REPUBLIC OF BURUNDI
IGEBU: INSTITUT GEOGRAPHIQUE DU BURUNDI

THE STUDY ON ESTABLISHING DIGITAL TOPOGRAPHIC DATABASE FOR BUJUMBURA CITY, BURUNDI

Final Report

(Summary)

March 2013

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

PASCO CORPORATION

EI
JR
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Currency exchange rate

Currency unit: Burundian franc (BIF)

1 dollar = 1,535.82 BIF (interbank exchange rate on 28 February 2013)

1 dollar = 91.84 JPY (interbank exchange rate on March 2013)

Table of Contents

List of Figures

List of Tables

Abbreviations

CAD	Computer Aided Design
CPU	Central Processing Unit
DEM	Digital Elevation Model
DF/R	Draft Final Report
DGPS	Differential Global Positioning System
GIS	Geographic Information System
GNSS	Global Navigation Satellite System(s)
GPS	Global Positioning System
GRS80	Geodetic Reference System 1980
GSD	Ground Surface Distance
IC/R	Inception Report
IGEBU	Institut Géographique du Burundi
IGN	Institut Géographique National
IGS	International GNSS Service
IMU	Inertial Measurement Unit
ISO/TC211	ISO/TC 211 Geographic information/Geomatics
ISABU	Institut des Sciences Agronomiques du Burundi
ITRF	International Terrestrial Reference Frame
IT/R	Interim Report
JICA	Japan International Cooperation Agency
MM	Minutes of Meeting
OJT	On the Job Training
REGIDESO	Régie de production et de distribution d'eau et d'électricité
RTK	Real Time Kinematic
SETEMU	Services techniques de la Mairie de Bujumbura
TIFF	Tagged Image File Format
UPS	Uninterruptible Power Supply
UTM	Universal Transverse Mercator

1. Outline of the Study

1-1. Objectives

The objectives of the Study are as follows:

(1) Aerial photography of Bujumbura City (approximately 230km^2) in the Republic of Burundi (hereinafter referred to as Burundi) shall be performed to create digital topographic maps and ortho photographs at a scale of 1/5,000.

(2) Aerial photography of the suburbs (approximately 800km^2) of Bujumbura city shall be performed to create digital topographic maps and ortho photographs at a scale of 1/25,000.

(3) Aerial photography of Gitega City (approximately 70km^2) shall be performed to create ortho photographs.

(4) Technology transfer for creating digital topographic maps shall be performed to the counterpart organization of Burundi, Geographic Institute of Burundi (hereinafter referred to as "IGEBU").

1-2. Study Area

Figure 1 shows the area for which digital topographic maps shall be created. Figure 2 shows the area for which aerial photography shall be performed in Gitega City.

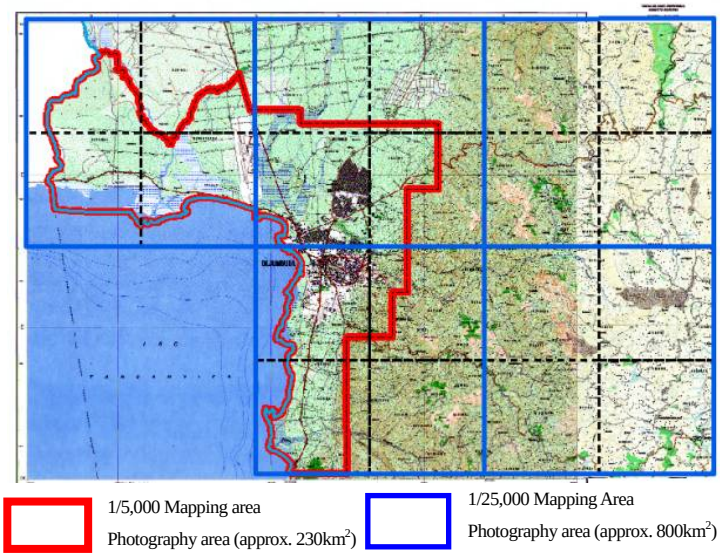


Figure. 1 Digital Topographic Mapping Area

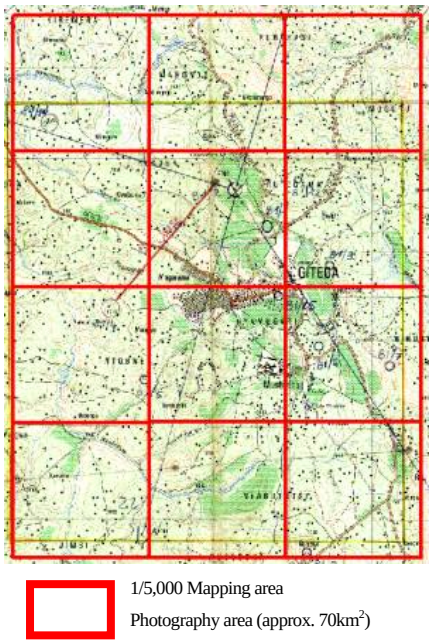


Figure. 2 Aerial Photography Area in Gitega

1-3. Details and Workload of Study

The following table shows details and workload of this Study:

Table. 1 Details and Workload of the Study

Study Items		Quantity	Details
Control point survey and installation of pre-marks	Bujumbura	13 points Control point origin: 1 Control points: 12	Work in Burundi Technology transfer targets (OJT)
	Gitega	5 points Control point origin: 1 Control point origins: 4	
Leveling	Bujumbura	4 routes (New simple leveling)	Work in Burundi Technology transfer targets (OJT)
	Gitega	1 route (New simple leveling)	
Aerial photography	1/5,000 (Bujumbura)	11 courses 184 images (GSD: 30cm)	Work in Burundi
	1/5,000 (Gitega)	3 courses 84 images (GSD: 30cm)	
	1/25,000 (Bujumbura)	5 courses 148 images (GSD: 50cm)	Work in Burundi
Aerial triangulation	1/5,000	257 models	Work in Japan Technology transfer (Indoor)
	1/25,000	143 models	Work in Japan Technology transfer (Indoor)
Field identification	1/5,000	46 maps (230km^2)	Work in Burundi Technology transfer (OJT)
	1/25,000	5 maps (800km^2)	
Digital Plotting	1/5,000	257 models 46 maps (230km^2)	Work in Japan Technology transfer (Indoor)
	1/25,000	143 models 5 maps (800km^2)	Work in Japan Technology transfer (Indoor)
Digital Compilation	1/5,000	46 maps (230km^2)	Work in Japan Technology transfer (Indoor)
	1/25,000	5 maps (800km^2)	Work in Japan Technology transfer (Indoor)
Field Completion	1/5,000	46 maps (230km^2)	Work in Burundi Technology transfer (OJT)
	1/25,000	5 maps (800km^2)	
Digital Completion	1/5,000	46 maps (230km^2)	Work in Japan Technology transfer (Indoor)
	1/25,000	5 maps (800km^2)	
Map Symbolization	1/5,000	46 maps (230km^2)	Work in Japan Technology transfer (Indoor)
	1/25,000	5 maps (800km^2)	
Data Structuralization	1/5,000	46 maps (230km^2)	Work in Japan Technology transfer (Indoor)
	1/25,000	5 maps (800km^2)	
GIS Model Systems creation	Bujumbura	・Flood countermeasures ・Landslide countermeasures ・Waste countermeasures ・Health care	Work in Japan Technology transfer (Indoor)

1-4. Workflow

The following figure shows workflow of this Study:

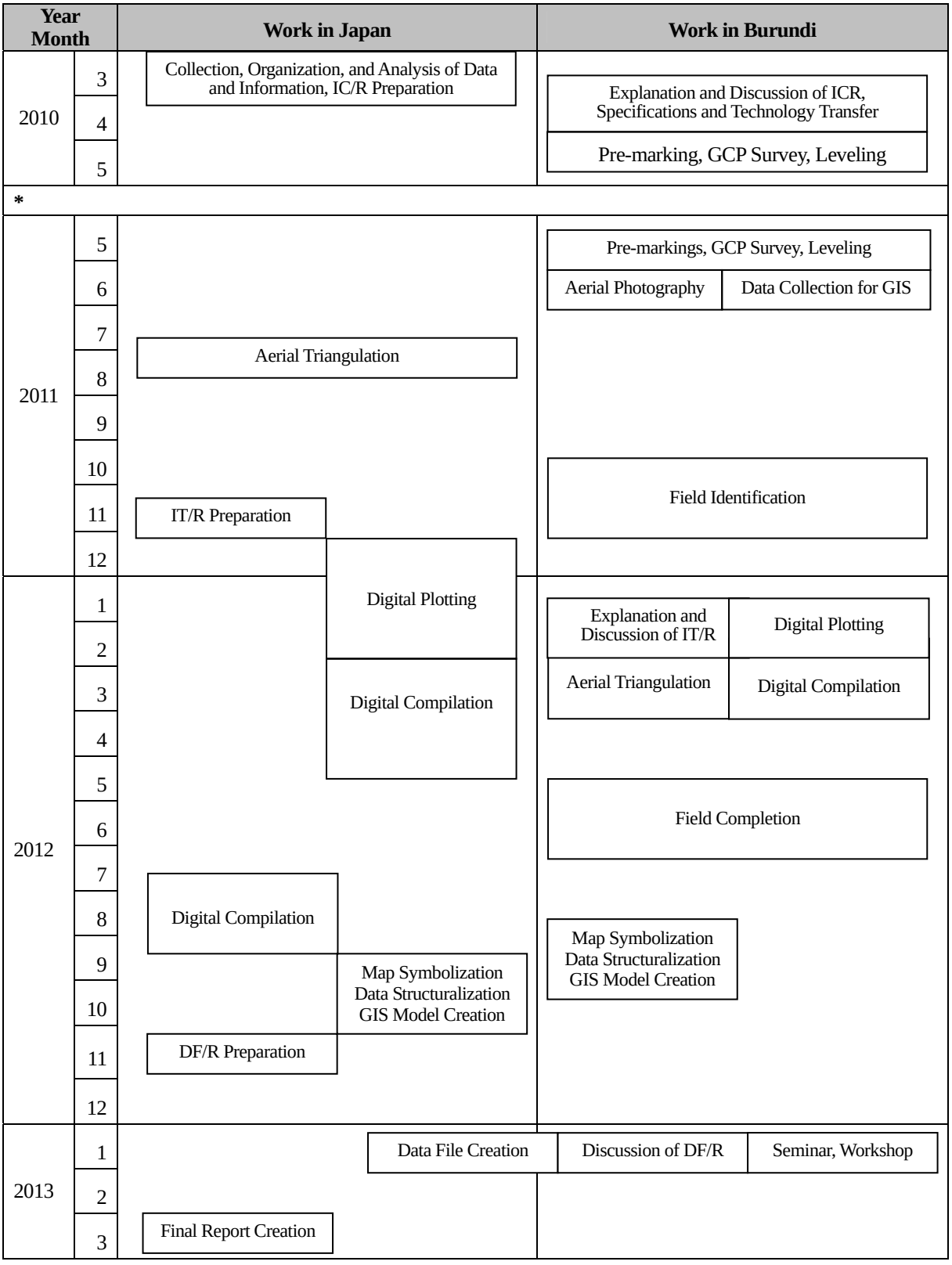


Figure. 3 Workflow of the Study

*The aerial photography was scheduled for the dry season in Burundi, *i.e.* May and June 2010, when the Project commenced. However, a travel restriction to Burundi was issued for the period between 15th May and 10th August 2010 because of the security situation. Since the past precipitation record predicted an increase in rainfall from mid-August in Burundi, it was impractical to go to Burundi and implement aerial photography after 10th of August.

The aerial photography is the critical path in the entire project and its progress will have significant effects on the entire operation process plan. Therefore, the Study Team concluded that it was appropriate to make a fundamental change in the project processes so that the aerial photography could be commenced in May 2011, when the weather was suitable for aerial photography.

1-4-1. Implementation structure in the Study

Implementation structure between Burundian side and Japanese side in the Study is shown below.

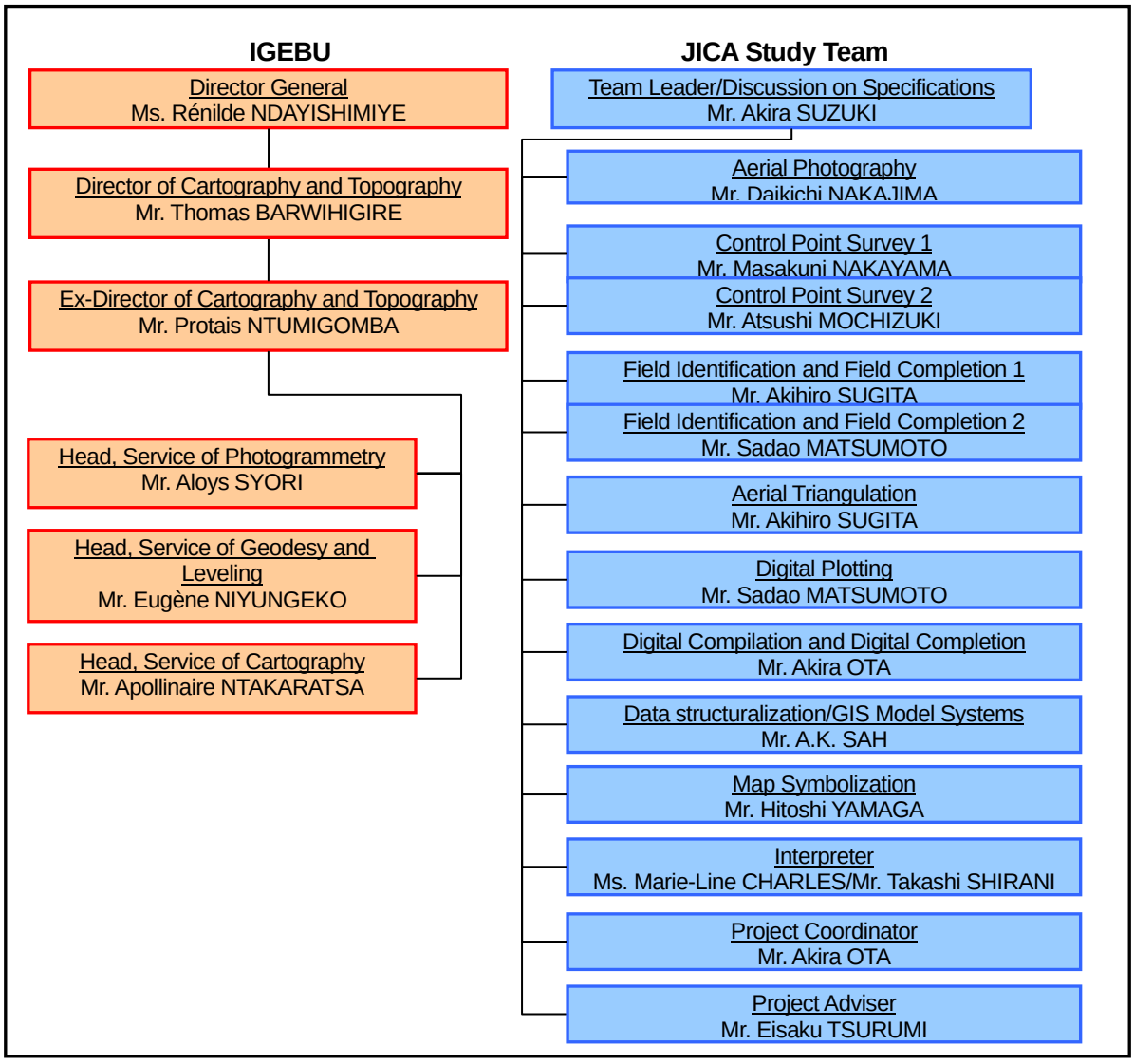


Figure. 4 Implementation Structure in the Study

2. Outputs of the Study and Their Outcome, Recommendation

The implementation of this Study has led to creation of highly accurate and up-to-date topographic maps of the capital city, Bujumbura, and its suburbs and creation of geospatial data required for the formulation and implementation of a capital development plan which is considered as the first step toward national development. The use of the geospatial data created in this Study in background maps will enable sharing of information among government offices using maps and international donor organizations and establishment of the consistency of the positional information. The use of the geospatial data is also expected in the formulation and implementation of various development plans. Additionally, because natinal original control points were installed and observed their coordinates in the study, new natinal original control points make up for shortage of existing national control points and will be used into various projects in the future.

2-1. Expected Cases of the Utilization of the Topographic Map Data

Two types of the data, 1/5,000-scale data and 1/25,000-scale data, were created in this Study. The characteristics of the respective maps are expected to create opportunities for their use in the cases described below. The study team discussed with IGEBU on these cases then determined 4 GIS sample models. (See chapter3, 3-22)

2-1-1. Expected Cases of Utilization (of the 1/5,000-scale maps)

- Urban planning

The use of the data as basic maps for urban planning, including projects for the development of the urban area and the port area and disaster prevention plans, will enable balanced development of the entire country and extension of public welfare.

- Infrastructure development and maintenance

The use of the data as background maps for data on the maintenance of ground and underground urban facilities (electric wires and water supply and sewerage pipelines) and for development planning will enable prompt service provision to the citizens.

2-1-2. Expected Cases of Utilization (of the 1/25,000-scale maps)

- Natural disaster prevention

As the tree felling for expansion of farmland has reduced the strength of the ground in Bujumbura and its suburbs, large- and small-scale landslides occur everywhere when it rains.

Bujumbura City has suffered from floods caused by rising water levels in Lake Tanganyika. The number of floods caused by overflow of rivers due to heavy rain has been on the increase in these few years. There are areas in the city which are permanently inundated during the rainy season.

The analysis of the topographic data and the data on land use and vegetation will enable the measurement of the scales of landslides and floods and the formulation of a plan for the natural disasters in which items to be protected are prioritized, countermeasures have been prioritized by urgency and their effects have been analyzed.

- Health care

It is now impossible for some of the residents in Bujumbura and those in the peripheral areas of the city, in particular, to receive sufficient medical services because of the shortage of medical facilities such as hospitals and health centers due to the influx people into the capital, Bujumbura, and the uneven areal distribution of these facilities.

Acquisition of the knowledge of the existing problems from the analysis of populasion of medical services and accessibility with the data on the locations of medical facilities and the population data by residential area in the city will enable the formulation of a plan to construct new medical facilities and upgrade medical services.

- Waste management

Private companies contracted by Bujumbura City dispose of waste in Bujumbura City. However, they are not able to dispose of all waste as the influx of people in the urban area has led to the increase in the amount of waste and a further increase in the amount of waste is expected. Under such circumstances, the use of the topographic maps will enable the government of Burundi or Bujumbura City to establish “a basic policy,” “concrete targets” and “basic conditions for the implementation of measures” on the reduction of waste and its appropriate disposal.

- Master plan for agricultural development in the suburbs of the capital

Rational land use will be realized with the use of the maps containing information on topography and land use as basic maps of a master plan for the development of land for agriculture, the main industry of

Burundi.

- Education

The maps have the potential to be used as teaching materials for learning how to read maps and interpret topography in elementary education.

2-1-3. Institutions Expected to Use the Topographic Map Data

Institutions expected to be user of above utilization, whom the study team conducted hearings and requested to be donner through the study is shown in the following table.

Bujumbura City has been very cooperative to this Study. It was an active data provider in the process of the GIS model systems creation in this Study. Staff of the city participated in the technology transfer in the data structuralization and GIS model systems creation.

Bujumbura City is also expected to be a potential GIS user. The staff of the city who participated in the technology transfer created a GIS model system for “tax collection.” The Study Team hopes that IGEBU and Bujumbura City will join efforts to make great use of the technologies transferred and the outputs created in this Study in the formulation of plans aiming at infrastructure development and service improvement.

The institutions mentioned in the table below which provided data for the creation of GIS model systems in this Study as with Bujumbura City are expected to utilize the outputs of this project.

Table. 2 Institutions Expected to Use the Topographic Map Data

	Expected areas of the utilization		Remarks
Bujumbura City	Urban planning Infrastructure development and maintenance	Utilization for waste management, housing and scools construction, management of roads.	Administrative data and road data are managed with GIS software
Régie des Services Techniques Municipaux (SETEMU)	Infrastructure development and maintenance	Improvement in the efficiency of the control system and quality of the services is expected from the use of the data created in this Study.	Sewage data is managed with GIS software
	Infrastructure development and maintenance	Digitialization of disposal of rainwater data achives data sharing.	Data sharing is inadequate
Département de Géologie et des Mines, Ministère de l'Energie et des Mines	Natural disaster prevention Agricultural development	Creation of updated geological maps with vector data is expected to create an opportunity for the use of the data created in this Study as background map data in the areas of agriculture and disaster prevention.	The data on the geological maps currently available is raster data and used in GIS software
Régie de production et de distribution d'eau et d'électricité (REGIDESO)	Infrastructure development and maintenance	Transfer of power transmission lines into a digital control system can be achieved with the use of the data created in this Study.	Networks of power transmission lines have been managed on hardcopy (analog)
	Infrastructure development and maintenance	Iimprovement in the efficiency of the maintenance system and quality of the services is expected from the use of the data created in this Study.	Production stations, water transmission pipes and water tanks have been maintained in GIS software
Ministère de la Santé Publique	Health care	Improvement in the efficiency of the management system and quality of the services is expected from the use of the data created in this Study.	While the ministry has digitized the list of hospitals and health centers, it does not have their positional information.
Institut des Sciences Agronomiques du Burundi (ISABU)	Natural disaster prevention Agricultural development	Creation of updated soil maps with vector data is expected to create an opportunity for the use of the data created in this Study as background map data in the areas of agriculture and disaster prevention.	Soil maps has been managed as hardcopy (analog)
Ministère des Travuax Pubulics et du Transport	Urban planning	Utilization into planning of new administrative zone and business zone, new road establishment.	National roads information has been managed as hardcopy (analog)
Institut de Statistiques et d'Etudes Economiques du Burundi (ISTEEBU)	Urban planning	Utilization into census division	Statistical Yearbook has been managed as hardcopy and digital.
University of Burundi	Study and research at the university	Utilization of the data as teaching materials	The university owns GIS software.

2-2. Mechanism for the Utilization of the Topographic Map Data

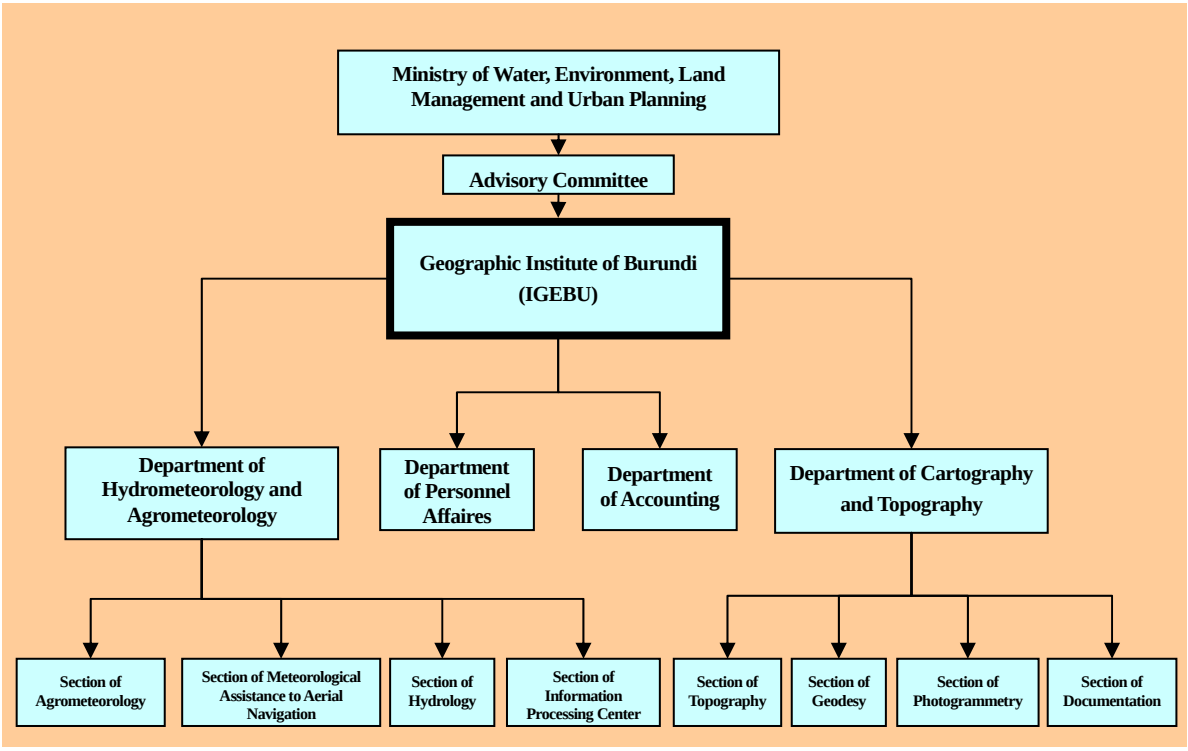
The utilization of the outputs of this Study will be administered by IGEBU. The mechanism for the administration is discussed in the following. It will be also important for IGEBU to cooperate with various government offices, private companies and foreign aid organizations in the administration of the data use.

2-2-1. Organizational Structure and Financial Affairs of IGEBU

IGEBU is under the jurisdiction of the Ministry of Water, Environment, Land Management and Urban Planning. It is headed by the Director General and composed of the Department of Hydrometeorology and Agrometeorology and the Department of Cartography and Topography. The Department of Hydrometeorology and Agrometeorology implements hydrological and meteorological studies and collects hydrological and meteorological data. It has observatories for meteorological observation throughout the country.

The Department of Cartography and Topography takes charge of surveying and map creation. It is the counterpart department of this project. The department has 21 staff members including the director: 5 for the section of geodesy, 4 for the section of photogrammetry, 6 for the section of topography, and 6 for the other service.

The figure below shows the current organizational chart of IGEBU.



The budget for projects excluding the personnel costs of IGEBU is approx 187.599,360 BIF (approx. 9,380,000 JPY). IGEBU does not have sufficient budget to install control points and create various types of topographic maps. A permanent mechanism for the provision of topographic map data will have to be established for the promotion and extension of the use of the outputs of this project, *i.e.* topographic maps and GIS data, after its completion. In addition, the continuous provision of the maps will always require a stock of consumables for printing. Therefore, financial arrangement will be required for the promotion and extension of the use of the maps and data.

The expected costs of updating the topographic maps will have to be considered when the sales prices of the data created in this Study, including topographic maps, are determined. The concept of the decision-making on the prices is described below. It will be essential to include the costs of depreciation and updating of the topographic maps in the sales prices.

Sales price of a topographic map ＝
(Cost of printing the map) ＋ (Personnel cost) ＋ (Cost of the depreciation of equipmnts) ＋ (Cost of updating the map)＋(Administrative costs)

The decision on the sales price of a topographic map mentioned above depends on the expected numbers of copies of the topographic maps to be sold in a year. As the number of annual sales of the existing map (1/50,000) is 500, a number of 500 to 1,000 is assumed as the number of annual sales of the topographic map sheets for the time being.

2-2-2. Issues related to Data Utilization

The topographic map data and GIS data to be created in this project are indispensable for the formulation and implementation of development plans for the capital city, Bujumbura, and its environs. Educational activities by IGEBU will be essential for the promotion of their use. IGEBU will have to implement training courses and seminars on the use of the outputs of this project independently. It will also have to promote implementation of GIS projects to be implemented jointly with Bujumbura City and other relevant institutions.

Appropriate control of this digital data will also be an important issue. The digital data shall be stored in appropriate folders in accordance with the rules to be established for data sharing within IGEBU and the stored data shall be backed up on a regular basis for the appropriate management of the digital data.

As Burundi does not have a law controlling unauthorized reproduction of digital data at present, IGEBU is studying an appropriate way to provide the data.

Enactment of such a law will enable establishment of a mechanism to control the unauthorized reproduction, in which a person who wishes to use the digital data published by IGEBU, such as topographic maps and orthophotos, may do so only after having submitted an application form for the use of the data to IGEBU and having received a permit from IGEBU. Such a permit should state prohibition of reproduction of the data provided by IGEBU, restrictions on the use of the data and prohibition of unintended use of the data.

2-2-3. Recommendation for Operation and Organization of IGEBU in the future

The 1/50,000-scale topographic maps depicting the entire area of Burundi represent the data obtained 30 years ago. Absence of topographic maps representing current data makes the formulation of various development plans difficult. Most of the geodetic control points, reference points for surveying, installed in the past have been lost. Improvement of such poor circumstances requires the implementation of the following projects:

- Creation of 1/50,000-scale topographic maps representing the entire country; and
- Establishment of a network of geodetic control points throughout the country.

The implementation of these projects will require support in the organizational and financial aspects.

For the implementation of these projects, GPS receivers (more than 6 set), Totalstations (more than 3 set), Levels and Staffs (more than 6 set) and vehicles for fieldwork (more than 4) in addition to human resources (more than 15) are recommended to Section of Geodesy. For Section of Topography and Section of Photogrammetry, securement of adequate human resources (more than 10) is recommended to utilize equipments procured in the study effectively. That means Department of Cartography and Topography is required expantion of human resources from present 21 staffs to 31 staffs and also trainings to improve skills of staffs.

What is required in the financial aspect is the increase in the allocation of budget to IGEBU from the Government of Burundi. The revenue from IGEBU's own project activities is also expected. IGEBU will also have to take positive action toward implementation of the projects with assistance from foreign aid organizations such as the EU, the Government of Japan and the World Bank.

2-3. Technology Transfer

2-3-1. Objectives of Technology Transfer

Technology Transfer was implemented about a sequence of work regarding mapping data for the purpose of updating, management and operation of data by IGEBU after the Study.

The Study Team made one of the goals of the technology transfer to give IGEBU staff capability to accomplish independent work such as data updates in the future. As for goal setting, the Study Team

considered the limited training period and elementary level of IGEBU staff who have low experience about basic work such as operation of equipment.

After the training, the Study Team evaluated the IGEBU staff based on the goal setting.

Details of each item are described in Chapter 4.

Table. 3 Goal Settings and Achievement Levels of Technology Transfer

Item	Operation	Goal Setting	Achievement Levels and Remaining Issues
Installation of Pre-marks	Installation of pre-marks	Capability of conducting the same operation as in training	The engineers understood appropriate materials, forms, and colors of pre-marks corresponding to image resolutions of photos and conditions on the ground. The speed of installation improved as they repeated the operation.
Control Point Survey and Analysis	Field reconnaissance for selection of control points	Capability of conducting the same operation (survey plan and GPS observation and analysis) as in training	The engineers understood the basic items such as coordinate systems and map projection.
			The engineers understood the point allocation in accordance with the photographing plan. They will be able to formulate a point allocation plan by themselves when they implement a new control point survey in future.
			The engineers understood the basic operations of handheld GPS receivers such as registration of points and point names. The remaining issue is to improve operation speeds, understand accuracies, and understand acquisition locations.
			Training on photo interpretation could not be provided because the technology transfer was conducted using topographic maps.
	GPS observation		The engineers understood basics and basic operations of static survey. They can conduct static observation of new points by themselves. They became capable of implementing applicative operations such as kinematic survey.
	GPS analysis		The engineers understood basic operations of analysis software. They understood analysis results and limit values. IGEBU became able to conduct observation and analysis of a new control point network on their own.
	Theory of GNSS (GPS) Basics of coordinate transformation	Capability of understanding GNSS theory and coordinate transformation	The engineers deepened their basic understanding of GNSS (GPS) theory, coordinate systems, and coordinate transformation.
Field Identification	Pre-Interpretation	Capability of implementing works with the same level as in training	The engineers understood works and targets (map symbols) of the Field Identification.
	Field identification		The engineers came up to the level of implementation of target identification in the field with Handheld GPS and Orthophoto.
	Work result arrangement		The engineers understood works in quality control and result arrangement (leaking, mistake, join).
Aerial Triangulation	Operation of PC and software	Capability of implementing	The engineers acquired basic function and operation.

	Understanding of theory of digital aerial Triangulation		The engineers basically understood general, need, work, and importance.
	Evaluation method of the result		The engineers basically understood investigation and solution of errors from result of adjustment.
Digital Plotting	Operation of PC and software	Capability of IGEBU's own creation for mapping data on Gitega city in the future	The engineers acquired basic function and operation.
	Operation of stereo plotter		The engineers acquired basic function and operation. Further understanding of TopoMouse is favorable.
	Data acquisition based on the SPEC and the map scale		The engineers acquired know-how of data acquisition of each feature after a considerable lag.
Digital Compilation / Digital Completion	Editing of plotting data	Capability of IGEBU's own creation for mapping data on Gitega city in the future	The engineers understood base of digital compilation and also errors occur frequently in digital plotting.
	Detection and modification of logical error (Data cleaning)		The engineers understood setting of tolerance in auto-detection of errors and difference between auto-processing and interactive-processing.
	Polygon creation		The engineers understood purpose and method of polygon generation and errors that occur frequently in polygon creation.
	Administrative boundary and annotation input		The engineers accomplished polygon creation of existing administrative boundary by referring to orthophoto created in the study.
Map Symbolization	Map symbolization	Capability of IGEBU's own creation for mapping data on Gitega city in the future	The engineers understood acquisition rule based on the scale.
	Head-up quality control and modification		The engineers acquired effective work skills such as feature based quality control.
	Printed map quality control and modification		The engineers understood the final picture of 1/50,000 symbolization by quality control with printed map in defined size.
Field Completion	Field completion	Capability of implementing works with the same level as in training	The engineers came up to the level of implementation of target identification in the field with Handheld GPS and maps for field completion.
	Work result arrangement		The engineers understood works in quality control and result arrangement
Data Structuralization	Understanding of GIS overview	Capability of implementing works with the same level as in training	The engineers understood the overview of GIS and definition of GIS structure.
	Operation of GIS software (ArcGIS)		The engineers acquired operation of the latest version of GIS software.
GIS Model Systems Creation	Applied operation of GIS software	Capability of generating GIS models with the same level as in training	The engineers were able to make a presentation about data generation and its result. Edification to concerned organizations and cultivation of new donors are favorable.

2-3-2. Thoughts on the Technology Transfer

The Study Team considers that the achievement in the technology transfer in this Study was satisfactory in all the subjects. The attitude of the IGEBU staff members in the technology transfer clearly showed their eagerness and enthusiasm for acquiring new knowledge and technologies and the eagerness and enthusiasm was a major factor contributing to the successful implementation of the technology transfer.

The IGEBU staff members conducted a ground control point survey independently using the equipment procured in this Study after they had completed the technology transfer. The fact that they managed to obtain outputs which satisfied the specifications proves that the technology transfer in the ground control point survey was successfully implemented.

The IGEBU staff members implemented the indoor processes from the field identification/aerial triangulation to the digital data structuralization independently using a map sheet of Gitega City. They were expected to practice these processes after the completion of the study. The fact that they managed to complete the work in each process proves that they have understood the concept of each process and how to implement basic work in each process during the technology transfer in these subjects.

The IGEBU staff members held discussion and created the four GIS model systems which they were expected to create by themselves in the technology transfer in the GIS model systems creation. This fact proves that their capacities have reached the level at which they can create model systems by themselves.

The Study Team hopes that the IGEBU staff members will improve the efficiency of the work by making use of the functions of the hardware and software provided in this Study while creating topographic maps of the rest of Gitega City with the knowledge and technologies which they have acquired in the technology transfer in this Study.

The Study Team also hopes that the IGEBU staff members will implement educational activities for the purpose of increasing the numbers of donors to other government offices and users of the GIS data.

3. Contents of the work performed

3-1. Collection, Organization, and Analysis of Relevant Data and Information [Work in Japan]

Map specifications (draft) were created based on the data collected by the preliminary Study Team and the results of independent investigation carried out and information collected in Japan by PASCO.

Existing information used for Map specifications was existing map (1/50,000) and in deliberation of Map specifications, Japanese map symbols (1/5,000 and 1/25,000) were referred for acquisition items and result of field reconnaissance was referred for acquisition standard.

3-2. Creation of Inception Report [Work in Japan]

After analyzing and examining the project instructions, preliminary study report, and the above-mentioned collected data, an inception report, which includes work policy of the study, method, and work process, was created.

3-3. Explanation and Discussion on Inception Report [Work in Burundi]

The content of the Inception Report proposed by the Study Team was discussed with IGEBU and the proposal was agreed upon by IGEBU.

3-4. Discussion on Specifications [Work in Burundi]

As a result of discussion between IGEBU and the Study Team, the specifications of topographical maps to be created were determined as shown in the following table:

Because Burundi is located between 2 UTM zones (zone35 whose central meridian is east longitude 27° and zone36 whose central meridian is east longitude 33°), IGEBU requested to have central meridian as east longitude 30° to manage whole country in a zone. Since the length in the east-west direction of Burundi is less than 200km, IGEBU figured out 0.9999 is adequate value as the scale factor.

Table. 4 Determined Map Specifications

Items		Decision	Grounds
Height criteria		The existing control points shall be used.	Elevation of existing benchmarks
Reference ellipsoid		WGS84	Request from IGEBU
Geographic coordinate system		WGS84	
Central meridian		30°E	
False-Easting (m)		500,000.0	
False-Northing (m)		10,000,000.0	
Scale factor		0.9999	
Map specifications (Acquired items)	1/5,000	Determined through discussion.	Discussion with IGEBU based on proposition of the Study team
	1/25,000	Determined through discussion.	
Map specifications (Contour line interval)	1/5,000	Principal contourline: 5m, Index contourline: 25m, Supplementary contourline: 2.5m	Based on Japanese standard
	1/25,000	Principal contourline: 10m, Index contourline: 50m, Supplementary contourline: 5m	
Sheet No. Sheet Name	1/5,000	Rule of Sheet No. was determined through discussion.	Divide 1/50,000 sheet into 100
	1/25,000	Rule of Sheet No. and name of each sheet were determined through discussion.	Determine in mind user convinience
Marginal information	1/5,000	Determined through discussion.	Conform to the rule of existing map 1/50,000
	1/25,000	Complied with the rules of existing topographical maps of 1/50,000 and determined through discussion.	
Annotation		Cette carte topographique a été réalisée conjointement par l'Agence Japonaise de Coopération Internationale (JICA) et le Gouvernement de la République du Burundi, dans le cadre du Programme de Coopération Technique du Gouvernement du Japon.	

3-5. Fact-finding [Work in Burundi]

By way of utilizing mapping data and GIS data created in the Study, the IGEBU and the Study Team implemented hearing and field reconnaissance for the purpose of ascertaining difficulties of Burundi and to create sample models exemplifying utilization which make use of characteristics of precision and work area of the mapping data.

Since natural disasters caused by rain fall are the most serious issue in the Bujumbura city, Flood control and disaster-prevention measures and Landslide control measures were chosen as GIS sample model. From the result of hearing, there were some requests concern about utilization of the outputs from the study such as planning of new load establishment from Ministère des Travuax Pubulics et du Transport, management and effective planning of location for medical facilities from Ministère de la Santé Publique, Waste management from Bujumbura City, Census division from ISTEEBU, after discussion between IGEBU and the Study team about these requests, Waste management and Health care were additionally chosen as

themes for GIS models.

Table. 5 Chosen GIS sample models

	GIS Sample Model	Description
1	Flood control and disaster-prevention measures	Detection of potential flood area and degree of hazard in urban area by using topographical analysis with contour line.
2	Landslide control measures	Detection of potential landslide area by using slope analysis with topographical data such as contour lines, soil data and land use data.
3	Waste management	Detection of solid waste emission by using special analysis with building, road, population data etc.
4	Health care	Selection of optimal sites for medical facilities through spatial analysis using road data, medical facilities data, statistical data, etc.

3-6. Collection of Survey Results [Work in Burundi]

The collected survey results and field reconnaissance results revealed that there is no national control point usable in this operation but confirmed several national benchmarks.

3-7. Fact-finding of Organizations, etc. Related to Dissemination of Maps and Geographical Information [Work in Burundi]

The Study Team investigated the current situation of organizations that are possible users of topographic maps and GIS data other than IGEBU and held explanatory meetings on this project for these organizations. In the meetings, the IGEBU director and Study Team members explained the outline of this project and the expected GIS models to be created in the project, etc. and promoted exchange of opinions, approximately shareable data and technology transfer. The questions raised in the explanatory meetings and participants are described as follows.

- Method of future update of data generated in the study
- Participation in the technology transfer
- Example of using elevation model generated in the study.

Table. 6 List of Participants in Explanatory Meeting

Name		Organization	Title
1	Gordien NGENDAKUMANA	Municipal Technical Services (SETEMU) of Bujumbura	Section chief of audit, planning, and investigation section
2	Jean-Marie MUCOMWIZA	Bujumbura City	Manager of information science department
3	Frédéric BIGIRUKWAYO	Bujumbura City	Manager of engineering department
4	Célestin MUSAVYI	Municipal Technical Services (SETEMU) of Bujumbura	Manager of road management and rainwater drainage department
5	Judith NTAWUYANKIRA	Municipal Technical Services (SETEMU) of Bujumbura	Manager of maintenance department for heavy machinery, vehicles, and other equipment
6	René MADEBARI	Municipal Technical Services (SETEMU) of Bujumbura	Manager of urban waste and real estate management department
7	Harouna HAMADI	Municipal Technical Services (SETEMU) of Bujumbura	Manager of business and finance department
8	Alice NIJIMBERE	Municipal Technical Services (SETEMU) of Bujumbura	Staff for wastewater piping network management
9	Théophile MAMIRAMPA	Bujumbura City	Staff in engineering bureau
10	Protais NTUMIGOMBA	IGEBU	Director
11	Eisaku TSURUMI	JICA Study Team	Adviser
12	Akira SUZUKI	JICA Study Team	Team Leader
13	A.K. SAH	JICA Study Team	GIS Engineer
14	Marie-Line CHARLES	JICA Study Team	Interpreter

Figure. 5 Presentation Meeting of the Study

3-8. Operations Related to Technology Transfer [Work in Burundi]

The IGEBU and the Study Team discussed and agreed with the technology transfer regarding items and contents.

Since the IGEBU side additionally requested for technology transfer on the outline and theory of GNSS (GPS) and coordinate transformation, agreement was reached on the implementation of it.

The equipment and materials procured for the technology transfer were received and their appropriate functioning was verified at IGEBU in October 2010. The equipment and materials for the technology transfer are described as follows.

Table. 7 Equipment and Materials for Technology Transfer

Name of Equipment		Q'ty
GPS Survey Equipment		2
Analysis software for GPS		1
Accessory (RTK mobile station)		1
Simple stereoscopes		4
Handheld GPS		4
Digital Cameras		4
Basic Software for Aerial Triangulation/ Plotting/Compilation	LPS Core	2
	LPS Stereo	2
	ORIMA DP-TE/GPS	1
	PRO600	2
	LPS ATE	1
	LPS TE	1
Software for Plotting/Compilation	MicroStation V8 XM Edition	2
	Bentley Map V8 XM Edition	2
Software for GIS Structuralization	ArcGIS ArcInfo	2
Software for GIS Application	ArcGIS 3D Analyst	2
	ArcGIS Network Analyst	2
	ArcGIS Spatial Analyst	2
Image Processing Software	Adobe Photoshop	1
Software for Map Symbolization	Adobe Illustrator	2
Document preparation software	Adobe Acrobat	1
Hardware	Mouse for Photogrammetry	2
	3D displays	2
	Work stations	2
	PCs	2
	LCD Monitors	4
	UPSs	4
	Printer and consumables for A0	1
	Printer and consumables for A3	1

3-9. Control Point Survey and Installation of Pre-marks [Work in Burundi]

The study implemented the Control survey and installation of pre-marks based on the following workflow.

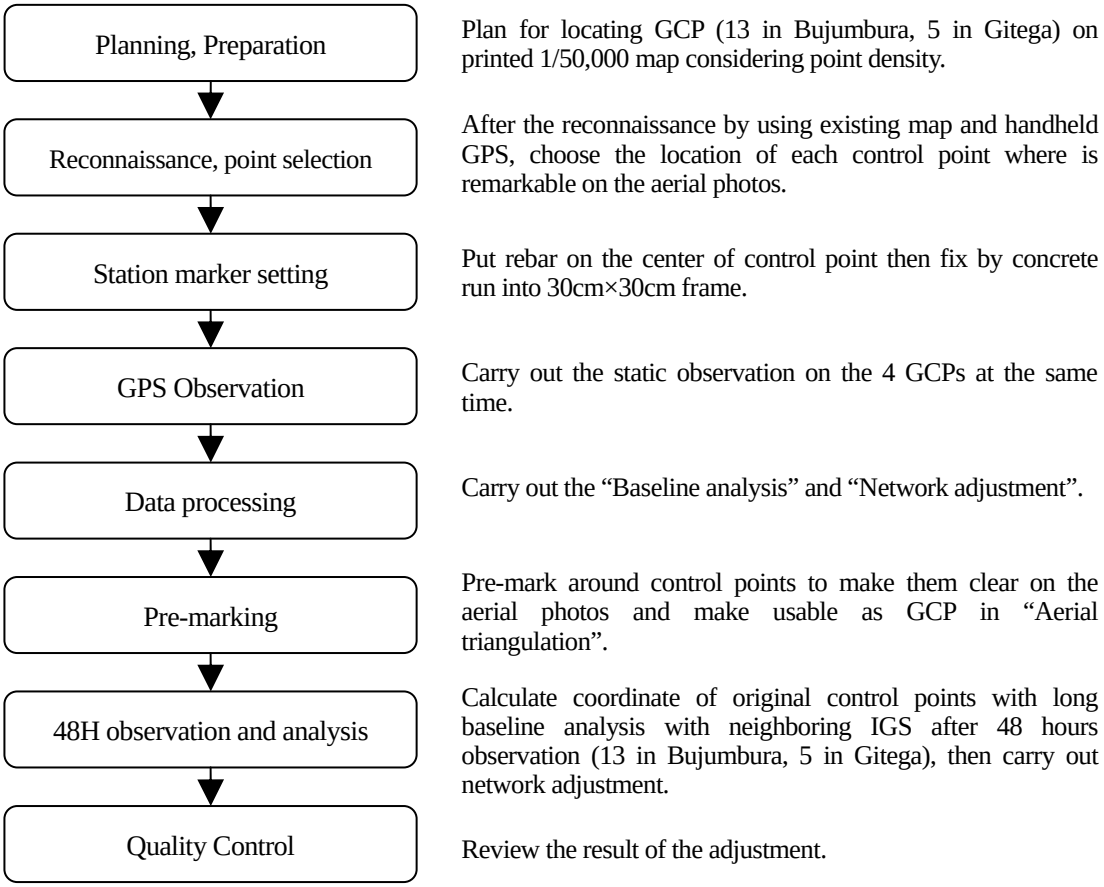


Figure. 6 Workflow of Control Point Survey and Pre-marking

Figure. 7 GPS Observation

(Left: scene of GPS observation, right: Trimble R7 GNSS receiver)

3-10. Leveling [Work in Burundi]

The Study Team implemented the Leveling based on the following workflow.

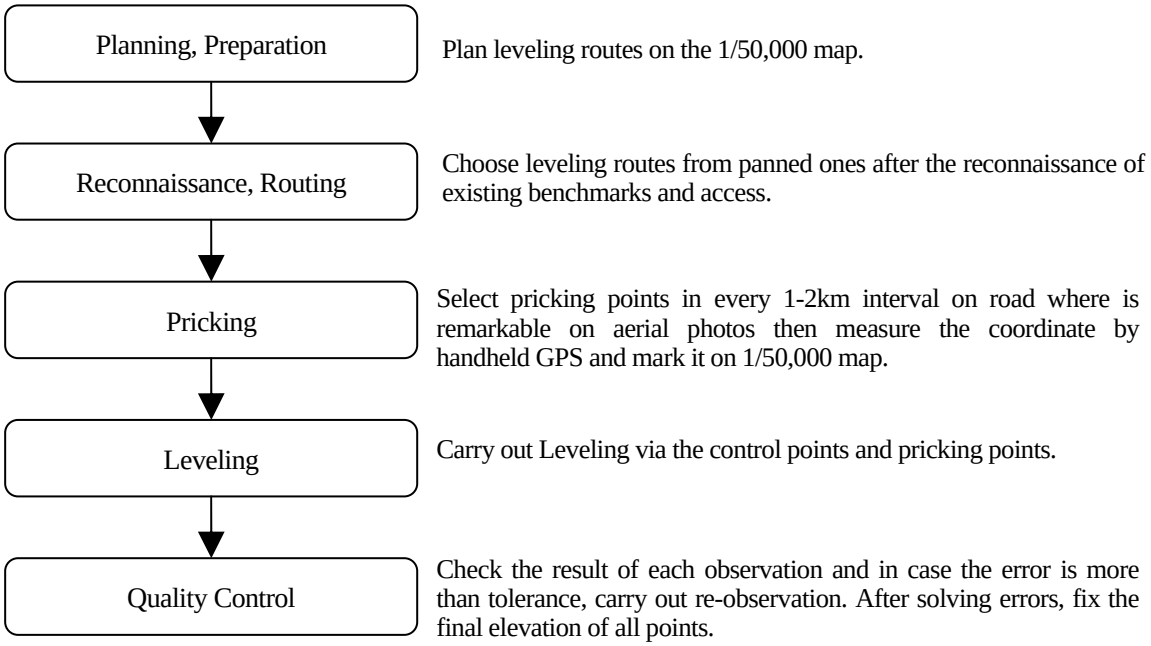


Figure. 8 Workflow of Leveling

Figure. 9 Leveling work

(Left: existing benchmark, right: leveling)

3-11. Aerial Photography [Work in Burundi]

In this Study, aerial photography was conducted using cutting-edge aerial digital cameras based on a combined use of GPS/IMU. Workflow of the aerial photography is shown below.

Planning, Preparation	Plan the flight on the 1/50,000 map.
Reconnaissance for GPS/IMU	Carry out reconnaissance to choose the point as base station for GPS/IMU observation.
Aerial photography	Carry out the aerial photography based on the specification.
Data processing of GPS/IMU	After download of DGPS/IMU data, calculate the principal points location of each photo by the processing with fore-sight and back-sight.
Image processing	Create final TIFF images from raw images by image processing.
Quality Control	Check each image and carry out adjustment of images such as color-balance hot-spot effect control, shadow control of mountains to make smooth following works.

Figure. 10 Workflow of Aerial Photography

Figure. 11 Photographing Equipment

(Left: aircraft used for photography, right: digital camera, GPS/IMU)

3-12. Aerial Triangulation [Work in Japan / Work in Burundi]

The aerial triangulation in this Study was conducted using the acquired aerial photo image data, GPS/IMU, and coordinates of control points as shown in the flowchart below.

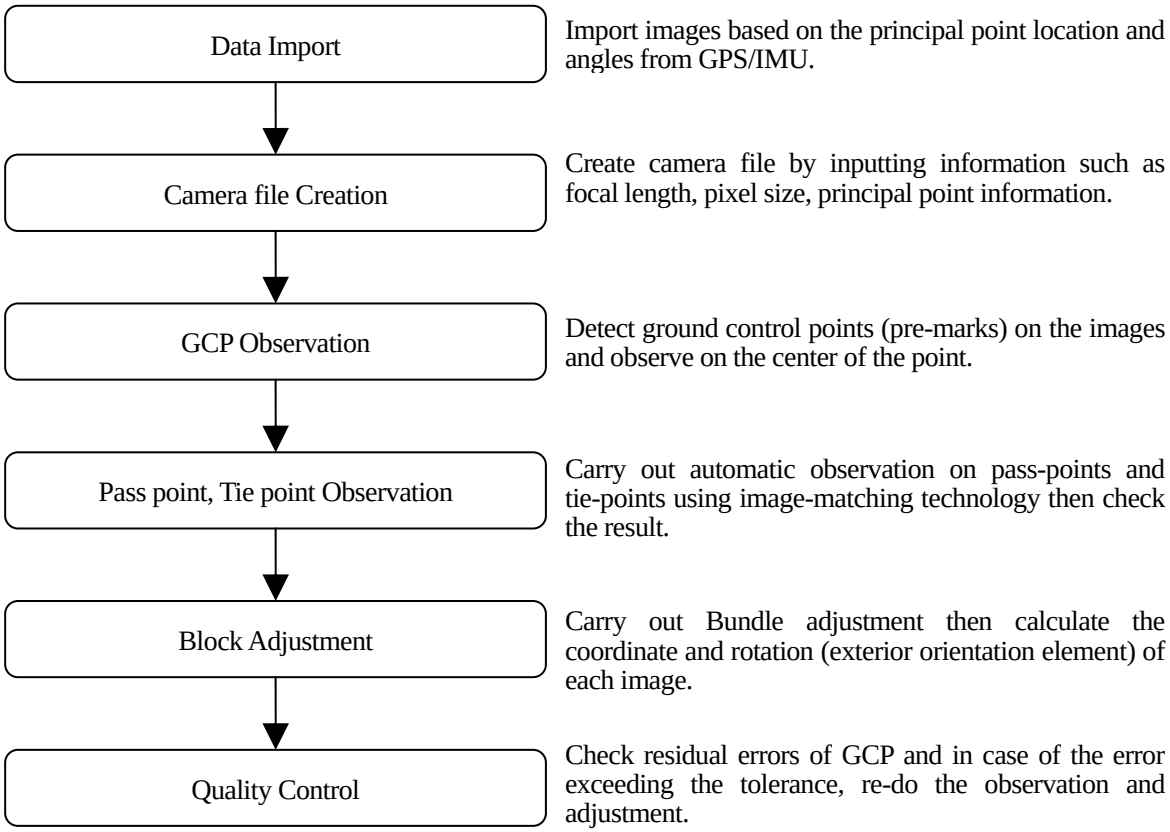


Figure. 12 Workflow of Aerial Triangulation

3-13. Preparation of Interim Report (IT/R) [Work in Japan]

The Interim Report was created to summarize the details and results, progress statuses, etc. of work completed so far.

3-14. Field Identification [Work in Burundi]

Field identification was implemented with existing documents and easily created Orthophotos along the following workflow.

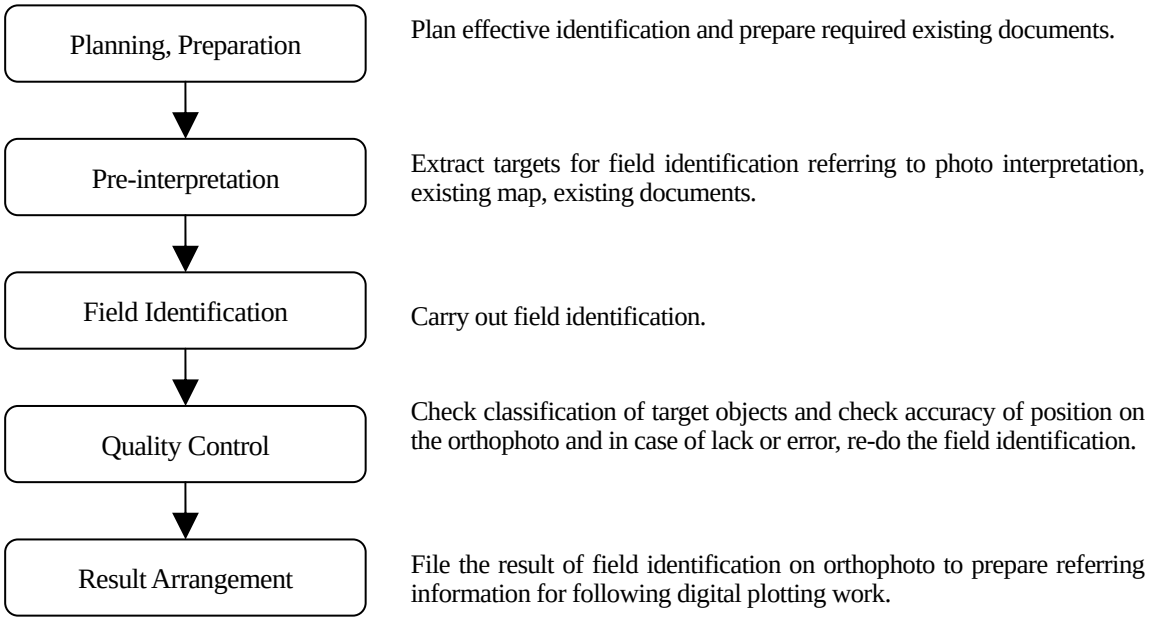


Figure. 13 Workflow of Field Identification

Figure. 14 Field Identification

(Left: location registration, right: Arrangement of Field Identification Result)

3-15. Explanation and Discussion of Interim Report (IT/R) [Work in Burundi]

The Interim Report was explained to IGEBU and discussion was held on the results of operations up to field identification, reference coordinate system of map, map specification, marginal layout, policy for technology transfer and GIS models, etc. Before the explanation and discussion, a presentation was

provided using a PowerPoint file prepared in advance to summarize the content. The result of the discussion was recorded in Minutes of Meeting, which was to be signed by both parties.

Figure. 15 Discussion for IT/R

(Left: on report, right: on marginal layout)

3-16. Digital Plotting [Work in Japan and Work in Burundi]

Digital mapping data for digital completion was generated through digital plotting with the field identification result and stereo models of the aerial photos from aerial triangulation and feature shapes and locations were acquired as geographic information along the following workflow. Data type and category of features were interpreted and classified based on the acquisition code and definition. Unclear parts in the interpretation work or toward field identification were extracted and filed as the target of field completion.

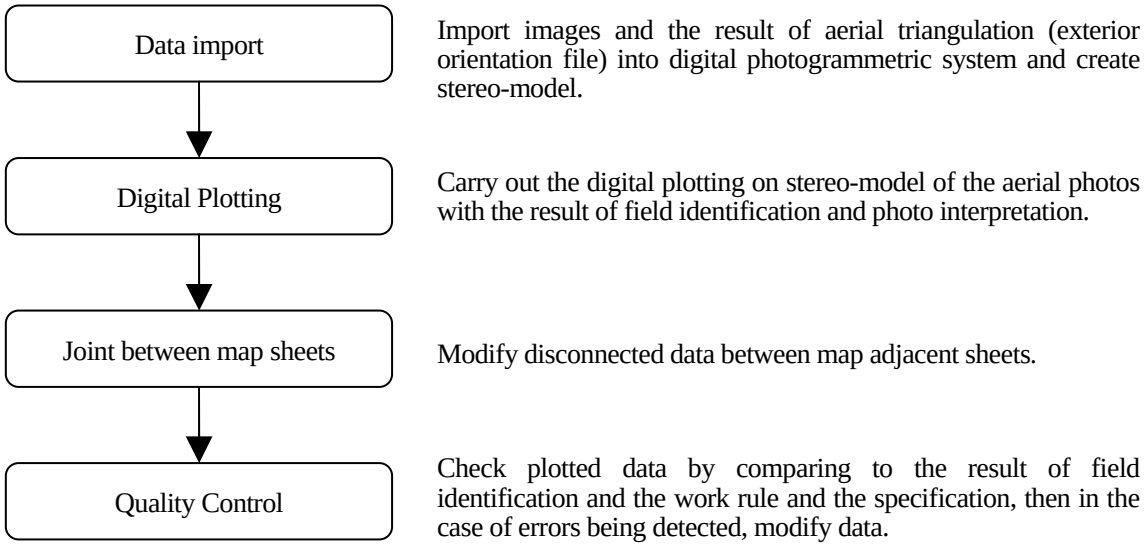


Figure. 16 Workflow of Digital Plotting

The Technology transfer was implemented with photogrammetric workstation and photogrammetric software (LPS: Leica Photogrammetry Suite) and CAD (MicroStation) on the target area which was determined between IGEBU and the Study Team.

3-17. Digital Compilation [Work in Japan and Work in Burundi]

Digital compilation of the plotted data was implemented based on map symbols and data acquisition rule, data cleaning such as modification of adequate data shape and elimination of unnecessary data was implemented then used to create topology in the areas which become polygons.

The technology transfer was implemented with CAD (MicroStation and Bentley Map) on the plotted data by IGEBU in the technology transfer of digital plotting.

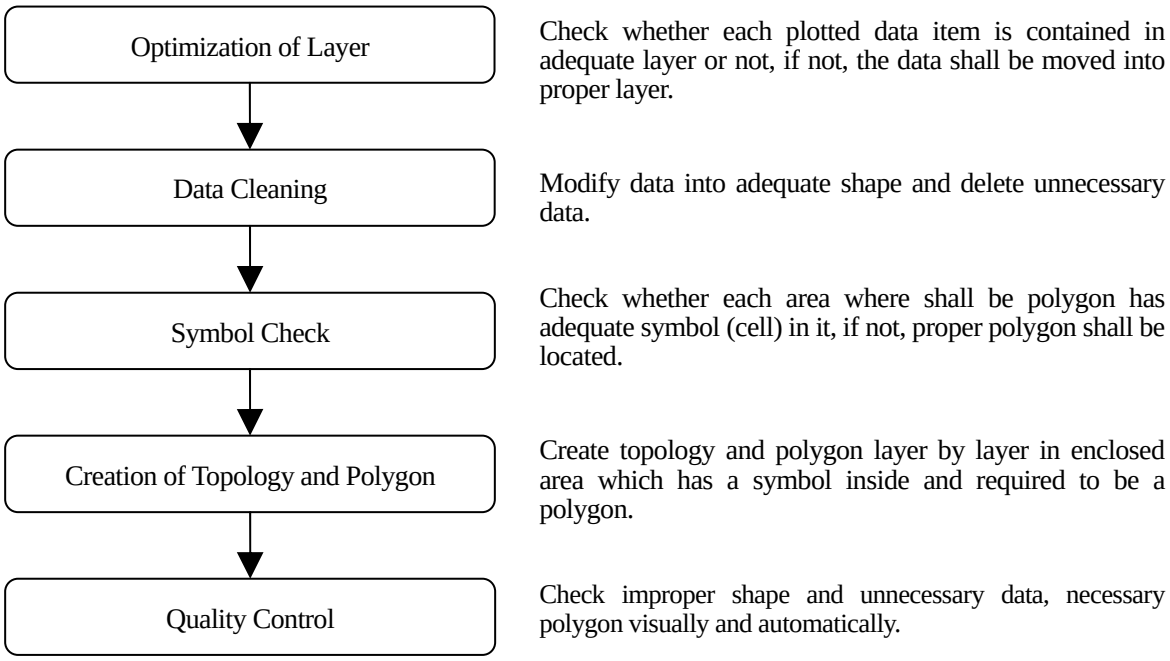


Figure. 17 Workflow of Digital Compilation

3-18. Field Completion for Topographic Maps [Work in Burundi]

Field completion was implemented for the purpose of obtaining high quality of mapping data with re-identification of uncertain information occurred from the digital plotting and the digital compilation work. Additionally, verification of annotations such as river names and university names was implemented. The work area was same as the field identification.

In the work, printed maps with simplified symbolization after digital compilation of both 1/5,000 and 1/25,000 scale were carried into the field.

As well as the field identification, duplicate areas in 1/25,000 area to 1/5,000 area use the result of 1/5,000

field completion. The workflow is described as follows.

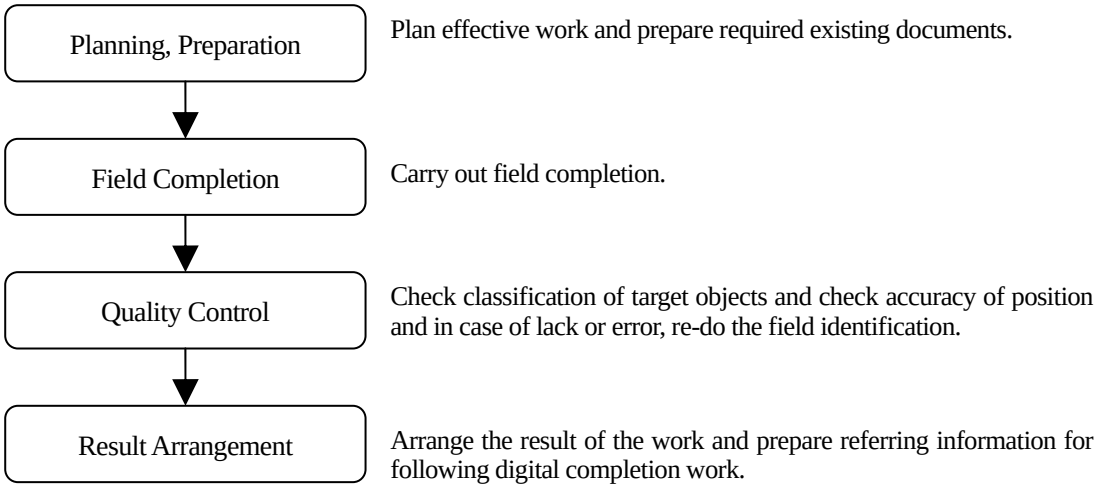


Figure. 18 Workflow of Field Compilation

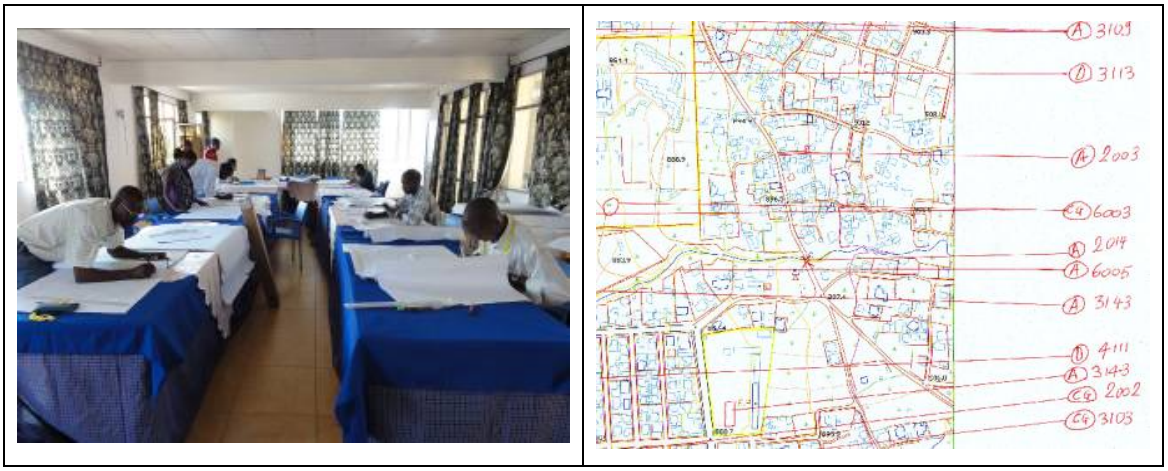


Figure. 19 Result Arrangement

(Left: work, right: result)

3-19. Digital Compilation after Field Completion [Work in Japan and Burundi]

The digital compilation after field completion was implemented for the purpose of incorporating the outputs of the field completion into the topographic map data. In practice, new data obtained in the field completion at certain positions was processed in the same way as in the digital compilation. The data on administrative boundaries and annotations were added to the output data of the digital compilation after field completion to create topographic map data.

The technology transfer was implemented with the data of the target area of the technology transfer selected in the consultation between the IGEBU and Study Team created by the IGEBU side, and the CAD application (Bentley Map).

3-20. Structuralization of Digital Data [Work in Japan and Burundi]

The topographic map data created in the digital compilation after field completion was structuralized into digital data which could be used in GIS in accordance with the provisions of the specifications determined in the Discussion on the Specifications. The topographic map data was structuralized into practical and easy-to-use GIS basic data which could be used for a wide variety of purposes.

The 1/5,000-scale and 1/25,000-scale topographic map data was structuralized into two sets of GIS data at respective scales.

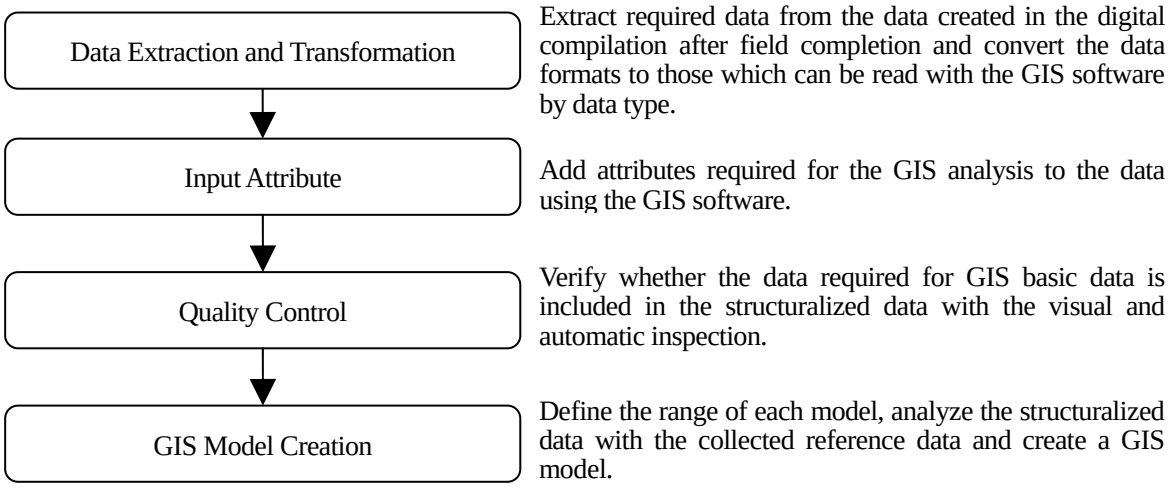


Figure. 20 Workflow of Data Structuralization

In the technology transfer, GIS software (ArcGIS) was used for the structuralization of the topographic map data of the target area of the technology transfer selected in the consultation between the IGEBU and the Study Team which were created by the IGEBU staff members in the digital compilation after field completion.

3-21. Map Symbolization of Topographic Maps [Work in Japan and Burundi]

Map symbols were provided to the topographic map data created in the digital compilation after field completion in the map symbolization in accordance with the map specifications determined in the Discussion on the Specifications. As the representations on topographic maps and data acquisition criteria differ between the topographic maps at the different scales, CAD software (MicroStation) and graphic software (Illustrator) were used in the map symbolization for the creation of the 1/5,000 and 1/25,000 topographic maps, respectively. While data of many planimetric features is acquired with actual shapes and at actual positions at the scale of 1/5,000, a large number of features are symbolized with simplified shapes and approximate positions at the scale of 1/25,000. Illustrator is very useful in the symbolization

of features for the creation of the 1/25,000 topographic maps as it is good at creating colors and printing in color. For the reasons mentioned above, the two different types of software were used in the map symbolization in order to maximize the work efficiency and to make the best use of the two types of software at the respective scales.

The technology transfer was implemented with the data of the target area of the technology transfer selected in the consultation between the IGEBU and the Study Team which was created by the IGEBU staff members in the digital compilation after field completion.

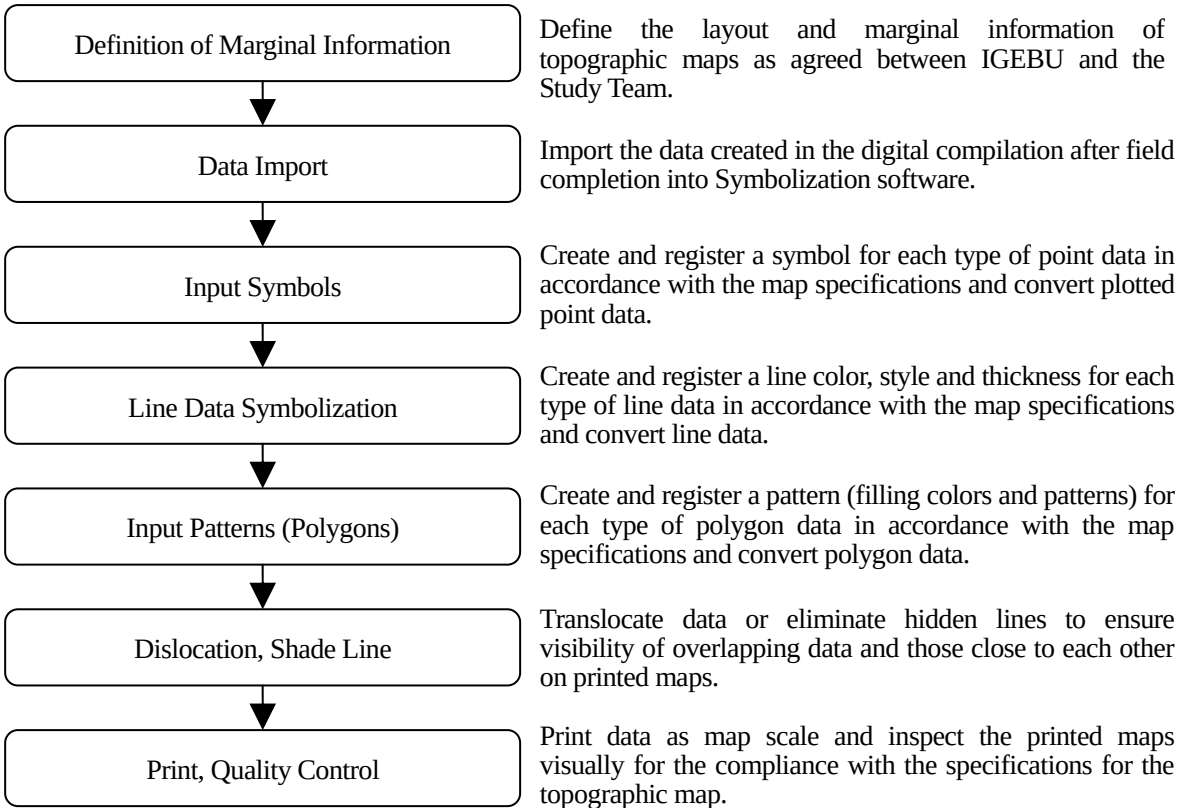


Figure. 21 Workflow of Map Symbolization

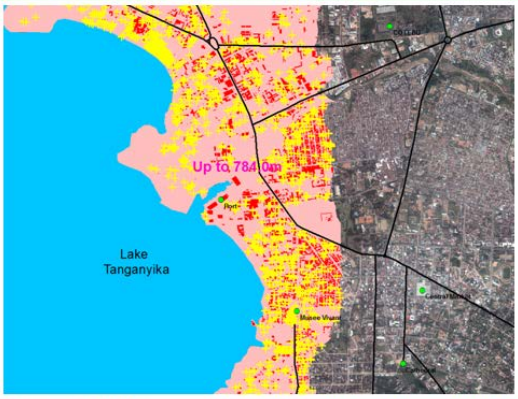
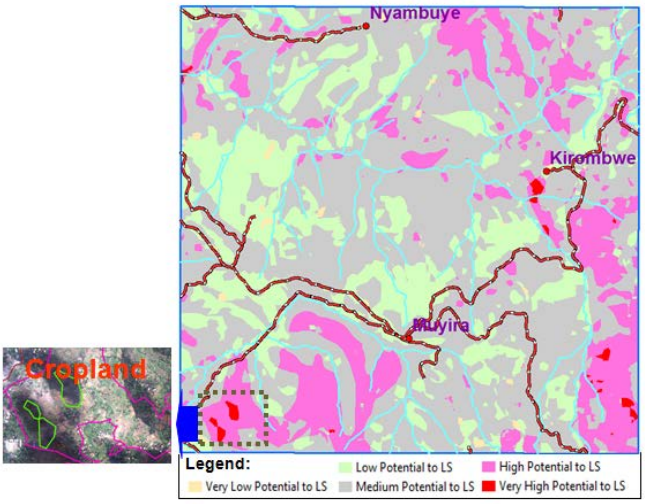
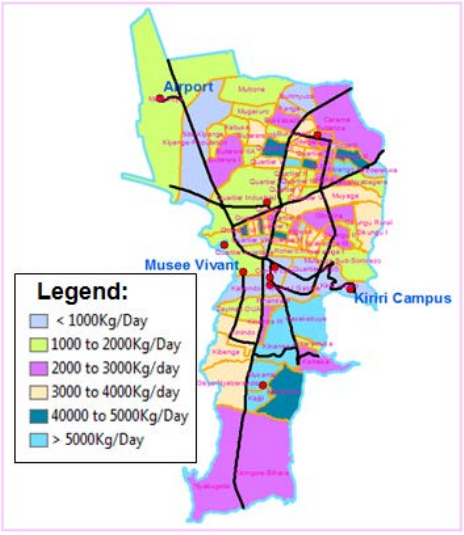
3-22. Creation of GIS Model Systems [Work in Japan and Burundi]

The contents of the created 1/5,000- and 1/25,000-scale GIS basic data, problems in Burundi and the results of the field study on the actual conditions were analyzed for the selection of GIS model systems to be created in the technology transfer. Then, the data required for the creation of the four selected GIS model systems was collected.

Table. 8 Data Collected for the Creation of GIS Model Systems

Data	Data provider	GIS model system
Geological maps (1/50,000)	Ministère de l'Energie et des Mines	Landslide control
Statistical Yearbook - 2009	Institut de Statistiques et d'Etudes Economiques du Burundi (ISTEEBU)	Flood control Waste management Health care
Data on the administrative boundaries in Bujumbura	Marie de Bujumbura	Flood control Waste management Health care
List of hospitals and health centers	Ministère de la Santé Publique	Health care
Soil maps (1/50,000)	Institut des Sciences Agronomiques du Burundi (ISABU)	Landslide control
Change in the water levels of Lake Tanganyika	IGEBU	Flood control
Household waste production	Marie de Bujumbura	Waste management

The figures below show the four types of GIS application models created with the collected data mentioned above and the topographic map data. A presentation on the GIS model systems created in this Study was made at the Seminar as the first step for the disclosure of the GIS data and extension of the use of geographic data in Burundi.

Flood control	To predict flood damage caused by the rising water levels in Lake Tanganyika by analyzing the data of the change in the water level, building data and elevation data	➢ ***Highest Water Level: 783.3m (In 1878)*** ■ With Water Level up to 784.0m (10m rise than normal level), then  ➢ **5,436 Large buildings and 2,341 Small building will be flooded.**
Landslide control	To identify the locations prone to landslides and the locations where urgent measures are required for them by analyzing data on slopes created from the data on soil and land use, and elevation data	■ Potential Land Slide Area and in Existing Cultivation Areas 
Waste management	To estimate household waste production per day by quarter by analyzing statistical data (on population) and data on administrative boundaries, household waste and buildings	■ Garbage Production in Each Cartier with Average Stand 

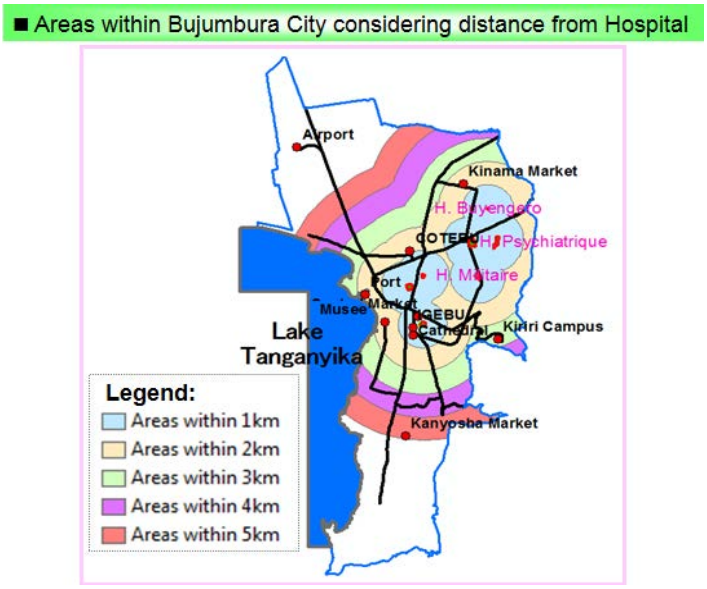
Health care	To elucidate distribution of healthcare facilities and access to the facilities by area residents by analyzing the positional data of hospitals and health centers and building data	

Figure. 22 Outline of GIS Models

3-23. Data File Creation [Work in Japan and Burundi]

The created 1/5,000- and 1/25,000-scale topographic map data, GIS basic data and orthophotos were converted into formats suitable for their use and saved in appropriate recording media. The technology transfer on the format conversion was implemented.

3-24. Creation of Draft Final Report (DF/R) [Work in Japan]

The Study Team prepared a draft final report (DF/R) which summarized the work implemented so far in the Study. The work manuals prepared in the process were also included in the report. The manuals were attached to the report for the convenience of use. The team also created materials for the presentation such as PowerPoint slides.

3-25. Holding of Seminar/Workshop [Work in Burundi]

The Study Team held the Seminar for the purpose of extending the use of the digital topographic maps, GIS data and geographic information on 14th February 2013. Ninety-two people from 23 organizations participated in the Seminar. The participants from the organizations that had interest in using the data asked questions and expressed their views on the use of the data and the GIS models. After the seminar, a ceremony to commemorate the presentation of the outputs of this Study to the Burundian side was held in the presence of the Second Vice President of Burundi and the Japanese Ambassador to Kenya. The Vice President expressed his gratitude for the creation of digital topographic maps. The Ambassador mentioned that the outputs of this Study would facilitate infrastructure development and farmland reform in Burundi and emphasized the necessity of topographic maps in his address.

The seminar and the ceremony were attended by many members of the media and reported on the radio and television on the same day. Newspapers had long articles on them on the following day. Through the media coverage, not only the members of the relevant institutions but also all ranks of people in Burundi became aware of the outline and the outputs of this Study. The subjects of the presentations at the seminar were:

- Explanation of the work in this Study;
- Explanation of the outputs;
- Explanation of the digital technologies used in this Study;
- Presentation on the use of the GIS basic data on the created digital topographic maps and GIS model systems; and
- Vision for the construction of a system for the extension of the use of the geographic data.

The table below shows the breakdown of the number of the participants of the seminar by organization.

Table. 9 Participants of the Seminar

	Organization	Number of participants
1	Cabinet de Deuxieme Vice-président	2
2	Ministère de l'Eau, de l'Environnement, de l'Aménagement de territoire, de l'Urbanisme	10
3	Ministère de l'Interieur	1
4	Comite pilotage, Bureau de centralisation geomatique	2
5	Bureau des etudes strategiques, Presidence de la Republique	1
6	ISTEEBU(Institut de Statistiques et d'Etudes Economiques du Burundi)	1
7	Ministère de l'Agriculture et l'Elevage	1
8	Ministère de l'Energie et des Mines	1
9	Ministère des Travaux Publics et du Transport	1
10	Ministère des Affaires Etrangères	3
11	Mairie de Bujumbura	2
12	Province de Gitega	1
13	SETEMU(Régie des Services Techniques Municipaux)	3
14	REGIDESO (Régie de production et de distribution d'eau et d'électricité)	7
15	Université du Burundi	4
16	Cadastre national	3
17	Ambassade du Japon	2
18	JICA Kenya	1
19	JICA Burundi	6
20	JICA Rwanda	1
21	JICA Study Team	6
21	IGEBU	22
22	PROJET EUROSHA(EUROPEAN OPEN-SOURCE HUMANITARIAN AID VOLUNTEERS)	2
23	Media organizations (five TV and radio stations)	9
	Total	**92 people**

Table. 10 Questions and Answers at the Seminar

Name	Affiliation	Questions and answers
NIKOBAGOMBA Nestor	Ministry of Water, Environment, Land Management and Urban Planning	1. Have the GIS models and orthophotos been made available? (Answer by the Director of the Department of Cartography and Topography, Mr. Thomas) No. IGEBU is having a discussion on the method to provide this data. 2. How will potential users exchange this data among themselves? (Answer by the Director of the Department of Cartography and Topography, Mr. Thomas) IGEBU is having a discussion on the way to exchange the data.
MINANI Bonaventure	Municipal Technical Service Corporation (SETEMU) of Bujumbura	1. What are the horizontal accuracies of these maps ? (Answer by the JICA Study Team) They are 3 m on the 1/5,000-scale maps and 15 m on the 1/25,000 maps.
SINDAYIHEBURA Bernard	University of Burundi	1. What coordinate system was used in the Study? (Answer by the Head of the Service of Geodesy and Leveling, Mr. Eugène) WGS 84 was used.
NAHIMANA Louis	University of Burundi	1. What is the number of layers? (Answer by the JICA Study Team) It is 170. 2. Is it possible to overlay the 1/50,000-scale old maps on the maps created in this Study? (Answer by the JICA Study Team) Yes, it is.
NGENDAKURIYO Daniel	University of Burundi	1. Why are the directions of the flight courses of the aerial photography of Bujumbura and Gitega different? (Answer by the JICA Study Team) Because there was a mountain range near Bujumbura, the flight courses of the aerial photography of Bujumbura were set parallel to it. 2. Was the contour data of the old maps used in this Study? (Answer by the JICA Study Team) No. The data on the old maps was not referred to in this Study.
RASTRY Florent	Central Control Room for Computer Mapping, the Office of the Second Vice President	1. How can this data be accessed? (Answer by the Director of the Department of Cartography and Topography, Mr. Thomas) IGEBU is having a discussion on the way to allow access to the data.
SINDAYIHEBURA Bernard	University of Burundi	1. Was the data of the floods in the past used in the creation of the GIS model for floods? (Answer by the Head of the Service of Geodesy and Leveling, Mr. Eugène) Yes. Past flood data was used as a reference.

Figure. 23 Seminar

3-26. Discussion of Draft Final Report (DF/R) [Work in Burundi]

The Study Team provided the IGEBU with explanation on the Draft Final Report and held discussion with them on the matters related to the creation of the digital topographic maps which had been implemented from the commencement until the completion of the Study, including the details of the surveys, the technology transfer and the map specifications. The proceedings of the discussion were compiled in a Minutes of Meeting (MM) and the minutes were approved by both sides, with the signatures of their respective representatives. (See Appendix-3 for the MM.)

3-27. Creation of Final Report (F/R) [Work in Japan]

The Study Team completes the preparation of the final report by editing the DF/R as necessitated by the comments on the DF/R of the Burundian side.

4. Technology Transfer

The Study Team transferred the technologies for implementing a series of work required for the creation of topographic map data to the counterparts in this Study.

4-1. Technology Transfer on Ground Control Point Survey and Installation of Pre-marks

The Study Team implemented the technology transfer on ground control point survey and installation of pre-marks in the format of OJT while implementing the scheduled work in these processes.

4-1-1. Purposes and Main Objectives

The technology transfer on ground control point survey and installation of pre-marks were implemented along the following objectives.

Table. 11 Impacts and Evaluation of the Technology Transfer on Ground Control Point Survey and Installation of Pre-marks

Subject	Main objective	Impacts on IGEBU
Reconnaissance and selection and installation of control points	Understanding of the basics of ground control point survey	Application to other projects
	Installation of control points appropriate for the photography plan	Application to other projects
	Operation of the handheld GPS devices	Application to other projects (Identification and registration of planimetric features in field identification)
	Selection of locations easily-recognized on imagery	Application to other projects (*e.g.* capacity development in photo interpretation)
GPS observation	Understanding of the ground control point survey Operation of the GPS devices	Reconstruction of a control point network Promotion of the use of GPS data
GPS analysis	Operation of the analysis software Interpretation of the analysis results	
Installation of pre-marks	Understanding of the aerial photography	Understanding of aerial photo interpretation Capacity development in interpretation of aerial photographs
	Selection of materials of markers	
	Selection of the size, shape and color of the markers	

4-1-2. Participants of the Technology Transfer

Eight survey engineers of IGEBU and survey assistants employed at the site conducted GPS survey and installed pre-marks under the guidance of a Study Team member. Four work teams, each consisting of two IGEBU engineers and two survey assistants, were formed. The Study Team provided the IGEBU engineers with training on how to operate the GPS receivers before the GPS observation.

The focus of the technology transfer on the GPS observation was on the basic operation of various types of equipment, in addition to the basics of "control point survey" and "analysis of the GPS survey results."

Table. 12 Participants of the Technology Transfer

	Name	Experience in the work concerned	Remarks
1	NIYUNGEKO Eugene	No	Team 1
2	NKUNZIMANA Didace	No	
3	SYORI Aloys	No	Team 2
4	BARIVUMA Tharcisse	No	
5	NSABIMANA Etienne	No	Team 3
6	HAJAYANA Gaspard	No	
7	NTAKARATSA Apollinaire	No	Team 4
8	NDAYISABA Elkana	No	
9	BANZIRUMUHITO Léopold	No	

The Study Team implemented the technology transfer on the outline and theories of GNSS (GPS) and coordinate transformation upon request from IGEBU. In this technology transfer, a member of the Study Team provided the counterparts with a lecture on the outline of the artificial-satellite-based GNSS (GSP) survey of late, the history of the changes in coordinate systems, the coordinate system used in the existing topographic maps of Burundi and coordinate systems widely used in recent years.

Figure. 24 Scenes in the Technology Transfer on the Ground Control Point Survey

4-1-3. Outputs of the Technology Transfer, Impact on IGEBU and Problems

The IGEBU staff members have been using the equipment for the ground control point survey procured in this Study frequently in other projects since the completion of the technology transfer and departure of the member of the Study Team in charge from Burundi. The Team has received a report that they have defined a coordinate system, installed the equipment and implemented the observation methods appropriately and obtained good analysis results.

The Study Team considers that the technology transfer on the above-mentioned subjects has achieved the goal as the team has confirmed that the IGEBU staff members have applied the transferred technologies to other projects and managed to complete the work independently.

4-2. Technology Transfer on Field Identification

4-2-1. Purposes and Main Objectives

The technology transfer on field identification was implemented along the following objectives.

Table. 13 Impacts and Evaluation of the Technology Transfer on Field Identification

Subject	Main objective	Impacts on IGEBU
Pre-interpretation	Understanding of the field identification Identification of the subjects of the field identification	Formulation of effective work plans Improvement in the understanding of subjects of identification
Field identification	Operation of the handheld GPS devices Comparison between the situation in the field and photographs Capacity development in photo interpretation	Acquisition of the effective way to use the handheld GPS devices Capacity development in spatial perception Application to the digital plotting
Arrangement of the results of the field identification	Acquisition of the methods for inspection and arrangement of the identification results	Improvement in quality of the results

4-2-2. Participants of the Technology Transfer

IGEBU selected the eight staff members as the participants of the field identification. An interview survey with the participants conducted before the technology transfer revealed that only one of them had experience in field identification.

Table. 14 Participants of the Technology Transfer

Name		Experience in the work concerned	Remarks
1	NIYUNGEKO Eugene	No	Team 1
2	KAZARI Zacharie	No	
3	SYORI Aloys	Yes	Team 2
4	BARIVUMA Tharcisse	No	
5	NSABIMANA Etienne	No	Team 3
6	KAMANA Michel	No	
7	NIDAYISABA Elkana	No	Team 4
8	HASAYANA Gaspard	No	

4-2-3. Outputs of the Technology Transfer, Impact on IGEBU and Problems

As in the technology transfer in the ground control point survey, the field identification was implemented by the eight IGEBU staff members in four work teams. The member in charge of the field identification of the Study Team accompanied different teams in turn every day and provided them with OJT. The Study Team had decided to evaluate the level of understanding of the details of the work in the field identification by the IGEBU staff members by inspecting their behaviors at sites and the quality of the results of their field identification in the second half of the field identification.

Although the participants were observed to make errors on code numbers and locations of the subjects for

the identification and omit subjects in the first half of the field identification, the number of the omissions and errors on locations decreased as their understanding of the identification subjects improved as the work progressed, with the daily instruction and advice from the member of the Study Team.

The Study Team noticed no problem in their attitude toward the work as they listened to the advice from the Study Team member intently.

The above-mentioned observations have led the Study Team to conclude that the eight participants have acquired the capacity to implement the work in field identification independently without serious problems.

Figure. 25 Scenes in the Technology Transfer on Field Identification
(Left: lecture, right: identification of a position on a photograph)

4-3. Technology Transfer on Aerial Triangulation

4-3-1. Purposes and Main Objectives

The technology transfer on aerial triangulation was implemented along the following objectives.

Table. 15 Impact and Evaluation of the Technology Transfer on Aerial Triangulation

Subject	Main objective	Impacts on IGEBU
Aerial triangulation	Operation of PC and the software Understanding of the concept of the digital aerial triangulation Understanding of the method for the evaluation of the results of aerial triangulation	Improvement in the efficiency and productivity and cost reduction with the use of digital technologies and an effective combination of automatic and interactive processing

4-3-2. Participants of the Technology Transfer

IGEBU selected two staff members from those who had participated in the field identification as the participants of the technology transfer on aerial triangulation on the basis that it was recommendable for

IGEBU to have someone who understands the entire process of the creation of the topographic maps. The Study Team conducted a questionnaire inquiry of the participants listed before the technology transfer.

The inquiry revealed that, although one of the participants had experience in the analog aerial triangulation, neither of them had experience in digital aerial triangulation or the use of the software for photogrammetry (LPS from ERDAS, Inc.) to be used in the technology transfer.

Table. 16 Participants of the Technology Transfer

	Name	Experience in the work concerned	Remarks
1	SYORI Aloys	Experience in analog aerial triangulation	Neither had experience in digital aerial triangulation or the use of the software concerned.
2	KWITONDA Sosthène	No knowledge of the theory of or the technologies for aerial triangulation	

4-3-3. Outputs of the Technology Transfer, Impact on IGEBU and Problems

The IGEBU staff members acquired the capacity to implement the aerial triangulation independently in the technology transfer. The results of their aerial triangulation satisfied the specifications for the 1/5,000 topographic map creation.

The same method as the one used by the Study Team in this Study (which used the outputs of digital aerial photography) was used in the technology transfer. IGEBU asked the Study Team whether the old analog photographs of theirs could be used on the digital plotter in future. In response, the Study Team provided a brief explanation on the method of aerial triangulation using analog photographs.

These facts suggest that the IGEBU staff members have acquired the capacity required for the independent implementation of aerial triangulation with analog and digital aerial photographs in projects in future. The Study Team recommended that the two IGEBU staff members who participated in the technology transfer should try to share the knowledge and technologies acquired in the technology transfer with other staff members (internal technology transfer), instead of keeping them to themselves, and train themselves to improve their capacity for the improvement of the functions of IGEBU as a whole.

Figure. 26 Scenes in the Technology Transfer on Aerial Triangulation

(Left: lecture on the theories, right: practice)

4-4. Technology Transfer on Digital Plotting

4-4-1. Purposes and Main Objectives

The technology transfer on digital plotting was implemented along the following objectives.

Table. 17 Impacts and Evaluation of the Technology Transfer on Digital Plotting

Subject	Main objective	Impacts on IGEBU
Digital plotting (1/5,000) (1/25,000)	Operation of PC and the software Operation of the stereo plotter Capacity development in three-dimensional measurement Data acquisition methods compliant with the specifications and appropriate for the scales	Improvement in efficiency and productivity and cost reduction with the understanding of the effective methods for the acquisition of 2-D and 3-D data and the data creation method

4-4-2. Participants of the Technology Transfer

The two IGEBU staff members shown in the table below participated in the technology transfer on the digital plotting. IGEBU selected them from its staff members who participated in the field identification as they did in the technology transfer on aerial triangulation. In order to prepare a plan for the efficient technology transfer, the Study Team conducted a questionnaire inquiry of the participants before the technology transfer. (See Appendix for the result of the inquiry.)

The inquiry revealed that neither of the participants had experience in using the photogrammetric software (LPS from ERDAS, Inc.) or the CAD software (MicroStation from Bentley Systems, Inc.) to be used in the technology transfer.

Table. 18 Participants of the Technology Transfer

Name		Experience in the work concerned	Remarks
1	NDAYISABA Elkana	No	He did not have experience in using the software used in the technology transfer.
2	HAJAYANDI Gaspard	No	He had PC skills, however, did not have experience in using the software used in the technology transfer.

4-4-3. Outputs of the Technology Transfer, Impact on IGEBU and Problems

The participants have mastered the basic operation of the hardware and software, on which the focus of the technology transfer was. However, the technology transfer on the use of the special mouse used in the digital plotting (TopoMouse) was limited to the use of the absolutely indispensable functions, despite the

fact that it had many buttons to improve the efficiency of the plotting and the effective use of all these buttons would increase the speed of the work significantly.

The most important and absolutely indispensable capacity required in the digital plotting is the capacity to measure a feature on a stereo model constructed with two aerial photographs accurately in 3-D space. This is because horizontal positions of features such as buildings and roads cannot be measured accurately unless their heights are measured accurately in the 3-D space. The Study Team considers that the IGEBU staff members have learned the important basics of the digital plotting as they have learned how to measure objects with correct heights in the 3-D environment.

The participants practiced the 1/5,000 plotting of a (approx. 7km^2) part of Gitega City in the technology transfer. Although it took them a long time, they managed to implement the work staying aware of the difference in the acquisition methods of the data of features which appeared in models. At the same time, they practiced creation of 1/25,000 data from the results of the above-mentioned practice. In this way, the participants managed to complete the technology transfer while learning the difference in data acquisition and representation methods at the different scales.

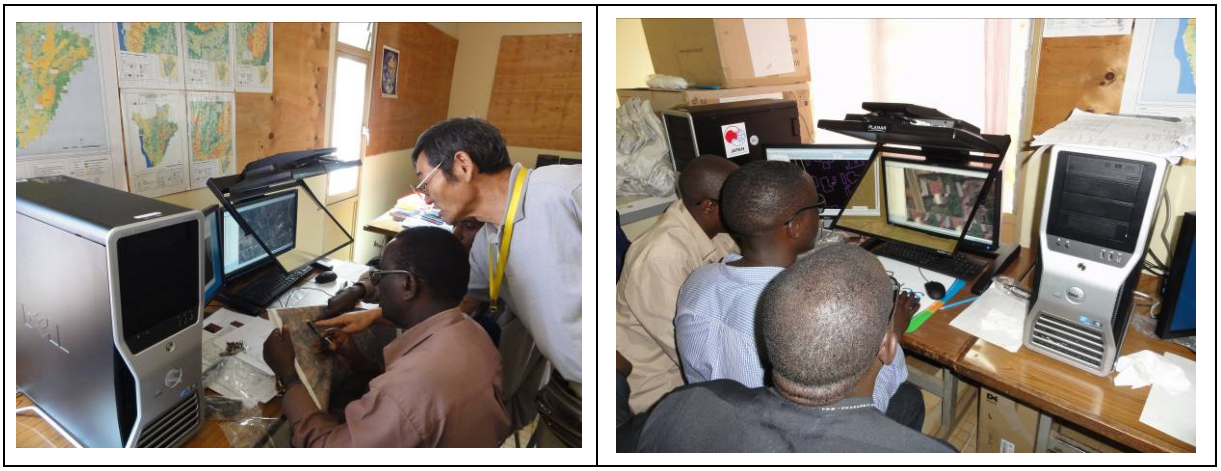


Figure. 27 Scenes in the Technology Transfer on the Digital Plotting
(Right: the member of the Study Team in charge of the digital plotting giving instruction to a participant, right: practice by the IGEBU staff members)

4-5. Technology Transfer on Field Completion

4-5-1. Purposes and Main Objectives

The technology transfer on field completion was implemented along the following objectives.

Table. 19 Impacts and Evaluation of the Technology Transfer on Field Completion

Subject	Main objective	Impacts on IGEBU
Field completion	Understanding of the field completion work Operation of the handheld GPS devices Verification of topographic maps in the field	Acquisition of know-how for implementation of the work Acquisition of the effective way to use the handheld GPS devices Capacity improvement in interpretation of topographic maps
Arrangement of the results of the field completion	Arrangement of the results on maps	Improvement in quality of the results Application to the digital compilation after field completion

4-5-2. Participants of the Technology Transfer

IGEBU selected the eight (nine) IGEBU staff members shown in the table below as the participants of the technology transfer on field completion. Most of them had participated in the field identification.

Table. 20 Participants of the Technology Transfer

Name		Participation in field identification		Remarks
1	SYORI Aloys	Yes	Participation in the first half	Team 1
2	KAMANA Michel	Yes	Participation in the second half	
3	KWITONDA Sosthène	No		
4	NIYUNGEKO Eugene	Yes		Team 2
5	SINZINKAYO Juvenal	No		
6	NDAYISABA Elkana	Yes		Team 3
7	KABERA Gilbert	No		
8	HAJAYANA Gaspard	Yes		Team 4
9	BARIVUMA Tharcisse	Yes		

4-5-3. Outputs of the Technology Transfer, Impact on IGEBU and Problems

The methods used in the field completion differ little from those used in the field identification. Topographic maps are used in the field completion where orthophotos are used in the field identification.

As in the technology transfer on field identification, the member of the Study Team in charge of the field completion accompanied different teams in turn every day and provided them with OJT. The Study Team decided to evaluate the level of their understanding of the work in field completion by observing their attitude in the field and inspecting the quality of the results of the field completion in the second half.

Partly because most of the participants had also participated in the field identification, they had no problem

in understanding the details of the work. Although they required some time to find correspondence between data on the topographic maps and features in the field in the beginning, the time required for finding correspondence had decreased as the work progressed. The Study Team concludes that the participants have identified the points to be noted in the fieldwork through the implementation of the inspection and arrangement.

Figure. 28 Scenes in the Field Completion
(Left: briefing, right: joint training)

4-6. Technology Transfer on Digital Compilation/Digital Compilation after Field Completion

4-6-1. Purposes and Main Objectives

The technology transfer on digital compilation was implemented along the following objectives.

Table. 21 Impacts and Evaluation of the Technology Transfer on Digital Compilation

Subject	Main objective	Impacts on IGEBU
Digital compilation (at 1/5,000 and at 1/25,000)	Operation of PC and the software Digital compilation of plotted data Data cleaning Polygon data creation	Improvement in efficiency and productivity and cost reduction with the understanding of the various commands for the digital compilation and the understanding of the combined use of the automatic and interactive error detection and correction

4-6-2. Participants of the Technology Transfer

The two IGEBU staff members shown in the table below participated in the technology transfer. The inclusion of participants of the digital plotting in the digital compilation gives them an opportunity to correct the errors which they made in the digital plotting by themselves and, thus, to learn the errors likely

to be made in the digital plotting. The participation is also expected to give them an opportunity to review the operation of the software and to deepen the understanding of the software operation, since the same software (MicroStation from Bentley Systems, Inc.) is used in both digital plotting and digital compilation. For these reasons, IGEBU selected the participants of the technology transfer on the digital plotting as the participants of the technology transfer on the digital compilation. In order to design an efficient technology transfer, the Study Team conducted a questionnaire study of the two participants before the technology transfer.

The study revealed that, although both participants had understanding of the basic drawing functions as they had learned them in the technology transfer on digital plotting with MicroStation, they knew almost nothing about the compilation functions.

Table. 22 Participants of the Technology Transfer

Name		Experience in the work concerned	Remarks
1	NDAYISABA Elkana	No	The participant attended the technology transfer on digital plotting.
2	HAJAYANDI Gaspard	No	The participant attended the technology transfer on digital plotting.

4-6-3. Outputs of the Technology Transfer, Impact on IGEBU and Problems

The Study Team evaluated the technology transfer on digital compilation in which data of Gitega City created by the counterparts at the scales of 1/5,000 and 1/25,000 in the digital plotting were used as follows:

The counterparts were able to master digital compilation at the scale of 1/5,000 and practice the appropriate digital plotting methods for the second time by revising unnecessary point data and the data of buildings and roads which had been acquired in shapes too complex for the scale of 1/5,000 in the digital plotting in the practice of the digital compilation for the creation of 1/5,000 topographic maps.

The counterparts managed to implement the digital compilation for the creation of 1/25,000 topographic maps with the understanding of the difference in the scale from the 1/5,000 topographic maps and by selecting appropriate compilation functions in the practice of the digital compilation at the scale of 1/25,000.

As the counterparts had multiple opportunities to practice data cleaning and polygon creation in the practices of creating polygons from the data plotted at the scales of 1/5,000 and 1/25,000, they managed to complete the last practice, the creation of polygon data of administrative boundaries, without relying on the member of the Study Team.

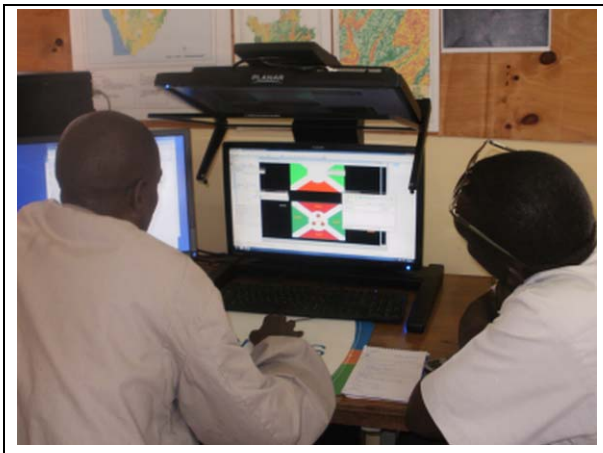
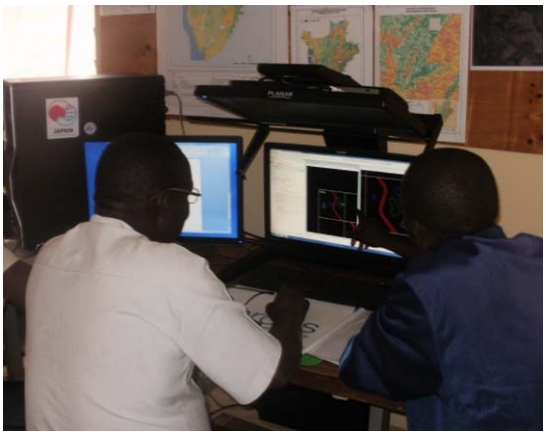



Figure. 29 Scenes in the technology transfer on digital compilation
(left: basic operation of the software, right: basics of digital compilation)

4-7. Technology Transfer on Map Symbolization

4-7-1. Purposes and Main Objectives

The technology transfer on map symbolization was implemented along the following objectives.

Table. 23 Impacts and Evaluation of the Technology Transfer on Map Symbolization

Subject	Main objective	Impacts on IGEBU
Map symbolization (at 1/5,000)	Operation of PC and the software (MicroStation) Creation of symbols by data type (point, line or plane) Symbolization of the data for printing 1/5,000 topographic maps	Understanding of map symbols and topographic maps Capacity development in the creation of data for printing
Map symbolization (at 1/25,000)	Operation of the software (Illustrator) Creation of symbols by data type (point, line or plane) Symbolization of the data for printing 1/25,000 topographic maps	

4-7-2. Participants of the Technology Transfer

Two IGEBU staff members participated in the technology transfer. The Study Team conducted a questionnaire study of them before the technology transfer.

The study revealed that, although neither of them had experience in using either MicroStation or Illustrator to be used in this technology transfer, they had knowledge of the concept of the symbolization because they had used the map symbols in the field identification and field completion.

Table. 24 Participants of the Technology Transfer

	Name	Experience in the work concerned	Remarks
1	SYORI Aloys	No	
2	KABERA Gilbert	No	

4-7-3. Outputs of the Technology Transfer, Impact on IGEBU and Problems

The Study Team evaluated the technology transfer on map symbolization as follows, on the basis of the quality of the map symbolization at the scales of 1/5,000 and 1/25,000 performed by the counterparts.

The participants seemed confused and disoriented with the use of the two different types of software for the map symbolization at the different scales (MicroStation at 1/5,000 and Illustrator at 1/25,000) in the beginning. However, they had managed to understand the advantages and characteristics of each type of the software by the end of the technology transfer. They were also able to deepen their understanding of the difference in the representations on maps at the different scales.

One of the two trainees had experience in using a CAD application, though not MicroStation, in the past and sufficient knowledge with regard to topographic maps including the understanding of the necessity for printed maps and implemented the work accurately while taking memos earnestly.

The training for the other participant had to begin from the introductory level as he had little experience in using computers. He improved his capacity extremely fast by taking notes all the time and repeating reviews. His interest in art contributed significantly to the work that required “artistic taste,” such as translocation of symbols. He performed even monotonous work without complaints.

As both of them have capacity to transmit information and apply technologies to other projects, the team expects them to play a central role in renewal of map data and creation of new maps.

Figure. 30 Scenes in the Technology Transfer on Map Symbolization
(left: basics of the symbolization at 1/5,000, right: symbolization at 1/25,000)

4-8. Technology Transfer on Data Structuralization

4-8-1. Purposes and Main Objectives

The technology transfer on data structuralization was implemented along the following objectives.

Table. 25 Impacts and Evaluation of the Technology Transfer on Data Structuralization

Subject	Main objective	Impacts on IGEBU
Definition of the GIS structuralization Creation of GIS basic data	Understanding of the outline of GIS Operation of the GIS software (ArcGIS)	Extension and promotion of the use of GIS in the assistance to formulation of priority projects in the National Development Plan and establishment of the basis for the existence of IGEBU
Creation of GIS model systems	Use of GIS	

4-8-2. Participants of the Technology Transfer

The following table shows the five IGEBU staff members who participated in the technology transfer. The Study Team conducted a questionnaire study of them before the implementation of the technology transfer. (See Appendix for the result of the study). The study revealed that four of them had already had experience in using ArcGIS.

Table. 26 Participants of the Technology Transfer

Name		Affiliation	Experience in data structuralization	Remarks
1	NTUMIGOMBA Protais	IGEBU Director	No	Experience in using ArcGIS
2	NIYUNGEKO Eugene	IGEBU Urban Planning	No	Experience in using ArcGIS
3	BARIVUMA Tharcisse	IGEBU Géomètre - Topographe	No	
4	NIBITEGUZA Sylvestre	IGEBU Photogrammètre	No	Experience in using ArcGIS
5	MUCOMWIZA Jean-Marie	Bujumbura Mairie Chef Service Informatique	No	Experience in using ArcGIS

4-8-3. Outputs of the Technology Transfer, Impact on IGEBU and Problems

The Study Team evaluated the outcome of the data structuralization and the GIS model system creation as follows:

All the trainees managed to master the basic operation of the software and reach the technical level at which they could structure the data created in the digital compilation and enter the created data into the software at an acceptable speed. All the participants were able to express their views on the basic concept of GIS and data analysis in GIS to the others and understood the views of the others fully through active exchange of views in the discussion.

The participants acquired the capacity to create data for presentation on the created GIS model systems and make presentations using the created data in the training.

Figure. 31 Scenes in the Technology Transfer on Data Structuralization