TOWARDS DEVELOPMENT OF A HIGH QUALITY PUBLIC DOMAIN GLOBAL ROADS DATABASE

Andrew Nelson, Alexander de Sherbinin*, and Francesca Pozzi

CIESIN, Columbia University, New York, NY 10027

*Email: adesherbinin @ciesin.columbia.edu

ABSTRACT

There is clear demand for a global spatial public domain roads data set with improved geographic and temporal coverage, consistent coding of road types, and clear documentation of sources. The currently best available global public domain product covers only one-quarter to one-third of the existing road networks, and this varies considerably by region. Applications for such a data set span multiple sectors and would be particularly valuable for the international economic development, disaster relief, and biodiversity conservation communities, not to mention national and regional agencies and organizations around the world. The building blocks for such a global product are available for many countries and regions, yet thus far there has been neither strategy nor leadership for developing it. This paper evaluates the best available public domain and commercial data sets, assesses the gaps in global coverage, and proposes a number of strategies for filling them. It also identifies stakeholder organizations with an interest in such a data set that might either provide leadership or funding for its development. It closes with a proposed set of actions to begin the process.

1 STATEMENT OF NEED

In many countries, roads and highways provide the dominant mode of land transport. They often carry more than 80 percent of passenger-km and over 50 percent of freight ton-km in a country. Consequently, roads, and highways form the back bone of the economy and provide essential links to the vast rural hinterlands (WorldBank, 2005a). It is estimated that the value added by transport accounts for 3 to 5 % of GDP and 5 to 8 % of total paid employment (WorldBank, 2002).

Given the enormous economic and social importance of road transport, it is surprising that there is a lack of good quality public domain[1] global and regional spatial data sets for road networks. This is even more surprising given that there are so many international agencies with large vested interests in transport

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[1] This report utilizes the term "public domain" to denote data that are free of copyright restrictions and that, at a minimum, are available and can be redistributed free-of-charge. For a more complete description of intellectual property rights related to data, and to the various types of restrictions on data use and redistribution, see de Sherbinin and Chen 2005 (pp. 17-20) and Dooley 2005 (pp. 12-15).

management and development, including the United Nations Economic Commissions, the Organization for Economic Cooperation and Development (OECD), the European Commission (EC), the World Bank, and the regional banks (e.g., EBRD, IADB, and ADB). The World Bank alone commits around US$2.6 billion per year (or 12% of its annual lending) to road transportation projects (WorldBank, 2005b). In addition, there are a number of global road associations (e.g., the World Road Association and International Road Federation) that are committed to road development, research support, and the dissemination of information and tools for decision making for all matters related to road transport, yet none has thus far ventured to produce a spatial global roads database.

The current best available public domain spatial global road network data set is the Vector Smart Map Level 0 (VMap0) data library from the National Imagery and Mapping Agency (NIMA, 2000).[2] The road network in this database comprises approximately 7.4 million km of road of which 6.5 million km are described as paved. In an effort to estimate the ability of VMap0 to represent the existing global road network, a tabulation of road length by country was made and compared to the data available in the Central Intelligence Agency (CIA) *World Fact Book* (CIA, 2005) and the International Road Federation's (IRF) *World Road Statistics* (Cropper and Kopits, 2003). The *World Fact Book* estimates that there are almost 28 million km of road, implying that VMap0 captures only 26.6% of the global road network. The IRF data for 1989 (the year in which VMap0 was constructed) estimates the global road network at that time as 22 million km, implying that VMap0 captures 34.1% of the global road network.[3]

Similar regional road statistics exist for 32 countries in Europe (EC and Eurostat, 2004), 33 countries in Latin America and the Caribbean (ECLAC, 2005) and the 40 countries with the longest road networks (Economist, 2005, p68). Comparing VMap0 against these three data sets shows that VMap0 captures 12%, 37% and 25% of the road network respectively and 26.3% when these three sources are summarized.

Even considering that the tabular road statistics cover many intra-urban streets and roads, from these comparisons it becomes apparent that the current best available public domain spatial roads data set represents only a fraction of the existing road network. If the comparison with the IRF road statistics is taken as a starting point, the situation is comparable to a 'global' land cover map that would have data for only Russia, Canada, the USA, and China (accounting for 34% of the global landmass). The distribution of the VMap0 road network as a percentage of the 'real' road network as derived from the previous sources is shown in Figure 1 by country and Figure 2 by UN Region.

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[2] NIMA is now known as the National Geospatial Intelligence Agency (NGA).
[3] It needs to be emphasized that IRF data include "other roads – urban" in its classification system, which are defined as "roads within the boundaries of a built-up area, which is an area with entries and exits especially sign posted as such." This indicates that streets and roads *within* urban areas are included, whereas VMap0 only includes long distance road networks *between* populated places.

Clearly, there are vast areas of the developed and developing world where the current standard public domain global road network data set is unacceptably poor. To demonstrate the importance of roads data, the next section addresses a range of applications of spatial road data for economic policy analysis, development and emergency aid, environmental policy and research.
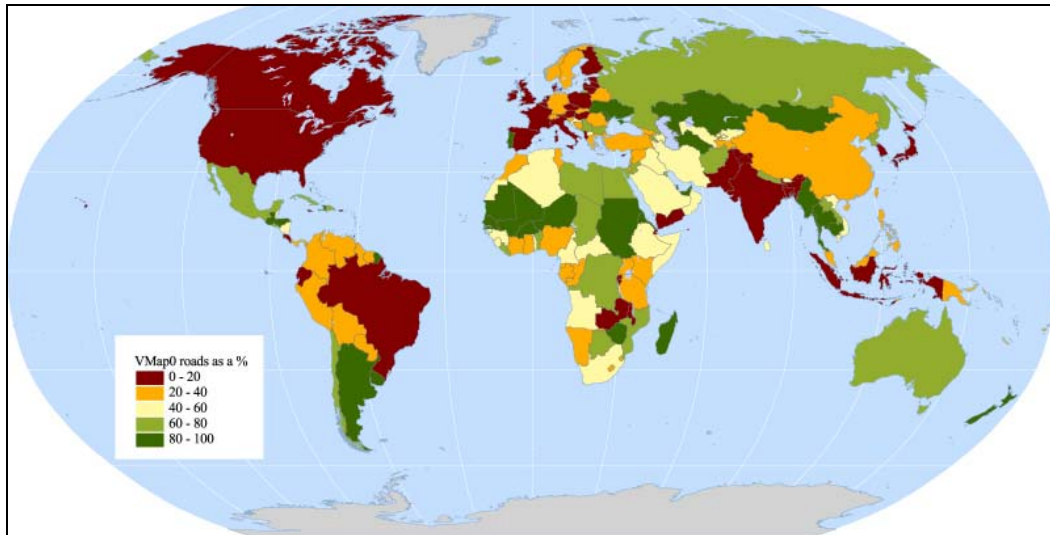

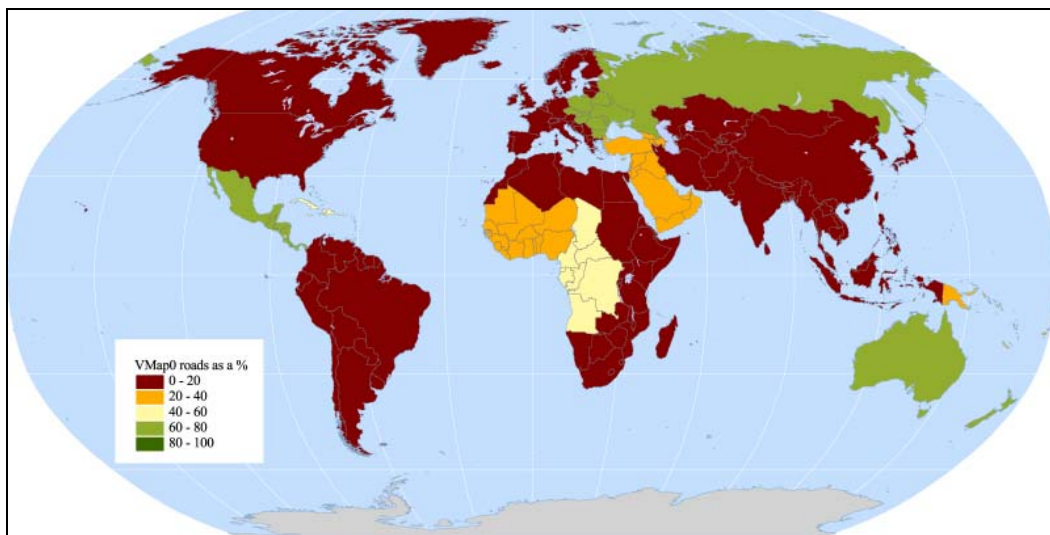**Figure 1.** Percentage of roads represented by the VMap0 road layer (by country)

Figure 2. Percentage of roads represented by the VMap0 road layer (by UN Region)

1.1 The need for a good quality roads data se*t*

Recent reviews and assessments of global geospatial information (de Sherbinin and Chen, 2005; Dooley, 2005) have underscored the growing gap between environmental data availability, which has grown considerably thanks largely to remote sensing, and the quality, consistency, and availability of socioeconomic and "framework" data. Contemporary global (or almost global) coverage for key environmental themes such as: forests, land cover, terrain and coastlines are available at resolutions from 30m to 1km.[4] In contrast, socio-economic data are available at much coarser levels of detail and have the inherent problem of being heterogeneous since data are collected at different dates, with different levels of quality, and are made available under differing licensing conditions from country to country.

It has been suggested that the term "global data sets" has two meanings (de Sherbinin and Chen, 2005, p.6). There is the standard definition that a global data set is one that covers the world, but it can also be defined as a data set that is required everywhere since it is applicable to many problems. The following list of applications and users demonstrates that a good quality public domain global roads data set is a vital input for a wide range of disaster relief, development, environmental, and research goals. Additionally, global data sets are often applied in national and regional level analysis since they are often the best available data in data-poor countries. This list of applications includes this kind of usage.

Transport and economy

- *Network analysis for resource allocation potential*

Many Geographic Information System (GIS) packages include powerful network analysis tools for calculating travel time along complex transport networks (Geertman and Reitsema van Eck, 1995; Deichmann, 1997a; Deichmann and Bigman, 2000; Nelson, et al., 2000), which can then be combined with geo-demographic databases to assess catchment areas and potential markets for services (Miller, 1999a; Ritsema van Eck and de Jong, 1999).

- *Location strategies for business*

Planning for new locations of businesses such as retail or industry can be greatly enhanced by the use of spatial planning models to identify optimal sites based on accessibility and the geodemographics of the population within a given catchment area (Arentze, et al., 1997; Shen, 2000). On the other hand, road construction often creates economic opportunities such as increased customer, supplier and labor markets.

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[4] For example, forest cover is available at 500m resolution, (MODIS Vegetation Continuous Fields, 2003), land cover will soon be available at 300m resolution (GLOBCOVER, 2006/7 est.), terrain data at 90m resolution (SRTM, 2005), and coastlines and water bodies at 30m (SRTM-SWBD, 2005).

- *Vehicle Routing and tracking*

Intelligent Transportation Systems are now a critical component for many transport management applications, such as: planning and design, navigation, routing, tracking, and traffic control (Miller, 1999b; Husdal, 2000; O'Sullivan, et al., 2000; Fotheringham, 2003).

Pre- and post-disaster planning

- *Emergency planning (evacuation strategies etc.)*

The resilience of a transport network, or its ability to accommodate unexpected conditions, is a key concept for planning evacuation strategies when dealing with the inherent uncertainty of natural and man-made disasters (Berdica, 2002; Litman, 2004; Morlok and Chang, 2004). Such resilience can be modeled and assessed by transport planners with good spatial road network information.

- *Impact assessment*

Following a loss of transport infrastructure, how can we ensure the best appropriation of often limited reconstruction resources? Who has been affected and where? Again, good spatial transport information is vital for rapid informed assessments for damage assessment, the loss of accessibility, the demographics of the population at risk, and the pros and cons of different resource allocation strategies (Winograd, et al., 1999).

- *Medium and long term planning*

The long term economic impact of loss of infrastructure cannot be underestimated. The time required to restore power or water to a community is much quicker than the time required to reconstruct a bridge or road section. For example, after the Kobe (Japan) earthquake in 1995, electric power and telecommunications were restored within the first few weeks, water and gas within 3-4 months, but the road networks took 21 months to be restored (Chang, 2000). The medium to long term effects due to the spatial disparities in the localized loss of accessibility are likely to have large impacts on the economic activity of individuals and businesses (Shen, 2000). Strategic planning using spatial transport information can help to minimize impact and aid economic recovery (Chang, 2000; Morlok and Chang, 2004).

Population

Good quality spatially referenced roads data sets are key inputs to many population-related applications. Spatial models of population distribution are frequently based on the assumption that population density is greatest in areas of good accessibility and high transport network density. Therefore, consistent and reliable road network information is vital for improving spatial population estimates at medium and high resolution (Deichmann, 1997b; Dobson, et al., 2000; Nelson and Deichmann, 2004; Hyman, et al., 2005).

Development

- *Poverty and inequality issues*

Lack of mobility and high transportation costs are key impediments that lead to the formation of 'spatial poverty traps' (Deichmann, 1999; Pender, et al., 1999; Bigman and Fofack, 2000). At the macro-level, access to safe water, electricity, and the road network have been shown to be positively correlated with national per capita income (Sarkar and Ghosh, 2000). Methods to identify areas of social and economic disadvantage are often dependent on spatial indicators of accessibility and connectivity to ensure accurate geographic targeting (Leinbach, 1995; Higgs and White, 2000). Hotspots of inequality in service provision (such as water, education, and health) can be assessed by deriving catchment areas around existing facilities in combination with population data (Williams, 1987; Airey, 1992; Hope, in press), and the catchment areas themselves can be defined by travel time which is mostly a function of road networks. Optimal locations for futures facilities can then be assessed.

- *Rural transportation*

Better rural transportation is a principal factor for improving livelihoods in developing countries through better access to markets, increased social mobility, migration, and greater economic opportunities (Leinbach, 1995; Barwell, 1996; Dixon-Fyle, 1998). Good road information is important to enable development organizations to assess the social and environmental impact of competing transportation strategies.

Food and agriculture

The movement, location, and sale of crops are all related to the transport network. It has been suggested that road surface improvements can have a substantial increase on farm gate prices (Hine and Riverson, 2001). Other potential applications include assessing the availability and accessibility of agricultural inputs, optimal locations for seed distribution centers and post-harvest facilities, and road construction for "opening" agricultural lands.

Environment and land use

- *Impact analysis for road development*

The ability of GIS to communicate and visualize the effects of roads on the environment is extremely valuable. Spatial models of the impact of road construction options can help to link the effect of road development on land cover change (Chomitz and Gray, 1996; Rapaport and Snickars, 1999; Laurance, et al., 2002; Nagendra, et al., 2003; Hawbaker, et al., 2004; Nelson and Leclerc, 2005).

- *Accessibility as a driver of land use change*

Land use and land pricing models have often been based on the von Thünen model (Hite, 2000). However, some recent studies have investigated the possibility of replacing distance to market (Euclidean distance)

with time to market (an economic distance) in such models to generate more realistic results for land use modeling (Chomitz and Gray, 1996; Verburg, et al., 2004; Nelson and Leclerc, 2005). Road types and conditions are the key factors in calculating economic distance.

Biodiversity

- *Threats to protected areas and in-situ conservation issues*

Poorly planned road developments can pose a risk to protected areas and regions of high biodiversity importance (Ji and Leberg, 2002). The possible consequences of road development, such as deforestation, habitat fragmentation (Jaarsma and Willems, 2002), increased wildlife mortality, and increased population pressure, are all factors that can increase the risk of biodiversity loss (Guarino, et al., 2002). Good transport planning aided by accurate and up-to-date road network maps can help to minimize the risk to such important areas and also to assess alternative transport options.

- *Planning of collections*

Plant Genetic Resource programs often face financial constraints for the collection of germaplasm. Increasingly, methods for optimizing and prioritizing areas for the collection of germplasm are being based on GIS targeting strategies that include areas that are accessible by road as well as more traditional inputs such as predicted species distribution, climate, and land cover. (Jarvis, et al., 2005)

1.2 Beneficiaries of such a data set

As can be seen from the previous discussion, there is a wide range of potential users for an improved global public domain spatial roads data set. These include important global and regional organizations in the following fields:

Transport, infrastructure and economic development
The International Road Federation (IRF), the World Road Association (PIARC), the World Bank and other regional development banks (IADB, EBRD, ADB etc.), the United Nations Economic Commissions, the European Commission Directorate General for Energy and Transport, and the European Commission Joint Research Centre (JRC).

Development and aid agencies
Such as the United Nations Development Programme (UNDP), the European Commission Directorate General for Development, and governmental agencies like the US Agency for International Development (USAID) and the UK Department for International Development (DFID).

Leading environmental institutes and organizations

Such as the United Nations Environment Programme (UNEP), the Global Environmental Facility (GEF), the World Resources Institute (WRI), and the Center for International Earth Science Information Network (CIESIN).

Agricultural research centers

Such as The Food and Agriculture Organization of the United Nations (FAO) and the 15 international centers that form the Consultative Group on International Research (CGIAR) and their associated programs for rural development, poverty alleviation, and natural resource management.

Biodiversity and conservation organizations

Such as Conservation International (CI), the World Wildlife Fund (WWF), the World Conservation Monitoring Centre (UNEP-WCMC), and the World Conservation Union (IUCN).

In addition to these global organizations, there are many more governmental agencies, non-governmental organizations (NGOs), research centers, and university programs that would benefit from access to an improved spatial global roads database. A more complete list of stakeholder organizations can be found in Appendix A.

1.3 Key elements of a global roads database

An ideal global roads database would need to have consistent road type definitions across all countries, a high degree of consistency in the level of coverage in every country, correct topology, and continuity across international borders. As a first cut on road definitions, we suggest the following IRF definitions. These would need to be vetted by an expert group before embarking on a data set creation.

Road types
- Motorway
- Highways, main or national road
- Secondary or regional road
- Other road

Road Surfaces
- Paved
- Improved surface
- Unpaved

Metadata

- Source
- Date (including reference date for each country's road network)
- Scale
- Notes
- Mapping from original source road classes into consistent road classes
- Restrictions on use (if any)

Section 3 explores different approaches to compiling a global roads data set, but whichever approach is used, the final product should be conform as closely as possible with this minimum standard. In the next section we review the state of the art in global road databases.

2 STATE OF THE ART

As described in the previous section, despite the social and economic importance of transportation, there is a lack of good quality public domain global and regional spatial data sets for road networks. In this section we review some of the currently available global road network data sets. For the purpose of evaluation, one freely available data set (VMap0) was downloaded from the internet, a commercial data set was purchased (ADC World Map v. 5), while the others were either evaluated based on samples available on the respective producers' websites (Europa technologies) or were only described based on available information (VMap1, WDB II, see also Dooley, 2005). The global data sets we assessed are listed in Table 1.

Table 1. Global road networks data sets

Data set	Data source	Scale	Reference Year	Availability
NGA VMap0 Ed. 5	National Geospatial-Intelligence Agency (NGA)	1:1 M	1979-1999	Public
NGA VMap1	National Geospatial-Intelligence Agency (NGA)	1:250,000	1992-1997[5]	Public for selected tiles
WDB II	U.S. Department of State (DoS) / Central Intelligence Agency (CIA)	1:3 M	Circa 1990	Public
ADC World Map, v.5	American Digital Cartography	1:1 M	1990-2002	Commercial
Europa Global Discovery	Europa Technologies	1:1 M and 1:3 M	unknown	Commercial

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[5] This is an estimate. It is very difficult to find precise dates in the available documentation.

2.1 Vector Smart Map Level 0

Vector Smart Map Level 0 (VMap0), Edition 5, is an updated and improved version of the National Imagery and Mapping Agency's (NIMA; now known as the National Geospatial-Intelligence Agency or NGA) Digital Chart of the World[6] (DCW) (**NIMA, 2000**). The VMap0 database provides worldwide coverage of vector-based geospatial data at the scale of 1:1 million. The database consists of geographic, attribute, and textual data organized in 10 thematic layers: major road and rail networks, hydrologic drainage systems, utility networks (cross-country pipelines and communication lines), major airports, elevation contours, coastlines, international boundaries, and populated places. VMap0 also includes an index of geographic names to aid in locating areas of interest. The primary source for the database is the 1:1 million scale Operational Navigation Chart (ONC) series co-produced by the military mapping authorities of Australia, Canada, United Kingdom, and the United States.[7]

Regarding the roads layer, the VMap0 comprises approximately 7.4 million km of road of which 6.5 million km are described as paved. It provides global coverage, and it is one of the best and most widely-used publicly available road network data sets. Nevertheless, there are serious limitations with this data set. As described in the previous section, the VMap0 only captures between one-quarter and one-third of the global road network as reported in other sources, and for regions such as Europe it covers only 12%.

Furthermore, there is no metadata describing the classification system or the dates of the roads data by country. Roads in the VMap0 database are classified as "Divided Highways," "Primary," "Secondary," and "Path/Trails," but the classification appears inconsistent across countries. The maps in Figures 3-5 show the global coverage of the three road types in VMap0. The square patches on the maps, which represent significant discontinuities in road density, are either artifacts of the separate tiles in which the data were produced and are delivered, or artifacts of the paper source maps utilized in the production of VMap0, in which one paper source map provides far more detail than an adjacent one. According to the data documentation:

> Attribution of features in adjacent sources may be different due to various factors (differing compilation dates of source material, etc). For this reason, edge matching attribution of these features may not logically occur. In these cases, features and/or particular attribution may end at the hardcopy source boundary. [8] (VMap0 metadata, downloaded 20 December 2005)

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[6] The name "Digital Chart of the World" officially applies to the 1st and 2nd editions of VMap0.

[7] The database is available for download at MapAbility (http://www.mapability.com/index1.html-?http&&www.mapability.com/info/vmap0_download.html) or as a seamless product from USGS for US$150 (http://www.agiweb.org/pubs/pubdetail.html?item=624108).

[8] Another related problem is artificial gaps between features in separate coverages, such as between populated places and road/railroad networks, even within an individual tile. This is acknowledged by NGA and reported by MapAbility as follows: "Features in VMap are collected into topologically structured coverages, originally extracted from feature separates. The VMap0 Specification does not permit cross
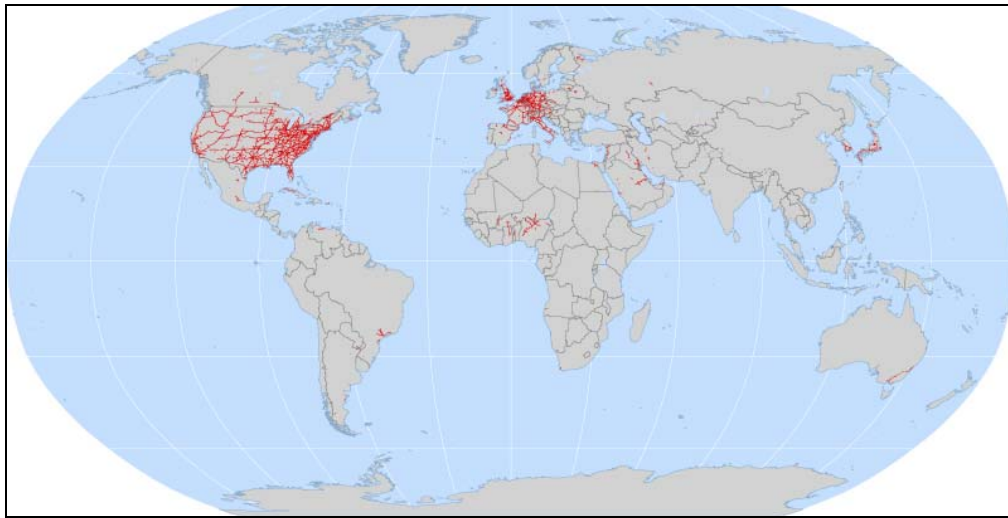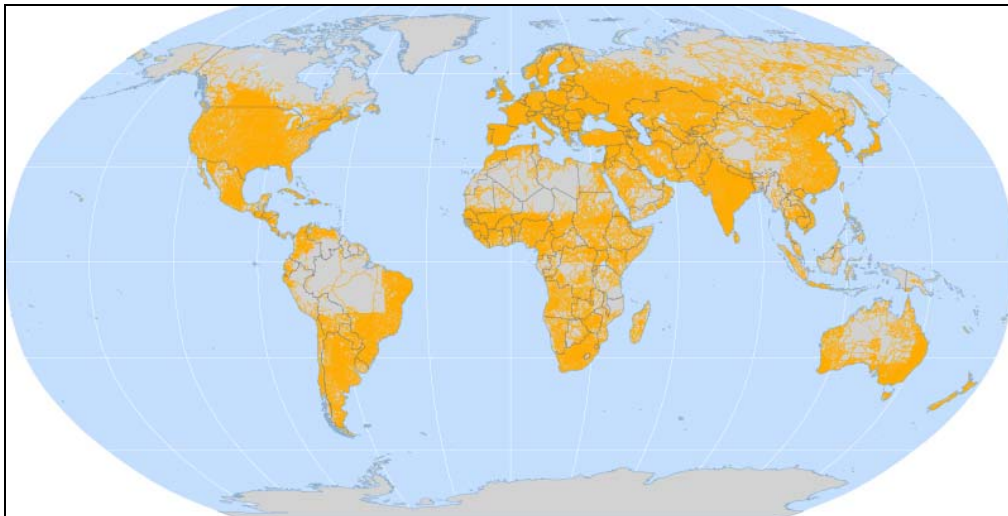
Figure 3. VMap0 Divided Highway

Figure 4. VMap0 Primary and Secondary roads

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coverage topology, and does not require precise geographic coincidence of features between coverages. Thus, the NIMA production policy is to allow gaps between features in different coverages according to certain guidelines (i.e.: if the source indicates that two features should be coincident or adjacent, but the features are not by definition coincident, then the gap in the digital VMap0 data will not be larger than 1000 meters)."
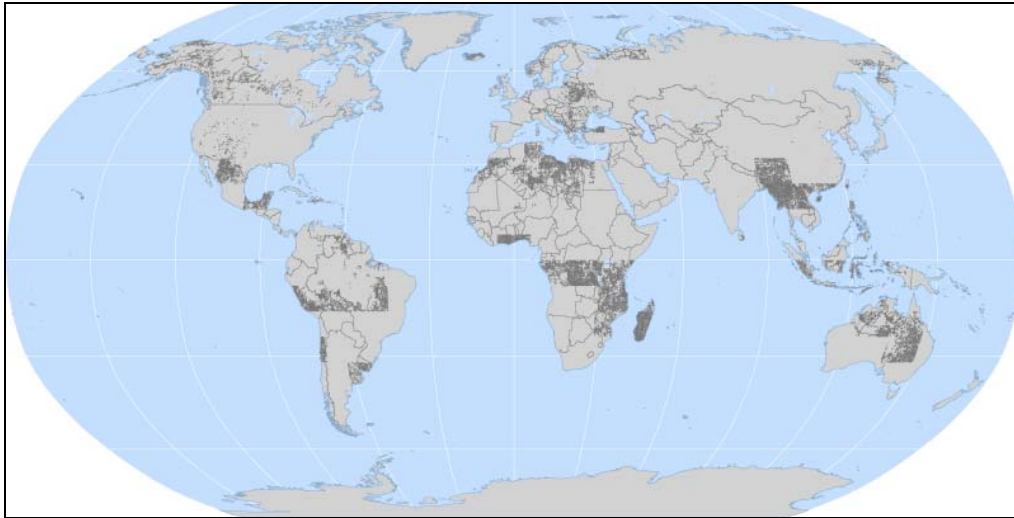
Figure 5. VMap0 Paths/trails.

If we look at the differentiation between Primary and Secondary roads (Figure 6) we can clearly see how the vast majority of the roads appear to be classified as "secondary" (71%), except in Europe, where the majority of the roads are "primary". More importantly, due to the intrinsic nature of the original data sources (assembled by country or by ONC tiles), in several locations there are sharp interruptions of the road network across tile lines or country boundaries, rendering it impossible to perform network analysis, not to mention a number of other analyses described in Section 1.1. This is particularly clear between Europe and Asia for the primary roads, and in China, Latin America and Africa for the paths/trails (see Figure 7).

The tiling problem is especially difficult to overcome when doing regional analysis, as the inconsistency of the data does not allow for cross-country comparisons or analysis. Metadata information that comes with the downloadable files states that "for Edition 5, verification procedures were performed to ensure that the ends of roads and railroad segments that were in close proximity to one another were connected together, so as to enhance the user's ability to perform network operations." Yet no additional information is provided about the verification procedures.
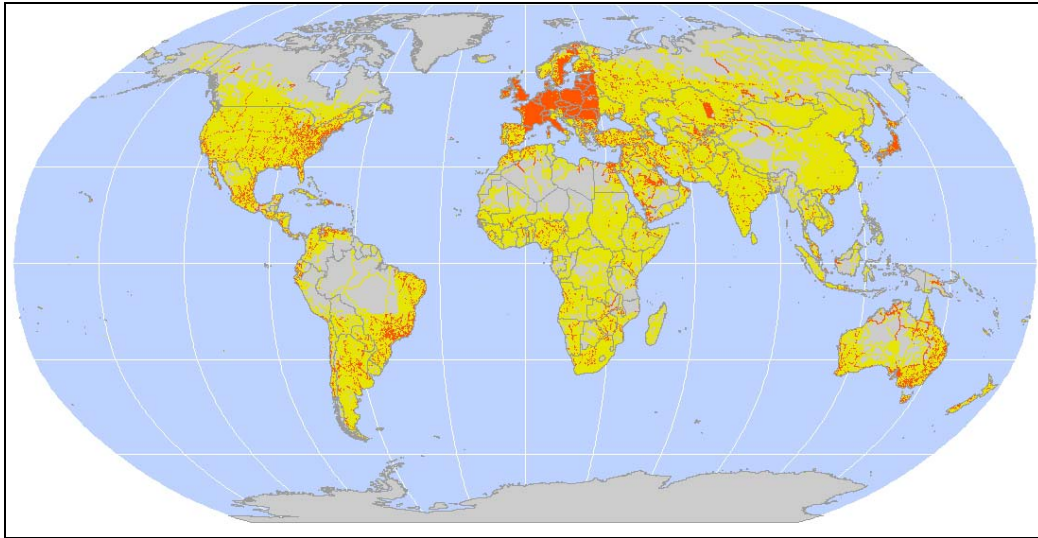
Figure 6. Differentiation between VMap0 Primary (red) and
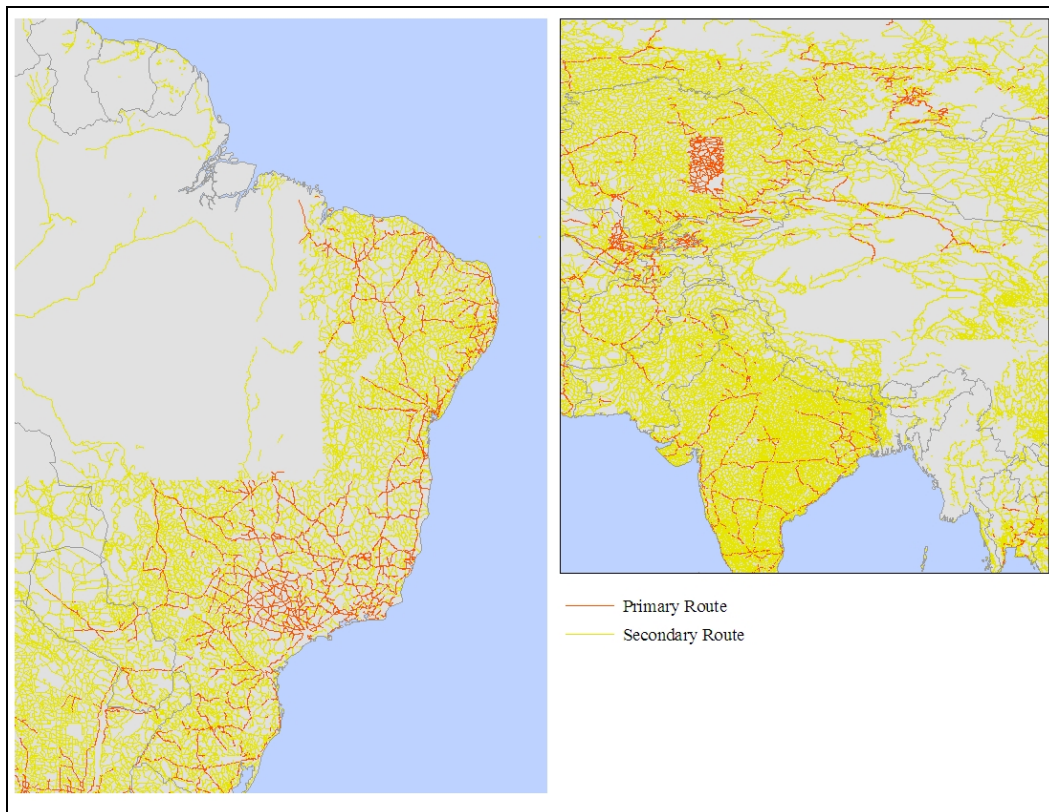Secondary (Yellow) roads.

Figure 7. Examples of the "tiling" effect in primary/secondary roads
in Latin America and Asia.

One of the attributes available in the VMap0 product is the classification of roads based on the accuracy of the database (accurate, approximate). About 85% of the roads are classified as "accurate", but again it is not clear what procedures were followed to determine the accuracy of the original data, and by definition there is no accuracy assessment for missing roads. This lack of precise metadata[9] is a continual source of frustration in the mapping community, and the specific problems associated with the VMap products are detailed in box 1.

Box 1. Efforts to assess the quality of the VMap products

The only reference to the reliability and accuracy of the VMap data is contained in a metadata document (included with each downloadable zip file) that refers to data quality control. For the roads layer it is reported that "[a]ll coverages were put through an automated software quality control procedure to ensure that no invalid feature codes or attributes values were present. Additional data checks were done through hardcopy plots and screen display of the coverages. NIMA staff performed an integrated visual review of the data before conversion to VPF format." Yet, it is not clear how the accuracy estimates were determined.

In terms of more general accuracy, MapAbility refers to two NIMA publications that discuss the specification and accuracy of the VMap0 product, but these two documents were not available for download at the time of this writing. Of particular interest to the transportation infrastructure is the horizontal accuracy. Absolute horizontal accuracy is defined as "the difference between the recorded horizontal coordinates of features and their true positions. Absolute horizontal accuracy is expressed as a circular error at 90 percent probability." The absolute horizontal accuracy of VMap Level 0 for all features derived from Operational Navigation Charts (ONCs) is 2,040 meters rounded to the nearest 5 meters at 90 percent circular error (CE), World Geodetic System (WGS 84).

Unless one invests in the USGS seamless product (at a cost of US$150), the time and effort required to process VMap0 data can be significant (Dooley, 2005). The data from MapAbility is available in four zip files that constitute a large library of files in VPF format. NGA has developed a VMap-visualization software that allows users to access and display VMap data. The software, called VPFVIEW v2.1, is not a GIS software and is designed specifically to enable users to view and perform spatial queries on data contained in any VPF database but its analytical capability is limited to constructing views and themes.[10] VPFVIEW, whilst fully functional, is no longer supported by NGA, and help queries are no longer answered. A complex and time-consuming conversion process is needed to format the layers for use in a

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[9] Metadata in this case is contextual information about spatial data sets that describes the original data sources, the data quality, the methodology employed, and any verification procedures used to validate the data.
[10] VPF files can also be viewed with other software, freely available on the web (ArcExplorer, MapInfo ProViewer, ERDAS ViewFinder, etc).

GIS and to assemble the tiles together. MapAbility provides a VPF-Shapefile converter on its website. However, it still takes time to stitch together the tiles.[11]

2.2 Vector Smart Map Level 1

More recently, NGA has released VMap version 1 (VMap1). The VMap1 resolution is based on 1:250,000 map scale sources, which is four times the resolution of VMap0. It is based primarily on the vectorized versions of 1:250,000 scale NGA Joint Operations Graphics (JOGs), which is comprised of nearly 10,000 sheets. Both VMap0 and VMap1 are structured similarly and contain all the standard vector data types familiar to GIS users. Data content includes 10 thematic layers: boundaries and coastlines; elevation and contour lines; road and rail networks; hydrography; utility networks; vegetation cover; and so on. These themes are arranged in over 100 vector layers of information, with large numbers of features, attributes, and geographic names appropriate to their respective scales.

The VMap1 data is divided into a rather complex global mosaic of 234 geographic zones, each available on a single CD-ROM. Unfortunately, at the present time NGA has only released 55 zones of the VMap1 data set (Figure 8), even though the whole data set has been officially de-classified and is nominally in the public domain.[12] Samples are available for download via MapAbility.com,[13] but, as with VMap0, these are not available in common GIS formats and the VPFVIEW software is required for visualization. Dooley (2005) compared VMap0 and VMap1 products for Namibia and concluded that VMap1 roads coverage represents a substantial improvement. Where 1:250,000 roads data are missing, NGA and partners have integrated VMap0 1:1 million scale data to fill gaps. However, encoding harmonization would still require some further effort to make a useable analytical product (Dooley, personal communication). Furthermore, like VMap0 the dates by country of road networks represented in the data set are not provided, and it is not clear if the database has been consistently updated.[14]

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[11] We believe that the original coverages were assembled as an ArcInfo library, at which point a number of quality control checks were also performed. This library was then converted to VPF format to be visualized in the VPFVIEW software.

[12] According to the MapAbility website, NGA has given a number of reasons for not releasing the entire data set to the public, including the protection of cartographic monopolies of its overseas partners, concern that the data are not ready for public use, lack of approval by the NGA security office, and fear that the public might 'misuse' it. NGA is apparently ignoring Freedom of Information Act (FOIA) petitions to release the data.

[13] http://www.mapability.com/index1.html?http&&&www.mapability.com/info/vmap1_index.html

[14] The metadata that comes with the zip files provides some useful information on the reference libraries, and on the coding schemes of the different layers. Nevertheless, very little information is provided on the actual data and the subsequent updates.
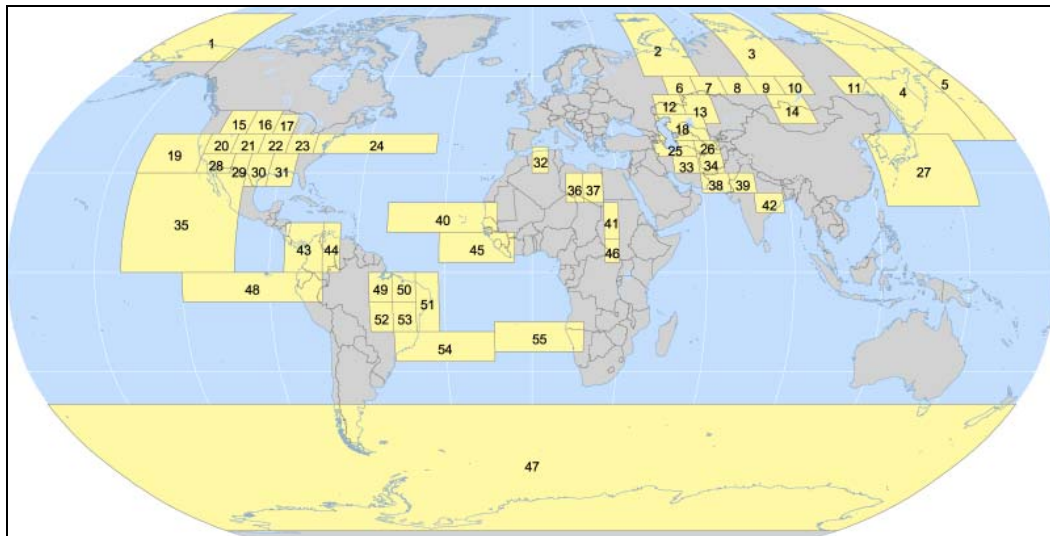
Figure 8. The geographic coverage of the 55 publicly available VMap1 tiles

2.3 World Boundary Databank-II

The original World Boundary Databank-II (WBDb-II) is a public domain data set whose sources are the U.S. Department of State (DoS) and Central Intelligence Agency (CIA). As with VMap0, the database is available by geographical areas and it consists of a variety of thematic coverages (coastlines, islands and lakes, rivers, national boundaries, internal boundaries, roads, railways). WBDb-II uses map scales from 1:1 million to 1:4 million, with a nominal scale of 1:3 million. The files are available in their original topology (lines not polygons).[15]

The database is available for download as ArcINFO export files from UNEP-GRID.[16] Users report that although most large countries exhibit reasonably detailed features (administrative boundaries, rivers, roads and railways), many smaller countries do not. More importantly, some of the WBDb-II coverage are inconsistent at the national level, and many countries lack at least one of the thematic types of information (e.g., internal boundaries and/or roads) altogether. Furthermore, only primary roads are available.

2.4 ADC World Map

American Digital Cartography (ADC) has recently released the WorldMap Digital Atlas 5.0 (WorldMap5), which appears to be a reasonably complete commercial digital atlas offering seamless global geographic

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[15] Users who require boundary-related data in polygon format (e.g., country polygons) are encouraged to obtain the generalized version of World Boundaries from UNEP-GRID.

[16] http://www.grid.unep.ch/data/data.php?category=human_related. At the time of the writing of this report, the WBDb-II was not available for download. A PC-updatable version is available, but it includes only national boundaries, islands and major lakes.

data.[17] It includes the same basic layers (e.g. administrative boundaries, airports, cities, etc.) as VMap0 and the WBDb-II. According to ADC, the base map for WorldMap5 is the Digital Chart of the World (VMAP0 Edition 1). ADC extracted the coastline, water and railway objects from this product and processed these to produce the basic reference file. Additional material is sourced from databases, published maps, indexes, directories, and listings and relevant archive material of all kinds for the purposes of correcting, updating, extending, or verifying all other data layers in DCW. All additional information from such sources is re-compiled by hand in relation to the basic reference file. The main sources of additional material are as follows: The Royal Geographical Society Map Library; the London School of Economics Statistical Archive; the NGA (formerly Defense Mapping Agency); The CIA World Database; the NGA database of Foreign Names; the United Nations; paper maps published in Germany, Russia, America and other countries; National Postal Organizations; National Telecom Organizations; the International Standards Organization; the European Union; and the Internet.

The roads database has been updated and incorporates more recent and better data than the VMap0. WorldMap5 includes 8.7m km of roads versus the 7.6m km found in VMap0, a 1.1m km improvement. The source of the roads data is a company called Where On Earth, which last updated the data in 2002. The roads are consistently classified as Motorways, Principal National Routes, Important Routes, Major Roads, and Other Roads (see Table 2), though no independent check was made to see if the classes are consistent across national boundaries. A comparison of WorldMap5 and the VMap0 roads layers demonstrates the additional road network coverage provided by WorldMap5 in Southern Africa and Asia (Figures 9 and 10 below). Although WorldMap5 provides improved data in both regions, the effects of DCW tiling are still easily discernable.

Table 2. Classification of WorldMap5 roads

Code	Feature	Length (in km)
RMO	Motorways	228,146
RPR	Principal National Routes	839,529
RIR	Important Routes	1,189,285
RMR	Major Roads	2,051,776
ROR	Other Roads	4,408,452
	Total:	8,717,187

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[17] WorldMap5 is available for the entire world for $3,250 or by continent (at $1,450 per continental volume) from http://www.adci.com.

Figure 9. Southern Africa: Red lines show where WorldMap5
provides more roads coverage than VMap0 (in blue)
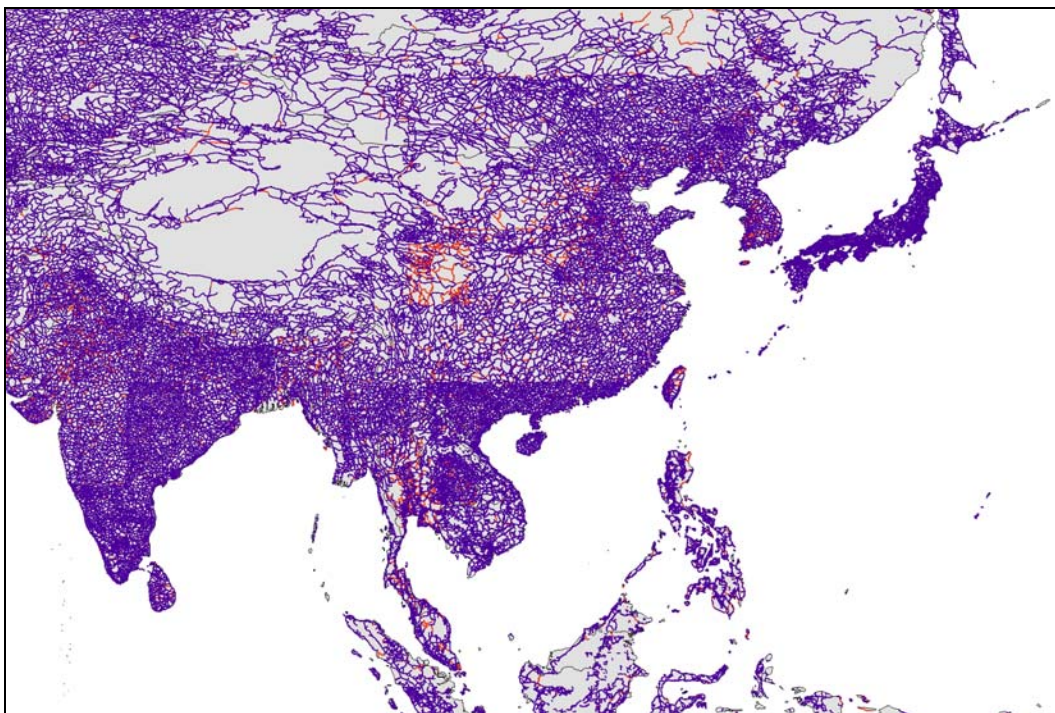

Figure 10. Asia: Red lines show where WorldMap5 provides
more roads coverage than VMap0 (in blue)

2.5 Global Discovery

Global Discovery is the main base map product by Europa Technologies[18] and is described as "the most detailed seamless world map data set available." It consists of several geographic layers from two separate products: Global Insight Plus and Global Profile, and it includes boundaries, named places, urban features, roads, rails, ports, and drainage at the scale of 1:1 million. As for the roads layer, the latest version (version 5) includes road names/numbers.[19]

A preliminary evaluation of the product (compared to VMap0) by the authors and by Dooley (2005) showed that although the Global Discovery's road layer contains some localized improvements, the majority of the features were directly derived from VMap0. It also did not appear to have significantly improved coverage for much of Africa, with WorldMap5 offering slight improvements over VMap0 for several parts of Africa (see Figure 9).

2.6 Comparison of VMap0, ADC World Map and Global Discovery

We have conducted a more thorough comparison of the three products that provide the best global coverage. Two of them have been acquired for the entire world, (VMap0 and WorldMap5), while the Global Discovery is available only for samples. The sample that is freely available on Europa Technologies website covers northern Italy and Eastern France, so we have chosen to compare an area around Turin in northern Italy (Figure 11). VMap0 presents one major problem in this case: almost all roads are classified as Primary, while the remaining are coded as "unknown" and are located in or around urban areas. The Global Discovery product, although it is clearly derived from VMap0, shows great improvements in terms of classification of road types, including those within the city boundaries. Nevertheless, the product that shows the most accurate representation of this area is the ADC World Map. We use a scanned map of the Touring Club Italiano (TCI) road map (lower-right inset, showing a smaller area around Turin) as "ground-truth." The ADC road layer appear to be the most faithful to the TCI's road map, in terms of capturing both the correct extents and the type of the major (highways and primary) and secondary roads.

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[18] http://www.europa-tech.com/
[19] The database is available in MapInfo and ESRI shapefile formats at the cost of US$4,495 for a single-user license.
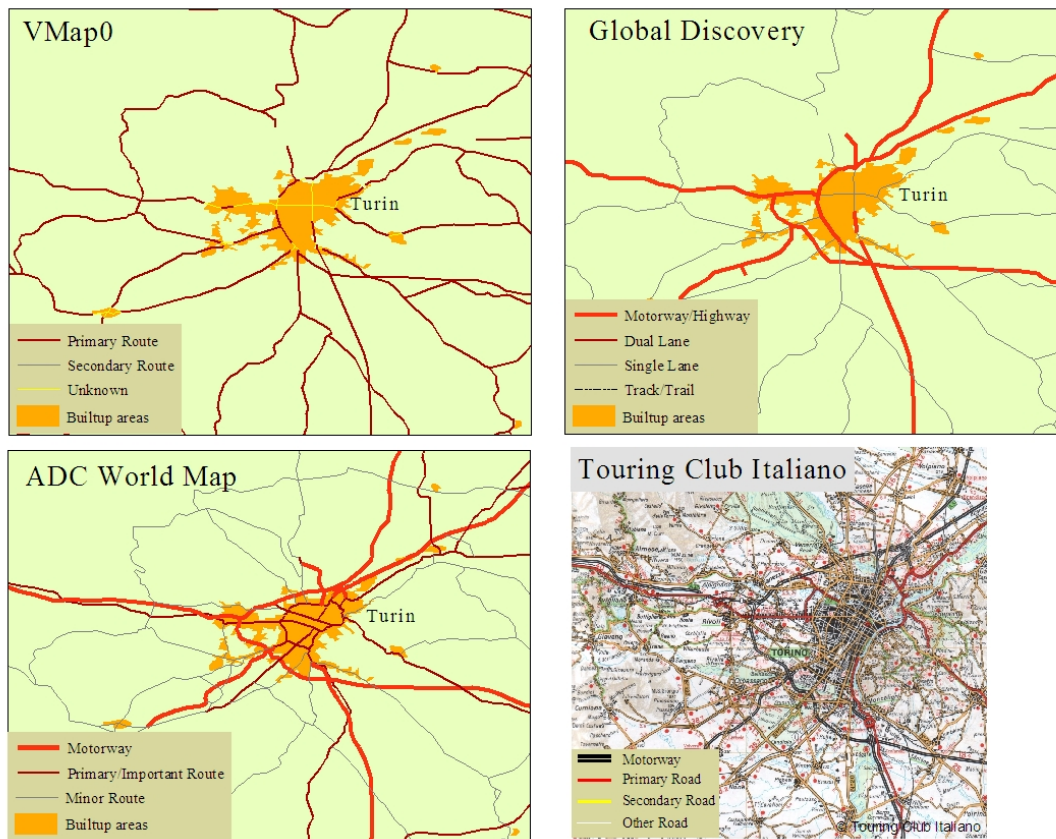
Figure 11. Turin, Italy: Comparison of VMap0, ADC World Map,
Europa Technologies' Global Discovery product, and a
scanned image of the Touring Club Italiano road map

3 STRATEGIES FOR FILLING THE GAPS

The first step in any strategy to develop a global public domain roads data set that meets the criteria laid out in Section 1.3 is to assess existing gaps in coverage. This should be followed by an assessment of the best methods to fill those gaps. Once an appropriate method is identified and the level of effort is determined, then funding must be secured and a "steering organization" identified to lead the effort. This last step is taken up in Section 5.

3.1 Gap analysis

An effort should be made to compile and document available digital country level data sets at 1:1 million scale and better. There are existing national and regional road data sets, but these need to be acquired and

assessed against a common set of quality indicators. Examples of such datasets which are available online include:

- Central America Monitoring and Visualization System (SERVIR)[20]
- TIGER data for the USA.[21]
- The Digital Millennium data sets from IBGE for Brazil.[22]
- Atlas of Namibia.[23]
- Kenya and Somalia[24]
- Tanzania and Afghanistan[25]
- Malawi and Swaziland[26]
- Indonesia[27]
- Australia[28], and
- Sri Lanka[29]

The Global Map project could provide a number of additional countries, but a download of the transportation layers for Kazakhstan and Kyrgyzstan, for example, yielded no roads coverages – only airfields in the case of Kazakstan and railroads in the case of Kyrgyzstan. There are undoubtedly many other such national or regional compilations that could be found with a more intensive search. Figure 12 shows, by country, the percentage of road lengths reported in statistical databases that are found in the VMap0 roads data set (as shown in Figure 1), overlayed with the two most promising sources for improved roads data: publicly available VMap1 tiles and the national or regional data listed above. Combining this information with a priority list from the potential users of road data would lead to a prioritized list of countries for targeting possible data sources and contacts.

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[20] http://servir.nsstc.nasa.gov/home.html

[21] http://www.census.gov/geo/www/maps/

[22] http://www.ibge.gov.br/mapas/

[23] http://www.uni-koeln.de/inter-fak/sfb389/e/e1/download/atlas_namibia/index_e.htm

[24] http://www.ilri.cgiar.org/gis

[25] http://www.fao.org/geonetwork/

[26] http://www.sahims.net/gis/

[27] http://www.globalforestwatch.org/english/datawarehouse/index.asp

[28] https://www.ga.gov.au/products/servlet/controller?event=DEFINE_PRODUCTS

[29] ftp://www.iwmidsp.org:1027/Sri-Lanka/data/GIS-data/sl-transporation.zip
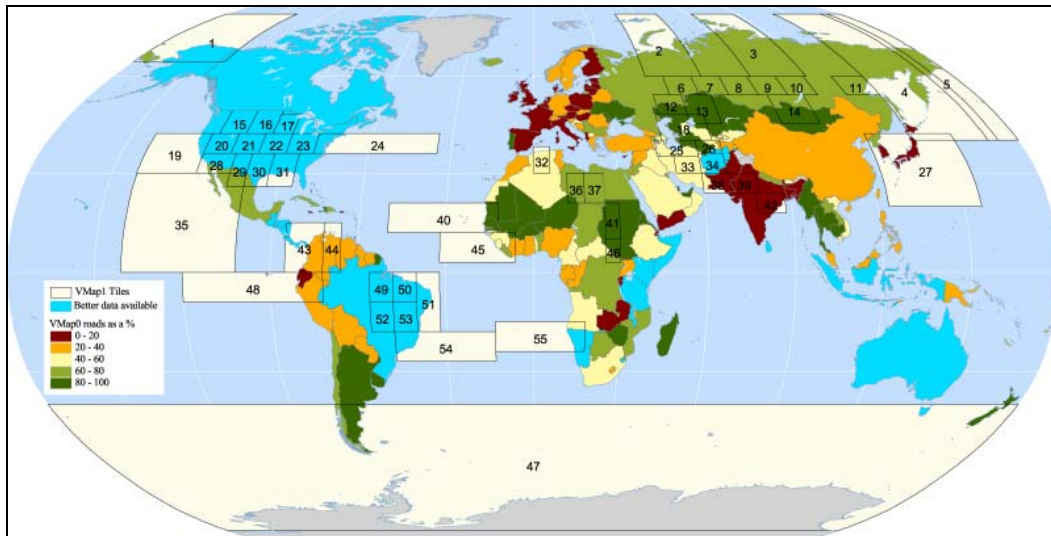
Figure 12. Gap analysis: this map is based on Figure 1 and overlays
VMap1 tiles from Figure 8 and countries for which
improved roads data are available in turquoise

3.2 Methods and sources for data improvement

Improved road data that would form part of a global spatial road data set can be acquired from: (i) existing digital data, (ii) hard copy maps, (iii) satellite imagery, and (iv) data collection from GPS and road surveys. Each of these data sources has its attractions and difficulties which are covered below.

Obtaining access to restricted or commercial road data

- *Access to global VMap1 data*

Vector Map Level 1 (VMap1) is based on 1:250,000 scale maps scale sourced from around 10,000 NGA Joint Operations Graphics (JOGs) map sheets (MapAbility, 2003). Vmap1 is a global coverage of 234 geographic zones, but as of December 2005, only 55 of these zones are available to the public (Figure 8), and oceans constitute a substantial percentage of the available coverage. These 55 tiles should be downloaded and assessed to determine the quality of the road data, since countries such as Japan, Turkmenistan, Guinea, Sierra Leone, Senegal, Liberia, Ecuador, and Colombia appear to have almost complete coverage. Although efforts have been made to convince NGA to release the remaining VMap1 tiles into the public domain, they have thus far been unsuccessful (see footnote 13).

- *Access to global or regional generalised data from detailed road networks*

The rapid growth of in car navigation systems and online travel planners has been partly based on the availability of high quality transport network information for most developed countries. The huge investment made by companies such as Navteq (with road data for 52 countries worldwide) and Michelin

(with road data for 40 European countries) to develop this digital map base is likely to prohibit a public release of the data. But it may be feasible for a donor to pay a private sector firm such as Navteq to take an existing product, make a public domain version – perhaps by omitting city street data in developed countries, and expand coverage slightly in the most data poor countries.

- *Dedicated data collection exercises to obtain national level data*

Not all national-level data are made available for download via the internet. With regional partners, especially in developing countries, data collection trips to neighbouring countries could be a cost effective solution to acquire digital roads data or to obtain permission to digitise existing hard copy maps. The International Center for Tropical Agriculture (CIAT) has made several such trips across Latin America and the Caribbean to obtain population and agricultural census data.

Digitizing hard copy road maps

- *To create new road maps*

Good quality topographic maps and road atlases exists for many countries at 1:100,000 - 1:250,000 scales or similar. For countries where there is no topographic map, an alternative source is the Tactical Pilotage Charts (TPC)[30] at 1:500,000, which form part of the global world aviation map series jointly produced by the USA, Canada, Australia, and the UK. However, digitizing and redistributing digital versions of these maps is usually prohibited without prior agreement with the publisher. Efforts to secure such agreements could be made where there is no acceptable digital data available, or alternatively the entire collection of TPC map sheets could be acquired and digitized in an effort to create a globally consistent database of roads (and other key data layers) at a level of detail which is twice as high as VMap0.

- *To update existing digital coverages*

Instead of digitizing entire cartographic products, it is often possible to use hard copy maps to update existing digital roads data. For example, if the hard copy map has more contemporary or more detailed data than the digital source, it can be used to identify missing vectors (road sections), which can then be added to the digital data. Also, if the hard copy map has better attribute data (road type/road quality), these attributes can be updated in the attribute table associated with the vectors. Whilst this is a very cost effective and quick solution to improving the quality of existing road data sets, such 'informational' use of hard copy maps may be prohibited by the publisher's copyright. Permissions would need to be obtained on a case-by-case basis.

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[30] These are topographic maps with aeronautical information. For more information visit
http://www.cartographic.com/TEMP/Resources/Topographic%20Maps/Downloads/TPC.PDF

Satellite imagery for road data generation

High resolution imagery, such as that provided by IKONOS and Quickbird (spatial resolutions of ~1m) and aerial photography (<1m resolutions) are excellent sources of information for generating road network data sets (Butenuth*, et al.*, 2003). However identifying the road features within the imagery and digitising them is both costly and time consuming, and the costs of obtaining the imagery are also very high.[31] Nevertheless, as new high resolution, cost effective imagery becomes available, road extraction from imagery could be a valuable source of information where there is no other available digital source available.

There are several efforts underway to automate (or semi-automate) the extraction of road vectors from imagery. The US based National Consortium on Remote Sensing in Transportation is one such body that develops technology for RS applications in transport. One example from the Interdisciplinary Center for Research in Earth Sciences Technology (ICREST) combines different sources of information such as Landsat 7 ETM (30m resolution), IKONOS, and aerial photography in an automated road extraction project (ICREST, 2004). Other approaches use imagery to verify and update existing road databases (Rellier*, et al.*, 2002; Gerke*, et al.*, 2004). Finally, Ngheim et al. (2001) propose using radar data, including data procured by the Shuttle Radar Topography Mission (SRTM), to create a road network topography. While automatic detection of roads from radar imagery has not been completely successful, semi-automatic and manual road extraction is possible.

This is a large and dynamic area of RS research and innovation. A recent edition of *Photogrammetric Engineering & Remote Sensing* included 16 articles dedicated to the topic (ASPRS, 2004). Engaging this research community and monitoring the progress of the various approaches should be a priority. However, it must be acknowledged that the technical and financial requirements are high.

Road mapping using GPS

- *Road surveys*

There are many applications of GPS for transportation network data collection. The Berger Group inventoried 24,000 km of the Guatemalan road network using GPS and video filming and created a detailed transport database (Berger Group, 2005). Such surveys are extremely expensive and time consuming but do demonstrate what is possible with GPS technology, especially in small and medium sized countries. Alternatively, if there are evident data gaps in a national data set, then equipping small survey teams with a vehicle and GPS system could be a quick way to obtain information. In developing countries, GPS data can be collected together with data on vehicle vibrations, which would indicate road quality. Such information is even more valuable than knowing the official road classification, since even commercial routes in parts of Africa can be impassable in all but four-wheel drive vehicles.

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[31] These high resolution images cover relatively small areas, hence many images are required to cover even a small country

- *Community approaches to developing a roads database*

With the cheap and ready availability of GPS technology and evolving internet mapping capabilities, there is a growing interest in "open" approaches to data collection. Confluence.org is collecting photographs of all the land-based latitude-longitude degree markers, a project greatly facilitated through GPS technologies. More germane to the topic of this paper is the OpenStreetMap, which is a free editable map of the whole world.[32] Operating as a WIKI[33], OpenStreetMap allows users to view, edit and use geographical data in a collaborative way from anywhere in the world. According to the website:

> OpenStreetMap is a project aimed squarely at creating and providing free geographic data such as street maps to anyone who wants them. This is because most maps you might think of as free actually have legal or technical restrictions on their use, holding back people from all walks of life who would like to use a map for one reason or another. (www.openstreetmap.org, accessed January 2006)

OpenStreetMap has created an online editing interface that allows anyone to upload its GPS tracks and contribute to the map. Streets, points, and areas can be entered and given metadata (e.g., names, types of vehicles permitted) using an applet editor. They then become part of the collective mapping of an area.

Although aimed at street mapping, it is conceivable that this or a similar WIKI could be used to construct a roads network database. Although innovative and attractive for its low cost and democratic principles, such an approach would have two notable limitations: (1) it might take years to cover the world on an "all volunteer" basis, and (2) there would be little ability to impose standards or to undertake a comprehensive independent data verification. Still, as these technologies advance, and the community of users grows, it is worth considering this as a possible model for roads data compilation.

Having identified some strategies for filling data gaps, we conclude this report by charting the way forward.

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[32] http://www.openstreetmap.org/
[33] A website or similar online resource which allows users to add and edit content collectively.

4 NEXT STEPS

In the forgoing sections we have identified the clear need for an improved global public domain spatial roads database. We then assessed the strengths and limitations of the major roads data sets that are currently available. From that assessment, it is worth noting that even if VMap1 tiles were available for all corners of the globe – which would be most desirable – there would still be the need for a significant investment in data cleaning in order to fulfill the minimum requirements described in Section 1.3. Finally, in Section 3, we provided some alternate methods for filling data gaps to compile a globally consistent roads data set.

Here we lay out the proposed next steps for developing a global roads database. We first discuss the need for the major stakeholders to meet to define a path forward. We then identify possible candidates for the role of global steering organization and discuss different models for organizing the effort. Finally, we identify some organizations that are potential funding sources.

4.1 A global roads workshop

The goal of a global roads workshop would be to bring together key individuals and stakeholder groups (data developers and consumers) to pool expertise, identify interests/needs, discuss the current status, and begin the process of laying out specifications for a global product. Experience from the global land-cover data community illustrates the benefits of a coordinated approach to developing specifications. In the past, land-cover data sets tended to be developed by individual organizations or agencies with a single purpose in view. As a result, users of the data with different needs often found themselves frustrated by the lack of certain attribute data that could have been easily added at the outset for little marginal cost if only consultation had taken place. Furthermore, lack of consistent classification systems rendered the compilation of global or regional land-cover data sets from national source data difficult if not impossible. In order to increase cross-border consistency and anticipate multiple uses, there has been a move to adopt the FAO Land Cover Classification System (LCCS), which includes a nested hierarchy of land cover classes that can be tailored to local needs, as a global standard (GLCN, 2005). A similar collaborative and consultative process for developing a global roads data set could eliminate much frustration down the line among sector-specific data users.

Table 3 identifies a few key organizations that might be expected to make significant contributions to a global roads workshop. The list is by no means comprehensive, but it is indicative of the kinds of organizations we'd like represented. It would be important to identify some representatives of the

commercial sector as well. In order to capitalize on interest and momentum within the global data community, this workshop should be organized within the next year.

Table 3. Key organizations for a global data workshop

Organizations
CIESIN, Columbia University
CGIAR centers (including the Consortium for Spatial Information or CSI)
SDS Mapping
World Bank
Global Map
Global Spatial Data Infrastructure Association
FAO Sustainable Development Division
WHO and UN Geographic Information Working Group
Humanitarian Information Unit, U.S. Department of State
Global Risk Identification Program (GRIP)
ReliefWeb, UN-OCHA
Jet Propulsion Laboratory (JPL), NASA
World Resources Institute
UN Cartographic Division

Note: See Appendix 1 for a more complete list of stakeholders

4.2 Identification of a global steering organization

Data management (collection and maintenance) on a global scale requires long-term investment and commitment from a globally recognized body that could coordinate efforts to develop and distribute road data. Such an organization (or consortium of organizations) would have responsibility to oversee the management and development of consistent country-level data. There are a number of potential candidates. One approach would be to identify a global roads association such as the International Road Federation (IRF) or the World Road Association (PIARC), and suggest that they take this on. A potential problem with this approach is that it is likely that the data would not be distributed free of charge unless the effort were fully funded and the donor required public dissemination. Furthermore, neither organization has expertise in the integration and management of geospatial data.

Given the importance of knowledge and expertise in handling geospatial data, it may be preferable to identify mapping groups or associations such as the United Nations Geographic Information Working Group (UNGIWG), the International Steering Committee for Global Mapping (ISCGM), or the Global Spatial Data Infrastructure Association (GSDI). In each case responsibility for data development could be distributed across several regional- and country-level project partners. UNGIWG and ISCGM are already involved in large-scale distributed data development and collection efforts – only not specifically focused on roads data. UNGIWG works with UN Agencies on core global data sets such as sub-national boundaries data, and ISCGM works with national mapping offices to develop 1:1 million scale maps with standard layers similar to those of Vmap (see ISCGM description in Appendix A). GSDI is not yet involved in data development, but it could serve as a forum for development of standards and possibly even coordinate such an effort.

If a distributed approach is taken – e.g., working with national mapping agencies, as in the case of ISCGM – then the costs would be less, but the time required to develop the database may be prohibitive. Global Map has been in operation for 13 years but is only now beginning to turn out data for major portions of the world, and as mentioned in Section 3, the quality of the transportation layers is highly variable.

Another alternative would be an approach similar to that used for CIESIN's Gridded Population of the World (GPW) and the Global Rural-Urban Mapping Project (GRUMP). Though the bulk of the work was carried out at CIESIN with its resources, there was a significant multi-organization effort in which many partnering organizations contributed staff and computing power to generate a jointly owned data product that is disseminated free-of-charge via the internet. The partners included the International Center for Tropical Agriculture (CIAT), the World Bank, the International Food Policy Research Institute (IFPRI), national statistical offices and NOAA's Night-time Lights Data Project. This model is certainly feasible and sustainable over longer time periods so long as funding is available.[34]

4.3 Potential funding sources

There are a number of stakeholders listed in Appendix A who may have an interest in contributing funds to this initiative. Because of its global investment in transport infrastructure, the World Bank Transport Group may be interested in funding a global roads database as a tool for assessing the need for road construction or improvement in developing regions (e.g., for agricultural marketing or inputs distribution, or for distribution of goods from major ports). Given the costs implied by poor road quality, both in terms of lost

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[34] GPW has had three releases over a 10 year period (1995-2005). Major funding for GPW is provided by CIESIN's NASA-funded Socioeconomic Data and Applications Center (SEDAC). Without this core funding development of GPW would have been impossible.

transport time and vehicle maintenance, road quality information would be particularly important in such a database.

The UN Economic Commissions may also have an interest in funding the development of such a database since roads have such a bearing on economic development. Other UN agencies would also have an interest in global roads data, and indeed many have already expressed an interest in such data. A modest initial investment of approximately US$30,000-40,000 per agency by several agencies (e.g., FAO, UNDP, UNEP, UNICEF, WFP, OCHA, and UNFPA) could advance the cause considerably.

5 CONCLUSIONS

Whatever approach is used, it will be important to secure ongoing support for updates. Road networks are dynamic, and the utility of the database will decline rapidly if it is not actively maintained. It could be that a remote sensing based change detection algorithm could identify the addition of linear features between two sets of global images compiled a year apart, and that once ground truthing or verification has been performed that these linear features could be converted to roads in the global database. Although technical details would need to be worked out, this would probably be the cheapest and most automated approach to maintain the database.

6 ACKNOWLEDGEMENTS

7 DISCLAIMER

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APPENDIX A: Key Stakeholders

This Appendix provides a list of key agencies/organizations involved or potentially interested in the development of roads data. This includes a brief description of the organizational mission (with particular reference to roads where available) and a short list of interests and expertise with respect to geospatial data (again with special reference to roads expertise).

Organization Name	Mission	Interest/Expertise
Associations		
International Roads Federation (IRF)	Through the diversity of its members, the IRF is a network of public and private sector entities all with a common interest in the development of modern, efficient and safe roads. The IRF's on-line Membership Directory provides key contacts in public and private entities involved in road planning, development, construction, management and usage, consultants and potential partners. A broad range of conferences and seminars organized by the IRF bring together all parties involved in road development and offer promotion possibilities at reduced rates for IRF members. The IRF Academic Grouping is a multidisciplinary group of academics from around the world with an interest in road transport related issues.	Produces *World Road Statistics*, promotes research on roads
The European Union Road Federation (ERF)	The European Union Road Federation (ERF) is a non-profit association which coordinates the views and concerns of Europe's road sector. ERF acts as a European platform for dialogue, condenses the road sector's input on mobility issues and promotes research leading to a more sustainable road transport. ERF Members represent a cross-section of the major stakeholders active in the construction, equipment and operation of Europe's road network. Membership is open to national road associations, industry associations and individual organizations.	Research, sustainability of road transportation, networking

Organization Name	Mission	Interest/Expertise
World Conference on Transport Research Society (WCTRS)	The objective of the WCTRS is to provide a forum for the interchange of ideas among transportation researchers, managers, policy makers, and educators from all over the world, from a perspective which is multi-modal, multi-disciplinary, and multi-sectoral. The Society has become a primary forum for such international exchanges in transportation. The World Conferences are the place where leading transportation professionals from all countries convene to learn from one another. One unique role for the WCTR is to identify emerging issues and opportunities of a policy, managerial, or technical nature which will influence transportation research, policy, management and education in future years. In this way, the Society and the Conference intend to play a strong leadership role in bridging the gaps between research and practice.	Transport policy, transport research
World Road Association (PIARC)	PIARC has more than 100 government members, mostly transport administrations. PIARC serves its members by: being a leading international forum for analysis and discussion of the full spectrum of transport issues, related to roads and road transport; identifying, developing and disseminating best practice and giving better access to international information; fully considering within its activities the needs of developing countries and countries in transition; and developing and promoting efficient tools for decision making on matters related to roads and road transport.	Road transport issues, developing country needs, best practices in road administration
International Organizations		
Conservation International, Center for Applied Biodiversity Science (CABS)	The Human Dimensions of Biodiversity Program (HDP) is housed in the Center for Applied Biodiversity Science (CABS) at Conservation International. The program explores the complex dynamics of the relationship between people and the conservation of species and their habitats. HDP researchers analyze historical, demographic, economic, and political trends to better understand the interrelationships between human activity and biodiversity. The results of these analyses are used to develop strategies that support biodiversity conservation, ecosystem services, and human welfare. The HDP has expressed interest in analyzing current and projected future road network developments with respect to their impact on biodiversity conservation.	Biodiversity conservation, spatial data, roads development as it impinges on conservation

Organization Name	Mission	Interest/Expertise
Consultative Group for International Agricultural Research (CGIAR), Consortium for Spatial Information (CSI)	The CGIAR-CSI is an initiative of the many geospatial scientists of the CGIAR, linking the efforts of CGIAR scientists, national and international partners, and others working to apply and advance geospatial science for international sustainable agriculture development, natural resource management, biodiversity conservation, and poverty alleviation in developing countries. The CGIAR-CSI facilitates capacity building, data sharing, data dissemination, and geospatial analysis amongst the fifteen CGIAR Centers and their global and regional collaborators.	Core data sets for agricultural research, rural-urban linkages, food distribution, agricultural inputs distribution
International Steering Committee for Global Map (ISCGM)	Global Map is developing digital geographic information at 1 km (approximately 1:1 million) resolution covering the earth's surface with standardized specifications and available to everyone at marginal cost. Global Map has 8 layers: Boundaries, Drainage, Transportation, Population Centers, Elevation, Land Cover, Land Use, and Vegetation. The maps are produced through international cooperation mainly by National Mapping Organizations participating in Global Mapping project. The purpose of the mapping project is to protect the global environment in the 21st century. The Global Map is useful for global change monitoring and environmental analysis. Japan's Ministry of Land, Infrastructure and Transport proposed the "Global Mapping Project" as a contribution to global environmental conservation from the mapping sector in response to Agenda21 adopted at the Earth Summit in 1992. ISGM aims to complete the development of the Global Map for the whole land area of the globe by 2007. After the completion, the data are to be updated at intervals of approximately five years.	Framework data, roads data
ReliefWeb Map Centre	ReliefWeb is the global hub for time-critical humanitarian information on Complex Emergencies and Natural Disasters. It is connected to the UN Office for the Coordination of Humanitarian Affairs (OCHA; see below).	Online maps, road infrastructure for relief work
UN Food and Agriculture Organization (FAO), Environment and Natural Resources Service, Sustainable Development Department (SD)	FAO's Sustainable Development Department (SD) advises governments on integrated policy, planning, and management of natural resources. SD coordinates the cross-sectoral programme on organic agriculture, promotes an ecosystem approach to agriculture as well as sustainable energy strategies and technologies, and helps developing countries use remote sensing, agrometeorology and geographic information systems to manage natural resources and monitor crop conditions.	Geographic information systems, core global data sets, road impacts on poverty alleviation

Organization Name	Mission	Interest/Expertise
UN Geographic Information Working Group (UNGIWG)	UNGIWG was formed in 2000 to address common geospatial issues - maps, boundaries, data exchange, standards - that affect the work of UN Organizations and Member States. UNGIWG also works directly with non-governmental organizations, research institutions and industry to develop and maintain common geographic databases and geospatial technologies to enhance normative and operational capabilities. Specifically UNGIWG aims to: improve the efficient use of geographic information for better decision-making; promote standards and norms for maps and other geospatial information; develop core maps to avoid duplication; build mechanisms for sharing, maintaining and assuring the quality of geographic information; and provide a forum for discussing common issues and emerging technological changes.	Geographic data coordination, geographic data development, core geo-database, roads data
UN Office for the Coordination of Humanitarian Affairs (OCHA), Geographic Information Support Team (GIST)	Information managers deployed by OCHA work closely with their humanitarian partners to develop information products and tools, such as geographical and thematic maps, databases and digital reference libraries that improve the coordination of humanitarian assistance. OCHA also facilitates the work of the Geographic Information Support Team (GIST). GIST is an inter-agency initiative that promotes the use of geographic data standards and geographic information systems in support of humanitarian relief operations. GIST members are technical experts and information specialists from the UN and donor agencies involved in disaster management and/or humanitarian assistance.	Disaster response, geographic information for humanitarian crises
UN Economic Commission for Europe (UNECE), Transport Sector	The work of the Transport Division is guided by the mandates and work programmes of the UNECE Inland Transport Committee (ITC) and its Subsidiary Bodies. The Transport Division also provides the secretariat to the ECOSOC Committee of Experts on the Transport of Dangerous Goods and on the Global Classification and Labelling of Chemicals as well as to the Administrative Committees of a number of UNECE legal instruments on transport. The Transport Division also received inputs from the UNECE Conference on Transport and the Environment and from the Third Pan-European Ministerial Transport Conference, whose follow-up activities are integrated in the ITC work programme. The Division also contributes to the implementation of the Pan-European Programme on Transport, Environment and Health (THE PEP).	Transport statistics, traffic statistics, transportation of hazardous wastes

Organization Name	Mission	Interest/Expertise
UN Environment Programme (UNEP), Energy Group: Transport	This group provides information and serves a convening function for dialogs with industry about the environmental costs of road and other transportation systems.	Sustainable transportation, environmental impacts of transportation
UN World Food Program	As the food aid arm of the UN, WFP uses its food to meet emergency needs and support economic development. The Agency also provides the logistics support necessary to get food aid to the right people at the right time and in the right place.	Humanitarian disasters, transportation of relief supplies
World Bank Transport Group	The mission of the transport group in the World Bank is to assist clients to reduce poverty by improving the efficiency and equity of transport policy and interventions. It works with the public and private sectors and communities to enhance the capacity of transport institutions to provide sustainable infrastructure and services.	Road construction, road financing, roads and the environment,
Governmental Organizations		
European Union Directorate-General for Energy and Transport	The Directorate-General for Energy and Transport is responsible for developing and implementing European policies in the energy and transport field. Its mission is to ensure that energy and transport policies are designed for the benefit of all sectors of the society, businesses, cities, rural areas and above all of citizens. The energy and transport sectors are pivotal to the European way of life and to the functioning of its economy; as such their operation has to be responsible in economic, environmental, safety and social terms.	Road policy, GALILEO European satellite navigation system, Community Road Accident Database
Eurostat Transport Theme (TT)	The mission of the Eurostat Transport Theme (TT) is the collection and dissemination of statistical information on European Community transportation systems.	Transport statistics, transportation and the environment, energy use

Organization Name	Mission	Interest/Expertise
US Department of State, Humanitarian Information Unit (HIU)	The mission of the Humanitarian Information Unit (HIU) is to serve as a U.S. Government interagency center to identify, collect, analyze, and disseminate unclassified information critical to U.S. Government decision-makers and partners in preparation for and response to humanitarian emergencies worldwide, and to promote best practices for humanitarian information management. To accomplish this mission, the HIU performs the following tasks: identifies key sources of geospatial and georeferenced data best suited to meet the information requirements of our consumers; collects timely, verifiable, and relevant data utilizing an extensive network of information partnerships; analyzes data using multi-agency expertise and applying proven technologies to determine significant trends and relationships; and disseminates information of value to all levels of consumers, from national-level policymakers to operational field managers.	Disaster response, geographic information for humanitarian crises
US National Geospatial-Intelligence Agency (NGA)	An agency of the US Department of Defense that manages and provides imagery and geospatial information for diverse military, civil, and international needs. Formerly known as the National Imagery and Mapping Agency (NIMA).	Roads data, high resolution satellite data
Private Sector		
American Digital Cartography (ADC) Incorporated	ADC focuses on digital map data for American civil, environmental, and utility engineers.	Producer of ADC WorldMap, vendor for Tele Atlas and NAVTEQ roads GIS data
Berger Group	The Berger Group focuses on the construction of roads and highways. It has developed major national and international routes, provided congestion relief and developed the critical secondary routes which form the backbone of all road networks. The Berger Group has utilized GPS for road network mapping in Guatemala.	Road construction, GPS road surveys
Land Info	Founded in 1993, LAND INFO maintains one of the world's largest commercial archives of digital topographic map data (currently 152+ countries). Markets served include mapping, GIS, national security/defense and other government applications, civil and environmental engineering, land surveying, wireless communications, rural/urban development, utilities, natural resources, conservation, aviation, vehicle tracking/fleet management/logistics and other uses requiring high-quality digital geographic data solutions.	Vector feature extraction, GIS software

Organization Name	Mission	Interest/Expertise
LeadDog Consulting	LeadDog Consulting, LLC, provides GIS street and road mapping worldwide. LeadDog creates and maintains GIS street and road maps for Iraq, Mexico, Latin America and the Middle East. It offers GIS and postcode maps for virtually every country in the world.	Latin America and Middle East roads data
Michelin Travel Assistance Services	Michelin's writers, inspectors and cartographers have traveled the world over for the past 104 years to ensure that Michelin Maps and Guides are accurate. ViaMichelin designs, develops and commercializes digital products and services providing mobility assistance.	Paper maps, roads database for navigation systems, internet mapping
NAVTEQ	NAVTEQ's flagship product is a roads database for 52 countries. The database is built by teams of field researchers who continually drive the roads using proprietary digital data collection tools to ensure NAVTEQ digital map data more closely reflects real world conditions. They include dozens of road attributes on each section of road and add points of interest to the database.	Roads database for navigation systems, internet mapping
SDS Mapping	Spatial Data Services & Mapping (SDS Mapping) is a small U.S. consulting company specializing in the institutionalization of spatial information technologies. The company provides tailored consulting services to organizations wishing to startup or develop capabilities and applications using Geographic Information System (GIS) and Remote Sensing (RS) technologies.	GIS, global framework data, VMAP, commercial providers, Africa
Tele Atlas	Tele Atlas is a digital mapping company. Their database contains all roads and streets for more than 20 countries in Europe, North America and South East Asia. Ultimately, Tele Atlas aims to deliver real-time data for every corner of the globe. Through access to key data sources, such as paper maps and existing databases close relationships with thousands of government agencies, and their own mobile mapping technology, they anticipate achieving this goal.	Roads database for navigation systems, internet mapping
Research and Academic		
Center for International Earth Science Information Network (CIESIN), Columbia University	CIESIN works at the intersection of the social, natural, and information sciences, and specializes in on-line data and information management, spatial data integration, and interdisciplinary research related to human interactions in the environment. CIESIN has considerable expertise in the development of spatially explicit population and poverty maps from diverse original source material.	Spatial data analysis, global spatial data, socioeconomic and population data

Organization Name	Mission	Interest/Expertise
Joint Transport Research Centre of the Organization for Economic Cooperation and Development (OECD) and the European Conference of Ministers of Transport (ECMT)	The mandate of the Centre is to promote economic development and contribute to structural improvements of OECD and ECMT economies, through co-operative transport research programmes addressing all modes of inland transport and their intermodal linkages in a wider economic, social, environmental and institutional context.	Road safety, road travel demand, road pricing
World Resources Institute	World Resources Institute (WRI) is an environmental think tank that goes beyond research to find practical ways to protect the earth and improve people's lives. WRI's mission is to move human society to live in ways that protect Earth's environment and its capacity to provide for the needs and aspirations of current and future generations. WRI has a team of GIS analysts who are involved in global data analysis for the environment.	Geospatial data, environmental research, sustainable development
Global Land Project	The Global Land Project is a proposed joint research project for land systems for the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP). The Global Land Project Science Plan represents the research framework for the coming decade for land systems. This development of a research strategy is designed to better integrate the understanding of the coupled human-environment system. These integrated science perspectives reflect the recognition of the fundamental nature of how human activities on land are affecting feedbacks to the earth system and the response of the human-environment system to global change.	Land cover change, land use, roads as drivers of land cover change, modeling

APPENDIX B: Acronyms

ADB	Asian Development Bank
ADC	American Digital Cartography
CGIAR	Consultative Group on International Agricultural Research
CGIAR-CSI	Consortium for Spatial Information of the CGIAR
CI	Conservation International
CIA	United States Central Intelligence Agency
CIAT	International Center for Tropical Agriculture

CIESIN	Center for International Earth Science Information Network
DCW	Digital Chart of the World (editions 1 and 2 of VMap0)
DFID	U.K. Department for International Development
DoS	United States Department of State
EBRD	European Bank for Reconstruction and Development
EC	European Commission
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
ERF	European Union Road Federation
ESCWA	United Nations Economic Commission for West Asia
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
GIS	Geographic Information System(s)
GPS	Global Positioning System
IADB	Inter-American Development Bank
IBGE	Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística)
ILO	International Labor Organization
IRF	International Road Federation
IUCN	The World Conservation Union
JOGs	Joint Operations Graphics map sheets
JRC	European Commission Joint Research Centre
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	United States National Aeronautics and Space Administration
NGA	United States National Geospatial-Intelligence Agency (formally NIMA)
NGO	Non Governmental Organization
NIMA	National Imagery and Mapping Agency (acronym superseded by NGA)
NRDC	Natural Resources Defense Council
OECD	Organization for Economic Cooperation and Development
ONC	Operational Navigation Chart
PIARC	World Road Association
SERVIR	Central America Monitoring and Visualization System
SRTM	Shuttle Radar Topography Mission
SWBD	Shuttle Radar Topography Mission - Water Body Data set
TIGER	Topologically Integrated Geographic Encoding and Referencing system

UN	United Nations
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNEP/GRID	United Nations Environment Programme / Global Resource Information Database
UNEP-WCMC	United Nations Environment Programme - World Conservation Monitoring Centre
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
USAID	United States Agency for International Development
USGS	United States Geological Survey
VMap0	Vector Smart Map Level 0
VMap1	Vector Smart Map Level 1
VPF	Vector Product Format
WBDb-II	World Data Bank Version 2
WRI	World Resources Institute
WWF	World Wide Fund for Nature (and U.S. World Wildlife Fund)