddressNumber_Person name/CPR_idPerson name/CPR` , `
            AddressNumber_Company name/GER_idCompany name/GER` )
240     REFERENCES `mydb`.`AddressObject` (`idAddressNumber` , `Person
            name/CPR_idPerson name/CPR` , `Company name/GER_idCompany
            name/GER` )
241     ON DELETE NO ACTION
242     ON UPDATE NO ACTION)
243 ENGINE = InnoDB;
244
245
246 -- -----------------------------------------------------
247 -- Table `mydb`.`Company name/GER`
248 -- -----------------------------------------------------
249 CREATE  TABLE IF NOT EXISTS `mydb`.`Company name/GER` (
250   `idCompany name/GER` INT NOT NULL ,
251   `AddressNumber_idAddressNumber` INT NOT NULL ,
252   `AddressNumber_Person name/CPR_idPerson name/CPR` INT NOT NULL ,
253   `AddressNumber_Company name/GER_idCompany name/GER` INT NOT NULL
          ,
254   `AddressNumber_P.O. box number_idP.O. box number` INT NOT NULL ,
255   PRIMARY KEY (`idCompany name/GER`, `AddressNumber_idAddressNumber
          `, `AddressNumber_Person name/CPR_idPerson name/CPR`, `
```

```
      AddressNumber_Company name/GER_idCompany name/GER`, `
      AddressNumber_P.O. box number_idP.O. box number`) ,
  INDEX `fk_Company name/GER_AddressNumber1` (`
      AddressNumber_idAddressNumber` ASC, `AddressNumber_Person
      name/CPR_idPerson name/CPR` ASC, `AddressNumber_Company name/
      GER_idCompany name/GER` ASC, `AddressNumber_P.O. box
      number_idP.O. box number` ASC) ,
  CONSTRAINT `fk_Company name/GER_AddressNumber1`
    FOREIGN KEY (`AddressNumber_idAddressNumber` , `
        AddressNumber_Person name/CPR_idPerson name/CPR` , `
        AddressNumber_Company name/GER_idCompany name/GER` , `
        AddressNumber_P.O. box number_idP.O. box number` )
    REFERENCES `mydb`.`AddressObject` (`idAddressNumber` , `Person
        name/CPR_idPerson name/CPR` , `Company name/GER_idCompany
        name/GER` , `P.O. box number_idP.O. box number` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB;



SET SQL_MODE=@OLD_SQL_MODE;
SET FOREIGN_KEY_CHECKS=@OLD_FOREIGN_KEY_CHECKS;
SET UNIQUE_CHECKS=@OLD_UNIQUE_CHECKS;
```

Appendix C

Similar addressing concept mapping

Table C.1: Mapping between addressing concepts in Greenland, Denmark, Sweden, Canada, Australia and Saudi Arabia

Greenland	**Denmark**	**Sweden**	**Canada**	**South Australia (rural)**	**Saudi Arabia**
Address object	Definite access address	No information	No information	No information	No information
Address point	Definite address point	No information	No information	No information	Can be derived from address code
Address number	Part of Definite access address	Address place designation	Linked to the street name	A distance based road number	Localisation Number (Building number)
Postcode	Post code	District (Subdivision of Municipality)	Postal code	Postcode	Postal code
Road/Street name	Named road	Address-area/ Street Address-areas/ village, farmstead, group of buildings	Street name	Road name	Road/Street name not included in address
Municipality	Municipality	Municipality	Municipality name	Locality	*None corresponding*
City/ Town/ Settlement name	Supplementary town name	Part of Address-area designator	*None corresponding*	Town name not included in address	Town name not included in address

Continued on next page

Table C.1 – *Continued from previous page*

Greenland	**Denmark**	**Sweden**	**Canada**	**South Australia (rural)**	**Saudi Arabia**
Combination of Floor and Door number	Unit address	Apartment/ Dwelling designation	*None corresponding*	*None corresponding*	Extended number
Building alias	Building name	Alias/ Registered common place name	SITE and/or COMP	*None corresponding*	*None corresponding*
None corresponding	Municipal road name	*None corresponding*	*None corresponding*	*None corresponding*	*None corresponding*
Not required for local addressing	Not required for local addressing	Country designator	Not required for local addressing	Not required for local addressing	Not required for local addressing
None corresponding	*None corresponding*	*None corresponding*	Rural route designator	*None corresponding*	*None corresponding*
None corresponding	*None corresponding*	*None corresponding*	STN or RPO numbers for directed post	*None corresponding*	*None corresponding*
None corresponding	*None corresponding*	*None corresponding*	Province/ Federal territory name	*None corresponding*	*None corresponding*

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