statistics include the numerous business travellers and people who are visiting relatives, leading to the recorded numbers of tourists entering the country being greatly inflated (Kraas/Häusler 2016). A cartographic representation of numbers of alleged tourists would be correspondingly misleading and could result in false conclusions being drawn.

DATA SOURCES AND CARTOGRAPHY

Drawing on topographical maps and satellite data, a Geographical Information System was created as a basis for the cartography, and linked to the statistical data and thematic contents. Great care was taken to ensure precise cartographical representations and meticulous checking of all the cartographic and data sources.

There are undoubtedly severe problems with the availability, quality and reliability of data, especially of statistics: ‘Under decades of authoritarian rule, data sensitivity was a political culture ... it is now time for Myanmar to move towards improving the quality, accuracy, credibility, timeliness and availability of economic and social statistical data and information as a first step in building a modern developed nation’ (Myint 2010, quoted in Than Tun Sein et al. 2014: 185). Against a background of very varied data quality and reliability, the temptation to create visualisations without quality control was resisted and a number of maps have not been produced that may otherwise have been possible.

The findings of the 2014 census and data from various ministries were vital sources for the Atlas. Many of the themes also drew on a synthesis of different academic sources, even when numerous very different sources had to be brought together and much work was necessary to accurately localise non-georeferenced information. Regionally detailed findings from the 2014 census have been published on population development, agriculture, education and health, allowing good and very accurate presentations of these topics. There are, in contrast, as yet limited data on industrialisation and flows of transport, trade and finance. The information on GDP, for instance, is incomplete simply because the informal sector is not included due to an understandable lack of data. There are to date no data available on the richly diverse crafts, the importance of which has scarcely been addressed, either in terms of cultural heritage or as a traditional source of local income.

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The core idea of producing a reliable and spatially detailed Socio-Economic Atlas of Myanmar could only be realized in a targeted manner with the help of a Geographic Information System (GIS) and the available source data. Visualisation of most of the thematic contents is carried out on the basis of the 330 townships, the administrative units of Level 3. All point and line elements of the Atlas geo-database were recorded with great positional accuracy and stored at an appropriate level of generalisation for the mapping scale of 1:7,850,000 in an A4 print format. The accuracy of contents and the consistency of the data, some of which were drawn from many different sources, were ensured by an elaborate plausibility assessment. A combination of close communication with Myanmar colleagues and knowledge of the country enabled the meticulous examination of outliers and spatial anomalies and thus the administration of a reliable database.

The geo-database was compiled using administrative and topographic vector data or remote sensing raster data with the help of the Geographical Information System ArcGIS 10.2. The satellite data provided the basis for recording new or correcting existing geo-data and were processed using ENVI. The final cartographic design of the maps was produced in Adobe Illustrator (Adobe CC 2015/2016). The add-on MaPublisher 9.6 (Avenza) installed in Illustrator proved to be indispensable when operationalizing the workflow between GIS-based data processing and cartographic visualisation in Illustrator. This software allowed the spatially fixed and to-scale import of the GIS data layers and their further attribute-based graphic processing. The combination of Illustrator and MaPublisher permitted the optimal construction of the maps through the establishment of the spatial data layers from the GIS. It furthermore allowed the use of very elaborate cartographic symbols and visualisations of the diverse topics, something that would not have been possible in GIS due to its considerably more limited graphical sophistication. In cooperation with the designers Luebbeke Naumann Thoben (Cologne), the ambitious overall layout was achieved using Adobe Indesign.

The fundamental coordinate system for the national data is a geographical coordinate system (GCS_WGS_1984 / Date: D_WGS_1984). For the regional maps of the urban area of Yangon the Universal Transvers Mercator-System was selected (UTM Zone 47 / WGS84). There was a lack of standards in the various source statistics/data in terms of the coding of the 330 administrative units and the Romanisation of the township names. This meant that the 330 spatial units were only linked after the adjustment of the township names in the statistics in line with the naming convention from MIMU (Myanmar Information Management Unit).

When preparing the thematic maps various steps were required, as follows:

- The basic topographic data were produced using a digital ground model (Shuttle Radar Topography Mission, SRTM 90m vers. 4.1) in combination with Landsat 8 OLI archive data (USGS, Earthexplorer). For Myanmar, a regularly updated archive of Landsat 8 OLI scenes is available to the project. An image sharpening process is used to calculate the Landsat 8 RGB images (channel combination 4, 3, 2) at 15 m; these images serve as the spatial base reference for both the national key maps and the regional maps. The rich objective image data and the accuracy of the ‘objects’ visible in the images is higher in the Landsat data.
than in the available topographic maps. Landsat 8 was used as a basis for the digitalisation of the water network, the updating and correction of the street network and railway lines, the localisation of hydropower plants and the updating of the position of towns. VHR-satellite data serve as the spatial reference for Yangon (WorldView2, GeoEye), supplemented by time periods from Google Earth image data. The topographic names and toponyms for landscapes, mountainous areas, rivers and mountains are derived from the topographic maps of Myanmar at the scale of 1:250,000 and 1:50,000, from the literature and from internet research.

The relevant dataset of the geo-data made available by MIMU (Myanmar Information Management Unit) was used as the administrative base data (download in August 2014). The data were digitized by MIMU on the basis of the topographic map 1:250,000. As this dataset includes flawed polygon data (gaps and sliver) and for certain regions is too generalized or too roughly digitized, the MIMU dataset was considerably reworked and refined in the Institute of Geography of the University of Cologne with the help of topographic maps and, especially, on the basis of the Landsat 8 image data. This applies particularly to the adjustment of borders where they follow the course of rivers, mountain ridges or roads. Furthermore, in Cologne a line and polygon dataset was created for the geo-database of the Atlas using the administrative codes and assigned names from the MIMU dataset (PCODE-list, MIMU/GAUL/DCW and translation of the GAD names). The very differing Romanisation of the township names by the different authorities or ministries represented a major problem, especially as the statistics and geo-data provided had to be linked to these names. A correct ‘fit’ could only be achieved by very elaborate linking procedures and checking the assignment of every individual data sequence to each township. All datasets in the Atlas are affected by this problem.

The individual thematic maps were subject to further conceptual deliberation, as described in the following. The workflow of GIS-based data processing in ArcGIS and cartographic finalisation in Illustrator applied to all maps.

- Topography and topographic profiles: For this map freely accessible datasets of heights were available (SRTM vers. 4.1). However, a water-network based on the Landsat 8 data and adjusted to the scale of the map was newly created. The corrected MIMU dataset was used as administrative data. Representative cross-sections were selected and calculated in ArcGIS.

- Land use / land cover: For the map the freely accessible datasets from NASA WorldView, MODIS and GlobCover 2009 v2.3 were straightforwardly transferred to ArcGIS, the exemplary districts were representatively selected and were fed into the final cartographic process (Photoshop and Illustrator).

- Population: Data from the 2014 Census were used for total population, population density, sex ratio and urban-rural population. The census statistics were prepared so as to match the GIS dataset of the towns. In light of the problems concerning the Romanisation of the census data it was necessary to ensure the fitting of the data.

- Modeled population density: The modeled Myanmar dataset of the licensed LandScan 2013 data was procured for the spatial visualisation of population density.

- Climate: The precipitation and temperature data were derived from the ‘Agricultural Atlas of Myanmar’ (FAO 2006); new digitisation of the map of precipitation and temperature distributions allowed for adjustments appropriate to the design of this Atlas. The base data of the diagrams of the selected regional locations come from the ‘Climate Change Knowledge Portal’ of the World Bank Group; they were consistently re-visualized in Illustrator in graphic form.

- Natural Risks: This map is a compilation of freely available digital data. Firstly, the time
series of all earthquake events with magnitudes over 4.0 of the last 200 years were drawn from the web archive of the USGS-National Earthquake Information Center. Secondly, the ground model data from SRTM 4.1 for the land and from ETOPO1 for the seabed were used. These data were overlaid with the modeled population (LandScan 2013) and supplemented with the fault lines and seismic zones from the literature (tectonic map of Myanmar - www.sagaingfault.info).

- National conservation area: The map was created on the basis of a content comparison of a combination of four primary sources (see sources listed in the map). The spatial assignment was mainly based on Beffasti/Galanti (2011), as here detailed maps showing the extent of the protected areas are available. The visualisation was completed using the Ministry map. The classification of the protected areas is based on the usual IUCN categories.

- Fuel minerals, metallic minerals, precious stones etc.: The Ministry of Mines provided data for these maps. Due to positional errors, omissions and inconsistencies the data needed to be supplemented. An accurate basis was provided by a publication with geological maps of Myanmar (UN 1996). Extensive research was necessary to create the basis for the supplementary contents included in the map on fuel minerals; the presentation of the coal basins and the oil and gas blocks was drawn from various scientific sources (sources cited in the map).

- Urban system of Myanmar: A list made available by the Ministry of Construction provided the basis for identifying the towns and cities. This shows the towns and cities in 2015, categorized in five classes according to urban population (Census 2014) and administrative status. The position of the towns was in some cases corrected using Landsat 8 images.

- Road network, railway lines, towns, harbours and airports (transportation networks and towns) – detailed overviews in four parts: The basis of the maps was provided by comprehensive maps of each state or region from the Ministry of Construction. In some cases no accurate information was available on the year in which the individual road sections were constructed. The course of the roads was sometimes very generalized or visualized as a simple link between towns, so that the exact course of the road could not be determined from the maps. The data provided by MIMU are in some cases more accurate, but the positions and connections of roads are also often incorrect. It was therefore necessary to refer to the current Landsat 8 image data as a basis for interpreting the exact course of roads; additional information from Google Earth images was used for more narrow roads or the course of roads through wooded areas. Interpretation was aided by maps from the Myanmar Transportation Master-plan. A comparison with detailed GIS maps (such as those that exist for the eastern Shan State) was not possible. New road links, for instance between Paletwa and Matupi via Samee, were added based on Landsat images and newspaper reports on the opening of the streets. All the streets were first captured in GIS and later combined with the other map layers in the overall layout of the infrastructure maps. The data on the railway network was provided by the Ministry of Rail Transportation in the form of network plans showing all stops but not their accurate positions. The railway network was also checked using Landsat 8 data and, as far as visible, ‘sections under construction’ were also digitized. The aim of the infrastructure map is to visualize all 367 towns as connected with the street network. This goal was not fully achieved as the network of paths linking very remote small towns was not accurately visible in either the Landsat 8 or the Google Earth images. The information on airports came primarily from the UNECE platform. Local interview partners and media reports augmented the information on the operational status of the airport, for instance whether it is used seasonally. In addition, research of Google Earth images was help-
ful in recognizing whether the airport was actually in operation: some of the airports listed as ‘domestic’ by MIMU or UNECE (with the note: no detailed information) could be excluded from the mapping (sometimes a defunct runway could be recognized). The ports were mapped with the help of information from the DLCA platform, which allowed a distinction to be made between ‘international exporting sea port’ and ‘sea port with domestic coastal traffic’. Presentations from the Ministry of Construction, and information from newspaper reports served for the designation of planned or already implemented Deep Sea Port projects. The background data on topography and vegetation (generalized) are freely available.

- Power plants: This map required some of the most extensive research of all the mapping projects of the Atlas. First, all the hydropower plants shown in the MoEP map (2015a, in addition 2015b) had to be pinpointed in their correct positions in GIS – here the Landsat 8 images and Google Earth or Google Earth time series were consulted. They were given attribute data (status, installed/proposed capacity). This literature-based information (especially Snider 2012) on the ‘Hydropower Plant’ and ‘Thermal Power Plant’ locations and attributes was compared with information on the status of the projects from burmariversnetwork.org, internationalrivers.org and newspaper reports. Capacity, type and status of the power plants were precisely cartographically visualized. The catchment areas of the large rivers were included as additional information. Furthermore, a summarized visualisation of the total capacities per Region/State according to type and status is included as a bar graph.

- Telecommunication: Data on the location of the towers (MPT, Ooredoo and Telenor) were transferred from the Excel tables to GIS point data. The number of towers was linked with data on availability of mobile phones per household per township from the individual Region/State data tables of the Census. The visualisation takes the percentage shares into consideration. This allowed a content-rich map to be produced.

- GDP main and per sector, economic classification of townships based on GDP 2015: Very good raw data was available for this map. Information on the main sectors and their sub-sectors was provided in the form of a table for each of the 330 townships. These tables were then manually reprocessed in a meticulous and time-consuming procedure to produce a GIS-compatible table. The attributes of each township were originally arranged in rows in 330 separate tables and had to be transferred to columns to enable linking. After the overall table had been produced with information on volumes of GDP in Kyat per sector/sub-sector and their percentages for each township, an additional link to the population was created in order to calculate GDP per capita. In the overall table the percentages per sector/sub-sector were then classified in 25% steps, an ‘outlier-category’ was identified and the result was visualized in four maps (1: % of the three main sectors, 2-4: % of the sub-sectors in the three main sectors). The visualisation of the percentages could only be undertaken semi-automatically. The workflow from the GIS-based data processing could be carried out specifically for the complicated semi-automatic assignment of the graphic attributes in Illustrator. The townships were classified according to their percentage share of the main sectors and their resulting position in a ternary plot. 16 categories with information on the percentage distribution of the sectors and the number of townships per category reflect the economic structure of Myanmar. Overall, the data preparation and semi-automatic visualisation were thus very complex and time-consuming. However, the depiction has decided advantages over a classic proportional circle map or a mono-themed choropleth map, as the interaction of the main sectors/sub-sectors is effectively presented.

- Rain and summer paddy: The Ministry for Agriculture and Irrigation provided de-
tailed data for this map, in some cases in temporal resolution for harvested area (ha) and yields (Tinn). From this data the distribution maps for rain paddy (absolute production, annual yield and change over time of both) and summer paddy (absolute production and annual yield, without time series data) were produced. The combination of absolute production and proportion of rain or summer paddy was depicted in color-graded classified symbols, allowing both variables to be effectively portrayed (as already used in the presentation of the percentage share of urban population in the total population of a township, and later again applied to the topics of health and the availability of mobile phones).

- Agricultural regions: The map represents a substantive combination of the regional distribution of the geographical characteristics of topography, climatic conditions and land cover/land use. It was decided not to carry out automated GIS analyses, for instance according to threshold values on the individual data layers. Instead the eight agricultural regions were identified as a synthesis of the factors considered (on the basis of freely available data layers).

- Aquaculture: The map is based on consistent datasets from the Ministry of Livestock and Fishery (MoLF). Both the datasets on shrimp and fish farming could be summarized in one map. It should be noted that data were missing from the dataset for many townships, e.g. in Shan State (although there are fish farming projects).

- Yangon garment factories: The map is based on two very detailed datasets from the Myanmar Garment Manufacturers Association (MGMA) that include almost 300 locations of garment-industry enterprises, primarily situated in Yangon, with information on addresses, investment type, type of factory, number of workers and product specifications. The pinpointing of the location of the almost 300 enterprises was undertaken by hand using the addresses of the individual industrial zones in the separate townships in Yangon (designation of the industrial zones according to information from Myanmar Industries Association, YCDC 2009, Tractus 2015b). Enterprises outside the industrial zones were grouped per township or per zone outside Yangon. The enterprise-specific data were transformed into township-summarized data that could then be processed in GIS and transferred to Illustrator for cartographic visualisation. The complex cartography visualizes the number of employees in proportional circles and the proportions of types of enterprise and investment. The current built area of Yangon, the industrial zones and the administrative structure are added as background information.

- Tourism map: in this map elements of tourism infrastructure (street/railway network, airports, selected towns and cities of the urban system of Myanmar) and tourism potential (protected area, world heritage sites) are visualized from existing data layers of the Atlas geo-database and combined with a classification in primary and emerging travel destinations.

- Electricity for lighting, availability of mobile phones: The map is based on data from the 2014 Census. It contains a combination of the variables ‘Number of households per township’ and the percentage share of ‘Township-households with mobile phones’. Color-graded symbols of different sizes were again selected. The proportion of households per township with access to electricity for lighting was added as background information. The preparation of the census statistics for the GIS dataset of the townships was subject to the problems of Romanisation.

- Health (regional health centers, sub-regional health centers; doctors, hospitals, midwives): The data were available in pdf format and contained comprehensive information on the number of hospitals, regional health centers, sub-regional health centers (all three variables: Ministry of Health, May 2015) and the number of hospitals, doctors, nurses and midwives (all
four variables: Ministry of National Planning and Economic Development MNPED, Aug. 2015). After the initial conversion/adjustment/linking process to the township object data in GIS the dataset could be directly used for the visualisation process. The Ministry of Health datasets also contain information on the number of beds per hospital and township, although these deviate strongly from the MNPED data (Ministry of Health: total number of hospitals in Myanmar: 1,083; MNPED: total number of hospitals in Myanmar: 1,001); in some townships the data concur, in others they vary widely. For the map the MNPED data on the number of doctors per hospital per township were used as these data were available in a coherent dataset. It is, however, unclear whether these data are more reliable. The datasets could not be mixed, which prevented information on hospital beds per 1,000 persons being provided. The three variables are presented using a color graduation in symbols classified according to size. The size classification was selected in order to permit a better visualisation of the 330 object data; the proportion of urban population was added as background information. The development of an operational workflow between GIS and the Desktop Publishing System was necessary for this so as to guarantee the error-free assignment of the color classes to each symbol – the aim was to minimize errors in the manual submitting of the graphic attributes; the graphic attributes were assigned through layer management.

- Education level: The three education maps are drawn from data from the 2014 Census. In all three maps the percentage share of over 25 year olds with a school qualification (primary to higher education) is related to a) the absolute number of over 25 year olds with a school qualification, b) the percentage share of 25 year olds with the highest school qualification in the township population, c) the percentage share of the school level of all those with a school qualification over 25 years old (classed in primary, middle and high School). The preparation of the census statistics for the GIS dataset of the townships was, as usual, complicated (Romanisation problem).

- Higher education, location and students: The three maps are based on data from the Ministry of Education on the 169 (as of 2016) locations of institutes of higher education in Myanmar; this includes universities, degree colleges and colleges. Interviews with colleagues helped in assigning the institutes to disciplinary categories. The locational data was linked to the towns in GIS. The resulting maps show a) the locations of the higher education institutions with their subject area classified by city, b) the number of students per city plus the proportion of students in each discipline. Furthermore, c) the number of students in each higher education institution and subject area is linked with the student-teacher ratio and recorded in a comprehensive list of higher education locations.

Overall, the automatic processing of the maps in GIS was hindered by the problems caused by the very varied Romanisation of the Myanmar names, which prevented automatic linking. This necessitated the very complex and time-consuming preparation of the statistical data for the 330 townships. Many of the datasets made available (maps and statistics) are characterized by inaccuracies and incoherency; in some cases they are incomplete. Little can be said about data reliability, as few verification or plausibility investigations have been documented, even in the academic literature. Experience from fieldwork shows that data from the lowest administrative levels are the most precise and reliable; the village-tract and ward-level data and data from the individual institutions are usually the most accurate. Often data were only available on the district level and were thus not suitable for use at the scale of the administrative basis of the 330 townships.

Regine Spohner and Frauke Kraas