Republic of Mali
Ministry of Equipment, Transport and Rural Development
Institut Géographique du Mali (IGM)

DIGITAL TOPOGRAPHIC MAPPING PROJECT

FOR THE BAMAKO METROPOLITAN AREA

IN THE REPUBLIC OF MALI

FINAL REPORT

(SUMMARY)

December 2016

Japan International Cooperation Agency (JICA)

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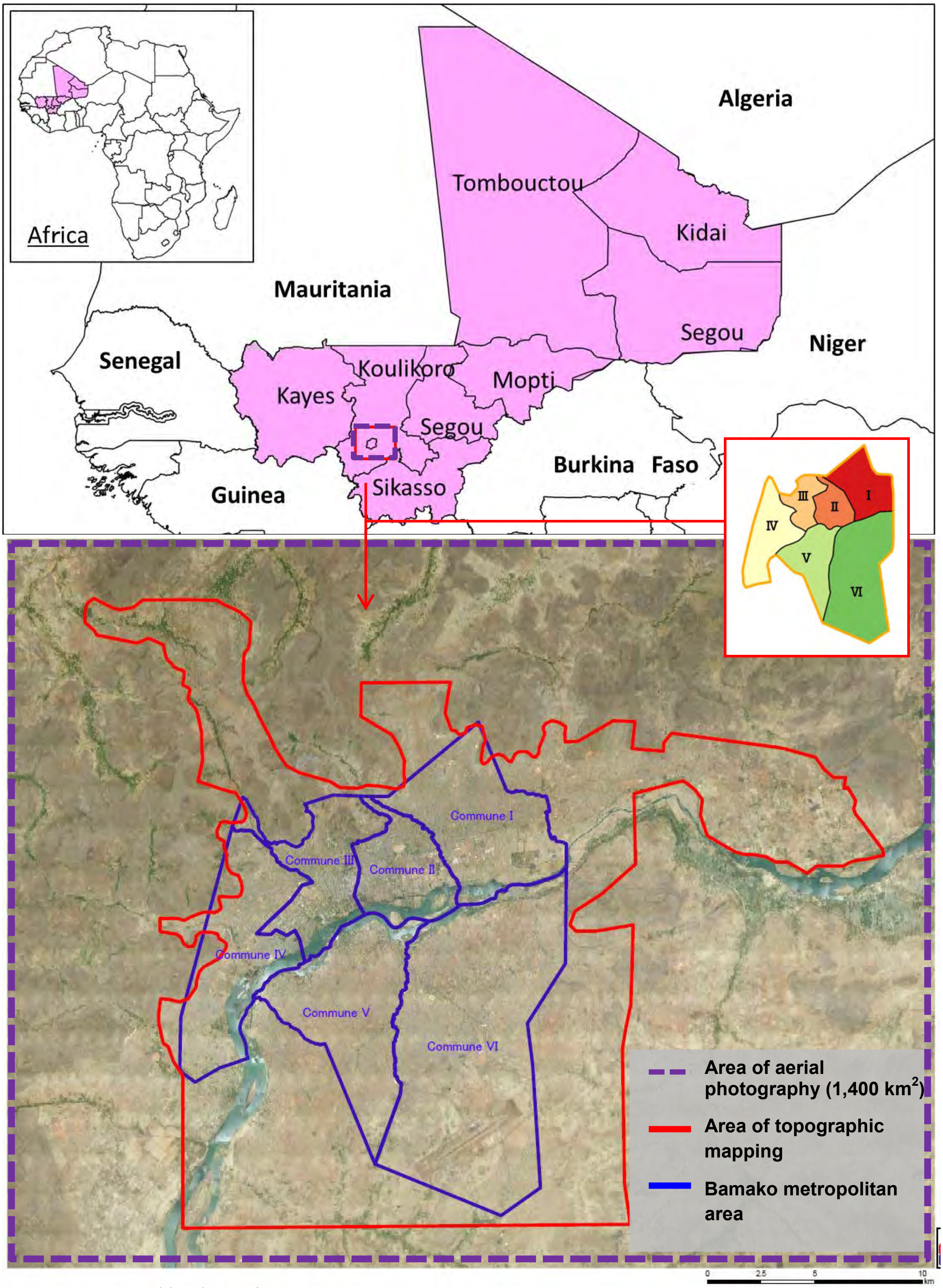
Map of the Target Area



Source: Prepared by the Project Team

Photo Album

Kick-off Seminar

Existing Geodetic Point (B-11)

GCP Survey Planning

Training on GNSS Antenna Installation

Training on Leveling

Leveling Work

Discussion on Mapping Specifications

Aircraft for Aerial Photography

Workshop for Field Identification

Training on the Use Field Survey Equipment

Field Survey Training

Field Identification

Field Completion Workshop

Technical Training on Field Completion

Scene of Field Completion

Preparation for Workshop (Facilitator Development)

Workshop for Working-level Personnel of GIS Users

Group Work by Theme

Group Presentation

Technical Training in 3-dimensional Measurement

Technical Training in Digital Compilation

GIS Training

IGM Open Forum (demonstration by staff of IGM)

List of Abbreviations

Abbreviation	Full Form
AFD	Agence Française de Développement
AGETIPE	Agence d'Exécution des Travaux d'Intérêt Public pour l'Emploi
ANAC	Agence Nationale de l'Aviation Civile
ANASER	Agence Nationale de la Sécurité Routière
CAD	Computer-Aided Design
CGIG	Centre de Gestion de l'Information Géographique
CIIG	Conseil Interministériel d'Information Géographique
CNIG	Comité National d'Information Géographique
CNPCT	Centre National de Production Cartographique et Topographique
CRIG	Comité Régional d'Information Géographique
CTAC	Cellule Technique d'Appui aux Communes
DEM	Digital Elevation Model
DGCT	Direction Générale des Collectivités Territoriales
DGPC	Direction Générale de la Protection Civile
DNACPN	Direction Nationale de l'Assainissement et du Contrôle des Pollutions et des Nuisances
DNCT	Direction Nationale de la Cartographie et de la Topographie
DNDC	Direction Nationale des Domaines et du Cadastre
DNH	Direction Nationale de l'Hydraulique
DNPD	Direction Nationale de la Planification du Développement
DNR	Direction Nationale des Routes
DNUH	Direction Nationale de l'Urbanisme et de l'Habitat
DRCT	Direction Régionale de la Cartographie et de la Topographie
DSM	Digital Surface Model
DTM	Digital Terrain Model
EO	External Orientation
EDM	Energie du Mali
GCP	Ground Control Point
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GLONASS	Global Navigation Satellite System
GSD	Ground Sample Distance
IGM	Institut Géographique du Mali
IGN France	Institut Géographique Nationale France
IMU	Inertial Measurement Unit
INT	Institut National de Topographie
ISO	International Standards Organization (International Organization for Standardization)
IT	Information Technology
JICA	Japan International Cooperation Agency
LGO	Leica Geo Office

MDB	Mairie du District de Bamako
NSDI	National Spatial Data Infrastructure
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OJT	On the Job Training
OMATHO	Office Malien du Tourisme et de l'Hôtellerie
PDF	Portable Document Format
PNIG	Politique Nationale de l'Information Géographique
POS-EO	Position and Orientation System/ External Orientation Parameter
RD	Record of Discussion
SHP	Shape File
SD	Standard Deviation
GIS	Geographic Information System
SOMAGEP	Société Malienne pour la Gestion de l'Eau Potable
TIFF	Tagged Image File Format
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

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Contents

List of Figures, Tables and Photos

1. Outline of the Project

1.1 Background of the Project

The population of Bamako, the capital of the Republic of Mali, is rapidly increasing because of economic development. According to the 1998/2009 census, the population increased from 1 million in 1998 to 1.8 million in 2009. Migration from other areas has resulted in the proliferation of unplanned settlement area and urban sprawl. Consequently, services such as water supply, sewerage system have deteriorated, resulting in a poor living environment. Furthermore, basic infrastructure such as roads, hospitals and schools are not sufficient, which impedes socio-economic growth of the country.

In light of the problems stated above, Bamako City, and the Department of Urban Development and Housing under the Ministry of Urban Planning and Housing of Mali (DNUH: Directeur Nationale de l'Urbanisme et de l'Habitat) prepared a master plan for Bamako urban development in 2011. The master plan also included improvement in infrastructure. However, it is imperative that the 1:50,000 base maps produced with assistance of the French government in 1988 are updated because existing maps are not suitable for urban planning, improving the changing infrastructure or managing the expanding informal sector. Taking into consideration the need for larger scale maps in order to update urban development master plan of Bamako City and its surrounding area, the government of the Republic of Mali requested the government of Japan to produce digital topographic maps of the Bamako metropolitan area at scale of 1:5,000 (including basic GIS data) as well as to transfer technology to Mali.

The Japan International Cooperation Agency (JICA) dispatched a Detailed Planning Survey Team. The Survey Team recognized the need for digital topographic maps and technology transfer for urban planning of the Bamako metropolitan area. The JICA Survey Team and the government of Mali agreed in the Record of Discussion of November 2011 to implement the study for developing basic GIS data.

The digital mapping project for Bamako was launched on 2nd March 2012. However, the project was discontinued following the coup that occurred on 21st March. This was attributed to the subsequent deterioration of security in the country. Nevertheless, the security situation stabilized in Bamako and its surrounding area. Therefore, the project was resumed from February 2015.

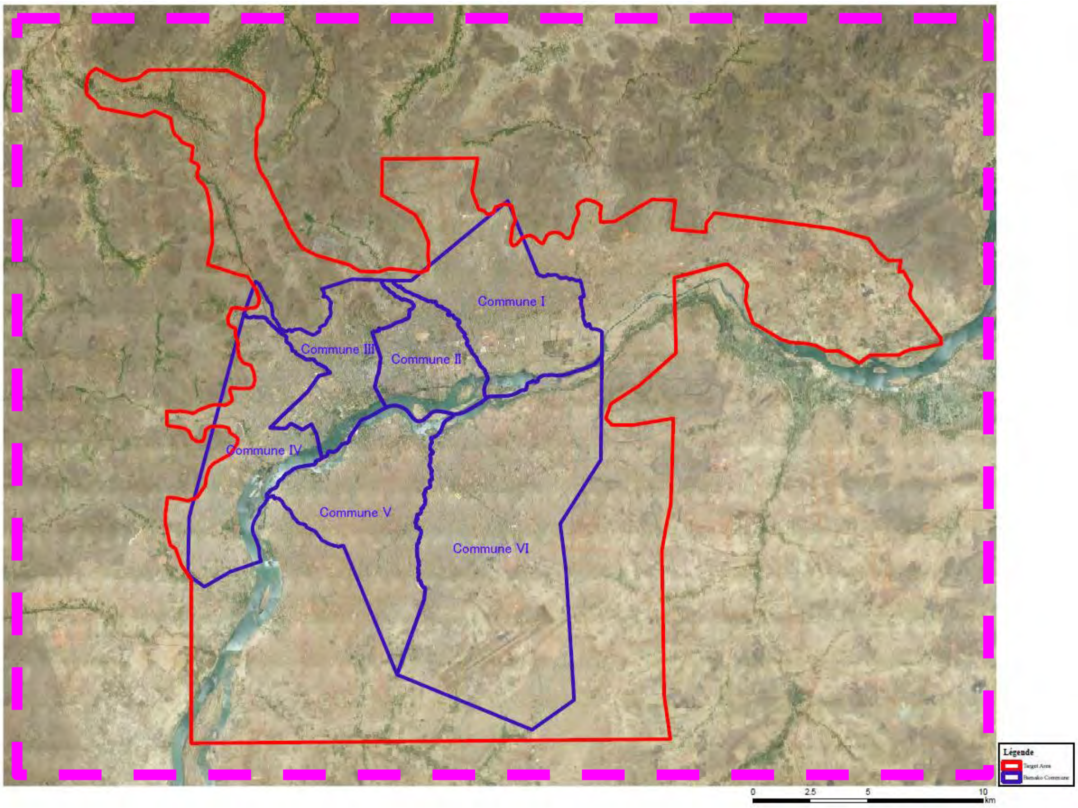
1.2 Project Objectives and Outputs

1.2.1 Objectives

In order to support the sustainable socio-economic development planning as well as improvement of urban infrastructure in the Bamako metropolitan area, the objectives of the project are to (i) produce 1:5,000-scale digital topographic maps and orthophotos, (ii) produce GIS data, and (iii) conduct technical training to IGM.

1.2.2 Target Area

Figure 1-1 shows the project area. The 1:5,000-scale topographic map covers approximately 520 km^2 (red line) in the Bamako metropolitan area, while the orthophoto map area covers approximately 1,400 km^2 (within pink colored dashed line) in Bamako and its surrounding area.



Source: Prepared by the Project Team

Figure 1-1 Target Area of Project

: Topographic map at 1:5,000 (covering approx. 520 km^2)

: Orthophoto maps covering approximately 1,400 km^2

: Bamako metropolitan area

1.2.3 Outputs

The project was implemented based on the Record of Discussion dated on November 17, 2011 in order to produce large scale digital topographic maps and GIS data in collaboration with the Geographic Institute of Mali (hereinafter called IGM). In order to achieve the objectives, the following products were produced based partly on the-job-training:

(1) Aerial photography (1,251 photos),
(2) Orthophoto maps (approximately 1,400 km^2),
(3) GCP survey results (point descriptions of GNSS observation and leveling),
(4) Result of aerial triangulation (a set of EO files),
(5) 1:5,000 digital topographic map data set (520 km^2),
(6) GIS data set (520 km^2),
(7) Topographic maps of booklet type,
(8) Technical specifications for large scale digital mapping and work manual,
(9) WebGIS Development and,
(10) Final Report (skill development of IGM in terms of creation and updating of digital topographic maps)

1.3 Counterpart Organization in Mali

IGM is the counterpart organization of this project. The counterpart organization, which is under the Ministry of Equipment, Transport and Rural Development is responsible for surveying and topographic mapping. IGM conducts surveys and produces topographic maps in response to orders or requests from other ministries and donors. IGM does not have a plan to create and update topographic maps with its own budget at present. It digitizes existing maps and creates thematic maps for clients to generate sales revenue. A detailed organization and structure of IGM is described in the next chapter.

In this project, staff members from the Map Production Department, namely, Geodetic Division, Topographic Map Division, Aerial Photogrammetry Division, Drawing Division and Printing Division implemented the assigned operations.

1.4 Content of Implemented Operations

1.4.1 Overall Composition of the Project

The project components are implemented within 21 months between late February 2015 and late October 2016. The project components focus on:

(A) Production of GIS data, and

(B) Technology transfer (see Figure 1-2).

This report has been compiled on the major operations implemented from February 2015 to October 2016 and their outcomes centered on the major activities shown in Table 1-1.

Table 1-1 Principal Activities in Mali

Work items		Activity period	Activities
Discussion on specifications (A)		Mar. – May 2015 Oct. – Nov. 2015 May – Jun. 2016 October 2016	Development of definition and standards of the 1:5,000 topographic features (Ver. 4.03) Development of technical specifications for the creation of 1:5,000 digital topographic maps (surveying system, marginal information, annotation and rules for the numbering of large scale topographic map sheet)
Aerial photography	(A)	Mar. – Apr. 2015	Selection of eligible bidders Completion of aerial photography (1,251 photos) in all the target areas (1,400 km^2)
	(B)		Implementation of technical training (Flight planning and quality control)
Ground Control Point survey	(A)	Feb. – Apr. 2015	Verification of existing national geodetic points needed for 1:5,000-scale digital mapping Completion of GNSS observation (27 points) Completion of Leveling (approximately 180 km)
	(B)		Implementation of GNSS observation in the form of OJT Implementation of leveling in the form of OJT Training in the quality control of observation results
WebGIS Development (A)/(B)		Feb. – Apr. 2015 Apr. 2016 Oct. 2016	Implementation of needs analysis and survey of IT environment Agreement on the basic design of WebGIS, training in the maintenance of WebGIS Installation and operation of WebGIS
Activities to promote utilization (A)/(B)		Mar. – May 2015 Feb. – Mar. 2016 May 2016 Oct. 2016	Kick-off seminar Interview to geospatial information stakeholders GIS workshop for the construction of NSDI Seminar for the promoting the utilization of data
Field identification survey	(A)	Oct. – Dec. 2015 Feb. 2016	Implementation of field identification survey in the form of OJT
	(B)		Implementation of workshop (understanding of definition and standards of topographic features and survey methodology) Implementation of field identification using simplified orthophoto maps
Field completion	(A)	Mar. – May 2016	Implementation of field completion survey using plotting manuscript
	(B)		Implementation of workshop (difference from field identification, capturing of question items)
Technology transfer program	Aerial triangulation (B)	Apr. – Jun. 2016	Instruction for implementation of aerial triangulation using aerial photos
	Creation of orthophotos (B)		Instruction for creating orthophoto maps based on the result of aerial triangulation
	Digital mapping (B)		Training in the measurement of elevation values and appropriate deciphering of features in 3- dimensional spatial model

	Digital compilation (B)	Apr. – Jun. 2016	Understanding topological structure and training in data input
	Symbolization (B)		Understanding 1:5,000 map symbolization criteria and training on symbol expression method
	GIS structurization (B)	Apr. – May 2016	Understanding database structure of digital geographic information and training in the construction of geodatabase
	Quality control (B) and partial modification (B)	Apr. 2016 Dec. 2015 Apr. – Jun. 2016	Understanding of the quality control method of captured aerial photographs Training on the quality control of observation results from ground control point survey Training on the quality control of data acquired in field identification Training on quality control including the accuracy control of each process of digital mapping (aerial triangulation, orthophoto creation, digital plotting, digital compilation, symbolization, GIS structurization) and training for the understanding of the difference between creation and updating (modification according to secular changes)

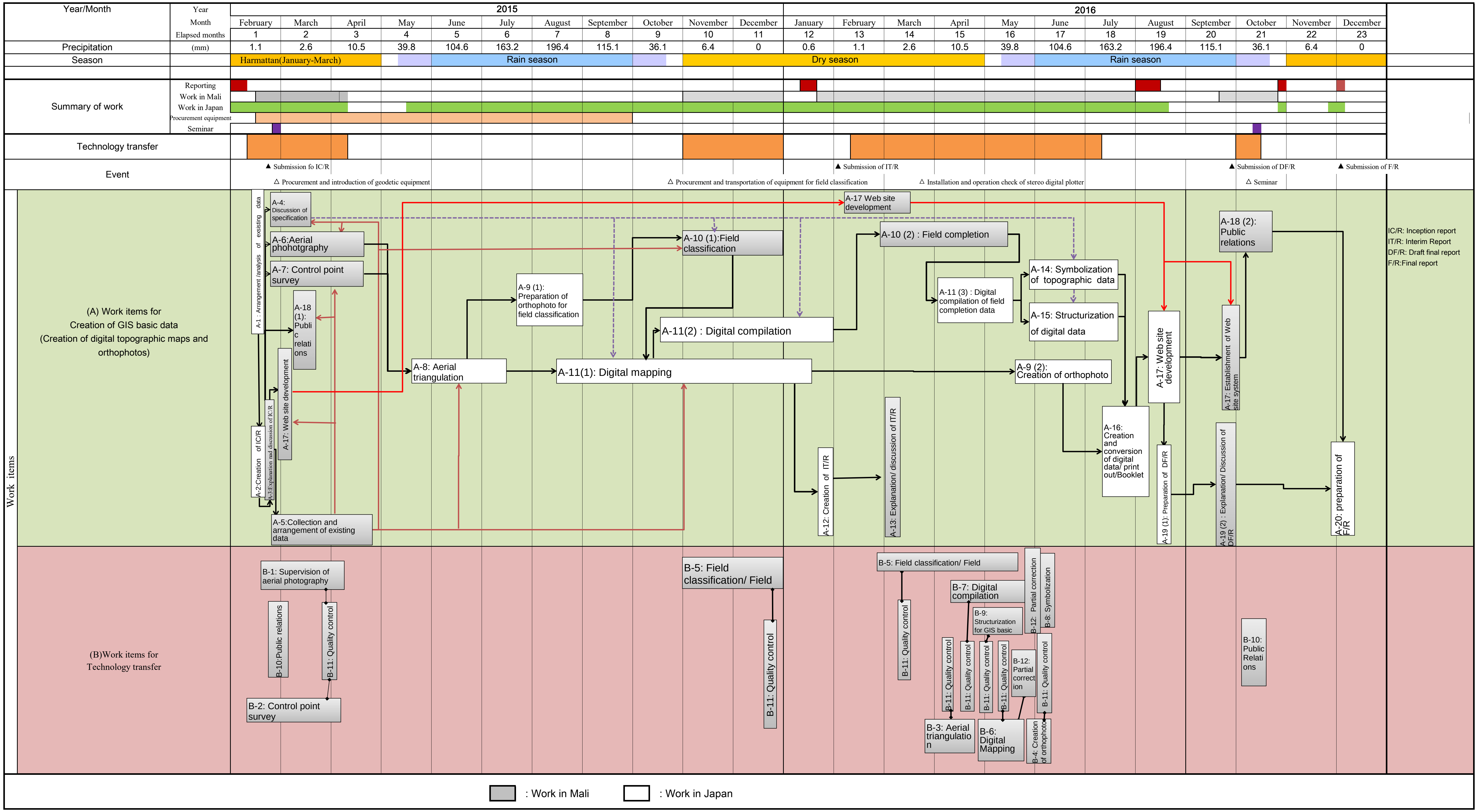


Figure 1-2 Workflow of the Project

2. Promotion of the Use of Geographic Information

It is assumed that the GIS data produced in this project will be shared by the government ministries, agencies and local governments comprising Comité National d'Information Géographique (hereinafter "CNIG") and Comité Régionale d'Information Géographique (hereinafter "CRIG"). The local government organizations were established within Conseil Interministériel d'Information Géographique (hereinafter "CIIG"), which will be described later. Therefore, it should be noted that the potential for mutual cooperation between IGM, and government ministries and agencies comprising CIIG already exists in Mali in order to upgrade and use geospatial data.

In order to promote the widespread use of the products of this project, it is important to develop a structure that will make it possible for IGM to maintain and update the content and the products of this project as their own new geospatial information in the future. In addition, geospatial information should be shared with the working level personnel of the other ministries, agencies and local governments associated with IGM. This will enable the accumulation of knowledge. Consequently, the following activities were undertaken during the implementation period of this project to promote the use of the data based on the current situation of the national spatial policy of Mali.

2.1 Previous GIS Data Development Initiatives

Geospatial information in Mali was produced before and after the independence from France, that is, in the late 1950's and early 1960's, under the technical cooperation of France. Therefore, IGM (known as DNCT in those days) has not produced geospatial information alone. However, from 1998 to 2001, JICA developed 1:50,000-scale digital topographic maps of Kita area (31,000 km^2) in the west of Bamako. Therefore, IGM used the small scale topographic mapping production technology learned during the technical training to produce thematic maps on their own. Note that only small scale topographic maps at 1:2,000,000 were available for the whole of Mali. However, National Geographical Institute of France (hereinafter "IGN France") produced 1:200,000 scale topographic maps in cooperation with IGM targeting the territory of Mali.

The four sheets of 1:20,000-scale topographic maps created by IGN France in cooperation with DNCT in the 1980's and the 10,000-scale city guide maps (thematic maps without height information) of six communes in Bamako created by IGM between 2005 and 2007 are the only available geographic information of the Bamako Metropolitan Area, the project area of this project.

Rapid influx of people in Bamako has led to expansion and development of new urban areas in recent years. However, newly developed topography and features in these areas have not been reflected in the currently available large-scale topographic maps of the city. Because of this discrepancy between the information on the maps and the actual situation, the available maps fail to satisfy the demand for geographic information of the actors in the development of the Bamako metropolitan area including government and donor organizations involved in the urban planning sector and private developers.

Large scale geospatial information is important for urban planning of the metropolitan area as well as to share data to other relevant ministries and agencies, which will enable effective planning and implementation of various development projects.

The government of Mali proclaimed an ordinance for the establishment of cabinet council and national committee on GIS data (No.02-565/P-PM) and setting-up CIIG on 16th December 2002, with the objectives of developing GIS data and actively introduces GIS to organizations. CIIG was defined as a forum of political decision-making with the ministers from different ministries as representatives and as the substructures of CIIG. In addition, CIIG was meant to serve working organizations, with the establishment of CNIG for the central government and CRIG for the local governments.

As the secretariat of CNIG, IGM has coordinated with 42 organizations, consisting of ministries, agencies, universities and research institutes with regard to the development of map data, code standardization, metadata and geographic information policy. The results of such coordination activities were compiled as the National Policy of Geographic Information (Politique Nationale d'Information Géographique, hereinafter "PNIG"), which was approved by the cabinet meeting in 2012. In addition, objectives to achieve the PNIG were established and a specific action plan was set up. Table 2-1 summarizes the PNIG outline and the contribution from this project.

Table 2-1 Outline of PNIG

Item	Content	Contributions from this project
General objective	Contribute to the socio-economic development of Mali through the establishment and continual updating of the national spatial data infrastructure (NSDI)	→ Support the NSDI initiative
Specific objective	1. Develop the basic structure of NSDI data 2. Strengthen capabilities of organizations in the production and management of geographic information 3. Strengthen cooperation on geographic information 4. Implement PR and promotion strategies in public and private sectors and in organizations that have interest in geographic information	→ Technical specifications of 1:5,000 topographic maps and GIS data → Promotion and awareness based on WebGIS, etc. → Hosting working-level GIS workshop → Hosting seminars and developing WebGIS
Action plan 2012-2016	• Establishment of Geographic Information Management Center (CGIG) • Procurement of the equipment of CGIG • Perusal of the ordinance concerning the installation of CIIG and CNIG • Collection of usable data • Identification of geographic information users • Training of organizations engaged in geographic information management	→ Self-funded → Procured part of the equipment → No contribution → Implemented in this project → Support by WebGIS, etc. → Calling at the final seminar

	・ Creation and updating of national metadata register ・ Production of basic topographic map at a scale of 1:200,000 ・ Strengthening of cooperation concerning geographic information ・ Implementation of public relations strategy, and information sharing between donors or development partners and users at organizations that have interests in geographic information	→ Implemented by IGN France → Activity after this project → Support through seminars and WebGIS
Financial resources	It is expected that the various activities contributing to the implementation of the policy will be funded by the national budget, external fund, and own revenue from the sale of products.	
National budget	Special investment budget through planned contract between the national government and IGM	
Own revenue	Revenue arising from the provision and sale of geographic information deliverables and survey services. It will be transferred to the National Geographic Information Fund (FNIG)	

Because the implementation of the policy has been delayed by turmoil in the country, practical activities in the next action plan to be implemented from 2016 on have not been decided. However, budget was allocated to the preparation for the establishment of CGIG (which was scheduled for 2012 in the Action Plan) in 2015 and IGM presented a tentative plan for the operation of CGIG in the workshop and the seminar mentioned below.

2.2 Capacity and Structure of IGM in Terms of Geographic Information

2.2.1 Organizational Structure of IGM

IGM was initially established within the Ministry of Public Works in 1964 as the National Mapping Institute (Institut National de Topographie: INT).

Figure 2-1 shows the latest organization chart of IGM, which was reorganized in 2015. The key point of the reorganization is the establishment of CGIG. Following is a brief summary of the newly established departments that are connected to this project.

(1) Geographic Information Management Center (CGIG)

With respect to CGIG, the draft budget, which was developed in accordance with the PNIG action plan, was approved in August 2015. However, preparations for installation began in March 2016. This center which collects geographic information produced by the ministries and agencies is controlled by the president of IGM. CGIG is going to be located on the first floor of the main building of IGM.

According to the current plan, CGIG will be comprised of five people. That is the head of CGIG, two experts for GIS processing, and two experts for promoting the use and management of GIS data. However, as of June 2016, no staff has been assigned yet. The Project Team was told that CGIG will be jointly managed by IGM and the staff of other ministries and agencies. CGIG is supposed to have the following three missions.

- Centralized management of geographic information produced by other ministries and agencies. However, it will not hold the right to market the information because of the copyright issue.
- As a clearing house, consultation with customers concerning GIS data and promotion of the use of GIS data.
- Implementation of training for GIS engineers from other ministries and agencies.

(2) Printing Division of the Map Creation Department

Printing Division was newly added to the previous organization. This division will be in charge of the sale of topographic maps. Currently, printing service is provided by using a large plotter. However, IGM is considering using the offset printing in the near future when the missing parts of the offset printer are purchased. The role of this division will be printing of topographic maps and plans and printing management within IGM. Printing operations will be classified into several technical ranks in accordance with the production policy. The division is scheduled to operate with a total strength of five people, consisting of a chief officer, a geodetics expert, a map adjustment expert, a photogrammetry expert, and a topographical survey expert.

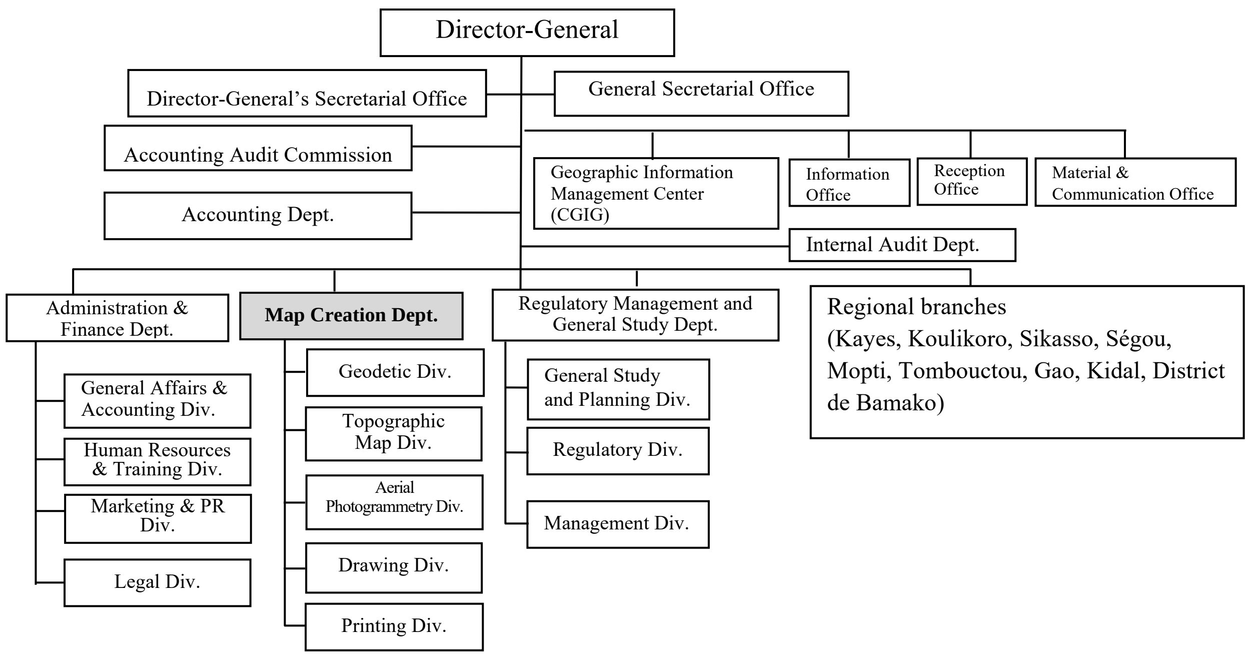


Figure 2-1 Organization of IGM

2.2.2 Human Resources and Technical Capabilities of IGM

With respect to the transition of the number of staff members of IGM, the number decreased from 204 in November 2011 to 161 and accordingly, the number of contract employees increased while that of regular employees decreased.

The counterpart of this project is the Map Creation Department of IGM. The personnel composition of this department is as follows.

Table 2-2 Personnel Composition of Map Creation Department

	Topographic Map Division	Geodetic Division	Drawing Division	Aerial Photogrammetry Division	Printing Division
Chief engineer	1	2	5	2	1
Engineer	4	4	4	2	3
Assistant engineer	4	6	3	1	
Trainee	35 for the Map Creation Department as a whole (non-regular staff)				
Office clerk	2 for the Map Creation Department as a whole				

Source: IGM, March 2016

Through the activities implemented in this project, the following findings were obtained about the current technical capabilities of the Map Creation Department of IGM, which is the implementing organization for supplying geographic information of Mali.

(1) GCP survey skill

As a result of the baseline survey by the Project Team, it was determined that the counterpart knows the procedures for basic GPS observation, which is necessary for this project. In this project, an observation method based on a 3-dimensional network created from GPS observation according to the radiation method was introduced to enable the counterpart to perform quality control. All the four engineers belonging to the Geodetic Division of IGM have sufficient experience in leveling using analog level.

(2) Technical skill in aerial triangulation and photogrammetry (digital plotting, DEM generation, orthophoto creation)

IGM has experience in digital plotting, but has not practiced aerial triangulation. Therefore, it was decided that the technology transfer should focus on the improvement of the basic technical skills. In addition, since IGM had expressed their wish to learn about the color tone adjustment of orthophotos although they have an understanding of DEM orthophotos, special care was taken in transferring such technology.

(3) Technical skills in map editing and symbolization/map reproduction and printing

IGM provides thematic map creation services to customers. However, IGM has no systematic and consistent methodology for digital mapping, creation and registration of map symbols, map output, etc. Therefore, IGM is expected to upgrade the manuals and specification standards prepared in this project.

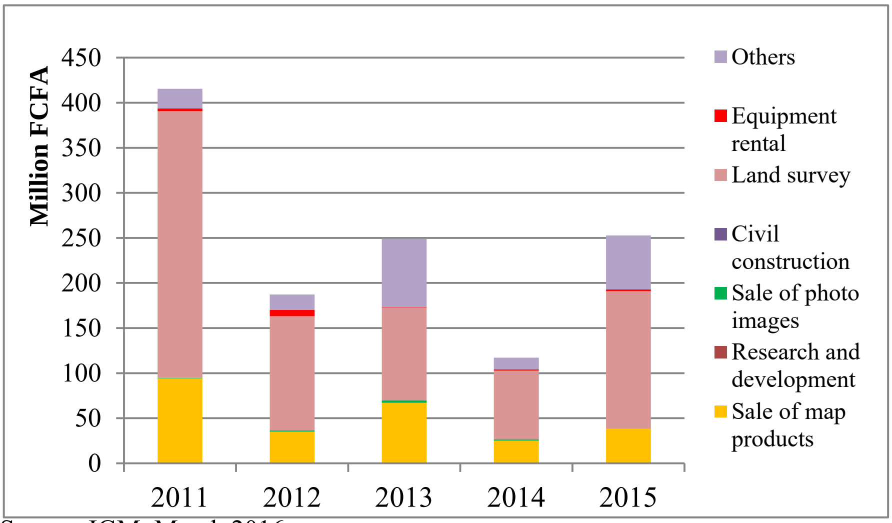
2.2.3 Financial Situation of IGM

According to the financial trends of IGM in the last five years (Table 2-3), national subsidy decreased from 2011. This may be due to the transfer of the cadastral section to another section in 2011 as well as to external factors caused by the coup and the civil war against the northern forces (2013). In particular, the impact of the transfer of the cadastral section is obvious from the fact that the needs for land survey (including cadastral survey) have decreased to half (Figure 2-2) that shows the technical services provided by IGM in the last five years. However, the situation improved after 2014 as the country regained stability, and budget for the establishment of CGIG was approved.

Table 2-3 Balance of Payments of IGM in the Last 5 Years (Unit: FCFA)

	2011	2012	2013	2014	2015
National subsidy	1,006,924,000	693,634,535	675,068,000	897,821,000	998,052,296
IGM Expenditures	1,006,852,000	92,011,152	659,802,724	602,906,622	934,625,948
Balance	72,000	1,623,383	15,265,276	294,914,378	63,426,348
Balance (in JPY)	12,744	287,338	2,701,954	52,199,845	11,226,464

Source: IGM, March 2016 Exchange rate: 1 FCFA = 0.177 JPY (average of August 2016)



Source: IGM, March 2016

Figure 2-2 Trends of Technical Services of IGM

2.2.4 Development Status and Selling Price of Geographic Information

IGM is responsible for the development and maintenance of existing geographic information, latest topographic maps, aerial photos, satellite images, orthophotos and ground control point results.

(1) Selling price

The selling price of geographic information is broadly divided into printed map and digital data. The prices of printed maps were relatively low during the days of DNCT, which is a precursor of IGM, because large volume printing was possible with offset printer. However, maps are currently printed using the ink jet printer.

IGM set new prices for the 1:200,000-scale topographic maps created by IGN France, the 1:1,000,000-scale topographic maps created by editing the 1:200,000 maps and the outputs of this project, *i.e.* 1:5,000-scale topographic maps and orthophoto maps and thematic digital data (shown in the table below). According to IGM, the prices of the maps created with the national budget used to be set to cover the cost of creating the maps (the costs of labor, materials and processing) without profit before this price revision. However, profit is included in the new prices to raise revenue in order to update the geographic data in future.

Table 2-4 List of Selling Prices of Geographic Information

Prices of the output/printed maps and digital data of the analog maps			
Designation (geographic information)	Content of geographic information	Price/Unit	Price/in JPY
Thematic map			
A0 version	Digital data	97,960 FCFA/sheet	17,339 JPY
A1 version	Digital data	50,480 FCFA/sheet	8,935 JPY
A2 version	Digital data	26,740 FCFA/sheet	4,733 JPY
A3 version	Digital data	14,870 FCFA/sheet	2,632 JPY
A4 version	Digital data	8,935 FCFA/sheet	1,581 JPY
Thematic map (Large-format plotter)			
A0 version	Output map	11,700 FCFA/sheet	2,071 JPY
A1 version	Output map	5,850 FCFA/sheet	1,035 JPY
A2 version	Output map	2,925 FCFA/sheet	518 JPY
A3 version	Output map	1,465 FCFA/sheet	259 JPY
A4 version	Output map	730 FCFA/sheet	129 JPY
Topographic map (Offset-printed maps)			
Scale 1:1,000,000 map	Printed map	5,000 FCFA/sheet	885 JPY
Scale 1:500,000	Printed map	5,000 FCFA/sheet	885 JPY
Scale 1:200,000	Printed map	5,000 FCFA/sheet	885 JPY
Scale 1:50,000	Printed map	5,000 FCFA/sheet	885 JPY
Scale 1:20,000	Printed map	5,000 FCFA/sheet	885 JPY
Scale 1:7,500	Printed map	5,000 FCFA/sheet	885 JPY
Topographic map			
All scales	Digital data	97,960 FCFA/sheet	17,339 JPY
Photo map (Monochrome, plotter)			
Scale 1:1,000,000	Output map	15,000 FCFA/sheet	2,655 JPY
Scale 1:50,000	Output map	5,000 FCFA/sheet	885 JPY
Prices of the new maps and digital data created in this project			
Designation (geographic	Content of	Price/Unit	Price/in JPY

information)	geographic information		
1:1,000,000			
Output on ordinary paper	Output map	60,000F CFA/sheet	10,620 JPY
Output on photographic paper	Output map	75,000F CFA/sheet	13,275 JPY
Vector data	Digital data	1,000,000F CFA/set	177,000 JPY
Raster data	Digital data	300,000F CFA/set	53,100 JPY
1:200,000 (Identical size)			
Output on ordinary paper	Output map	7,500F CFA/sheet	1,328 JPY
Raster data	Digital data	30,000F CFA/sheet	5,310 JPY
Vector data	Digital data	100,000FCFA/sheet	17,000 JPY
1:5,000 (Bamako)			
Topographic map on ordinary paper	Output map	10,000F CFA/sheet	1,770 JPY
Orthophoto on ordinary paper	Output map	13,000F CFA/sheet	2.301 JPY
Topographic map on photographic paper	Output map	15,000F CFA/sheet	2,655 JPY
Orthophoto on photographic paper	Output map	20,000F CFA/sheet	3,540 JPY
Vector data	Digital data	150,000F CFA/set	26,550 JPY
Raster data	Digital data	50,000F CFA/set	8,850 JPY
Orthophoto raster data	Digital data	75,000F CFA/set	13,275 JPY
Thematic digital data			
Administrative boundary	Digital data	20,000F CFA/Group	3,540 JPY
Road	Digital data	20,000F CFA/Group	3,540 JPY
Infrastructure	Digital data	20,000F CFA/Group	3,540 JPY
Water body	Digital data	20,000F CFA/Group	3,540 JPY
Topography	Digital data	20,000F CFA/Group	3,540 JPY
Land use	Digital data	20,000F CFA/Group	3,540 JPY

Source: IGM, October 2016 Exchange rate: 1 FCFA = 0.177 JPY (average of August 2016)

2.3 Needs and Requirements for GIS Information in the Bamako Metropolitan Area

Requirements of high potential users of basic GIS data can be summarized to the provision of easy-to-use geographic information as well as the provision of technical training on GIS. These potential users would like to implement the GIS system to utilize different kinds of geographic information. However, they do not have many technicians who can make full use of geographic information. Therefore, it became clear that IGM needs to take the leadership in implementing activities to raise the awareness and promote the use of geospatial information.

The geographic information products from this project comprises 1:5,000 scale topographic maps, orthophoto imagery, DEM etc. complete with elevation information. Currently, ministries and agencies involved in the development of the Bamako metropolitan area create and update their own thematic maps and other maps based on the needs and requirements. However, these maps do not have elevation information. The reference elevation information for Bamako metropolitan area, which was obtained in this project, will make useful data all stakeholders. In particular, such data are required for river utilization, flood control, development of water and sewerage works, where elevation information is important.

2.4 Implementation of Activities to Promote Utilization

2.4.1 Kick-off Seminar

Prior to the implementation of this project, a draft Inception Report was presented to IGM on February 27, 2015. An agreement was reached by both parties after discussions.

Following the Inception Report, a kick-off seminar targeting potential users of spatial information was held (Table 2-5) in order to publicize the expected project results. His Excellency the Ambassador of Japan and the Honorable Minister Mamadou Hachim Koumar (Ministry of Equipment, Transport and Rural Development) attended. Both the Japanese and Malian officials expressed high expectation from Japan's technical cooperation project. Then, JICA Project Team presented an outline, overall schedule and final project results.

Table 2-5 Brief Summary of Kick-off Seminar

Date	6th March 2015
Venue	Conference Hall, Azalai Grand Hotel
Number of participants	71 participants Related institutions: 40 participants Guest: Minister of Transport, Equipment and Rural Development Ambassador of Japan IGM: 17 participants Japanese: 11 participants Press: 3 participants
Main discussion points	Methodology and expected outputs/outcomes of this project Main role and obligation of IGM for this project Discussion on digital mapping techniques Utilization of 3D data as product of this project

2.4.2 GIS Workshop

After being established as a cross-sectoral organization of different ministries and agencies, CIIG had been stagnant in terms of its activities since 2012, which was partly due to security issues. However, as the updating of small scale topographic maps was completed by IGN France project and the creation of large scale topographic maps, which is the first attempt for Mali, was started by this project, in order to ensure that the product of this project will be utilized extensively, in 2015, preparations were started to establish CGIG as a receptacle for such geographic information basic data.

The Project Team held several meetings with IGM on the promotion of the use of the products of this project under such circumstances. They reached a common understanding that making the member organizations of CIIG, the assumed users of the geographic information, recognize the usefulness of the products of this project was an effective way to promote the use of geographic information in Mali. Therefore, they decided to provide the members of CIIG with an opportunity to practice group work of visualizing the administrative problems in Bamako (creating thematic maps of the city) from the geographic information created as an output of this project.

The Project Team organized a workshop to provide working-level personnel (division managers) in various areas with such an opportunity. The aim of the workshop was to create common understanding that geographic information is a tool applicable to urban administration among the participants and raise the sense of ownership of the geographic information not only in IGM but also in the ministries and agencies concerned (those that were members of CNIG, in particular).

In this workshop, the participants were provided with an explanation on the outline and outputs of this project and an opportunity to learn the process of creating thematic maps in inter-ministerial group discussion (Table 2-6).

Table 2-6 Outline of the Workshop for Working-Level Personnel

Date	9th May 2016
Venue	Conference Hall, Equipment and Accounting Department, Ministry of Equipment, Transport and Rural Development
Number of participants	65 participants Related institutions: 32 participants from 27 ministries and agencies Guest: Technical advisor to the Ministry of Equipment, Transport and Rural Development Chargé d’Affaires ad interim of Japan in Mali IGM: 19 participants Japanese: 14 participants
Major content	• Fields of geographic information in Mali and the positioning of this project • Establishment and roles of Centre de Gestion de l’Information Géographique (CGIG) • Significance and purpose of thematic maps • Participatory workshop (creating thematic maps by theme) (1) Group work to create thematic maps (2) Presentation of the result by group (3) Workshop evaluation

Three themes, 1) security and protection of citizens, 2) water supply and health/sanitation and 3) tourism and education, among the developmental problems of Bamako described in "Bamako 2030," an urban development plan prepared by Bamako City office in 2015, were selected for the participatory workshop. The participants from 32 government ministries and agencies were divided into six groups in accordance with their areas of expertise. They had inter-ministerial group discussion and practiced the creation of thematic maps (zoning) in these groups for approx. one hour.

IGM assigned one of its staffs to each group as a facilitator to help the participants learn the ways to utilize large-scale topographic maps in general and in their specific areas of work with products of this project. Table 2-7 below summarizes the workshop thematic map creation results for each group.

Table 2-7 Presentation Results of the Participatory Workshop (Thematic Map Creation)

Theme	Group	Content
Security and resident protection	1	Thematic map theme: Security and resident protection Purpose: Ensuring the security of critical security point SOMAGEP (Potable Water Public Corporation) Fire fighting against fires of residences and markets **Necessary data:** Detailed road information, electric light, road sign, signal and security facility information
	2	Thematic map theme: Minimizing the incidence of traffic accidents in Bamako Purpose: Importance of the maintenance of crossings **Necessary data:** Traffic signs, signals, traffic plan
Water supply, health and sanitation	3	Thematic map theme: Water and health in Commune 3 Purpose: Relationship between health and facilities (distribution of healthcare facilities and pharmacies, water and drainage channels) **Necessary data:** Waste disposal sites, detailed information of water and drainage channels
	4	Thematic map theme: Health and sanitation of Commune 2-3 Purpose: Grasping the sanitary environment of overpopulated Commune 2-3 **Necessary data:** Healthcare facility information, waste disposal sites, detailed information of water and drainage channels
Education and tourism	5	Thematic map theme: Tourist map of Mali Purpose: Tourist information of Commune 2-3 including the national museum, national zoo and football stadium **Necessary data:** Monument information
	6	Thematic map theme: Tourist map, school distribution map Purpose: Grasping the distribution of tourism resources by administration, hotels and schools **Necessary data:** Hotel information, educational facility information

After the workshop, the participants were requested to report to their immediate superiors in order to raise awareness of CNIG, CRIG and CGIG. Furthermore, this was done to ensure that the project products would be fully understood by the working-level personnel. In addition, as a follow-up, IGM prepared a report of the results of this workshop and submitted the report to the director general or the equivalent of each department and bureau.

2.4.3 Seminar for the Promotion of Utilization

Based on the Draft Final Report, a seminar for the promotion of the use of geographic information was held (Table 2-8). The users of the geographic information in Mali including the member ministries and agencies of CNIG and CRIG were invited to participate in the seminar. The Ambassador of Japan to Mali, Chief Representative of JICA Senegal Office and the Permanent Secretary of the Ministry of Equipment, Transport and Rural Development of Mali, the ministry supervising IGM, gave speeches on the technical cooperation by the Government of Japan in Mali.

After the speeches and the ceremony, members of the Project Team explained the outline of the project and officer of IGM made presentations on the basic policy on and prospect of the administration of geographic information after the completion of this project and the technologies they had acquired in the project. Staff members of the City Planning Bureau and the Civil Protection Bureau of the Bamako City Office also gave lectures on the application of the outputs of this project that they had conducted with sample data provided by the Project Team, as representatives of the data users. At the end, a question-and-answer session was held. In this session, questions were asked and discussion was held on such matters as the specifications of the products of this project and technical extension of the geographic information technologies acquired by IGM in this project, before closing the seminar.

Table 2-8 Summary of the Seminar for the Promotion of the Use of Geographic Information

Date	6th October 2016
Venue	Palais des Sports de Bamako
Number of participants	129 participants Related institutions: 57 participants from the invited organizations, Guest: Permanent Secretary, Ministry of Equipment, Transport and Rural Development, Ambassador Extraordinary and Plenipotentiary of Japan to Mali, Chief Representative of JICA Senegal Office IGM: 52 participants Japanese: 13 participants Press: 7 participants
Main discussion agenda	Impact expected of the outputs of this project Outline and products of this project (WebGIS, rules on the technical specifications) Future development for the realization of NSDI Initiative Policy on the activities of IGM after the completion of this project Utilization of products of this project (Civil Protection Bureau, Bamako City Office) Presentation on the outputs of the technology transfer (on aerial triangulation, digital compilation and GIS)

Source: Project Team

Photo 2-1 Seminar for the Promotion of the Use of Geographic Information

2.4.4 Open Forum

Large-scale topographic maps and GIS data (1:5,000-scale) of the Bamako Metropolitan Area were created in this project. The equipment required for the revision, including updating, of the maps and data has been provided to IGM and its staff members have acquired a certain level of technical expertise on the use of the provided equipment in the technology transfer program also implemented in this project. Meanwhile, the needs survey in this project revealed that not all the users of geographic information had an accurate knowledge. This finding confirmed the indispensability of the sharing of basic understanding of the data between the provider and users and a significant responsibility of IGM in providing technical support service in GIS and other geographic information technologies to the users.

In order to make the users of the geographic information data aware of not only the technologies that staff of IGM had acquired in the project, but also what the GIS data were and how they had been created, IGM Open Forum was held (Table 2-9). This forum was a follow-up to the workshop on the creation of thematic maps for the working-level personnel held in May this year. The Forum was expected to produce the following impact.

- Improving the understanding of the geographic information, increasing the opportunities to utilize it and increasing its potential users by providing its users, including the people engaged in providing administrative services who played an active role in the data sharing and provision in this project, and staff and students of universities, who were expected to lead the country in future, with an opportunity to watch and ask questions about the actual work conducted at IGM and its outputs;
- Making staff of IGM aware of their responsibility on the large-scale digital stereo mapping technologies transferred to them in this project and the output geographic information data to be created with these technologies by making them actively involved in the demonstration and by making them answer questions from the guests on the contents of the technology transfer and the process of creating geographic information data in the forum.

Table 2-9 Summary of IGM Open Forum

Date	13th October 2016
Venue	Laboratory and Main Conference Room in IGM
Number of participants	151 participants Related institutions: 25 participants from the invited organizations Universities: 12 participants IGM Headquarters: 91 participants IGM local offices: 23 participants
Program	Explanation of the reasons for holding this open forum by the Project Team Staff of IGM and the Project Team members conducted the demonstration on the subjects mentioned below with actual data for the participants in several groups at four locations in the laboratory and the conference room on the 2nd floor. They also answered questions from the participants during the demonstration. (1) Demonstration (on the digital mapping technology); ・Table 1: on 3D measurement by IGM ・Table 2: on GIS database management by IGM ・Table 3: on digital topographic maps by IGM ・Table 4: on Open source GIS by Project Team (2) Demonstration (on the GIS technology); ・Table 5: on WebGIS by IGM ・Table 6: Presentation of pioneering cases of the application of geographic-information-based technologies in Japan with video images on tablet computer by Project Team

A questionnaire survey of the participants was conducted after the conclusion of the open forum. The participants also provided valuable comments, in addition to their appreciation of and interest in this open forum, in the comment space in the questionnaire. The following is a summary of those comments.

- The forum was a good opportunity to learn QGIS and ArcGIS software. I would like IGM to prepare similar opportunities and provide technical assistance on geographic information to its partner organizations.
- Please organize an open forum like this one for university students who are expected to lead the country in future.
- Please correct the administrative boundaries on the topographic maps of Bamako as soon as possible because the maps with correct boundaries are essential for the urban planning.
- I would like IGM to be always ready to disclose geographic information to its users by providing them with technical training.

- Please consider to have a plan for updating topographic maps every 10 years. Please relocate the boundary of Commune VI on the maps to its official location.
- I would like to use the geographic information in the planning of a pipeline immediately.
- Please prepare a pamphlet including the price list and user's guide of the topographic maps.
- IGM should continue providing opportunities like this forum. However, I was not fully satisfied with this forum because the number of participants was too large. Please organize a series of opportunities like this for 10 or so people.

The responses of the participants mentioned above suggest that the forum has generally achieved its purpose, *i.e.* to publicize the role of IGM to the users of geographic information, to facilitate the improvement of their understanding of the basics of geographic information data and the method for the creation of topographic maps and to disseminate the outputs of this project to the geographic information users including staff of universities and working-level administrators through the active involvement of the staff of IGM in the dissemination of the knowledge they acquired as an output of this project in the technology transfer program to the users.

Implementation of this forum and the workshop in May has undoubtedly generated a certain level of recognition of the assistance to IGM and in the geographic information sector at the field-level. The senior officials of IGM are expected to take lead in the activities of the Government of Mali for the standardization of the geographic information and realization of NSDI (National Spatial Data Infrastructure) Initiative in cooperation with the relevant bureaus and departments of the ministries and agencies that are the members of CNIG and CRIG.

2.5 Development of WebGIS

WebGIS development was proposed in order to enable various urban development stakeholders and other potential users to visualize selected Bamako Metropolitan area GIS data from this project. The WebGIS design concept were first discussed, and then approved after much consultation with IGM

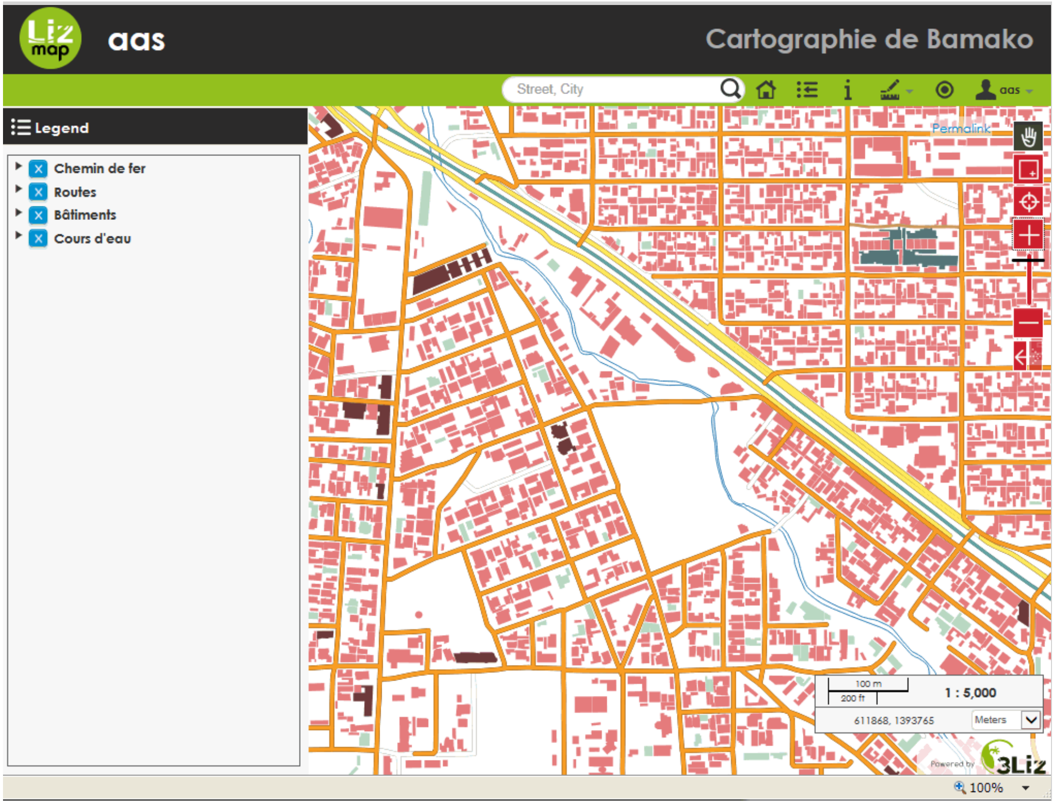
2.5.1 WebGIS Design

The WebGIS content represents selected GIS datasets that will be open to the public (that is, available on the internet) (see Figure 2-3). For security reasons, the final WebGIS content will be represented as follows:

(1) Use selected GIS vector layers without location (no coordinate information);
(2) Mask sensitive "Public facilities" layers such as embassies, international organizations, military institutions or facilities, hotels (this means users cannot see these layer information or names on the map); and

(3) Mask the “Building” layer (DataCodes 2101 – 2106) and replace it with a general “urban area/ built-up” category.

(4) Mask the elevation layer (DataCodes 6101 – 7107) in order to reduce the WebGIS data size. Note that the internet connection is in Bamako. Therefore, a reduced GIS data size will increase upload performance.



Source: Prepared by the Project Team

Figure 2-3 Sample image of WebGIS

2.5.2 Installation of WebGIS and system management

The design and implementation of a WebGIS is highly iterative process, whereby GIS data is configured and loaded using Lizmap, a QGIS plugin. The “Bamako Digital Topographic Mapping WebGIS” is an interactive spatial data platform, which allows visualization of selected GIS datasets derived from the 1:5,000 scale topographic maps.

In addition, GIS dataset as the contents of the WebGIS has been operated in Italian server for five years from 2016 because of accessibility and IT infrastructure weakness in Mali and procedure of operation of WebGIS was lectured to IGM officer in charge of IT field.

From 2021, IGM will have to perform maintenance of dataset in Italian server by IGM’s own effort or IGM will move dataset in Italy to IGM’s own server and manage WebGIS, if IT infrastructure is improved dramatically.

2.6 Future Directions

The GIS data will be shared by Conseil Interministériel d'Information Géographique (CIIG) and Comité National d'Information Géographique (CNIG). To date, no major activity has been carried out. Therefore, the following recommendations were made to IGM to encourage IGM to continue collecting information and implementing practical activities for the purpose of promoting the utilization of the project geospatial products.

(1) Additional development of GIS data

As prescribed in the map symbolization criteria, GIS data are composed of items that can be treated as common themes selected out of the features comprising topographic maps. Considering the diversified needs of GIS, the product of this project cannot satisfy all users. As shown by the results of the workshop described earlier, cross-sectoral discussions can help in clarifying the information that needs to be added to the basic GIS data to meet the needs arising from the duties of each ministry or agency. As such, IGM should assume the responsibility of coordinating among the member organizations of CNIG, etc. for each theme to avoid duplicated development of the same basic GIS data and to clarify the information to be added, thereby enabling the efficient addition and updating of the data.

(2) Expansion of the coverage of 1:5,000-scale topographic maps

The population of Bamako has been increasing in recent years. The urban population increased from was about 1 million in 1998 to 1.8 million in 2009 (1998/2009 census in Mali). The residents who have moved into the city live in the urban periphery in a disorderly manner and the city area is sprawling. As such, development actors consider that the geographic information in and around Bamako City is indispensable for the development of residential areas, sanitary infrastructure and water and sewerage facilities.

While aerial photographs cover an area of 1,400 km^2, the 1:5,000-scale topographic maps cover only 520 km^2. Therefore, remaining 880 km^2 of the outskirts of the Bamako metropolitan area need to be mapped. Note that aerial triangulation has been carried for the remaining unmapped area. It is important that IGM continues to develop data including height information, using these 3-dimensional models and the knowledge and knowhow of each work process learned from the technology transfer program.

(3) Cooperation with CGIG

The preparation for the establishment of CGIG was commenced in 2015. This is based on the action plan of PNIG. However, CGIG was scheduled to be established in 2012 according to the initial plan, which was the first year of the activity to achieve the special target (that is, the development of NSDI).

In view of this, it is essential to take this opportunity to step up the effort to implement the activities necessary for the achievement of the special target in the initial plan, namely, creation of 1:200,000 topographic maps by IGN France project, creation of metadata inventory of the product of this project and development of technical specifications and legal framework. Furthermore, it is urgently required to develop human resources capable of implementing the introductory training on basic GIS data for the member ministries and agencies of CNIG and CRIG.

3. Production of Digital Topographic Maps and GIS Data

3.1 Determination of Technical Specifications

Survey standards and digital mapping method and rules for 1:5,000-scale topographic map and orthophoto were determined with IGM before the starting the digital topographic mapping.

3.1.1 Discussion for Setting Technical Specifications

IGM did not have a systematical framework for the survey criteria and standard (method and accuracy), map symbols (acquired feature items) and applicable rules, and specification (size, language and marginal information) for producing the final products of 1:5,000-scale topographic maps.

As described in the previous chapter, the national geographic information policy of Mali, which was determined by cabinet meeting in 2012, sets forth the establishment of NSDI as the high-level goal to be achieved. Standardization of geographic information data in Mali and development of technical specifications are essential in achieving this goal. In the management of national geospatial information of Mali that IGM is implementing as the secretariat, development of unified technical specifications is as important as the 1:5,000 topographic maps that is produced by this project.

3.1.2 Technical Specifications

Various specifications and rules were discussed with IGM. Finally, IGM agreed to five specifications, which are shown below (for the 1:5,000-scale base map specifications).

(1) Bamako mapping project: Briefing document on UTM

(2) Bamako mapping project: Marginal information of 1:5,000 base maps

(3) Bamako mapping project: Methodology of numbering system for basic maps

(4) Bamako mapping project: 1:5,000-scale map symbols and application rules

(5) Bamako mapping project: 5,000-level specification of annotation

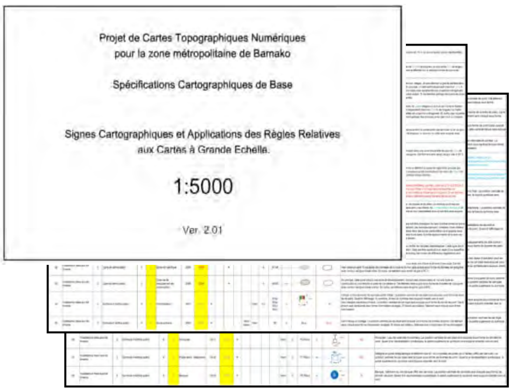


Figure 3-1 1:5,000-scale Map Symbols and Application Rules

3.1.3 Survey Standards

The following survey standard for aerial photography, GNSS observation, leveling, aerial triangulation, field identification, digital mapping and digital editing were discussed with IGM. With respect to the national standard coordinate system, as IGM had been considering transition to the world geodetic system since 2012, the survey standard to be adopted in this project was established, while checking the progress of the standard system conversion work of IGM. Table 3-1 shows survey standard, with which the basic GIS data developed in this project comply.

Table 3-1 Survey Standard

Standard items	Adopted specifications
Reference spheroid	WGS84 (World Geodetic System 84)
Projection method	UTM (Universal Transverse Mercator), Zone 29N
Coordinates system	WGS84 coordinates system
Height reference	Mean sea level of the Port of Dakar (= existing benchmarks of IGM)

Surveying specifications are essential in implementing ground control point survey for basic GIS data production was discussed with IGM. The work specifications needed for GNSS observation, leveling and aerial triangulation were determined as shown in Table 3-2.

Table 3-2 Adopted Accuracy Standards in this Project

Survey items	Standard and specifications
GNSS observation	Observation sessions: 20 sessions Observation time: 60 minutes Data acquisition interval: within 15 seconds Common satellite number: more than 5 satellites Observation method: Simultaneous observation
Direct leveling	Pricking distance: 2-4 km Closure: 40 mm√S Closure between existing point: 50 mm√S Discrepancy of round trip: 40 m√S S = observation distance (one way km)
Aerial photography (Digital camera)	Overlap: 60% standard Side lap: 30% standard Fixed point and slave point: more than 5 satellites shall be acquired as same time

Next, tolerances regarding data acquisition and calculation from GNSS observation, leveling and aerial triangulation were adopted as shown in Table 3-3.

Table 3-3 Tolerance of Topographic Map

Survey items	XY position	Height
Ground control point survey	Within 0.2 m	Within 0.2 m
Proof point of aerial triangulation	Within 1.5 m	Within 1.5 m
Adjustment of aerial	Within 1.5 m	Within 1.0 m

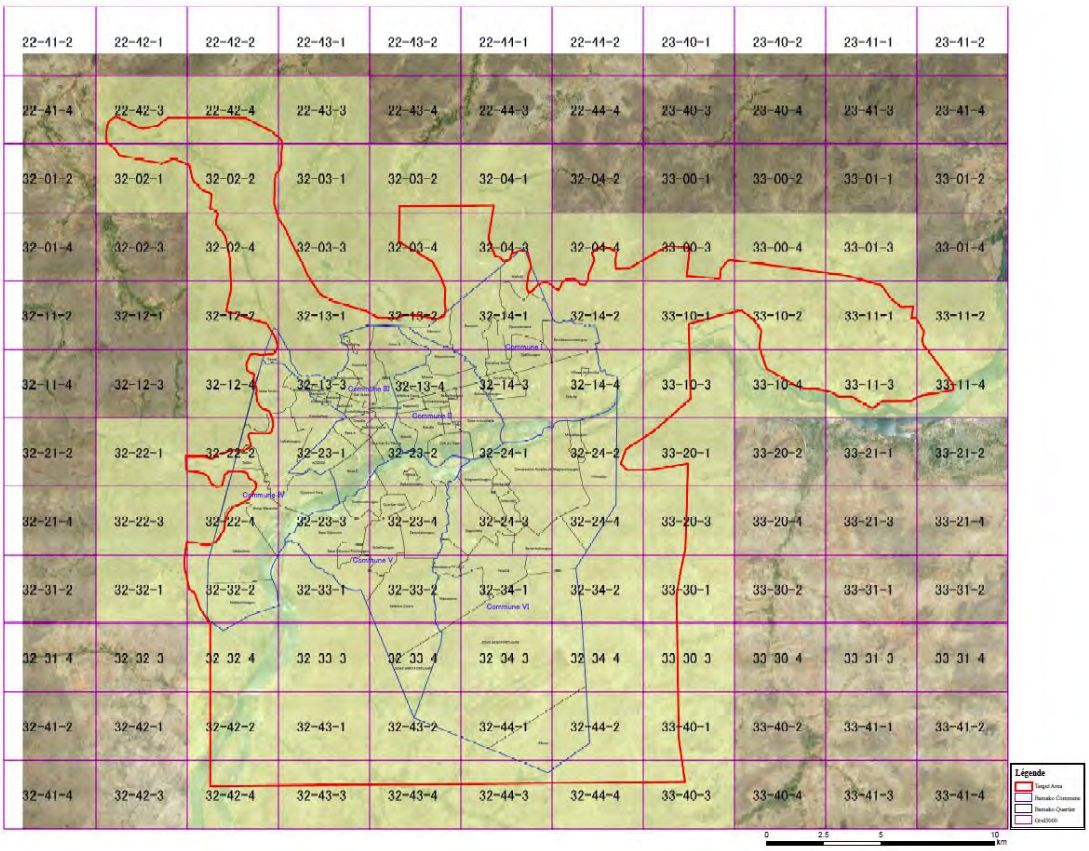
triangulation		
Digital mapping	Within 1.5 m	Within 1.0 m
Basic GIS data	Within 3.5 m	Within 1.66 m (Contour lines: within 2.5 m)

Contour interval and spot height's density of the products, 1:5,000-scale basic GIS data were agreed as shown in Table 3-4.

Table 3-4 Contour Interval of Topographic Map

Map scale	Main contour	Index contour	Supplementary contour	Spot height (on the map)
1:5,000	5 m	25 m	2.5 m	4 points / 10cm^2

Finally, according to the methodology of numbering system for basic map defined respecting consistency with the small scale maps managed by IGM, the layout of 1:5,000-scale map sheet for 1:5,000-scale topographic maps and orthophoto maps was agreed as shown in Figure 3-2.



Source: Prepared by the Project Team

Figure 3-2 Index for each Sheet of 1:5,000 Topographic Maps

Red: Coverage of topographic map, Purple: All the 1:5000-scale map sheets, Blue: Commune boundary, Yellow: Map sheets of the topographic maps created in this project

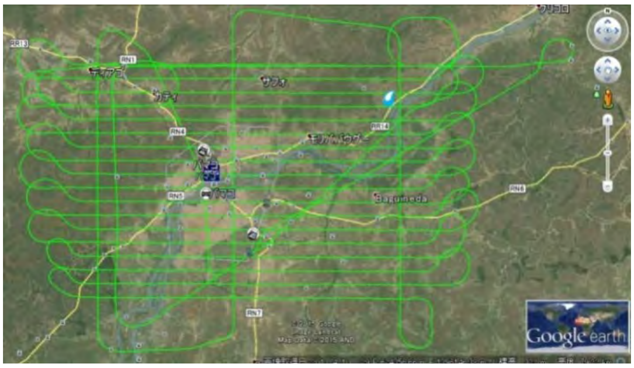
3.2 Supervision of Aerial Photography

3.2.1 Aerial Photography

Aerial photography was subcontracted to a Netherlandsaerial photography company since there is no aerial photography company in Mali. The subcontractor used a UltraCam Eagle (a Microsoft digital aerial camera, that isequipped with GNSS and an inertial measurement unit) to acquire digital aerial photographs with a ground resolution of approximately 20cm.

3.2.2 Results of Aerial Photography

The flight lines comprised 18 lines in the East-West direction and 3 lines in the North-South direction. The total numbers of photographs were 1,251. The flight used existing geodetic point (B11) managed by the IGM for getting GPS/IMU data as the principal point coordinates of camera position (see Figure 3-3).



Source: Map data © 2015 GoogleEarth

Source: Prepared by the Project Team

Figure 3-3 Flight Lines and Result of Sample Image
(Left: Flight lines, Right: All exposures)

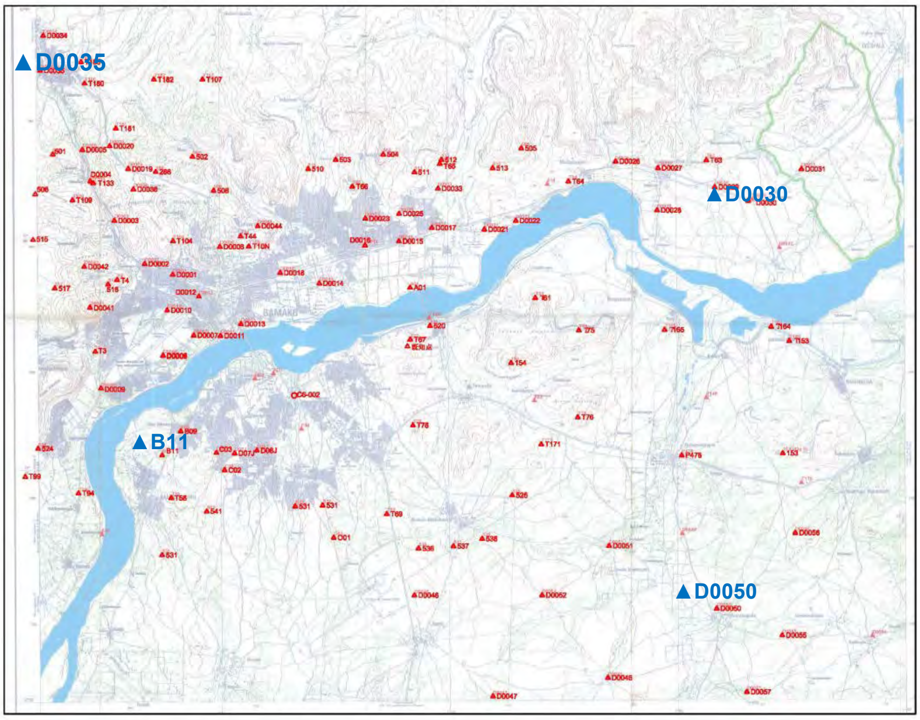
3.3 Ground Control Survey

3.3.1 GNSS Observation

The ground control point (GCP) survey was executed to determine the planimetric position for the digital topographic mapping at scale of 1:5,000 based on the existing geodetic points managed by IGM.

(1) Validation of existing geodetic points

Figure 3-4 shows distribution of existing geodetic points managed by IGM in the Bamako metropolitan area. Based on this distribution map, geodetic points were selected within the target area. For the inspection of existing points, selected points were determined by GNSS observation. Then those results were confirmed within a threshold or not.



Source: Created by Project Team based on IGMs

Figure 3-4 Distribution map of geodetic points

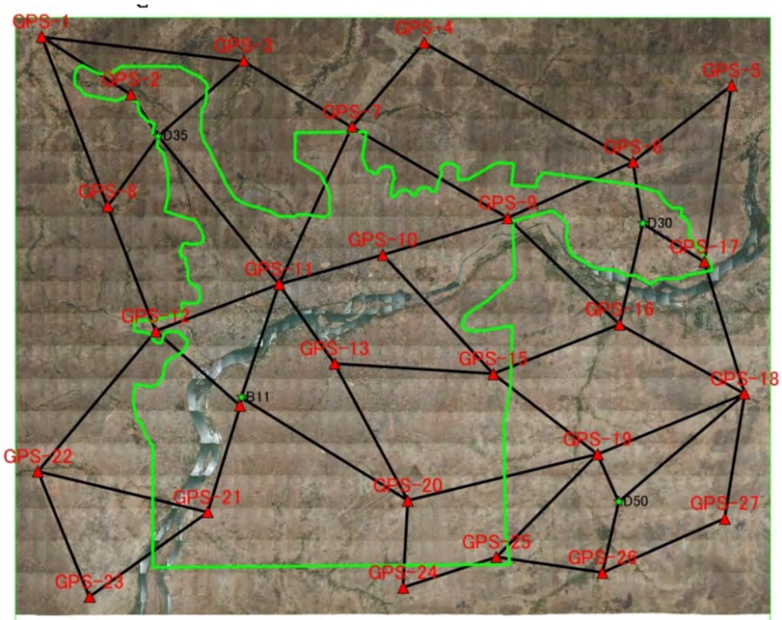
The inspection survey was conducted using radial method based on the computation of the coordinates among D0035, D0030, D0050 and B11 as a fixed point.

(2) Field reconnaissance of the selected GCPs

After preparation of selection point, 27 control points (GCP-01 to GCP-27) for the aerial triangulation work was confirmed on the sight.

(3) Execution of GCP survey

Four GCP survey teams were organized to observe 27 control points using 4 sets of GNSS equipment. In total, 20 sessions GNSS observations were executed (Figure 3-5). Polygonal network observation and calculation method were used for the GCP survey in this project.



Source: Prepared by the Project Team

Figure 3-5 Index of Observation Session Planning

3.3.2 Leveling

The purpose of leveling was to determine elevations of ground control points, necessary for aerial triangulation of 1:5,000-scale digital topographic mapping. Leveling was implemented based on the existing benchmarks which are maintained and managed by IGM.

(1) Confirmation of geodetic points in the Bamako metropolitan area

According to the information prepared by IGM, the elevations of some geodetic points, which were established by IGM were determined based on the result of past leveling work. Therefore, the existing geodetic points (the elevations were determined by leveling) were checked in the field. According to inspection result, the height of geodetic points could be used seven points of eleven points provided by IGM (A-01 could not be used in this project).

(2) Execution of leveling

Based on the leveling route plan prepared in Japan, final leveling routes was determined (Figure 3-6) taking into consideration the locations of the existing benchmarks, geodetic points (elevations were determined by leveling), road conditions and so on.

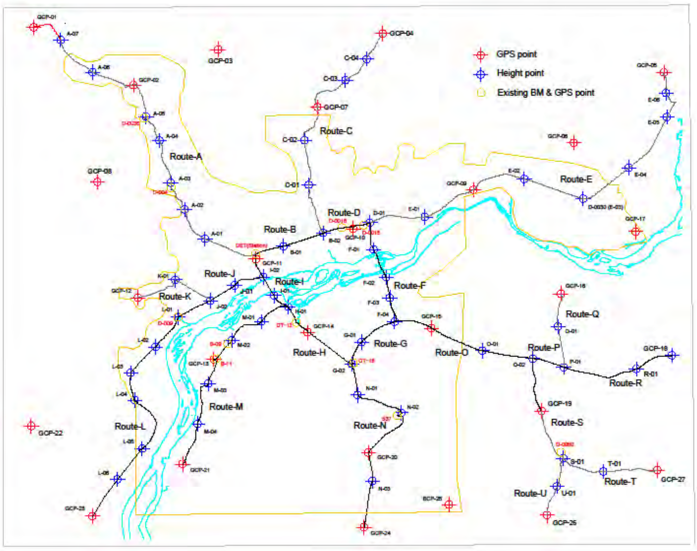


Figure 3-6 Index of Leveling Route

Source: Prepared by the Project Team

Leveling with total distance of 196.78 km (which was executed by three parties) started from March 9 and completed in April 26, 2015. In parallel with the leveling, observation notes and calculation notes were prepared and all elevations of ground control points were determined by April 28, 2015 including points that were measured again.

3.4 Aerial Triangulation

For the area covered by the aerial photography (about 1,400 km^2), aerial triangulation was carried out in Japan according to the work process shown in Figure 3-7.

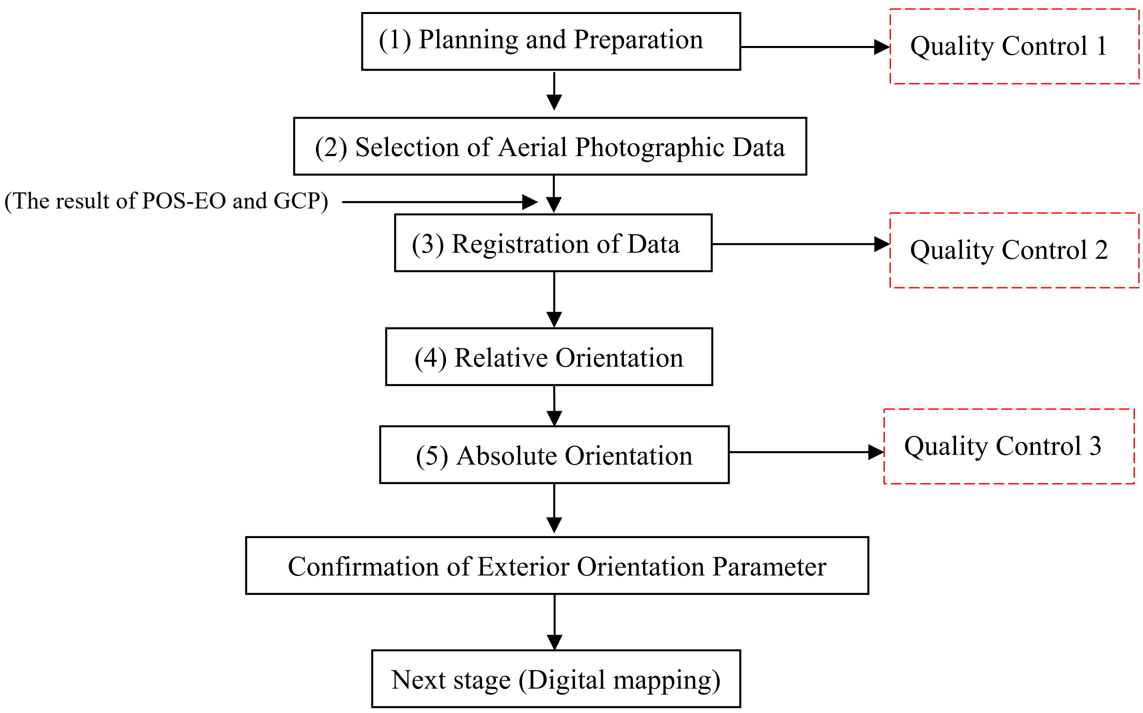


Figure 3-7 Flowchart of Aerial Triangulation

Figure 3-8 shows the aerial photographs captured in this project.

Source: Prepared by the Project Team

Figure 3-8   Index of Aerial Photography

Aerial photography accuracy assessment results were good since the aerial photos were acquired in one day. In addition, there were few variations of flight height from the results of POS-EO. Finally, aerial photos for triangulation were determined. In total, 1,077 aerial photos were acquired based on 18 east-west lines.

Residual of absolute orientation (GCP coordinates by GNSS and computed GCP coordinates) and relative orientation (vertical parallax of pass-points and tie-points) were confirmed.

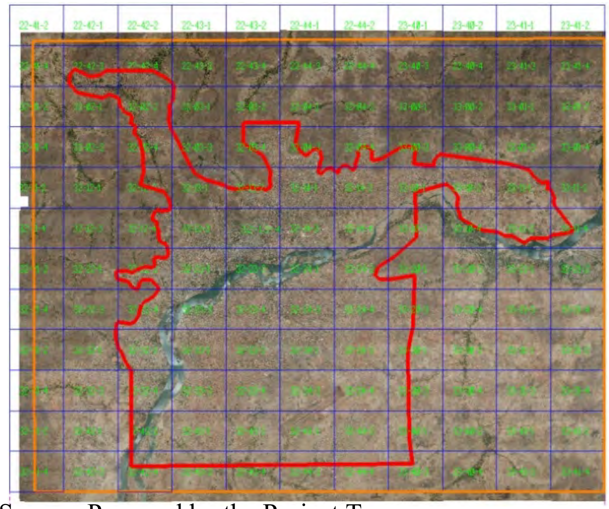
As the final result of quality control, aerial triangulation realized a positive outcome as follows:

Standard deviation (XYZ) of GCP: = 0.143m, 0.134m, 0.438m
Standard deviation of planimetric position: = 0.198m

3.5 Orthophoto Creation

3.5.1 Coverage of Orthophoto Maps

In this project, orthophotos were created by dividing the whole area of the Bamako metropolitan area of about 1,400 km^2 (132 map sheets (1 map sheet = 4.0 km×3.0 km)) extracted from the coverage of aerial photos into the area subject to 1:5,000 digital plotting (520 km^2) and the area not subject to digital plotting (880 km^2) as shown in Figure 3-9.



Source: Prepared by the Project Team

Figure 3-9 Coverage of Orthophotos
(Orange: Coverage, Red: Area subject to digital plotting, Blue: Neatline)

3.5.2 Creation of Orthophoto Data

Figure 3-10 shows the procedure for producing orthophotos.

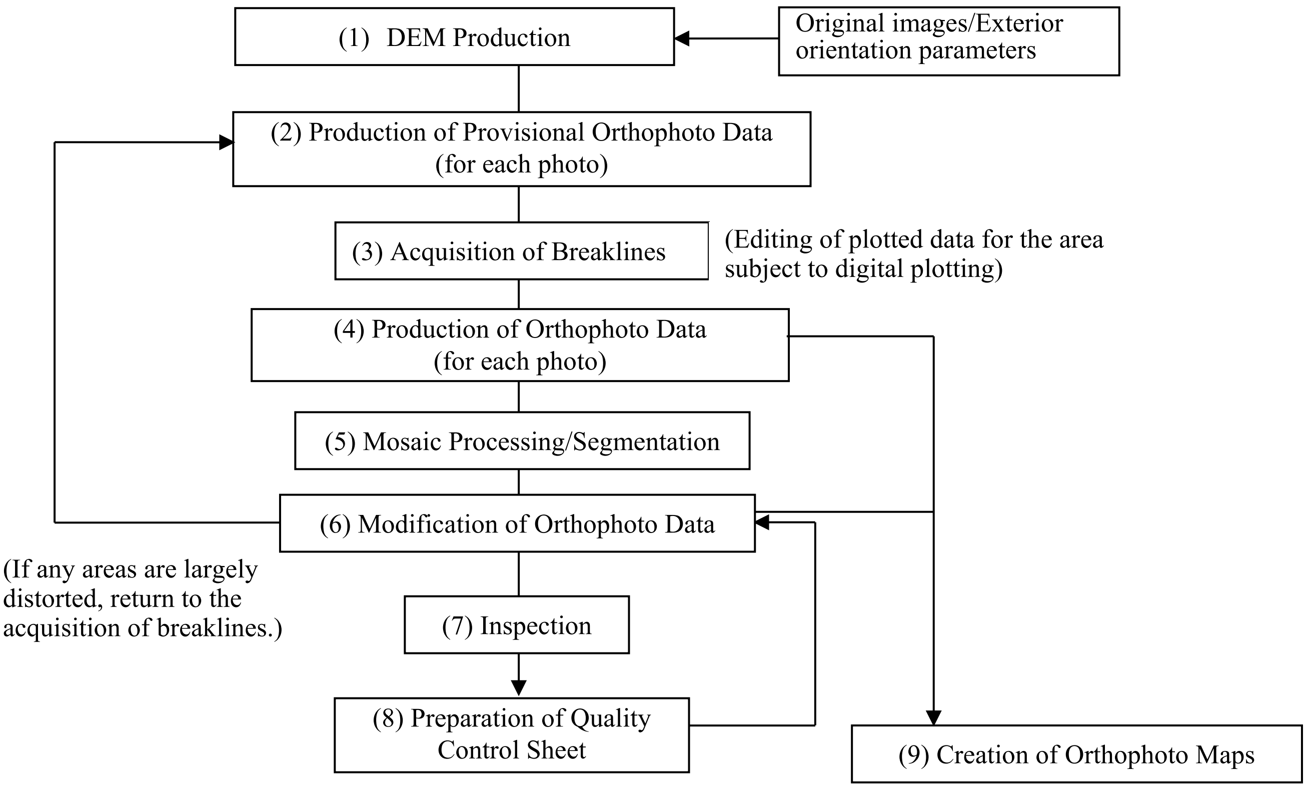
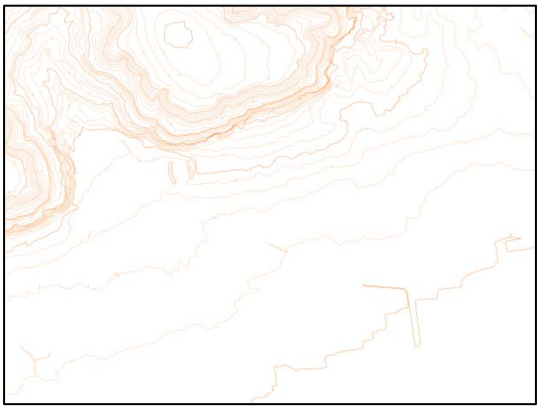


Figure 3-10 Flowchart for orthophoto Production

For the creation of orthophoto maps, with respect to the area not subject to digital plotting, contour lines were generated based on the DEM used in creating orthophoto data and the breakline data. On the other hand, for the area subject to digital plotting, contours lines of digital editing data were edited to create the contour line data for orthophoto maps (Figure 3-11).



Source: Prepared by the Project Team

Figure 3-11 Contour Line Map (Left Map) and Orthophoto Map (Right Map)

3.6 Digital Plotting

In this project, digital plotting data were created in accordance with the work flow shown in

Figure 3-12 as follows.

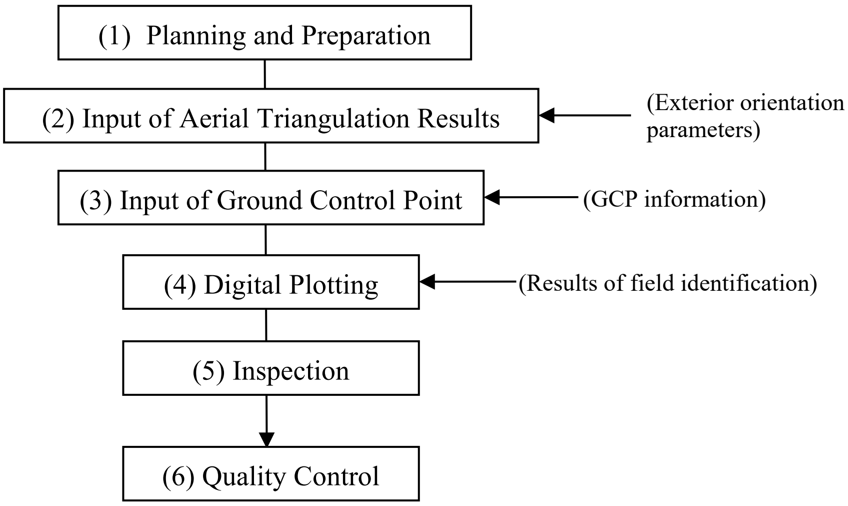


Figure 3-12 Digital Plotting Work Flow

Visual inspection was implemented for each map sheet using 3-dimensional spatial models in order to (i) see if appropriate features have been acquired, (ii) make sure that all the features have been acquired and no excessive acquisition was carried out, and (iii) check the position and property of the acquired features for abnormality.

3.7 Field Identification Survey

3.7.1 Field Identification Workshop

According to the initial plan, Japanese experts would accompany the IGM engineers participating in the field identification so that the field identification could be implemented in a form of OJT. However, the plan was changed because of the security problem in Bamako. Therefore, it was decided that the IGM personnel should independently acquire feature information without the Japanese experts.

Therefore, a field identification workshop was conducted to train the IGM counterparts (Photo 3-1).

Source: Project Team

Photo 3-1 Field Identification Workshop

3.7.2 Analysis of the Existing Information (1:10,000 Topographic Map)

Names of the roads and the designations of the main buildings appear on the 1:10,000-scale topographic maps published between 2005 and 2009 by the IGM. Even though the maps were developed a long time ago, such names are important source of information. A period of field identification was shortened by pre-interpreting/validating such data and updating existing data before field identification.

3.7.3 Performing of Field Identification

In total six teams comprising two field personnel conducted the field identification. The field identification was initially scheduled from November 16, 2015 to January 6, 2016. However, due to the worsening of security situation caused by the hotel attack that occurred in Bamako City on November 20, 2015, the field identification was temporarily suspended on December 23, 2015.Howver, the survey was resumed on March 2, 2016.

3.7.4 Ordering of the Survey Results and Digitalization

The indicated codes, names, numbers of photo, longitude-latitude of the positions of the map features noted in the field notebook have been compiled in an Excel table. The positions of the map features compiled in the Excel table have been integrated in the GIS software. Furthermore, the precision of the position of the map features was verified through the comparing of its shown position in the map and the real position of the object in the field.

3.8 Field Completion

Field completion is a work to resolve the doubts that arose in the plotting and compilation operations by conducting field identification again. It is also a work to confirm the information that could not be identified in the field identification (road names, river names, district name, etc.) based on materials. Therefore, final field identification was conducted in Mali with regard to (1) adjustment of annotations on the maps, (2) confirmation of road and river names as well as the starting point and endpoint, (3) confirmation of transmission line connections and (4) final adjustment of administrative boundaries.

3.8.1 Field Completion Workshop

A three-day workshop was conducted for the IGM engineers who conducted the field identification. First, a lecture was given to explain the outline of field completion and the "1:5,000-scale Map Symbols and Application Rules". Then, practical training was conducted at the IGM office, which was used as a pilot study area. The study results from each team were reviewed and shared with all the members.

3.8.2 Preliminary Confirmation of Areas Requiring Final Field Identification

Field completion refers to clarifying unclear points that were identified in the digital plotting and digital compilation. Due to time constraints, the following two points were checked in the office work prior to the field completion.

(1) Unclear points that need to be confirmed
(2) Names of buildingsthat need to be reconfirmed

3.8.3 Implementation of Final Field Identification

Final field identification was conducted by six teams for 17 days from April 5 to April 27. Based on the result of field identification, the list for field completion (list of unclear points and names of buildings, etc.) was updated.

3.8.4 Identification of Roads and Rivers

Names and sections of roads and rivers were investigated to obtain the topographic map annotations information of. After discussions with IGM, it was agreed that only the existing annotations should be used as attribute data (Table 3-5).

Table 3-5 List of Collected Materials

Type	Collected material	Format
Road	・Road management map (CTAC*) ・Plan d'ensemble Bamako et Kalabancoro (within Bamako City, Kalabancoro District) ・Sangarébougou (Sangarébougou District) ・Kati adressage (Kati District)	Digital (DWG format) Arbitrary coordinates
	・1:10,000 city map (IGM)	Paper
	・Road network data (OCHA)	Digital (Shape format)
River	・1:25,000 Bamako metropolitan area map (created by IGM)	Digital (Shape format)

* CTAC: Cellule Technique d'Appui aux Communes (Office for Technical Support to Communes)

(1) Confirmation of names, starting points and endpoints of roads

The final data output was inspected for errors and omissions, and modified as necessary. Only national highways were extracted and displayed on the maps, while other roads were retained as attribute information.

(2) Confirmation of river names and starting and end points

GIS data layers (in Shapefile format:) derived from the Bamako metropolitan area map (1:25,000) were used to confirm river names as well as the starting points and endpoints.

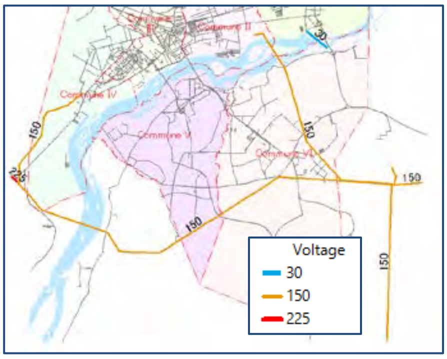
Subsequently, data codes relating to rivers namely, "4101: Cours d'eau", "4102: Ligne de côte", "4103: Canal" and "1205: Caniveau", were extracted from the topographic mapping data. Furthermore, river names were addes as attribute information.

Source: Created by Project Team based on information from IGM

Figure 3-13 River Data after Extraction (Thick Blue Lines)

3.8.5 Confirmation of Transmission Line

High voltage transmission lines are one of the important infrastructures of Bamako. Therefore, EDM (Energie du Mali) which manages transmission lines was consulted in order to confirm the direction and connection points of transmission lines on the map. Voltage information provided during the discussion was included as attribute information.



Source: Prepared by the Project Team

Figure 3-14 Transmission Lines in Bamako City (Voltage in kV)

3.8.6 Identification of Quartier Boundaries

Quartier boundaries were derived from the "1:25,000 Bamako Metropolitan Area Map", which was produced by IGM. The administrative boundary data provided by IGM was overlayed on the topographic mapping data to check topographic elements, such as rivers. Then the person in charge at IGM inspected and finalized the boundary positions and names (Figure 3-15).

The quartiers outside of the Bamako metropolitan area (Kati Commune) only has names. Therefore, it was agreed with IGM to describe only the quartier names on the topographic maps without creating the boundary lines.

Source: Created by Project Team based on information from IGM

Figure 3-15 Quartiers in Bamako Metropolitan Area

3.9 Digital Compilation and Symbolization

Digital compilation/completion editing and symbolization were carried out for the Bamako Metropolitan area, which covers 520 km^2 (that is, 73 map sheets in total), for which digital plotting had been completed.

Figure 3-16 shows digital compilation and symbolization editing work flow.

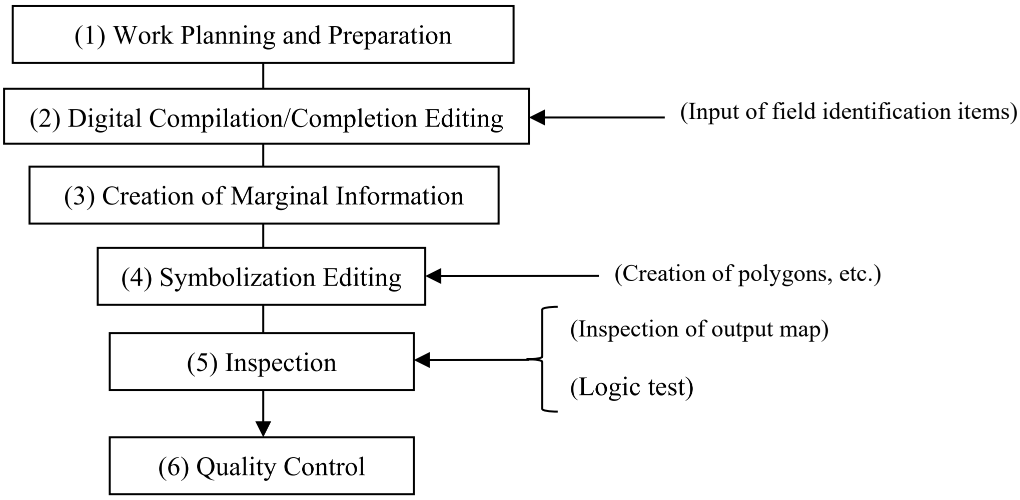
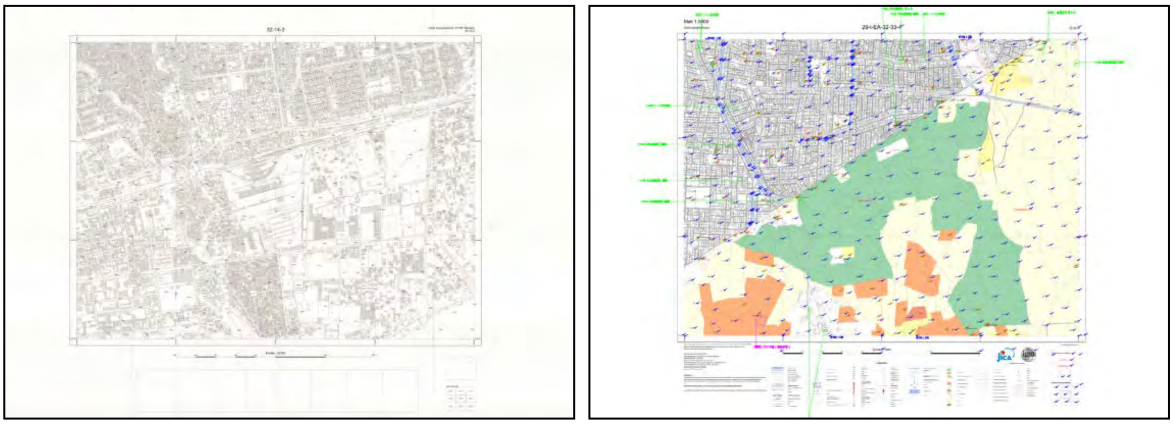


Figure 3-16 Digital Compilation and Symbolization Editing Work Flow

Following digital compilation and symbolization editing, visual inspection was carried out in order to check for omissions and errors. In addition, logical testing was also carried, and corrections were made whenever data type classification, structure or topology errors were detected.

The output maps were visually inspected for consistency and form. On the other hand, symbolization editing data were combined with the marginal information data to output the raster of the final printing images. Building annotation data and road name data were compiled the digital compilation data. Those data were superimposed on a map, then executurted visual checks (Figure 3-17).



Source: Prepared by the Project Team

Figure 3-17 Examples of Inspection Maps (Left: Output Inspection, Right: Monitoring Inspection)

3.10 GIS Data Structurization

In this project, GIS data structuralization refers to the procedures for creating and organizing GIS datasets, which were acquired during the project implementation. In total, 128 feature layers derived from the "1:5,000 scale Map Symbol and Application Rules" document were used for GIS data structurization.

3.10.1 GIS Data Structurization Workflow

Figure 3-18 shows the GIS data structurization workflow.

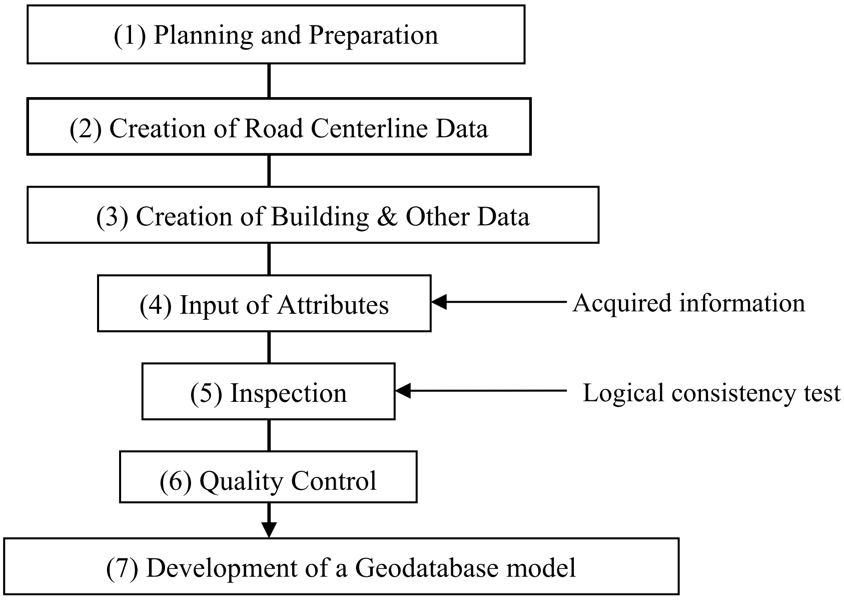


Figure 3-18 GIS Data Structurization Workflow

While a Geographic information system (GIS) data is important for urban infrastructure development, its successful use depends on its quality as well as an efficient database management system. In this project, an efficient geographic information database management using geospatial data acquired during the project implementation was designed.

The conceptual model comprise seven feature datasets, which were compiled from 128 feature layers that include spatial features and annotations. The 128 feature layers were derived from the "1:5,000 scale Map Symbol and Application Rules" document. In addition, the conceptual model includes the raster dataset (orthophoto imagery). Table 3-6 shows the main feature datasets, which are described in the subsections below.

Table 3-6 Main feature datasets compiled from the 1:5,000 scale map symbol specifications and rules.

Feature Dataset	Map Use	Data Source	Representation
Administrative	Administrative and legal boundaries, national parks.	IGM	Lines and polygons
Building Infrastructure	Represents buildings, cultural, landmark features and building related facilities	IGM/ this project	Mainly polygons. Includes annotations
Public services	Represents government buildings, banks, schools, religious institutions e.t.c	IGM/ this project	Point. Includes annotations.
Hydrography	Represents surface water and features for moving, storing, and managing water	IGM/ this project	Points, lines and polygons. Includes annotations
Hypsography	Represents terrain	IGM/ this project	Elevation points, contour lines, DEM. Includes annotations.
Imagery	Map background and reference	IGM/ this project	Aerial photos, orthophoto imagery
Surface overlays	Represents land use/cover such as urban areas, bareland, forest	IGM/ this project	Polygons. Includes annotations.
Transportation	Represents roads, rail, and the associated infrastructure	IGM/ CTAC/ this project	Lines and points. Includes annotations.

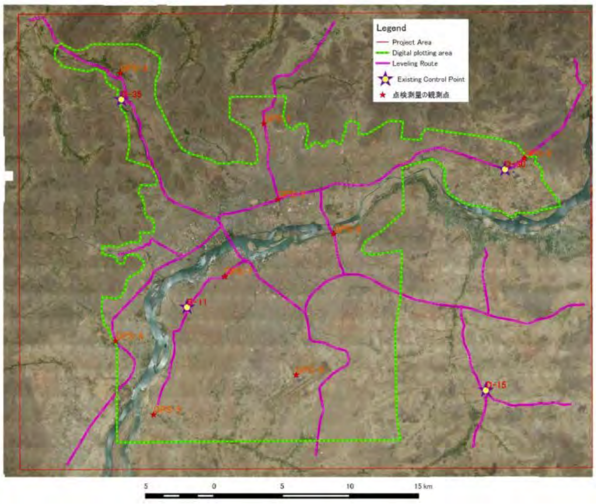
3.11 Quality Control

This project was implemented with an emphasis on security control. Therefore, Japanese experts did not participate in the field work in most cases. As a result, the project products were produced based on field identification and verification surveys that were carried out by IGM engineers.

3.11.1 Implementation of Inspection Survey

For the inspection survey, nine points arranged on both sides of the rivers in the area covered by this project with the two known points, namely B-11 and D-30, as the baseline, were simultaneously observed with four units of GNSS equipment. Nine points that are clear on the topographic map were selected, and the coordinates of the locations that are flat, whose position can be easily located and where GNSS observation can be carried out on the stereo image* were measured.

Coordinate values retained by IGM were adopted for planes and elevation values determined by direct leveling in this project were adopted for heights (Figure 3-19).



Source: Prepared by the Project Team

Observation point	X	Y	Height
GPS-1	611,799.617	1,405,693.456	368.250
GPS-2	612,827.091	1,399,738.743	328.338
GPS-3	601,244.131	1,409,008.185	426.400
GPS-4	600,906.118	1,389,309.176	336.882
GPS-5	603,706.274	1,383,907.407	327.015
GPS-6	616,937.584	1,397,205.435	320.209
GPS-7	608,923.969	1,394,046.776	342.793
GPS-8	630,969.092	1,402,760.514	325.549
GPS-9	614,172.210	1,386,819.218	377.592
B-11	606,154.302	1,391,800.147	348.776
D-30	629,561.054	1,401,956.434	338.376
D-35	601,333.098	1,407,075.265	471.762
D-50	628,153.783	1,385,708.276	341.862

Figure 3-19 Inspection Survey Index Map

After carrying out the observation using the GNSS equipment at the verification points configured as described above, 3-dimensional analysis was conducted for the data acquired by the observation to determine the coordinate values of each verification location.

*: Locations whose position can be easily identified are, for example, ends of bridges and corners of manmade structures.

3.11.2 Analysis Results of Verification Points

Positional coordinates measured from the topographic maps and results of the inspection survey by GNSS observation are summarized. Based on the results, with respect to the nine verification points, the standard deviations of plane and height were: SD =±14cm for plane (X direction), SD =±25cm for plane (Y direction) and SD =±40cm for height (H).

Based on the results described above, it was verified that the comprehensive 1:5,000-scale basic GIS data set that was producted in this project, which included quality control at each process, is a product of the series of operations for the production of digital topographic maps. Totally, these digital topographc maps retains an adequate accuracy in terms of both position and height.

4. Technology Transfer Program

4.1 Program Implementation Background

The technology transfer program in this project was implemented with the following points.

1) Implementation of the program should improve the technology level of IGM to enable them to carry out the maintenance of the GIS information of the area covered by this project, including the addition and updating of such information, on their own.
2) The products of this project should be recognized and utilized by the ministries and agencies comprising CIIG as the GIS data of Mali and contribute to the development planning of the Bamako metropolitan area as part of NSDI.

If the spatial information data are to be provided to the ministries, agencies and local governments belonging to CNIG and CRIG, which can be the direct beneficiary of the products (geographic information user), a certain level of accuracy, supply system and responsibility based on uniform inspection criteria and technical reliability must be ensured of such data. As such, for the purpose of nurturing the ownership of IGM for the products of this project, since the beginning of this project, discussions have been conducted with IGM to exchange opinions with them on the program content and prospective participants for each technical field.

Prior to the training, baseline surveys were conducted to determine the skill levels of the IGM participants. The training program for each technical field was designed with the objective of enabling IGM to produce large scale topographic maps and upgrade geographic information after the completion of this project.

Furthermore, a workshop on utilization of the project geospatial datasets should be held for geographic information users as part of the activities to promote the utilization. This would promote a common understanding among the ministries and agencies of CIIG.

4.2 Achievement of Technology Transfer

A baseline survey was conducted to understand the technology level of IGM prior to the start of the program. After confirming the current technology level of IGM, the program content was determined with an aim of strengthening the practical skills in each field. The following table summarizes the results of the technology transfer program implemented in this project.

Table 4-1　Achievement of Technology Transfer Program in Each Field

Field	Subject of technology transfer	Baseline skill level	Achievement
Supervision of aerial photography	Achievement goal: Able to learn photography planning and process management based on the judgment of timing and weather conditions in accordance with the photography purpose	－	△
	Photography planning	×	△
	Direct orientation measurement (GNSS, IMU)	×	△
	Inspection of photographed data	×	△
	Quality control	×	△
Ground control survey	Achievement goal: Able to perform quality control of survey results using the quality control sheet based on the basic understanding of quality control	－	○
	Point selection planning	○	○
	Pricking	△	○
	GNSS observation	○	◎
	Leveling	○	◎
	Quality control	×	○
Field identification/ field completion	Achievement goal: Able to develop investigation plans in accordance with the target scale and implement investigations for field identification based on the understanding of the work content	－	◎
	Understanding of the difference in the scales of topographic maps	×	◎
	Understanding of specifications, map symbols and application rules of map symbols	×	○
	Understanding of the content of investigation (acquisition items)	○	◎
	Understanding of the difference between photograph field identification (field identification) and map field identification (field completion)	×	◎
	Implementation of field identification/completion using digital terminal	×	○
	Analysis of investigation results	×	◎
Aerial triangulation	Achievement goal: Able to perform aerial triangulation independently based on the understanding of all the processes	－	○
	Preparation	△	◎
	Determination of interior orientation	×	○
	Determination of exterior orientation	×	○
	Quality control	△	○
Orthophoto	Achievement goal: Able to learn how to create orthophotos while controlling the quality based on the understanding of the basic concept of orthophotos	－	○
	Understanding of the work process and utilization method of orthophotos	△	○
	Understanding of the relationship between the pixel size and quality	△	○
	Creation of orthophotos	△	○
	Implementation of image adjustment and mosaic processing	△	○
	Understanding of quality control	×	○
Digital plotting	Achievement goal: Able to read digital information from 3-dimensional models composed of stereo aerial photographs and perform quality control of the acquired data based on the understanding of the specification and map symbolization criteria	－	○
	Learning of elevation measurement (single point observation)	△	○
	Learning of feature interpretation accuracy (feature classification)	○	◎
	Understanding of large scale digital data content	○	◎
	Understanding of specifications and map symbolization criteria	×	○
	Learning of preparation for digital plotting (environment setting, analysis of results)	○	◎

	Drawing of topography, feature measurement, elevation point and contour line	○	◎
	Understanding of quality control method and quality control sheet	×	○
Digital compilation	Achievement goal: Able to compile digital data and perform quality control of the compiled data based on the understanding of specifications, map symbols and map symbol application rules	−	○
	Understanding of the matching of joint coordinates between map sheets	○	○
	Understanding of the data type and acquisition classification of each feature	○	◎
	Compilation of plotted data	○	○
	Understanding of topology structure	○	○
	Understanding of appropriate method to input data from the results of field identification and field completion	×	○
	Understanding of appropriate method to input data from collected materials	×	○
	Understanding of the basic concept of quality and process control	△	○
GIS structurization	Achievement goal: Able to perform GIS structurization and quality control of the basic GIS data based on the understanding of specifications, map symbols and map symbol application rules	−	○
	Understanding of point data structure	○	◎
	Understanding of line data structure	○	◎
	Understanding of plane data structure	○	◎
	Understanding of attribute data structure	△	◎
	Learning of basic operations of GIS software	○	◎
	Understanding of metadata	△	○
	Quality control and accuracy control	△	○
Map symbolization	Achievement goal: Able to perform map symbolization and quality control of the symbolized data based on the understanding of specifications, map symbols and map symbol application rules	−	○
	Understanding of map symbols and map symbol application rules	△	○
	Creation of map symbols, line types and patterns to be used	○	◎
	Understanding of map symbol expressions based on the image of final output map	△	○
	Learning of the method to create marginal information and legends	△	○
	Learning of modification method for secular changes	×	○
	Understanding of quality control	×	△
Promotion of utilization	Achievement goal: Capture the needs of potential geographic information users involved in the development of the Bamako metropolitan area and clarify the method to operate the organization able to respond in accordance with the needs	−	○
	Clarification of services and needs	△	◎
	Scope of copyright	○	○
	Policy concerning information disclosure (clarification of security policy)	×	◎
	Design and operation of website	×	○
	Checking of disclosure information and supply of topographic maps	×	○
	Holding of seminars and workshops to promote utilization	○	◎

Qualitative evaluation criteria (4 grades)
Baseline: (×: Lack theoretical knowledge or practical experience, ▵: Have knowledge but no experience, ○: Have theoretical knowledge and practical experience, ◎: Able to perform independently)
Achievement: (×: Underachieved, ▵: Learned only the theory, ○: Understood the theory and put it into practice, ◎: Able to perform independently)

4.3 Implementation of Technical Training

4.3.1 Supervision of Aerial Photography

(1) Technical level of IGM

The technical transfer focused on the theoretical and technical aspects of aerial photography since IGM does not own an aircraft and aerial cameras.

(2) Assessment each work component item

The technical training focused on skills to plan aerial photography taking into account photo acquisition period, weather conditions, and quality control.

1) Plan of aerial photography

Expected aerial photogrammetry results were explained in terms of the features of the aerial camera used, and the development of the aerial photography plan. However, IGM does not have lot of experience in subcontracting or the supervising aerial photography. Therefore, the aerial photography implementation program was not sufficient for IGM to understand aerial photography. Nonetheless, IGM understood the difference between analog and digital aerial photography planning.

2) Direct measure of orientation (GNSS, IMU)

IGM understood the basic elements such as GNSS and IMU measurements, flight plans for digital photography as well as ground observations.

3) Inspection of the photographic data

Aerial photography was completed in a short time due to good weather. As a result, the quality of the aerial photograph was good. Whilethe acquired photographic data did not have distortions or errors, the Project Team noted that IGM understood the inspection workflow for digital aerial photography.

4) Work manuals

- The aerial photography documents (images of aerial photographs, aerial photography log, aerial photography index map, etc.) and work manuals such as (i) introduction to digital photography, (ii) digital camera calibration report, and (ii) data management and quality control

4.3.2 Ground Control Point Survey

IGM ground survey technicians had experience on GNSS and leveling observations. In addition, the technical level of the technicians for topographic survey was above average. Technical transfer on GNSS and leveling observations, and ground control point survey was done through on-the-job-training (OJT).

(1) Verification of the technical level related to the ground control points

1) Management of the geodesic infrastructure of IGM

As indicated in Chapter 3, all geodesic points and the points of leveling managed by IGM around Bamako have not been verified. However, as the results of the inspection survey for the existing geodetic points, the rate of subsistence of the geodetic points managed by IGM is about 60% and that of existing leveling points is estimated to 50%.

Therefore, the Project Team recommended IGM to conduct a visual inspection periodically to know if the known points are normal or not, to take the coordinates numbers and to verify the disappearance of the points with the passing of time (construction of new buildings) in the city of Bamako, as well as to manage some precisely and without mistake on a card of distribution of the points.

2) State of management of the GNSS devices possessed by IGM

The GNSS observations were conducted using devices possessed by IGM. The devices were checked for external damages, the degree of precision of the levels, the interval of the receipt times, and the control of the battery. This inspection showed that the observation devices were managed correctly and without problems.

3) Abilities of the technicians of IGM concerning GNSS observation

During the GNSS observations, IGM technicians set up of the GNSS devices. Installation of the tripod, centering and fast leveling, and height measurements were checked. No problem was noted during observation.

4) Abilities of the technicians of IGM concerning the leveling

Four engineers who work in the IGM Geodetic Division have the experience of leveling with conventional method. However, one engineer has experience of using digital leveling.

(2) Evaluation

The objective of the ground control point survey was to acquire skills for planning and conducting topographic surveys. The Project Team assessed the level of understanding by item of IGM based on the ground control point survey.

1) Development of plan for the selection of points

The development of the ground control points (GCP) plan by both the Project Team and IGM was not achieved due to the security threats, and limited time for field work. However, the Project Team explained to IGM the reasons for developing GCP selection plan. Furthermore, the Project Team concretely indicated the reasons and the bases of the distribution of the ground control points (GCP) of the project in the field. The IGM technicians understood efficient observation plan and the point measurement sites and acted efficiently with travel time/installation environment in mind. The Project Team therefore noted that IGM understood the importance of point selection plan in consideration of efficient and minimum required number of points.

2) GNSS observations

Technical transfer on GNSS observations was done through on-the-job-training (OJT). The following was done:

- Rigorous checking of the height of the GPS antenna
- Determining and fixing points used for the analysis of the baselines
- Checking the coordinates of the record of the observations and order of an observation session
- Error checking and accuracy control for each observed point

3) Leveling

IGM has a good experience of leveling and the Project Team did not observe any problems.

4) Accuracy control

While the ground control point survey capacity is good, IGM has to improve on data management. This is because some data input errors have been detected in the previous leveling survey data. The observation and the calculation of leveling done to define the value of elevation of the geodetic point were correct. However, the Project Team observed data input errors during creation of the table of coordinate values and elevation values of geodetic points. Therefore, the Project Team recommended IGM to check the data more rigorously.

4.3.3 Field Identification/Field Completion

4.3.3.1 Field Identification

In order to get accurate field identification results in a limited time, it is necessary to understand the field identification method according to the objectives and map scale. Therefore, the Project Team organized a workshop in order to give an orientation on basic field identification survey. This is important since it would help IGM to better understand photographic and cartographic techniques (*e.g.*, reading symbols) as well as attain the same knowledge. The training was conducted in the form of OJT.

4.3.3.2 Field Completion

In order to get accurate field identification results in a limited time, it is necessary to understand the field identification method according to the objectives and map scale. Training was given in a form of OJT. A workshop was also held before starting the work.

4.3.3.3 Evaluation

The objective of the field identification and completion survey training was to learn how to conduct field identification and field completion survey based on the survey plan and the target scale. The were evaluated for the following components:

(1) Understanding of the survey content for a medium-scale topographic map and a large-scale topographic maps
The actual work, survey results and questionnaire results indicated that all the survey participants understood this component.

(2) Understanding of specifications, map symbols, and application rules
Some participants forgotten or had inadequate understanding of parts of the map symbols that were not used during the field identification in the beginning of the field completion survey. This is due to the fact that there was a three months gap between field identification and completion surveys. However,the survey results and questionnaire results indicated that most participants understood specifications, map symbols, and application rules.

(3) Understanding of the content of the survey
The participants increased their understanding of the acquisition items by confirming how the items acquired in the field identification are expressed on the map as the survey was conducted.

(4) Execution of field identification using a digital device or tablet
As with the field identification, the participants implemented the survey without any problems, using tablet, GNSS camera, etc. However, the preliminary preparations were made by the Japanese Project Team. It remains to be seen whether or not IGM will be able to make preparations smoothly when they make preparations independently. Therefore, IGM is recommended to continue to make practical use of such devices.

(5) Classification of survey results via the control of the accuracy
Although the final inspection of the survey results was carried out by the Japanese experts, intermediate inspections during the survey process were conducted by the participants from IGM. In particular, lists input by using Excel and road data input by using GIS software were inspected not only on the screen but also after being output to make sure that they were correctly input and updated. It was determined that by repeatedly carrying out inspections in this way, they understood the accuracy control method in addition to the importance of inspection.

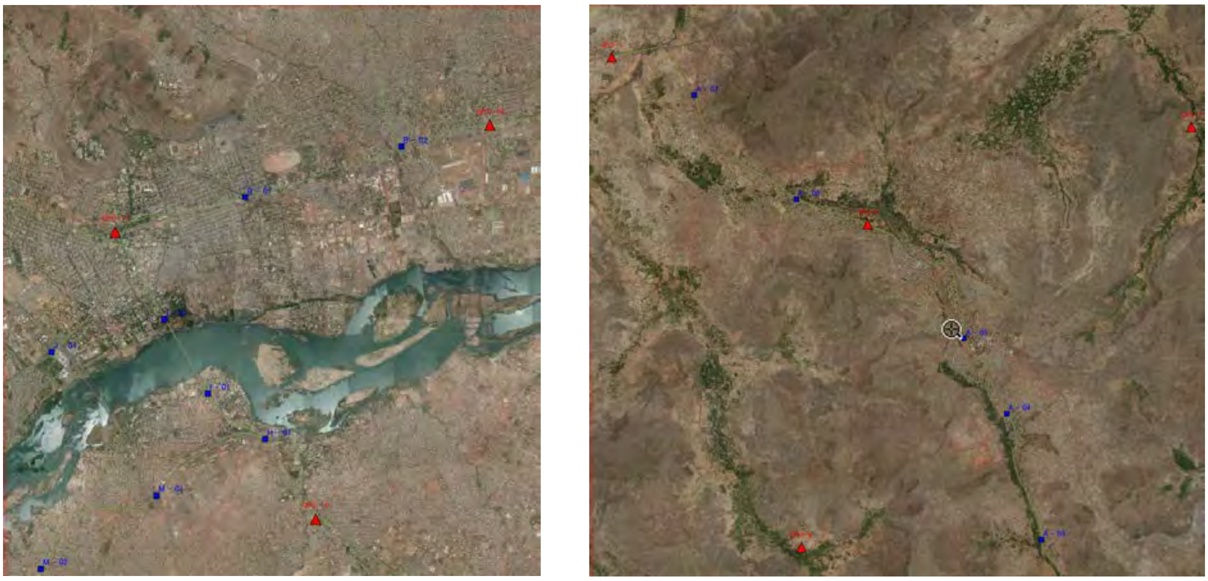
4.3.4 Aerial Triangulation

The training content of aerial triangulation consists of interior orientation, exterior orientation (relative, absolute) and quality control. A preliminary questionnaire and an interview was conducted to understand the skill levels of two participants selected by IGM. Trainingbegan after intial surveys.

The baseline survey revealed that the participants had little experience in aerial triangulation. Therefore, repetitive training was conducted with a focus on technical skill and technical knowledge in order to improve the accuracy in stereoscopic interpretation. In particular, training on “stereoscopic viewing of aerial photographs” and “measurement of ground control point and tie point” was conducted for two participants for 14 days (April 5 to 22, 2016).

(1) Setting the target area in practical training

Simple topographic patterns were used for training to enable the participants to learn 3-dimensional measurement technique in a short period Figure 4-1 shows the area that was selected for the technical training.



Source: Prepared by the Project Team

Figure 4-1 Areas Selected for Training: Flat Urban Area (A: Left) and Mountainous Area (B: Right)

(2) Content of technical training

Lectures on the technical content and knowhow of aerial triangulation mainly covered the work process of aerial triangulation and the basic concept of aerial photogrammetry. With respect to practical skill training based on the lectures, using the 3-dimensional plotting system provided in this project, technical training of the aerial triangulation of two points located in the target areas was implemented.

(3) Technical training evaluation

The goal of this technical training program is to enable IGM to carry out aerial triangulation based on the understanding of the entire work process (preliminary preparation, interior orientation, exterior orientation and quality control)..

1) Understanding of preparatory work

IGM had no previous experience in the operation of digital aerial camera with POS-IMU. The technical training enabled the participants to understand the difference from analog camera and the work process of using digital aerial camera with POS-IMU as well as the necessary information.

Source: Project Team

2) Understanding of work process

The participants learnt the methodology to import digital aerial photograph data and to input photography position (POS-EO) and camera information. The participants reached the level of being able to carry out aerial triangulation through measurement accuracy of control points as well as the method for eliminating tie point errors after repeated training.

3) Implementation of each process and quality control

The participants were able to set the accuracy level of ground control survey results, set the density in automatic tie point measurement, carry out large-scale aerial triangulation analysis and set the visualization display of different types of errors by themselves. In addition, it was determined that they understood the method of evaluating the analysis result to record in the quality control sheet.

4) Achievement after the training

According to the result of the baseline survey, the participants did not have experience in aerial triangulation. As such, pre-training evaluation scores were low. However, as a result of repetitive and intensive technical training, it was confirmed that the participants have reached a working knowledge level.

4.3.5 Orthophoto

According to the result of the baseline survey and checking of existing orthophoto products created by IGM, IGM had a track record and a certain level of skills in creating orthophotos. However, in addition to the lack of experience in DEM editing, they had the following issues.

- They have little experience in creating orthophotos by using aerial photos in which the color tones are not uniform unlike satellite photos and the inclination of structures tends to be large.

- They are unable to determine the joining position of photos, which is important in aerial photo processing
- They have little experience in re-measuring ground elevation (DTM) to correct the ground elevation in editing.

In order to overcome the issues as described above, the technology transfer program was designed to implement practical training focused on the knowhow and techniques unique to aerial photo processing for seven days (June 2 to 20, 2016).

(1) Setting of the target area of training

To enable the participants to learn the orthophoto creation method in a short period, studies were carried out to select an area that would make it easy to learn the series of operations for creation. In the end, four models (six aerial photos) that were chosen for the aerial triangulation training, which included a mountainous area, an urban area and a plain area, were selected as the area for the practical training (about 7.8 km^2).

(2) Content of technical training

In this program, technical training focused on the knowhow and techniques unique to aerial photo processing was implemented for the two participants from IGM and the training of each process consisted of lectures and practical training.

1) DEM generation and editing

2) Creation of orthophoto images and quality control

(3) Evaluation

The achievement of the two participants from IGM with regard to the creation of orthophotos was evaluated as described below.

1) DEM generation and editing

In the beginning of the practical skill training, it took them a long time to learn the operation of the mouse dedicated to 3-dimensional measurement as they were not used to it. However, in the end, they became skillful enough to perform the elevation correction of automatically processed DEM on a 3-dimensional monitor by themselves.

2) Creation of orthophoto images and quality control

With respect to the technical skill, since they do not have experience in using the digital photogrammetry system introduced in this project and in editing seamlines, repetitive skill training was intensively carried out and it was confirmed that they have reached a certain level.

Furthermore, the participants acquired a working knowledge level of knowledge with respect to the creation of DEM and orthophotos, definition of orthophotos (transformation into orthographic projection) and principles of other elevation models (DTM: Digital Terrain Model, DSM: Digital Surface Model). Consequently, they gained an understanding of the basic concept of digital orthophotos and quality evaluation based on accuracy control.

3) Creation of orthophoto maps

Figure 4-2(a) shows an orthophoto image created by the participants during the training program. The orthophoto image is almost similar to the one created in Japan (Figure 4-2(b)). Since the participants were familiar with the field conditions, they had no problem with color tone correction.

Source: Prepared by the Project Team

Figure 4-2 (a) Orthophoto Image produced by trainees, (b) Orthophoto Image produced in Japan

4) Achievement after training

As a result of implementing repetitive training in 3-dimensional interpretation, it was determined that the participants from IGM have reached a working knowledge level with respect to the creation of DEM and orthophotos, principles of elevation models and definition of orthophoto (features of transformation into orthographic projection).

4.3.6 Digital Plotting and Partial Modification

The baseline survey indicated that IGM had experience in analog plotting, basic aerial triangulation knowledge and had basic technical skills (visual interpretation of 3-dimensional models and interpreting features). However, digital plotting was new to IGM. Therefore, it was necessary to improve their digital mapping work process knowledge. It was noted that IGM had working experience on partial modification since they had modified existing 1:20,000 maps using satellite images.

Therefore, the technical training content focused on understanding the procedures for producing digital topographic maps, sharing technical knowledge on digital plotting and practicing accuracy control.

(1) Setting of the target area of practical training

One map sheet equivalent to 1/64 of Bamako Metropolitan project area (or 12km^2)was selected for the technical training.

(2) Content of technical training

The technical training was conducted for 25 days (from April 25 to June 1, 2016) to improve the skill level of the staff. In the training, which consisted of lectures and practical training, PRO-600 module (hereinafter "PRO-600") of the digital photogrammetry system provided in this project (IMAGINE Photogrammetry) was used to explain 3-dimensional digital plotting and data structure, acquisition standard of the topographic map data at a scale of 1:5,000, work procedures of practical modification and reconnaissance method.

(3) Technical training evaluation

The goal of digital plotting training was to capture digital information using 3-dimensional model and to acquire accurate data.

1) Understanding of preparatory work and work process of digital plotting

Since IGM had experience in modification from secular distortions (changes) bu using analog plotting method satellite images, IGM was simple to understand an approach and knowledge required for digital plotting.Evaluation results indicated that the participants understood the preparatory work and digital plotting work procedures

2) 3-dimensional digital plotting data acquisition

Both participants had a satisfactory ability and no additional training was required. However, as they had little experience in 3-dimensional drawing, they were not accustomed to the stereoscopic vision of stereo screens. Therfeore, it was necessary to repeatedly train them in the acquisition of contour line data, which took up a lot of time.

At the beginning, in the middle and at the end of the training, measurement was made to determine the digital information acquisition speed of the participants. The measurement results were 1.56 points/minute, 4.86 points/minute and 11.19 points/minute, which showed that the speed had steadily increased. As such, it would be important for them to continue the practice of data acquisition by acquiring digital plotting data in the area other than the target area of this project after the completion of the project.

3) Improvement of the ability to planimetric features

The ability to interpret planimetric features requires in accordance with the map symbolization criteria and measurement of height at a high accuracy in accordance with scale 1:5,000. The participants from IGM were highly capable of determining the classification of features and the deciphering accuracy was high, but the measurement accuracy of height was inconsistent.

As technical training in the acquisition of the elevation values of target features were conducted again and again, the measurement accuracy of height gradually stabilized. However, since it still takes too long to measure digital information because of lack of interpret skill, continuous training is essential for them to become able to measure elevation instantaneously.

4) Understanding of partial modification

IGM has updated topographic maps by partial modification based on satellite photographs. Therefore, practical training was conducted by allowing the participants to modify digital plotting data that had undergone secular distortions by using aerial photographs and stereo photographs.

It was determined that the training promoted the participants' understanding of the work of updating topographic maps based on the latest aerial photographs and they learned the basic technology required for IGM to modify 3-dimensional topographic maps according to secular changes by themselves in the future.

5) Digital plotting results

The digital plotting data that the participants actually created are as shown in the top left of Figure 4-3. Comparison with the digital plotting data of the same area created in Japan (top right in the same figure) revealed that the two sets of data almost conformed to each other in terms of the measurement of features in planes and the measurement errors of the elevation single points were within the allowable limit.

Source: Prepared by the Project Team

Figure 4-3　Map Created by Overlapping the Plotting Data from Practical Training with Standard Plotting Data (Bottom)

(Top Left: Result of Practical Training in Digital Plotting by IGM, Top Right: Standard Plotting Data)

6) Accuracy control

Because there was no quality control record in IGM, the quality and accuracy information of the acquired results was unclear. Accordingly, based on the quality control sheet adopted in Japan, lectures and exercises were conducted about the recording format of quality results and the method of quality control.

As a result, with respect to the quality control method, that is, to evaluate the defectiveness of 3-dimensional digital plotting data in quantitative terms to take corrective measures, a certain level of understanding was achieved.

7) Achievement after training

As described earlier, since IGM had experience in analog plotting, they had an adequate understanding of the basic preparations and work process and had adequate abilities of stereoscopic vision and to decipher features. However, since they had little experience in digital plotting, it was necessary to promote the understanding of configuration and operation method unique to digital plotting.

In conclusion, although the explanation of the 3-dimensional data structure and the operations to acquire topography and features (it took time to determine the plane position and height) required more time than necessary, from the evaluation of the result of practical training, it is determined that they acquired a certain level of knowledge and skills.

4.3.7 Digital Compilation, Map Symbolization and Partial Modification

Prior to the start of training, a document describing the outline of the digital compilation and map symbolization technologies was distributed to the four participants of this program to explain the schedule and outline of technology transfer.

After that, a questionnaire survey was conducted to grasp their skill level and requests for the technology transfer, etc.. According to the result of the questionnaire and the self-evaluation table, although they use digital compilation software in their work, they have not been able to use it efficiently as a practical work tool.

In view of the degree of their understanding and considering the achievement goal of this program, it was decided to focus on the repetition of basic operations.

(1) Setting of the target area in practical training

In order to let them learn the techniques and methods of digital compilation, map symbolization and quality control in a short period of time, the northwestern quarter of a map numbered “29-I-EA-32-13-4” was selected as the target area of the practical training.

(2) Content of technical training

Lectures on the technical content and knowhow of digital compilation and map symbolization mainly covered the basic concepts and they were given by using the manuals prepared beforehand.

On the other hand, practical training was given repeatedly in accordance with the skill level of the participants and the importance of the items. More specifically, technical training covering the content as described in Table 4-2 was given to two engineers from IGM for 35 days (from April 14 to June 3, 2016).

Table 4-2 Major Content of the Technical Training Program (Digital Compilation and Map Symbolization)

Item	Objective	Work content
Understanding of the content of basic operations for digital compilation	Understanding of the basic operations of the software	Practical training in command operations necessary for this project

Data modification in digital compilation	Understanding of data cleaning Understanding of the measures to be taken against errors	Elimination and adjustment of map lines that are unnecessary for the creation of topology, data modification by visual judgment
Understanding of map symbolization	Understanding of the basic operations of the software Understanding of symbols necessary for map expressions Understanding of judgment in mapping in accordance with the scale	Creation of symbols and line types necessary for map expressions Mapping with data composed of points, lines and planes Creation of the data for output
Modification according to secular changes	Understanding of data insertion considering the feature attributes acquired in completion survey Coordinate conversion where necessary Insertion of reference system data Quality control of mapping result	Data modification considering the consistency with existing data, reconstruction of topology, coordinate conversion, input of raster and vector, insertion of text data Inspection and modification, creation of quality control sheet

(4) Evaluation

The goal of the technology transfer program concerning digital compilation and map symbolization is to acquire data at the accuracy suitable for compilation from digital plotting data based on an understanding of the specifications and map symbolization criteria. The achievement of the three participants from IGM with respect to the skills of digital compilation, map symbolization and partial modification confirmed from the technical training described above is evaluated for each item as follows.

1) Digital compilation

It was determined that through repeated exercises in the training, the participants from IGM understood the operations necessary for digital compilation and the commands and functions of the digital compilation system. However, additional training needs to be provided on a continuous basis to enable them to perform appropriate checking of data based on understanding and to take appropriate actions in an instant with respect to modification (data cleaning), creation of topology and modification according to secular changes.

2) Symbolization

It was determined that they fully understood map symbolization and acquired the knowledge and knowhow of the procedures for creating symbols and line types. It is desired that they will apply the acquired skills in their work.

3) Achievement after training

IGM had little experience in the digital compilation of GIS data including 3-dimensional data and as such, it was necessary to promote their understanding of the basic operations and configuration.

Consequently, it took them more time than necessary to acquire the knowledge needed for basic operations, such as cleaning of 3-dimensional data and creation of topology.

It was expected that the participants from IGM perform the work by applying the basic operations and knowledge that they learned in the training, but their skills did not reach the working level. By giving repeated explanations to them in the latter half of the program, a certain level of understanding was achieved, but they were advised that continuous training was necessary.

4.3.8 GIS Data Structurization

(1) Baseline survey

The purpose of the pre-training questionnaires was to capture baseline information such as previous experience in GIS and database management, participants' perspectives on GIS and expectations on geodatabase training.

(2) Content of technical training

A training workshop was organized on geodatabase management systems. The specific objectives of the training were to:

1) develop an understanding of geodatabase design concepts;
2) design geodatabase schemas to efficiently model and store data;
3) create and modify geodatabase components including subtypes, and topology; and
4) migrate and load the project GIS data into a designed geodatabase.

The training workshop comprised approximately 10% lectures and 90% hands-on laboratory exercises using ArcGIS 10.3 (Advanced version) and sample Bamako mapping project datasets. Three selected staff members from IGM participated in the training for two weeks.

(3) Training evaluation

In general, all the participants encountered problems with components five and six (that is, importing raster dataset into a geodatabase, and creating topology). This is partly attributed to lack of understanding of GIS data models (that is, raster versus vector data models). In order to resolve these problems, the consultant explained again basic GIS concepts and data models, and assisted the participants in performing topology, and raster processing. Following that, the trainees were given additional assignments using administrative boundary data from IGM and free online GIS data. While difficulties concerning geodatabase design and management components such as topology and importing raster data were noted, the participants worked very hard. Generally, the participants are confident of managing GIS data at IGM. Although the participants have great potential, the following are recommended:

4.3.9 Quality Control

4.3.9.1 Ground control point survey

The accuracy and quality control of the ground control points were based on four points outlined below. Note that the results were compiled as point description of ground control points, and used for the subsequent aerial triangulation.

(1) Accuracy control of existing geodetic points

In collaboration with IGM, the Project Team checked the quality of the geodetic points so that it does not affect GNSS observation.

The Project Team used GNSS observation to check if the ground control points coordinates (X, Y, Z) maintained their precision so that they could be used as ground control points. The Project Team observed if IGM staff members could set up the observation instrument as well as perform the initial calibration in order to receive GNSS data from the satellites.

Later, the Project Team compared the observed results with the existing control points in order to check for differences.

The Team observed four points; D0035, D0030, D0050 and B11, and then evaluated the results of the adjustment calculation of the network as resorting to four existing geodetic points. These accuracy control works allowed the Team to judge that these points can be adopted as control points of the skeleton in the ground control point survey.

(2) Accuracy control of the GNSS observations

IGM used to conduct some GNSS observations to this day by means of radiation observation. However, traverse observation was used in this project. The Project Team gave some instructions to the staff members of IGM since this method uses four GNSS devices for observation.

(3) Accuracy control of the leveling

The accuracy control of technology transfer on leveling was carried out based on OJT (data management and accuracy control). IGM had enough leveling experience and observation accuracy of a leveling route was within standards. However, a considerable number of errors were found in the data management method which had adverse effects on the final results.

This is believed to be because there is no system in place to check of input errors and those in calculation at each stage of preparing intermediate results of leveling. Therefore, the Project Team provided thorough instructions on quality control through technology transfer on data management method and accuracy control at each stage in the form of OJT.

(4) Accuracy control of baseline analysis

A 3D analysis was executed for the results of the GNSS observations using software for ground control point analysis, Leica Geo Office (LGO) procured in the Project. The results showed the standard deviation of 18cm, and the subsequent aerial triangulation was conducted using this value.

4.3.9.2 Field Identification/Field Completion

Quality control of the field identification and the field completion was carried out with a focus on the following two points.

(1) Understanding of working criteria and map symbolization criteria

With regard to the positioning of field identification and field completion survey in the creation of large-scale topographic maps, the participants understood the significance of surveying in accordance with work manual and map symbolization criteria through repetitive learning by OJT.

(2) Implementation of inspection, correction of errors and control of quality and process (creation of quality control sheet and process chart)

For process control, the progress of each team was shown on a graph, which was posted at the office of the Project Team so that everyone could see it. This made it possible to compare the progress of each team at a glance and let them recognize the importance of daily control and progress control.

4.3.9.3 Aerial Triangulation

With respect to the calculation of aerial photogrammetry, with the coordinates of the ground control point as the verification point, principal point position (X, Y, Z) and inclination (rotation angle of the X, Y and Z axes, namely, omega, phi and kappa) of the camera in photography were determined, and at the same time, based on the value that quantitatively represents the degree of defectiveness (sigma) and the control point residual error of the ground control point, acceptance or rejection of the calculation result was determined. By lectures and practical skill training, it was taught to the technical training participants that the acceptance criteria are determined by the photography scale of the aerial photographs used and the CCD size of the aerial camera. The IGM staff became able to perform quality control based on the acceptance criteria.

The results were recorded on the "aerial triangulation quality control sheet" and saved. As described in 4.3.5, in this project, a general format for accuracy control was prepared and the quality control sheet was prepared after the quality evaluation of the digital plotting data created by the IGM staff in the practical skill training. It is desired that IGM will continue to use the quality control sheet by improving the format to comply with the design standards and specifications of the national geographic information of Mali that CIIG will prescribe in the future.

4.3.9.4 Orthophoto

Generally, for the quality control of DEM, elevation points randomly extracted from a part of DEM are inspected and recorded. However, the quality of DEM currently created by IGM is partly inconsistent and as such, the product quality will be varied if the DEM is inspected in this way. Therefore, in this technology transfer program, training was conducted on the method of visually inspecting the elevations of the DEM by using a 3-dimensional monitor (100% inspection).

4.3.9.5 Digital Plotting and Partial Modification

For the quality control of 3-dimensional plotting data of digital plotting and partial modification, since these operations are performed in series, quality control sheets of the same format were used. Quality evaluation was carried out by comparing the digital plotting data acquired in the lectures and practical training with 3-dimensional images to check for "excessiveness, omission and 3-dimensional position" of the digital plotting data and "errors and quantitative attributes" of classification. It was taught to the participants that errors found in quality evaluation should be corrected and features should be added to complete the digital plotting data to be transferred to the next process.

4.3.9.6 Digital Compilation and Map Symbolization

It was explained that topographic maps are inspected on the computer screen or by using the output map. If inspected on the computer screen, it is possible to scrutinize minute data structures by zooming in on the screen, but there is a limitation that only a part of the data is inspected by expanding on the screen. On the other hand, in analog inspection using output map, it is possible to check a wide area at one time and as such, this method is suitable for inspecting the whole area of a topographic map for uniformity.

Figure 4-4 Inspection Map and Quality Control Sheet of Training Area

Source: Project Team

It was repeatedly explained to the training participants that, since IGM has the technology for creating analog topographic maps because of past experience, advice from skilled engineers can be easily obtained and in this respect, implementation of the inspection of output, in addition to the inspection on the computer screen, has a significant meaning as it enables cross checking by several people.

Moreover, the participants were advised to record the result of inspection on the quality control sheet not only during this training but after the training and that this will help them understand the error situation and make improvements to the next project.

5. Future Prospects and Expectations Going Forward

Some challenges were observed with respect to the results of the baseline surveys and activities in IGM conducted in this project. It is expected that IGM will tackle the following challenges to develop as an organization responsible for the national geographic information and demonstrate its leadership to the ministries and agencies, which are prospective users of basic GIS data, as a service provider of geographic information technology and GIS data.

(1) Definition of the operations of the new organization and the services to be provided

In addition to providing geographic information, such as aerial photographs, satellite images and topographic maps, it is necessary to clearly define the operations of and technical services to be provided by the newly established CGIG and promote the products of IGM and technical services to be provided on the website.

(2) Management and redevelopment of ground control points

One of the missions of IGM is the management of the national geodetic points which make up the skeleton of the land of Mali. However, currently, the national geodetic points (triangulation points and benchmarks) in Bamako City have been destroyed and lost.

As such, it is essential that IGM survey all the ground control points in Bamako as soon as possible and redevelop new ground control points (including the installation of electronic control points) as necessary before providing support to other ministries and agencies in the development of geographic information.

(3) Updating the product of this project

1) Method of updating information concerning roads and rivers

With respect to road information, it is expected that it will be created upon receiving the road management map used by Cellule Technique d'Appui aux Communes (CTAC) for the management of road facilities, updated to be basic GIS data with accurate positional information and provided back to CTAC to be utilized in road administration. However, the road management map does not cover the entire metropolitan area and road names are not registered in some districts. Moreover, since the provided data are not subject to coordinate management, some areas have a low positional accuracy, and as such, areas that could not be identified were regarded as unregistered.

It is considered that providing the large scale topographic map data that were developed in this project to CTAC and establishing a system for CTAC to update the data and make feedback to IGM will make it possible to develop the road information, while maintaining unified accuracy, thereby contributing to improved efficiency in road administration in the future.

With regard to the names of rivers and water channels, because the topographic map data were created by using only the information stored on the existing 1:25,000 data, the names other than those of major rivers are not registered. Since some rivers and water channels are also used as drainage channels, it is expected that IGM will closely collaborate with the ministries and agencies managing them so that the large scale topographic maps will be utilized for the management of rivers and water channels.

2) Improvement of the accuracy of administrative boundaries (commune and quartier boundaries)

Administrative boundaries, such as commune and quartier boundaries, are basic information for the formation of communities and such information is frequently used for grasping the current situation and issues of communities.

In developing the basic GIS data in this project, commune boundaries were developed from 1:20,000-scale topographic maps created in the 1980s and quartier boundaries were developed from 1:25,000 metropolitan area map and accordingly, high positional accuracy cannot be expected. Moreover, with regard to Kati Commune, since boundaries could not be drawn because of the lack of materials, only the community names were registered. Going forward, it is necessary to finalize the administrative boundary information based on the data that were created in this project, while coordinating with the Ministry of Interior and relevant agencies.

3) Data development for the area outside the area subject to the creation of topographic maps

Using the results of aerial triangulation conducted in this project, 3-dimensional stereo models have already been constructed. As such, it is expected that topographic map data will be developed for the area of 880 km^2, which is not covered by the topographic maps created in this project, to provide for the requests that may arrive in connection with the development plans of other ministries and agencies and the master plan of Bamako City Office.

4) Modification according to secular changes for the area subject to the creation of topographic maps

The 1:5,000-scale topographic maps (520 km^2), which are the product of this project, were developed by using the aerial photographs captured in March 2015. The selling point of this product is that it extensively includes ground height information which did not exist in previous maps and for the time being, it can be sufficiently used as reference data for height. On the other hand, since some parts of the Bamako metropolitan area are being developed rapidly, freshness of the data is gradually declining. As such, when there is any change in the structure or topography, it is necessary to perform plane modification according to the change by using orthophoto images.

5) Cooperation with DNDC (Direction Nationale des Domaines et du Cadastre)

The orthophotos and 1:5,000-scale topographic maps from this project are accurate enough to be used by DNDC in developing the cadastral survey plan. Accordingly, cooperating with DNDC and supporting their cadastral survey services will indirectly contribute to the improvement of administrative services in Bamako City.

(5) Technical specifications of geographic information

In this project, technical specifications for the creation of 1:5,000-scale digital topographic maps and geodatabase of basic GIS data were developed. Considering the concept of shared geographic basic data, such specifications should not be applicable only to IGM, but they should be the technical specifications of the basic information of Mali. It is necessary for IGM to fully understand this point and make effort to publicize the specifications to all geographic information users by developing guidelines, etc.

Also, it is expected that the various technical specifications developed in this project will be revised or updated so that they will be also applicable to the ministries and agencies.

(6) For the construction of NSDI initiatives

Geographic information is merely one of the basic pieces of information of the national land spatial and it does not directly resolve the various issues of Bamako or promote urban development. For this reason, issues concerning the utilization of geographic information are caused by the vulnerability of horizontal collaboration and.it is important to establish mutual understanding and communication between IGM, which is the supplier of geographic information, and users of such information with respect to the sharing of responsibilities.

In this regard, efforts must be made to study the overall framework of Mali and develop operational guidelines so that geographic information will extend across all the ministries and agencies as well as all the sectors using such information. This is already clearly indicated in PNIG and all the geographic information that is needed (or lacking) to meet the needs of the geographic information users will be developed and managed on the basic GIS data (base map) to be created by IGM and ultimately, each geographic data (thematic information) will be shared among the ministries and agencies.

Looking back on the findings from the workshops, IGM recognized the basic concept of NSDI, that is, IGM prepares the base map from its duties and other user organizations develop thematic data on it and on the other hand, member ministries and agencies of CNIG, etc., that are the user organizations, also mostly understood this concept. As such, immediate challenges that IGM needs to tackle firstly, considering the fact that preparations have begun for the development of CGIG, which is the receptacle of the geographic information, are provision of easy-to-use (user friendly) data, GIS technical support and dissemination of information, which were clarified as a result of the attempt to unearth the needs described in Chapter 2.

(7) Conclusion

This project was jointly implemented by the Project Team and the IGM counterparts for about 21 months from February 2015 to October 2016. In the first half of the project, due to the worsening of the security situation of Bamako City, IGM took the initiative in the ground control point survey and the field identification/field completion survey. With respect to the activities in the latter half of the project, technology transfer program was developed on 1:5,000-scale digital mapping based on the aerial photogrammetry using the equipment procured in this project and technical training was

IGM had experienced small scale analog mapping in the past and had created 1:200,000 digital topographic mapping data in a recent project of IGN France, but they experienced the creation of large scale topographic maps for the first time in this project. For this reason, it took a lot of time for the IGM participants to understand and learn the difference in approaches and creation methods due to the difference in scales.

The 1:5,000-scale topographic maps developed in this project are digital data that can be easily added or modified. It is important that IGM will update the data in accordance with the changing situation of Bamako in the future based on the skills and experience acquired in this project. Of course, the technology transfer program that IGM went through in this project must not be enough for them to acquire complete technology.

However, IGM is now equipped with the materials and equipment necessary for the creation of large scale topographic maps and the work manual of each process. In addition, they also have the aerial photographs captured in this project and orthophotos (1,400 km^2) from the result of aerial triangulation. As described earlier, IGM must be ready to start the work for the area of 880 km^2, which is outside the area subject to the creation of topographic maps in this project (520 km^2).

Therefore, the Project Team expects that after the completion of this project, IGM will independently develop 1:5,000-scale topographic maps of the area that such maps have not been created and establish the method of creating large scale topographic maps in Mali through trial and error in the process of this attempt.

This project, which was executed against the unstable security situation of Mali, was supported by a great many people. In conclusion, the Team would like to express their deepest appreciation to the president of IGM and IGM counterparts, the Japanese embassy in Mali, JICA Senegal Office and experts dispatched to Mali for their kind consideration to ensure safety as well as their tremendous support and cooperation to the Team, whose members had to work under constraints during the stay in Bamako, having to perform operations smoothly in a short period of time.