The Republic of Côte d'Ivoire
National Office of Technical Studies and Development (BNETD)
Center of Cartography and Remote Sensing (CCT)

The Republic of Côte d'Ivoire
Digital Topographic Mapping Project for Urban Infrastructure Development

(A Fast Track Project)

Final Report

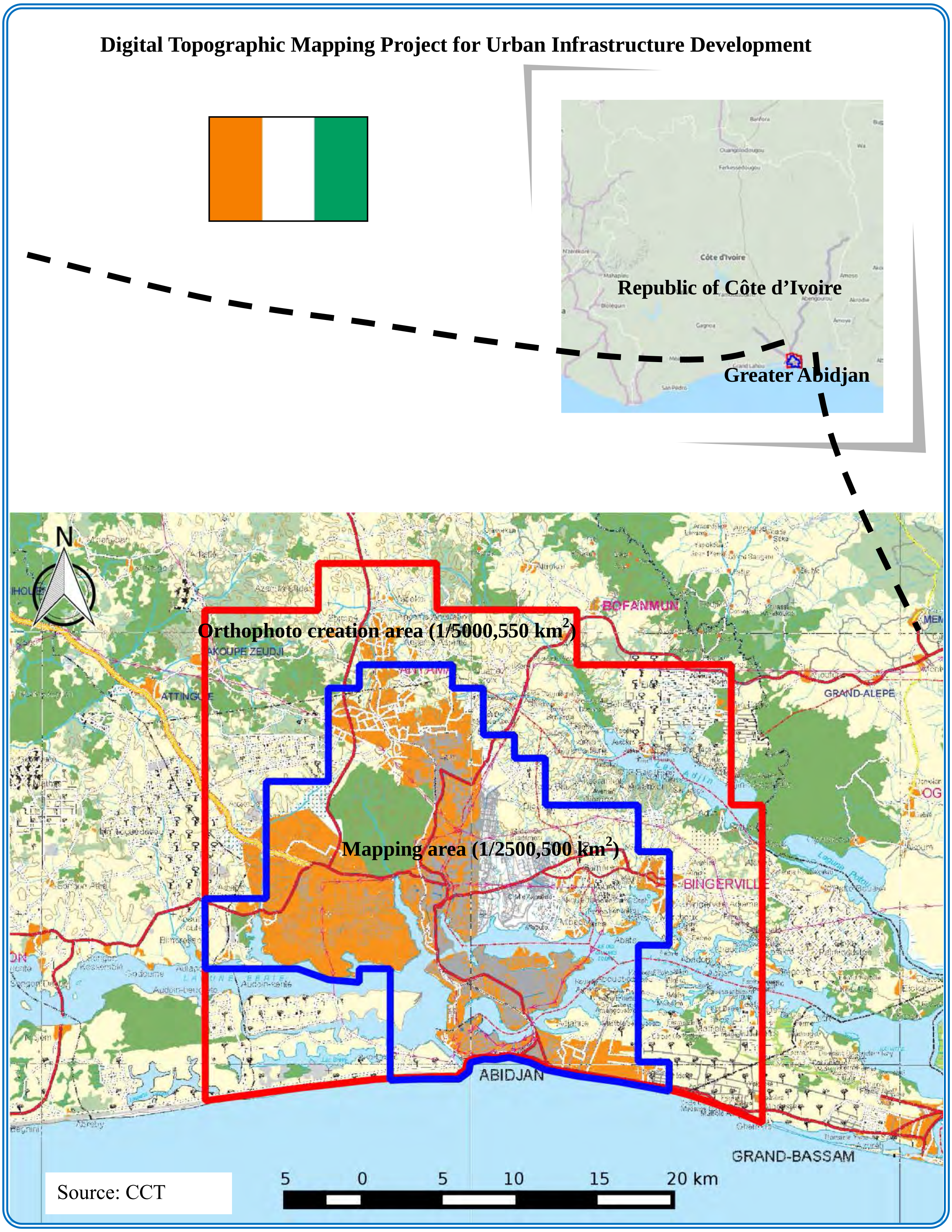
October 2015

Japan International Cooperation Agency (JICA)
Asia Air Survey Co., Ltd.

EI
JR
15-162

Foreign exchange rate
1 euro = 143.62 yen (TTS)
1 euro = 655.957 FCFA
Averages in April 2014

Project Location Map



Source: CCT

Outline of the Study

Outliene of the Study is as follows;

Table S-1 List of the Outputs of this Project

	Subject	Detail	Quantity	Remarks
1.	Aerial photography	Ground resolution (equivalent to a map scale)	15cm	At approx. 1:13,000
		Camera used	DMC	
		Photographed area	1380km^2	
		Number of flight strips	37 strips (43 strips)	6 strips: including one for the bore-sight calibration
		Number of photographs	2382 sheets	(excluding 166 sheets for the bore-sight calibration)
		Aerial photography data	1 set	On a hard disk
2.	Outputs of ground control point survey	Survey results	1 set	CCT , Separate volume
		Baseline analysis	105 points	
		3-D analysis/ adjustment calculation	105 points	
		Preparation of the description and data list of the ground control points	105 points	Sepalete volume
3.	Outputs of leveling	Leveling	180km	
		Calculation	180km	
		Preparation of the description and data list of the pricking points	73 points	26 points＋47 points (5km)
		Point description	1set	Sepalete volume
4.	Discussion on the survey specifications	Survey standards		Reported to ITR
	Map specifications and applicable rules	Number of data capturing items at 1:2,500	Number of the types of items: 134	Compiled in the Final Report (Ver. 5.01)
5.	Outputs of the aerial triangulation	Number of stripes: 27	1 set	Supplement (result of the adjustment calculation) Number of photographs: 1,816
		Number of models	1,789 models	
6.	Simplified orthophotos	Number of images (intermediate outputs)	Full: 172 images 1/4: 664 images	To be used in the field identification
7.	Controlled orthophotos	1:2,500 (500 km^2)	1 set	To CCT (data on a hard disk)
		1:5,000 (550 km^2)	1 set	
8.	Digital data files	1:2,500-scale topographic map data	2 copies	1 copy each to CCT ,JICA
		1:2,500-scale GIS basic data	2 copies	1 copy each to CCT, JICA
		1:2,500-scale topographic map data in the PDF file format	3 copies	1 copy to CCT, 2 copies to JICA
		Digital aerial photograph data	1 copy	1 copy each to CCT ,JICA
		1:5,000-scale orthophoto data	2 copies	1 copy to CCT
		Final Report (in the PDF format)	2 copies	1 copy each to CCT,JICA
9.	Work manual	GPS observation, leveling,	2 sets	1 copy each to

		aerial triangulation, digital plotting, digital editing, GIS structurization, data editing for symbolization		CCT ,JICA
10.	Construction of a WebGIS system	Basic survey, procurement of equipment, system construction, data installation and handover of the licensing	1 set	BNETD/CCT
11.	Kick-off Seminar	Introduction of overall schedule and the products Data utilization discussion	Presentation program	Described in the final report
	Final Seminar	Presentation and handover of the outputs Presentation of the cases of data utilization Outcome of the technology transfer	Catalog/topographic maps bound in a book Cadastral data, water resources Map specifications, GIS	Described in the final report
12.	Procurement of equipment	Leveling instrument, GPS observation equipment, A0 plotter, photogrammetry system (for digital plotting, digital editing and editing for GIS structurization), laptop PCs, portable cameras, handheld GPS devices, etc.	Report on the equipment management record	1 copy each to CCT and JICA
13.	Inception Report	Overall schedule, presentation of the details of the work in each process, request for cooperation to CCT	6 copies in English 15 copies in French 5 copies in Japanese	
	Interim Report	Interim Report (ITR)	6 copies in English 15 copies in French 5 copies in Japanese 15 copies of supplement	5 copies to JICA and 1 copy to CCT 5 copies to JICA and 10 copies to CCT 5 copies to JICA 5 copies to JICA and 10 copies to CCT
	Draft Final Report	Draft Final Report (DFR)	6 copies in English 15 copies in French 5 copies of Japanese summary	5 copies :JICA and 1 copy to CCT 5 copies to JICA and 10 copies to CCT 5 copies to JICA

	Final Report	Final Report (FR)	Report in English: 15 copies Report in French: 15 copies Report in Japanese: 10 copies Summary in Japanese: 10 copies Summary in English: 15 copies Summary in French: 15 copies	5 copies to JICA and 10 copies to CCT 5 copies to JICA and 10 copies to CCT 10 copies to JICA 10 copies to JICA 5 copies to JICA and 10 copy to CCT 5 copies to JICA and 10 copies to CCT
14	Publicity material	Publicity material (in French)	Printed in color on both sides of A3 paper	200 copies (50 copies to JICA and 150 copies to CCT)
15	Report on the quality control	Report on the quality control (in Japanese and English)	Report in English: 1 copy Report in Japanese: 1 copy DVDs (containing the report and quality control sheets)	1 copy to CCT 1 copy to JICA 1 copy each to JICA and CCT
16.	Collection of the digital images	Collection of digital photographs of the entire project (with Japanese and English text)	Collection of digital photographs The collection on CD-R or DVD: 1 copy	Disc of the digital images: 1 copy

The purpose and contents of the Study

The purpose of this Project was to implement the following three activities which were expected to contribute to the infrastructure development in Abidjan, the economic capital of Côte d'Ivoire.

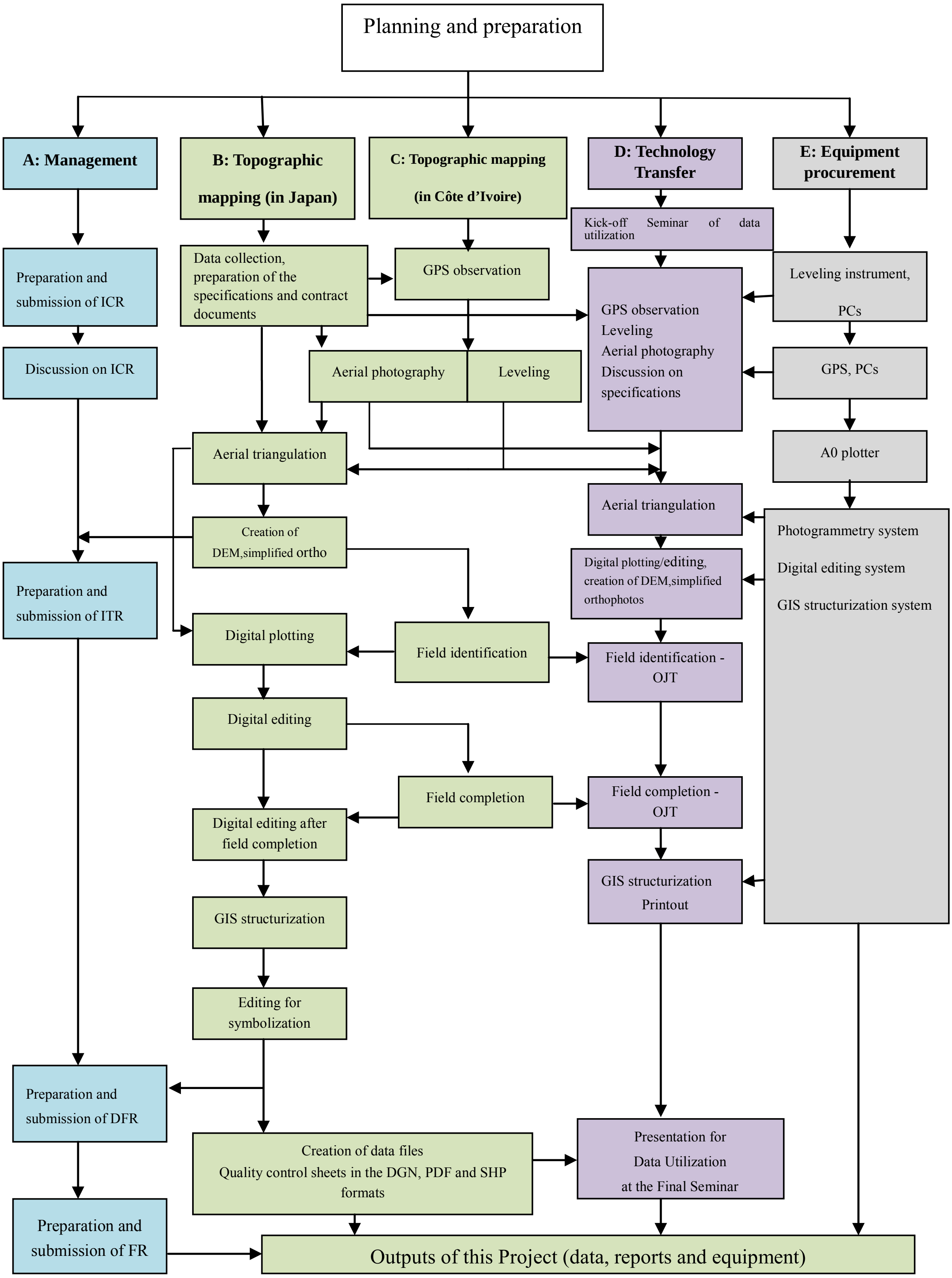
1. **Production of 1:2,500-scale digital topographic maps and GIS basic data of about 500 km^2 area of the central part of Abidjan;**
2. **Creation 1:5,000-scale orthophotos of about 550 km^2 area surrounding the central area of Abidjan; and**
3. **Capacity development and functional improvement through the technology transfer throughout the project implementation**

The Center of Cartography and Remote Sensing (hereinafter referred to as "CCT") under the National Office of Technical Studies and Development (hereinafter referred to as "BNETD") of the Republic of Côte d'Ivoire (hereinafter referred to as "Côte d'Ivoire") did have neither any new equipment, nor a system of maintenance after the destruction of installations and equipment following the post-electoral crisis in 2011. The Government of Côte d'Ivoire filed a request to the Government of Japan asking them a technical help relative to the production of digital topographic maps for the urban development of the city of Abidjan. In response to this request, JICA implemented this Project for the period of 24 months, from October 2013 to October 2015.

In order to achieve the above-mentioned purpose, the work to be implemented in this Project was classified into the five categories mentioned below. Study has been conducted in each of these categories.

- **A: Work related to the management of the progress and quality of the entire project**
- **B: Work related to the topographic mapping (in Côte d'Ivoire)**
- **C: Work related to the topographic mapping (in Japan)**
- **D: Work related to the technology transfer**
- **E: Work related to the procurement of equipment**

Figure S-1 Overall workflow



A: Work Related to the Management of the Progress and Quality of the Entire Project

In order to achieve the above-mentioned purpose in the 24-month-long project period beginning in October 2013 and finishing at the end of September 2015, the Study Team has submitted a series of reports. (See the list of the outputs above for the details.)

In order to achieve the purpose of this Project, the creation of 1:2,500-scale digital topographic map data, the structuration of GIS basic data, and the creation of 1:5,000-scale orthophoto map, the Study Team controlled the aerial photography and conducted the field work of the control point survey and leveling and subsequent office work for the photogrammetry both in Côte d'Ivoire and in Japan. At the same time, the team managed the progress of the entire project to transfer the technologies used in the photogrammetry to the staff members of CCT.

B: Work Related to the Topographic Mapping (in Japan)

The Study Team controlled the accuracy of work in each process in the work in Japan and reinforced the accuracy control by explaining questions and requests arisen in a process to the person in charge of the subsequent process. The team controlled the quality of the work in each process and compiled the result of the quality control in quality control sheets.

(1) Preparation of the Quality Control Sheets

The Study Team controlled the quality and accuracy of the work in the processes in the work in Japan mentioned below and compiled the results of the quality and accuracy control in a report.

1) Aerial photography: Inspection of the images, existence/non-existence of missing images, presence/non-presence of smoke and haze on images and their area coverage
2) Aerial triangulation: Standard deviation of the horizontal positions and elevations of the ground control points
3) Digital plotting: Inspection of the data for omissions, errors and details of representation and inspection of contours and single points
4) Digital editing: Inspection of the details of representation for the compliance with the map specifications and applicable rules
5) Digital editing after field completion: Inspection of the data for omissions and errors in the editing of the data captured in the field completion
6) Editing for structurization: Inspection of the point, line, polygon and attribute data for logical consistency
7) Data editing for symbolization: Inspection of colors, line widths and sizes of the data and the marginal information for the compliance with the map specifications and applicable rules
8) Creation of data files: Virus check, inspection of the metadata which describes the details of

individual GIS basic data when they were stored in a storage medium

C:Work Related to the Topographic Mapping (in Côte d'Ivoire)

The Study Team implemented the work required for creating digital topographic maps with photogrammetry among the work related to the topographic mapping (in Côte d'Ivoire), *i.e.* the aerial photography, GPS observation, leveling, pricking, field identification and field completion, in the quantities mentioned in the Table S-1.

The team was able to complete the aerial photography of Abidjan, which was particularly considered as the largest problem, during the dry season without problem. The team designed the schedule so that the work in Côte d'Ivoire could be completed in the dry season between November and March. The outline of the study in each process of the work in Côte d'Ivoire is described in the following.

(1) GPS observation (including the installation of aerial signal markings)

It was revealed in the OJT of GPS observation that the staff members of CCT were fully capable of conducting it up to the data analysis. Meanwhile, as they did not have experience in the installation of aerial signal markings, the team gave them thorough training on it. They will be able to do it without problem with further experience.

The team conducted the GPS observation as described above in the list of the outputs in cooperation with CCT.

(2) Digital Aerial Photography

The original period for the aerial photography was extended by two months to complete the photography of the entire project area. The staff members of CCT had sufficient understanding of the theory of aerial photography as they had experience in aerial photography with an analog aerial camera. Therefore, the technologies not used with analog cameras but used with digital cameras were transferred to them in this Project.

The team completed the digital aerial photography in the quantities mentioned in the list of the outputs.

(3) Leveling (including pricking)

While the staff members of CCT had experience in the leveling with an analog leveling instrument, they had never used the digital leveling instrument used in this Project. Therefore, they practiced the adjustment of the instrument and conducted trial observation before the commencement of the leveling.

As the percentage of the re-leveled route was 25 %, they should accumulate practical experience in the leveling in different roles (as an observer, an assistant, a staff holder and a calculator).

(4) Field Identification/Field Completion

The Study Team firmly implanted the importance of the standardization of the understanding of the field identification in their minds using the method for the medium-scaled mapping which had been used by them and a workshop held before commencing the large-scale field identification conducted in this study. Staff members of CCT understood the contents of the workshop, in general, and they were able to perform and complete the field identification systematically. The team hopes that they will become able to sort data efficiently using the methodology.

D: Work related to the technology transfer

The Study Team conducted a gap analysis to identify “the technologies not used in CCT” and select “required technologies” in accordance with the policy of the technology transfer in this Project of maximizing its impact in the limited time. On the basis of the result of the analysis, lectures and demonstration of the theories and new technologies of the surveying and a practical approach using OJT were used in the technology transfer.

(1) Thoughts on the Result of the Technology Transfer

The focus of the technology transfer in this Project was not on the practical procedures in the digital topographic mapping, because the staff members of CCT had been recognized to have sufficient level of technical capacity and knowledge, but on the establishment of a data management system with the main purpose of the improvement in the capacity concerning the accuracy control to be implemented in each process in a specific technical area and the quality control of the outputs. In practice, the Study Team had intensive discussion with the people in charge of this Project in CCT after they conducted a baseline survey on the technical skills of staff members of CCT. The team requested full-time assignment of staff members of CCT to the project in the discussion. Then, the team decided the actual contents of the technology transfer in each technical area with the full understanding of the request of CCT. The table below summarizes the outputs of the technology transfer.

(2) Discussion on the Technology Transfer and Expectation in Future

The gap analysis revealed that CCT had lost outputs of various surveys and manuals in the unfortunate events and turmoil in the country in the past. In many cases, the remaining analog data were found to be managed, not in organized ways, but by individual staff members. These data are not only important data for CCT, but also national assets. The Study Team hopes that

CCT will establish a system for the centralized management of data and reference materials by digitizing those analog data immediately with the recognition of the importance of the reference materials shared among its staff members. If such a system is established, CCT will have to utilize the server system provided in this Project to the maximum to manage the geospatial data created in this Project (aerial photograph data, topographic map data, structured GIS data and surveying data) in the form of digital data.

1) The Study Team performed public relations activities to create awareness and facilitate utilization of the outputs of this Project for various stakeholders and actors in development who were assumed to be potential users of the output. As a result, the team received various requests during the project implementation period. The team hopes that CCT will voluntarily revise geospatial data of Abidjan where remarkable change is taking place because of a large number of development activities, as the demand for the use of the geospatial data of the city from the developers is increasing.
2) The Study Team examined the level of technical capacity of the trainees of CCT in each technical process before the training and provided them with the training with the contents which allowed realization of its outcome in a short period of time in each work process. The Study Team provided a guidance to CCT members to prepare their own work manuals during the training period and mke presentation at the final seminar. As a result, it is infellable that the technical capacity of the CCT members has been sufficiently improved and the Study Team hopes that CCT will commence the updating works by using the manuals to meet the social expectation and demand.
3) The ground control point survey was implemented as collaboration between CCT and the Study Team in the form of OJT. The focus of the instruction provided in the ground control point survey was on the importance of accuracy control. The team recommends CCT to establish National survey standards urgently to ensure the accuracy of the data and maintain reproducibility of the survey results. Meanwhile, the focus of the instruction in the technology transfer on field identification was on efficient and consistent data capture for the large-scale topographic mapping. It is expected that CCT will act as advisory organization on geospatial data quality control in Côte d’Ivoire.
4) The technology transfer on aerial triangulation, digital mapping and GIS structurization was implemented as theoretical and practical training. As complicated procedures are used in these processes, repeated practice is recommended in the technology transfer on these subjects. The transferred technologies are not those which can be mastered in a day. The staff members of CCT has already begun their own project of creating topographic maps after the completion of the training utilizing the equipment provided

and manuals prepared in the project. Improvement of their technical capacity is expected from this voluntary and independent activity.

5) The head of the Geodesy Department submitted the compiled manuals for the GPS observation, installation of aerial signal markings, leveling, pricking and aerial photography to the Study Team. The team hopes that these manuals will be maintained and utilized for the transfer of the technologies to young engineers.
6) The team designed the plan of the technology transfer in such a way that the participants would strongly feel the necessity of coordination and cooperation between and within organizations and teams and that the experienced and young engineers in the Project Team work together in cooperation in the technology transfer. Then, the team gave the responsibility of the work to the trainees in the technology transfer which hopefully results to encauledge the CCT members to brush up individual technical capacity and team management knowledge.
7) The quality control of completed output can be ensured by establishing a system in which both the creator of the output and the leader of the groups to which the creator belongs inspect the quality and accuracy of the output. As this system allows production of output which satisfies clients, it will contribute to the revitalization of the organization and improvement of its function.

E: Work Related to the Procurement of Equipment

The equipment procured in this Project consisted of that procured by the consultant and that procured by JICA. All the equipment has already been procured. The lists below are the equipment procured by the consultant and JICA.

(1)Procurement of Materials and Equipment by the Contractor

The equipment (to be) procured in Japan, Côte d'Ivoire and in third countries in accordance with the contract on this Project, (planned) time of procurement and its current state are reported in the following: The Study Team requested CCT to issue a receipt whenever the team had handed over equipment to CCT.

a) Equipment procured in Japan
1) Levels: 2 sets (handed over to CCT in February 2014)
2) Handheld GPS devices : 6 sets (handed over to CCT in April 2015)
3) Handheld digital cameras : 6 sets (handed over to CCT in April 2015)

b) Equipment (to be) procured in Côte d’Ivoire and in third countries

1) Laptop PCs : 2 sets (handed over to CCT in April 2015)
2) Printing equipment (A0-size plotter with scanner) : 1 set (handed over to CCT in October 2014)
3) Equipment for the editing and GIS (plotting, editing and GIS structurization) : 1 set each (handed over to CCT in April 2015)
4) Printing equipment (Color laser printer) : 1 set (handed over to CCT in September 2015)
5) Printing equipment (A3-size color copier) : 1 set(handed over to CCT in September 2015)
6) Equipment for data sharing (server, WebGIS) : 1 set (handed over to CCT in September 2015)

(2)Procurement of Materials and Equipment by JICA

The equipment procured in third countries and Côte d’Ivoire in this Project is described in the following:

a)Equipment procured in Japan

None

b)Equipment procured in Côte d’Ivoire and in third countries

1) GPS observation system : 3 sets (handed over to CCT in August 2014)
2) Software for editing and printing (Dry) : 1 set (handed over to CCT in April 2015)
3) Software for the digital plotting system : 1 set (handed over to CCT in March 2015)

Abbreviations

Abbreviation	Full form	English translation / Remark
ANAC	Autorité Nationale de l'Aviation Civile	National Civil Aviation Authority
AfdB	African Development Bank	
AGEROUTE	AGENCE DE GESTION DES ROUTES	Road Management Agency
BNETD	Bureau National d'Études Techniques et de Développement	National Office of Technical Studies and Development
CAP-A	CAP-A	Software name for absolute orientation using in LPS system
CCT	Le Centre de Cartographie et de Télédétection	Center of Cartography and Remote Sensing
CP	Counterpart	
CURAT	Centre Universitaire de Recherche et d'Application en Teledetection	Cocody University of Research and Application of remote sensing
DAA	District Autonome d'Abidjan	Autonomous District of Abidjan
DAFR	Département Agriculture et Foncier Rural	Department of Agriculture and Rural Areas
DAUDL	Département Aménagement Urbain et Développement Local	Urban Development and Local Development Department
DCCT	Direction CCT	Head Office of the Center of Cartography and Remote Sensing (CCT)
DCEP	Département Construction et Équipements Publics	Department of Construction and Public Facilities
DCF	Délimitation de Circonscription Foncières	District demarcation point
DDC	Direction des Domaines et du Cadastre	Directorate of Land and Cadastre, Ministry of Economy and Finance
DEAH	Département Environnement Assainissement et Hydraulique	Department of Environment, Sanitation and Water
DEM	Digital Elevation Model	
DIEM	Département Industrie Energie et Mines	Department of Industry, Energy and Mines
DIT	Département Infrastructures et Transports	Department of Infrastructures and Transport
DFR	Draft Final Report	

DGI	Direction Générale des Impôts Direction du Cadastre	General Directorate of Tax, Ministry of Economy and Finance Directorate of Cadastral
DMC	Digital Mapping Camera	
DSM	Digital Surface Model	
DTIC	Départment des Technologies de l'Information et de la Communication	Department of Information Technologies and Communications
DTC	Direction de la Topographie et de la Cartographie	Directorate of Topography and Cartography, MCLAU
DTM	Digital Terrain Model	
ECOWAS	The Economic Community of West African States	
ESA	European Space Agency	
FR	Final Report	
GCP	Ground Control Point	Ground control point (used in photogrammetry)
GIS	Geographic Information System	
GNSS/IMU	Global Navigation Satellite System/ Inertial Measuring Unit	
GPS	Global Positioning System	
GPS/IMU	Global Positioning System/ Inertial Measuring Unit	
Geo TIFF	Geo TIFF	Standard format for restoring the image rater data with reference coordinates (Tagged Image File Format)
HTML	Hyper Text Markup Language	
ICR	Inception Report	
IGCI	l'Institut Géographique de Côte d'Ivoire	Geographic Institute of Côte d'Ivoire
IGN-France	l'Institut Géographique National France	National Geographic Institute
IGS	International GNSS Service	
ITR	Interim Report	
JCC	Joint Coordination Committee (Comité conjoint de coordination)	

JICA	Japan International Cooperation Agency	
LPS	Leica Photogrammetry Suite	
MCLAU	Ministère de la Construction, du Logement, de l'Assainissement et de l'Urbanisme	Ministry of Construction, Housing, Hygiene and Urban Development
M/M	Minutes of Meeting	
NASA	National Aeronautics and Space Administration	
NRGAE	Nouveau Réseau Géodésique de la Ville d'Abidjan et ses Environs	New geodetic network for Abidjan and its environs
OJT	On The Job Training	
ORIMA	ORIMA	Aerial triangulation application software using in LPS system
PAA	Port Autonome d'Abidjan	Autonomous Port of Abidjan
PDOP	Position Dilution of Precision	Positioning Dilution Accuracy by distribution of satellite
POS-EO	Position and Orientation System- / External Orientation Parameter	
QGIS	QGIS(Former:Quantum GIS)	Free GIS software name
R/D	Record of Discussion	
RC10	RC10	RC10 – A model of analog aerial camera of Wild specifically designed for photogrammetry
RGCI	Réseau Géodésique de Côte d'Ivoire	Geodetic Network of Côte d'Ivoire
RGIO	Réseau Géodésique Ivoirien Opérationnel	Ivorian Operational Geodetic Network
RGIR	Réseau Géodésique Ivoirien de Référence	Ivorian Geodetic Control Point Network
SACM-GP	Service Actions Commerciales, Marketing et Gestion des Projets	Department of Commercial Activities, Marketing and Project Management, CCT
SAFC	Service Administration, Finances et Compatibilité	Department of Administration, Finance and Accounting, CCT
SASIG	Service Applications SIG et Innovations Géomatiques	Department of GIS Applications and Geomatics Innovations, CCT
SCDT	Service Collecte des Données de Terrain	Department of Terrain Data Collection,

		CCT
SIBD	Service Informatique et Bases de Données	Department of Informatics and Databases, CCT
SMIT	Service Management des Informations et Technologies Géospatiales	Department of Information Management and Geospatial Technologies, CCT
SODExAM	Société d'Exploitation et de Développement Aéroportuaire, Aéronautique et météorologique	Airport, Aeronautical and Meteorological Management and Development Corporation
SOTFR	Service Operations Techniques du Foncier Rural	Department of Technical Operation for Rural Land Ownership, CCT
SRCPD	Service Rédaction Cartographique et Produits Dérivés	Department of Cartographic Editing and Derived Products, CCT
SRTM	Shuttle Radar Topography Mission	
STDA	Service Traitement des Données Aérospatiales	Department of Aerospatial Data Processing
UEMOA	Union Économique et Monétaire Ouest-Africaine	West African Economic and Monetary Union
UPS	Uninterruptible Power(-supply) System	
UTM 30N	Universal Transverse Mercator 30 North	
WB	World Bank	World Bank
WGS84	World Geodetic System 1984	WGS1984 (a standard coordinate system of GPS established by the U.S.A, World Geodetic System) WGS84 (also means a reference ellipsoid)
WebGIS	World Wide Web of GIS	
ZI Imaging	Zeiss/ Intergraph Imaging	

Digital Images


Kick-off seminar


Field identification survey


Discussion on mapping specification


Verification of field data acquisition


GCP survey (GPS observation and aerial signal)


Technical training on digital 3D mapping


GCP survey (Leveling)


Technical training on web GIS

Seminar photos

Guests

Speech :General Director of BNETD

Speech: Director of CCT

Speech of Resident represent of JICA

Speech of Ambassador of Japan in Côte d’Ivoire

Speech of Minister of foreign Affairs

Family Photo

Presentation of WebGIS

Utilized equipments

Presentation of Project results

Presentation of Availability of data

Digital Topographic Mapping Project
For
Urban Infrastructure Development
In
The Republic of Côte d'Ivoire
Final Report

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1. Outline of the Study

This document describes the outline of the study for “The Digital Topographic Mapping Project for Urban Infrastructure Development” (hereinafter “Project”) in the Abidjan Urban Area in the Republic of Côte d’Ivoire.

1.1 Background of the Study (the request from GOCI and the contents of the study)

The Greater Abidjan Area, consisting of the economic capital of Côte d’Ivoire, Abidjan, (the central area: approx. 500km^2) and its environs (the surrounding area: approx. 250km^2), became the city with the most developed social infrastructure in West Africa in the 1970’s with the development of social infrastructure in the era of “Ivorian Miracle” in which the economy of the country grew at an annual rate of 8%. However, the economic, political and military crisis since the 1990’s has resulted in the failure to manage the population, capital and urban functions and continuous deterioration of the developed social infrastructure. The excessive demand caused by the population growth on the infrastructure in such a state has become a bottleneck of economic activities.

Urban planning and development of urban infrastructure based on highly accurate data are urgently required for the alleviation of this problem. However, the large and medium-scale topographic maps, a type of the basic information essential for the development of such various urban infrastructure, have not been updated because of the long-lasting turmoil and financial difficulty. In addition, the Center of Cartography and Remote Sensing (CCT), the organization responsible for topographic mapping in Côte d’Ivoire, of the National Office of Technical Studies and Development (BNETD) has the problems of loss of essential equipment and data and loss of human resources in the confusion in the country. Therefore, capacity building in the CCT is also a significant issue to be addressed.

Against this background, the Japan International Cooperation Agency (JICA) dispatched the Detailed Design Study Team to Côte d’Ivoire in June 2013 and agreed with Government of Côte d’Ivoire on the implementation of technical cooperation for the development of geospatial information as basic information contributing to urban infrastructure development and human resource development and capacity building in CCT.

1.2 Purposes and Outputs of the Study

The Project in the Abidjan Urban Area in the Republic of Côte d’Ivoire has the following three main purposes for achieving its goal of contributing to infrastructure development in the Greater Abidjan Area:

(i) To produce 1:2,500-scale digital topographic maps and GIS basic data of an approx. 500km^2 area of the central part of the commercial capital of Côte d'Ivoire, Abidjan City;

(ii) To produce orthophoto maps of an approx. 550km^2 area surrounding the central area of the City of Abidjan; and

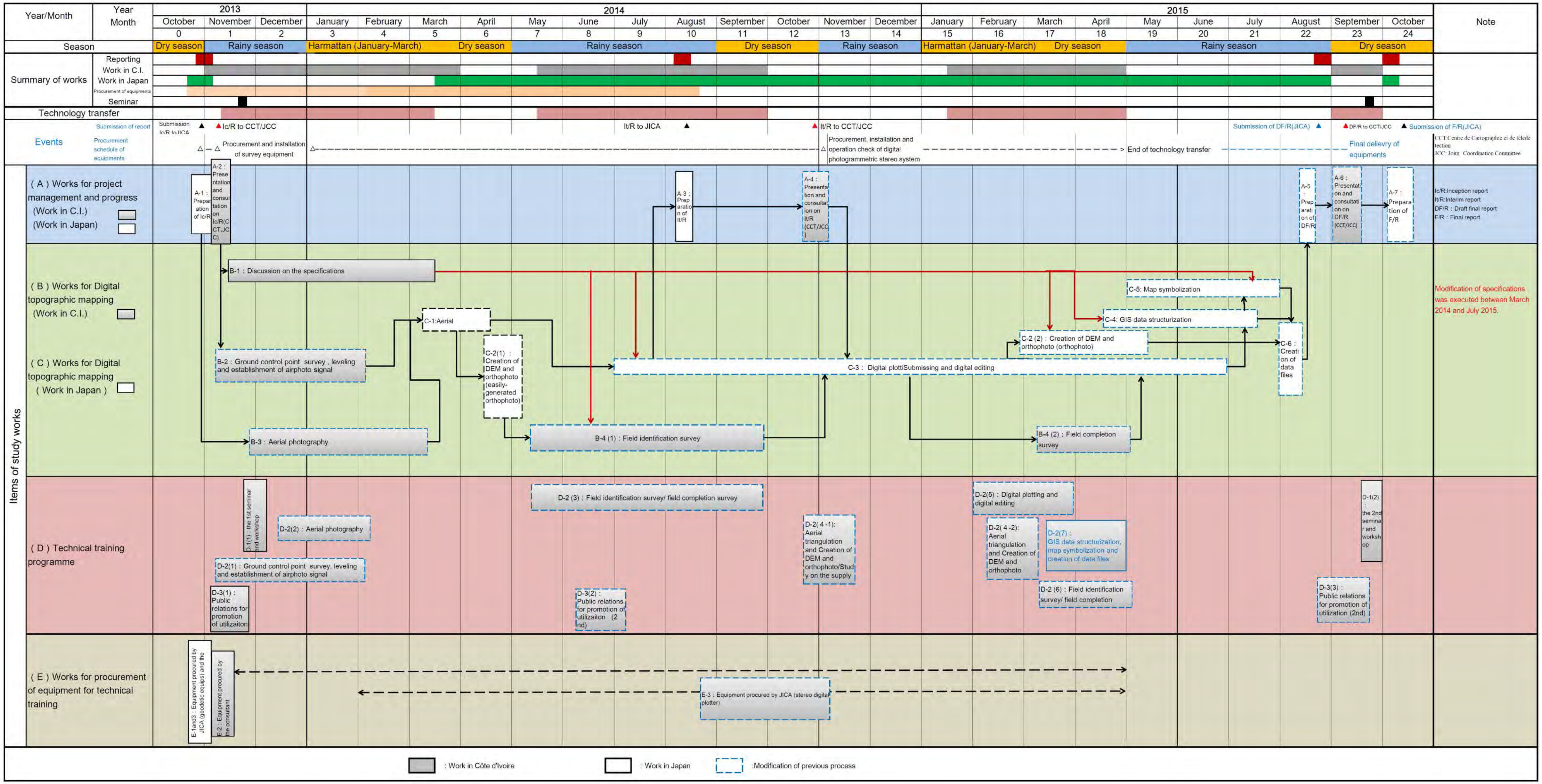
(iii) To restore the technical services of CCT which it used to provide as the national institution of topographic mapping, implement the technology transfer to strengthen the capacity of CCT to the level at which it is able to update the basic geographic information data compliant with the specifications established in the Project independently and prepare a recommendation for the strengthening of the administration of geospatial information

1.3 Study Schedule (Actual Schedule)

Table 1 shows the implementation schedule for the entire (24-month-long) study schedule of the Project.

Table 1 Impelmented Schedule

Executed work schedule of the Digital Topographic Mapping Project for Urban Development

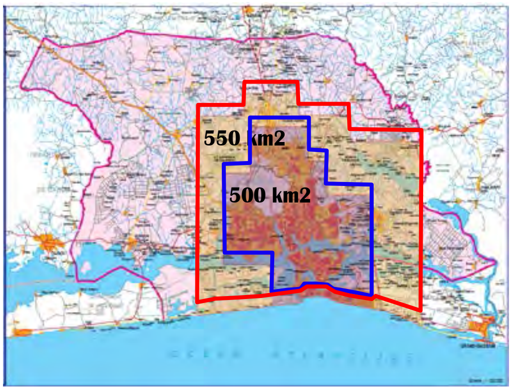


1.4 Study Area

The study area of this Project included the City of Abidjan and the surrounding area. Figure 1 shows the study area.

(1) Area for the creation of 1:2,500 digital topographic maps: An approx. 500km^2 area including the City of Abidjan in its center (the area inside the inner blue line)

(2) Area for the creation of 1:5,000 orthophoto maps: An approx. 550km^2 area in the environs of the City of Abidjan (the area between the inner blue line and the outer red line)



🟪 : Greater Abidjan Area

Figure1 Study Area of the Project

(Source:CCT)

1.5 Composition of the Study Team

Table 2 describes the technical fields in this Project and the departments in CCT (Figure 2) responsible for them. Table 3 shows the Japanese experts and counterparts of the project by the technical field. The Study Team composed of the engineers of the departments of CCT responsible for the technical fields and the Japanese experts was formed and the Japanese experts and the counterparts of CCT implemented the project jointly in the team.

Table 2 Subjects in the Technical Cooperation and Counterpart Departments Responsible for the Subjects

Technical field	Department in CCT responsible for the technical field
Aerial photography with the aerial camera of the latest model	Aerial Photography Section, Department of Terrain Data Collection
Ground control point survey, leveling, pricking, installation of aerial signal markings, field identification	Department of Terrain Data Collection
Aerial triangulation, digital plotting, DEM, orthophotos	Department of Aerospatial Data Processing
Discussion on specifications, digital editing, map symbolization	Department of Cartographic Editing and Derived Products

Data structurization, GIS, data files	Department of Informatics and Databases, and Department of GIS Applications and Geomatics Innovations
Promotion and extension of the utilization of geospatial information data	Department of Commercial Activities, Marketing and Project Management

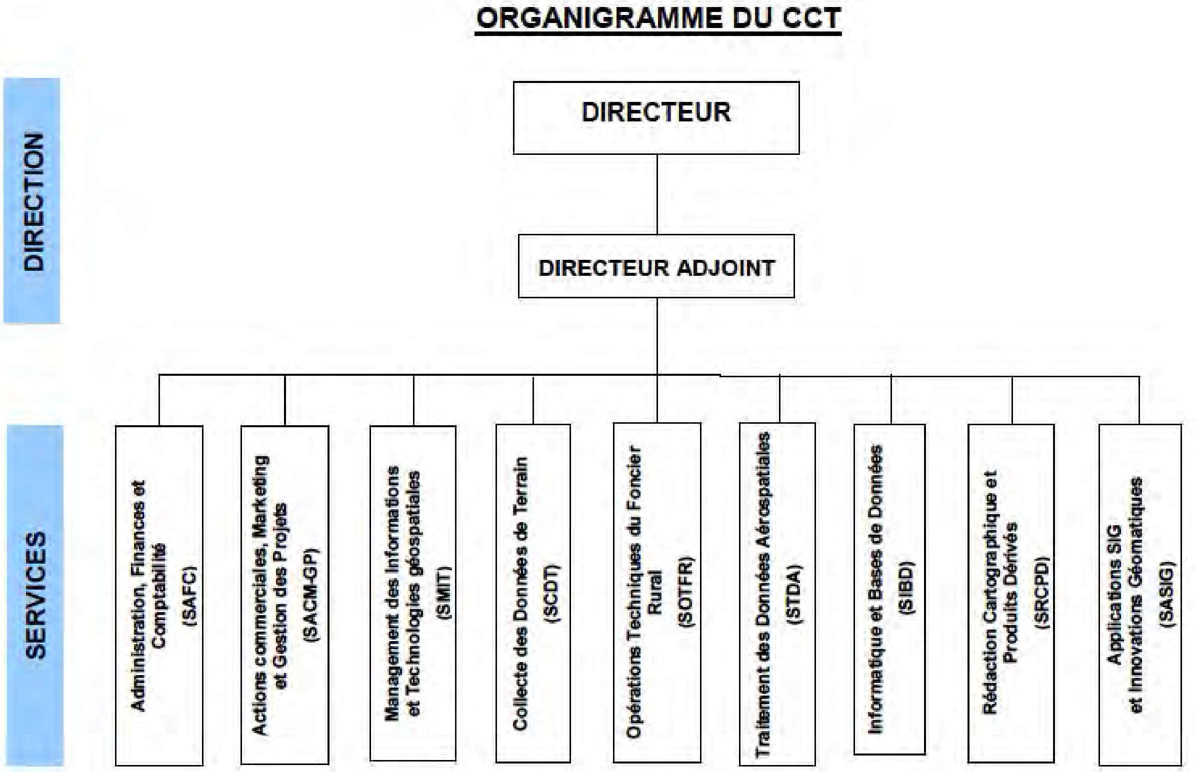


Figure 2 Organization Chart in CCT

Table 3 Main Counterpart Engineers

Area of responsibility in the technical cooperation in the study	JICA expert	Counterpart	Position in CCT
Team Leader/topographic mapping	Nobuo SHIMIZU	M'BRA Kouadio Séverin	Director of CCT
Assistant Team Leader	Shunsuke TOMIMURA	SABENIN Yao	Assistant Director of CCT
Ground control point survey, leveling, pricking,	Tsuneo TERADA	KONE Bourahima	Head of the Department of Terrain Data Collection

installation of aerial signal markings, field identification	Manabu MAYA Shunsuke TOMIMURA		(SCDT)
Aerial triangulation, DEM, creation of orthophoto, digital plotting	Tsuneo TERADA	COULIBALY Gogninniga	Head of the Department of the Aerospatial Data Processing
Discussion on specifications	Shunsuke TOMIMURA	KOUAME Aimé Louis	Head of the Department of Cartographic Editing and Derived Products (SRCPD)
Data Structurization, GIS, creation of data files	Courage KAMUSOKO	NIAMKE Solange Assié	Head of the Department of Informatics and Databases (SIBD)
		KOUAKOU Philippe Olivier	Head of the Department of GIS Applications and Geomatics Innovations (SASIG)
Data utilization plan	Nobuo SHIMIZU Matteo GISMONDI	N'DOUME Claude Thierry Aké	Head of the Department of Commercial Activities, Marketing and Project Management (SACM-GP)
		KOUAME Loukou Jacob-Charles	Head of the Department of Information Management and Geospatial Technologies (SMIT)
Aerial photography	Yuji YOSHIDA	N'GUESSAN Kouakou Privat	Navigator
		OUATTARA Baba Danouma	Pilot

1.6 Overall Composition and Schedule Planning of the Project

This report describes the work items implemented within the 24-month period between late October 2013 and late October 2015. The work is divided into five categories (A) to (E) by implementation method, as shown in the work schedule on the following page.

Table 4 Work Schedule

Fiscal year		2013						2014												2015						
Work items		10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10
(A)Work for project and progress management																										
A-1	Preparation of Inception report(Ic/R) (work in Japan)		□																							
A-2	Presentation and discussion on Ic/R (work in Côte d'Ivoire)		■																							
A-3	Preparation of Interim report(It/R) (work in Japan)											□														
A-4	Presentation and discussion on It/R (work in Côte d'Ivoire)												■→	■												
A-5	Preparation of draft final report(DF/R) (work in Japan)																							□		
A-6	Presentation and discussion on DF/R (work in Côte d'Ivoire)																								■	
A-7	Preparation of final report(F/R) (work in Japan)																									□
(B)Work for production of digital topographic maps (work in Côte d'Ivoire)																										
B-1	Discussion on the specifications		■	■	■	■	■▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
B-2(1)	Ground control point survey and establishment of airphoto signal		■	■	■▨	▨																				
B-2(2)	Leveling and pricking			■	■																					
B-3	Aerial photography		■	■	■	▨	▨																			
B-4(1)	Field identification survey							■	■	■	■	■	■													
B-4(2)	Field completion survey																■	■	■	■						
(C)Work for production of digital topographic maps (work in Japan)																										
C-1	Aerial triangulation						□	□																		
C-2(1)	Creation of DEM and orthophoto (simple orthophoto)							□	□																	
C-2(1)	Creation of DEM and orthophoto (orthophoto)															□	□	□								
C-3	Digital plotting and digital editing									□	□	□	□	□	□	□	□	□	□	□	□	▨	▨			
C-4	GIS data structurization																			□	□	□	▨			
C-5	Map symbolization																				□	□	▨			
C-6	Creation of data files																							□		
(D)Technical training programme																										
D-1(1)	1st seminar and workshop		■																							
D-1(2)	2nd seminar and workshop																								■	
D-2(1)	Aerial photography		■	■	▨																					
D-2(2)	Ground control point survey, leveling and establishment of airphoto signal		■	■	■▨	▨																				
D-2(3)	Field identification survey/ field completion survey							■	■	■	■	■	■				■	■	■	■▨						
D-2(4)	Aerial triangulation and Creation of DEM and orthophoto											■		■												
D-2(5)	Digital plotting and digital editing																■	■	■							
D-2(6)	GIS data structurization, map symbolization and creation of data files																		■	■						
D-3(1)	Public relations for promotion of utilizaiton (1st)		■▨	▨																						
D-3(2)	Public relations for promotion of utilization (2nd, 3rd)									■															■	
(E) Work for procurement of equipment																										
E-1	Equipment procured by the consultant (work in Japan)	□																								
E-2	Equipment procured by the consultant (work in Côte d'Ivoire)		■→	→	→	→	→	→	→	→	→	→	→	→	→											
E-3	Equipment procured by JICA (geodetic survey)		■→	→	→	→	→	→	→																	
E-4	Equipment procured by JICA (stereo digital plotter)										■→	→														

■ work in Côte d'Ivoire □ work in Japan ▨ Revised schedule

2. Topographic mapping activities in the Greater Abidjan

The work conducted in Abidjan for the creation of the 1:2,500-scale topographic map data and the 1:5,000-scale orthophoto data is described in the following.

2.1 Discussion on Specifications (B-1)

The Study Team held a discussion with the engineers of CCT on the map specifications which the team had prepared in advance for the creation of new 1:2,500 topographic maps.

(1) Establishment of the General Specifications

CCT has used the specifications of the 1:50,000 digital topographic maps produced by its database BDGéo 200 as the basis for the preparation of specifications of other scale of topographic maps. Since the creation of large-scale (1:2,500) topographic maps in this Project would be the first opportunity for CCT to perform this type of work, CCT had requested preparation of the map specifications as the framework of the large-scale map creation since the beginning of the discussion on this Project. Discussion on the map specifications continued until end of July 2015 and was completed throughout the implementation period of this Project. The goal of the discussion in the first phase of Work in Côte d'Ivoire was to reach agreement on matters of special importance mentioned below.

- General specifications to be used in this Project;
- Rules for numbering large-scale topographic map sheets and a map sheet division system
- Selection of the topographic features to be represented on 1:2,500 topographic maps
- Definition and standards of the topographic features to be represented and documentation of the definition and standards
- Marginal information of 1:2,500 topographic maps

(2) Outputs

An agreement was reached on the subjects mentioned below in the end of a series of discussion on the subjects mentioned above and the representatives of CCT and the Study Team put their signature on the record of discussion describing the agreement.

・ Systems to be used:	Geodetic system: UTM/WGS84 Language: French System of measurement: Metric
・ Map specifications:	Sheet size: A0 format^{*1} Measure within the neat line: 60cm x 80cm (1.5km x 2.0km)^{*1} Map sheet division system: to create a new system by

shifting 500m south from that of the existing 1:5,000 maps[*2]
Map sheet numbering system: to follow the rules for the existing 1:5,000 maps[*2,]
Number of data captured items: 134 (the final version - Ver. 5.01) [*3]
Intervals of contours: index contour – 10 m, intermediate contour – 2m, supplementary contour – 1m

*1 See “Renseignement marginal relative à la carte topographique à l’échelle 1:2.500”
(English translation: the marginal information of the 1:2,500-scale topographic map)
*2 See “Méthodologie du système de numérotation cartographique à l’échelle 1:2.500”
(English translation: the numbering system for the 1:2,500-scale topographic map sheets)
*3 See “Spécification cartographique de base – Signe cartographique et application des règles relatives aux cartes à grande échelle 1 :2.500”
(English translation: the basic specifications for the topographic maps - map symbols and applicable rules of the 1:2,500-large-scale topographic maps with signature)

2.2 Ground control point survey (installation of aerial signal markings, GPS observation, leveling and pricking) B-2 (1), B-2 (2)

With regard to the ground control point survey conducted in Côte d’Ivoire, the installation of aerial signal markings, GPS observation, leveling and pricking conducted in the field are described in the following. Ground control point survey is the process consisting of the field surveying of (the coordinates of) ground control points required for the analytical calculation in the subsequent process of aerial triangulation and in the digital plotting, the installation of aerial signal markings before the aerial photography, the marking of the control points on aerial photographs (pricking) after the photography and the determination of the horizontal positions of the control points.

(1) Description of the work

The ground control point survey of 105 points (including selected 31 points of aerial signal marking installation and 74 pricking points, and one verification point) to be used in the aerial triangulation was conducted. Before the survey, the Study Team obtained the result of the survey of the geodetic origins of this Project. Then, the team and the counterparts jointly conducted the survey while the team provided the counterparts with the guidance on the point selection method, the method to install aerial signal markings suitable for a site condition and the pricking method.

(2) Origins of Coordinates

In the discussion with CCT before the ground control point survey, it was agreed that the primary control point network developed throughout the country should be the reference coordinates of Côte d'Ivoire. The geodetic origins mentioned below were selected from the points in the network to be used in the creation of 1:2,500 topographic maps in this Project.

Horizontal reference points:	RGIR-001 in the CCT building and RGIO-19 in Anyama District
Elevation reference points:	Elevations of the existing benchmarks (BE8 and BE10) based on Dakar Original Benchmark

Before the field works, the Study Team prepared a draft ground control point arrangement plan from the above-mentioned geodetic origins and satellite imagery, conducted field reconnaissance of the points in the plan and determined locations appropriate for aerial signal marking installation and pricking. During the field reconnaissance, the team also prepared a description (sketch maps) of the control points.

(3) Survey Implementation Structure

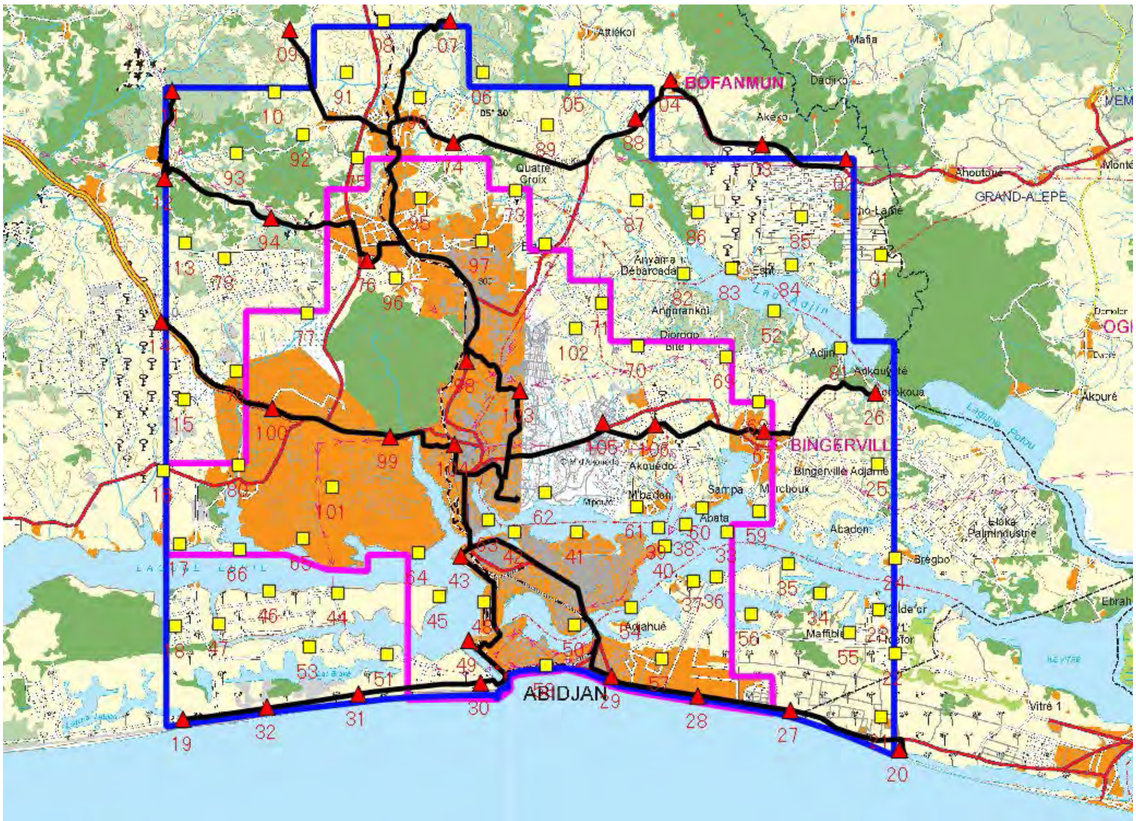
The results of the pre study on the natural and geographical conditions of the survey area, a total 105 points of ground survey was conducted by four work groups.

Members of the survey groups: Staff members of the Department of Terrain Data Collection (SCDT)

・ Work group leader	: Kone Bourahima
Group 1	: Djea Ngoran Aubert
Group 2	: Goha T. Gedeon
Group 3	: Kassi Kouame Rich
Group 4	: Souleymane Traore

(4) Arrangement of the Ground Control Points

In the ground control point arrangement plan, 31 and 74 points were selected for the installation of aerial signal markings and pricking, respectively, with the complicated natural condition (lagoons) taken into consideration, as shown in Figure 3. One of those points was selected as a location of a benchmark, which served as a verification point to control the accuracy of the data to be created.



(Source: CCT. Study Team)

Figure3 Ground Control Point Arrangement Map

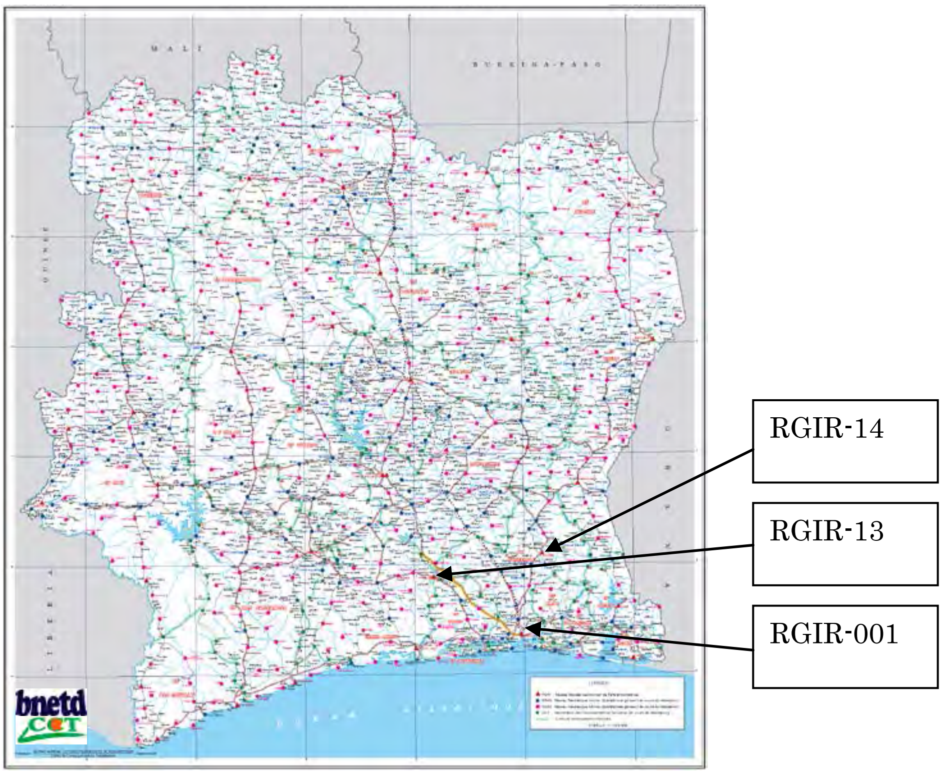
🟦 : Area for orthophoto creation
🟪 : Area for the creation of 1:2,500 topographic maps
▲ : Location of the aerial signal marking installation (31 locations)
🟨 : Location of the aerial signal marking installation or pricking (74 locations)

(5) Result of Various Surveys for the Installation of Aerial Signal Markings

The inspection of the existing control points and an inventory study of specifications revealed the following:

1) Inspection of the Horizontal Positions

The Study Team verified the accuracy of the geodetic origins of this Project and inspected the existing control points in and around the study area. RGIR-001 (primary control point), a geodetic origin of this Project, is a national control point whose coordinates were measured with simultaneous GPS observation for a long period from the two primary control points, RGIR-14 and RGIR-13 which exist away more than 100 km from RGIR-001. The survey result owned by CCT shows that the coordinates of RFIR-001 satisfy the accuracy required for the primary control point. The inspection in this Project proved that the horizontal positional data of the coordinates of this control point was accurate enough to be used in this Project.



(Source CCT)

Figure 4 GCP network for 1st order and second order of Côte d'Ivoire

2) Inspection of Elevation

The Study Team confirmed that there was no problem in using RGIO-19 (secondary control point) in Côte d'Ivoire in the creation of 1:2,500 topographic maps with GPS observation. However, because of the need to verify the accuracy of the elevation (H) at the control points RGIR-001 and RGIO-19, the team measured the elevation of these points with the direct leveling from the existing benchmarks. The result of the leveling proved that the elevation data of those control points were accurate enough to be used in this Project.

3) Quality Control

Despite having experience in small-scale (1:10,000 or smaller) topographic mapping, CCT was found to have the problems mentioned below in the installation of GCPs and the analysis of the observation data in the large-scale (1:2,500 or larger) topographic mapping.

- The data of the existing points have not been digitized.
- The existing data are not sistematically organized but also individually by staff

members.

- CCT does not have specifications for the control point survey at the large scale, 1:2,500.
- Staff members do not have experience in working at a large scale.

On the basis of the observations mentioned above, the Study Team concluded that it was absolutely necessary for CCT to strictly enforce the quality and accuracy control and output management. Therefore, the team facilitated the understanding of the expertise in the quality and accuracy control by the staff members of CCT in the technology transfer mentioned below.

(6) GPS Observation

In this Project, GPS observation was implemented as mentioned below after identifying the locations of aerial signal markings and pricking points.

1) Implementation schedule

December 3, 2013 – January 10, 2014	GPS observation (39 days)
January 13, 2014 – February 3, 2014	GPS calculation and processing (22 days)

2) Description of the work

GPS observation was conducted at a total of 105 control points, 31 points at which aerial signal markings were installed and 74 selected pricking points. The inspection survey for continuous observation was conducted with GPS observation devices located at the two fixed points, the geodetic origins, RGIR-001 and RGIO-19, prior to the GPS observation at the 105 points.

3) Observation Implementation Structure

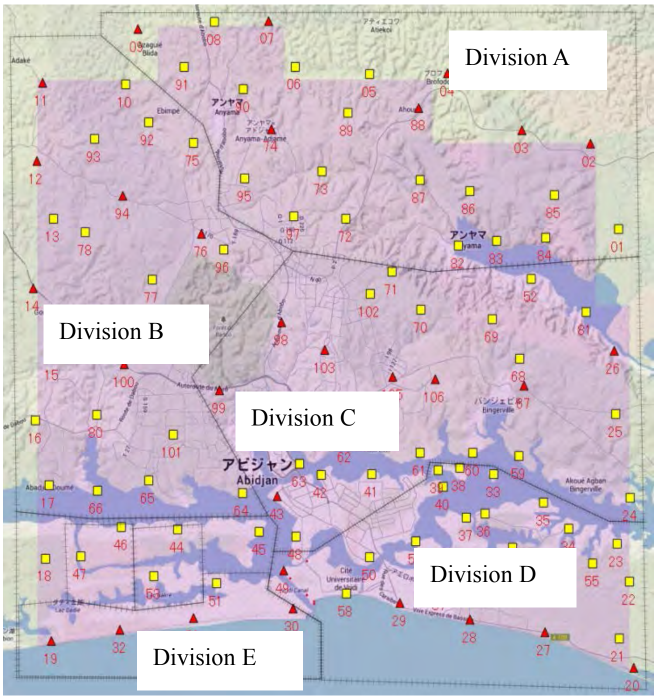
The original plan was to conduct GPS observation with three work groups and three GPS devices. However, the field reconnaissance revealed the need to increase the number of ground control points because of the topographic and natural conditions of the study area (the existence of lagoons in the study area) and the possibilities that the traffic congestion would compromise the efficiency of the work and that poor weather would delay the aerial photography. In order to complete the ground control point survey (GPS observation and installation of aerial signal markings) in a short period of time, the Study Team changed the implementation structure and conducted the GPS observation with four work groups. (See the figure below.)

Members of the survey groups: Staff members of the Department of Terrain Data Collection (SCDT)

- Work group leader : Kone Bourahima

Group 1 : Djea Ngoran Aubert
Group 2 : N' GUESSAN Kouassi KAK Ezechias
Group 3 : Samassi Ismaila
Group 4 : Souleymane Traore

Each of the four groups carried out the GPS observation in each of the four divisions, Divisions A, B, C and D, where they could carry out the observation without overnight stay. The GPS observation in Division E which is located in a remote area was conducted by all four groups.



（Source:Map data ©2015 Google, Study Team）

Figure5 Locations of the 105 GPS Observation Points and the Divisions Map

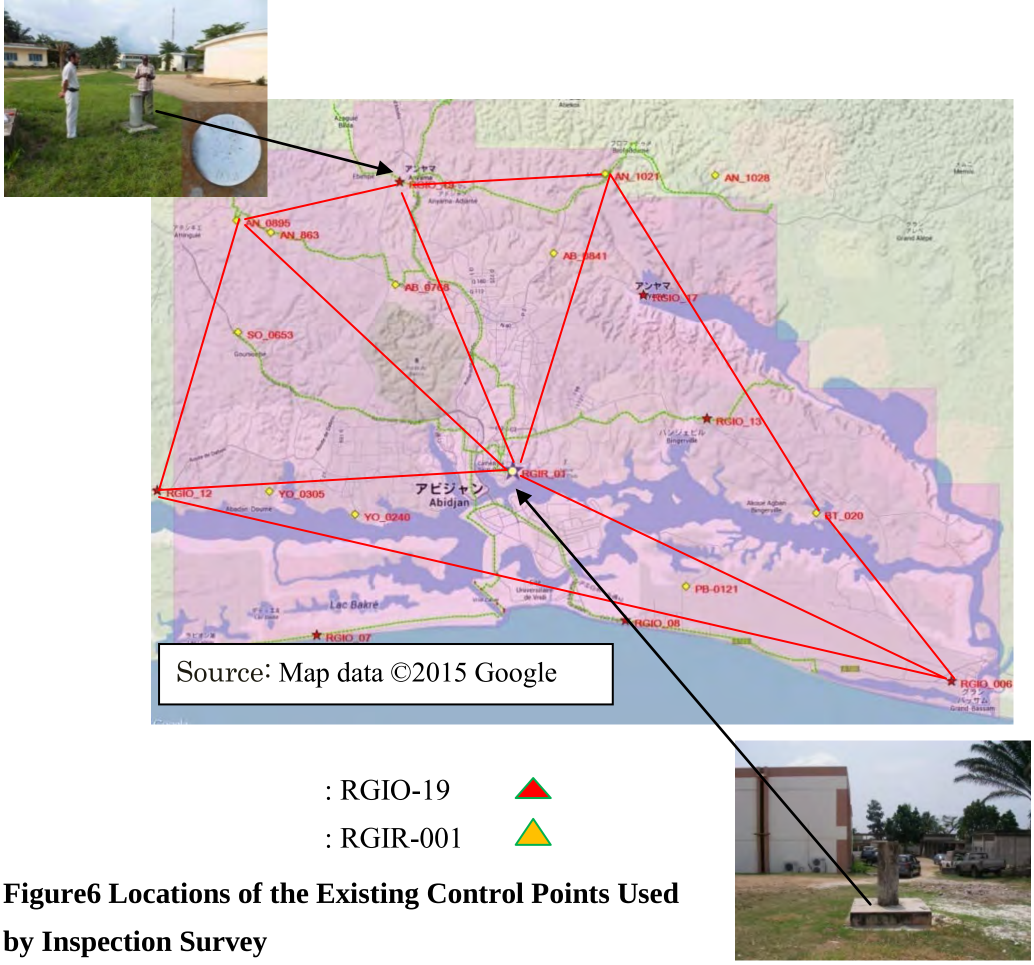
4) Implementation of the GPS Observation

After the inspection survey of the existing points with the GPS survey, GPS observation of the 105 new points was carried out using the two fixed points, RGIR-001 in the CCT Building and RGIO-19 in Anyama town.

a) Inspection Survey

In the inspection survey, the control points existing in the area of the aerial photography including RGIO-19 in Anyama town were surveyed and the survey result was inspected. Because of the limited time available for the survey, GPS observation was carried out at the two fixed points and four existing control points. The coordinates of those points calculated from the result of the GPS observation were proved to satisfy the accuracy standards. The coordinates of RGIO-19 in Anyama District were determined in the inspection survey. (See Figure 6)

RGIO-19



Source: Map data ©2015 Google

: RGIO-19 🔺

: RGIR-001 △

Figure6 Locations of the Existing Control Points Used by Inspection Survey

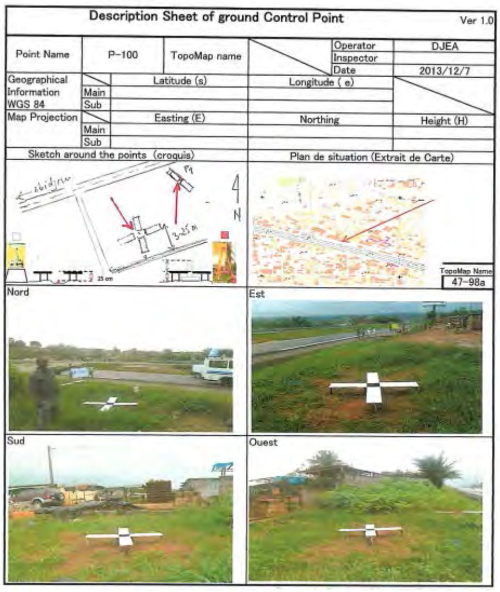
RGIR-001

b) Result

As shown in Figure 6, the GPS observation was conducted at the 105 new points using RGIR-001 and RGIO-19 as the fixed points. Simultaneous observation was carried out at each point, excluding the fix stations, continuously for two hours at ten-second data acquisition intervals. The quality of GPS signal received at each point was ensured with visual verification of PDOP (positional dilution of precision), an index of the accuracy of positional information of GPS, at the time of observation.

The result of the GPS observation was produced by the baseline analysis with the analysis software in LEICA Geo Office. The horizontal coordinates of the 105 points (XYZ) were obtained as the result of the net adjustment of the result of the baseline analysis based on the result of the direct leveling, and the coordinate data were listed in the point description for the aerial triangulation.

Two types of control point descriptions, one for the aerial signals installed before the photography (Photo 1 on the left) and the other for the pricking points where clearly-distinguishable features on the ground had been selected as GCPs (Photo 1 on the right), were created.



Description Sheet of ground Control Point Ver 1.0

Point Name	P-100	TopoMap name		Operator	DJEA
				Inspector	
				Date	2013/12/7

Geographical Information WGS 84		Latitude (s)	Longitude (e)	
	Main			
	Sub			
Map Projection		Easting (E)	Northing	Height (H)
	Main			
	Sub			

Sketch around the points (croquis)

Plan de situation (Extrait de Carte)

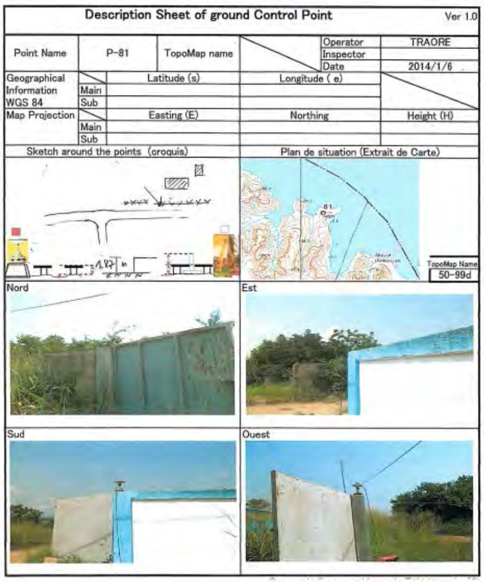
TopoMap Name 47-98a

Nord

Est

Sud

Ouest



Description Sheet of ground Control Point Ver 1.0

Point Name	P-81	TopoMap name		Operator	TRAORE
				Inspector	
				Date	2014/1/6

Geographical Information WGS 84		Latitude (s)	Longitude (e)	
	Main			
	Sub			
Map Projection		Easting (E)	Northing	Height (H)
	Main			
	Sub			

Sketch around the points (croquis)

Plan de situation (Extrait de Carte)

TopoMap Name 50-99d

Nord

Est

Sud

Ouest

Photo 1 Point Description of Aerial Signal Marking Installation (left) and Pricking Point Description (right)

(7) Leveling and Pricking

Leveling is the process of determining the elevation of ground control points at which the GPS observation was conducted and pricking points marked on aerial photographs using the vertical datum adopted in the country concerned. In order to improve the accuracy of the elevation data, the leveling includes leveling along roads and establishing fixed points at a regular interval as new benchmarks. Leveling and pricking was carried out in the 48-day period between December 14, 2013 and January 28, 2014, in order to determine the elevations of the ground control points to be used in the aerial triangulation.

1) What are the direct leveling and the pricking?

Leveling is a method of surveying to determine elevation of a point by repeatedly measuring the difference in elevation between two points using two staffs erected at the two points and a leveling instrument placed at the midpoint between the two points (Figure 7). Pricking is the work of specifying locations of benchmarks to be used as ground control points in photogrammetry on photographs and images.

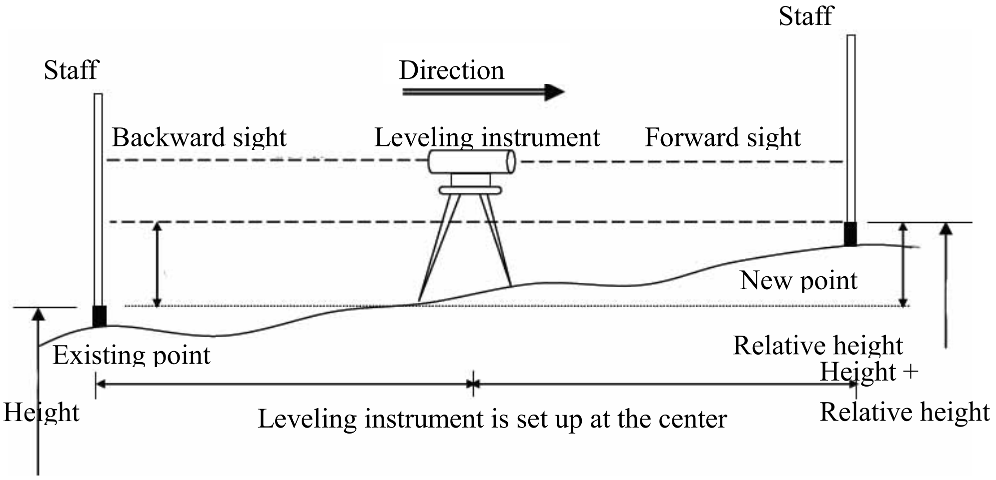


Figure 7 Principle of the Direct Leveling
(Source: Study Team)

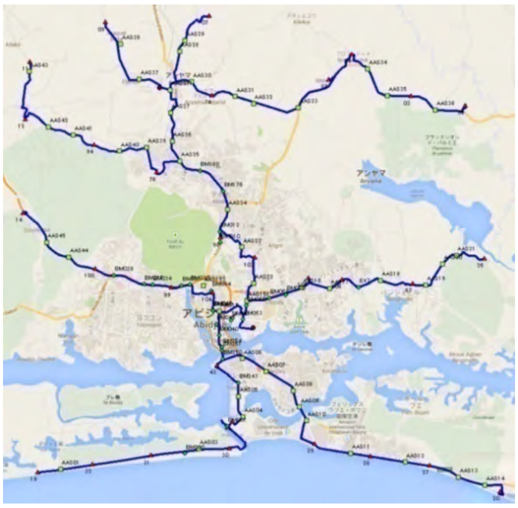
2) Planning and Collection of Existing Documents

The leveling plan map (Figure 8) of this Project was prepared with the plan of the aerial photography of the areas for topographic mapping and orthophoto creation, topography of the area and locations of the existing benchmarks taken into consideration. The total length of the leveling route is approx. 180km. Table 5 shows the breakdown of benchmarks of pricking points using only GPS points and elevation as benchmarks. The total number of those points is 105.

Table 5 Quantities of the GPS Points and the Points to be Surveyed as Pricking Points

Category	Quantity
GPS Point	32 points
Pricking point selected from the existing benchmarks (Point name: BM***)	26 points
New pricking point (Point name: AAS***)	47 points

Total 105 points



(Source: Study Team)

Figure 8 Planned Leveling Route Network Map
(Blue line: Planned leveling route)

The Study Team designed the planned leveling route shown in Figure 8 to improve the efficiency of the leveling by using as many existing benchmarks as possible. However, there were areas with no benchmarks in the study area, *i.e.* Anyama town in the north, Bingerville Commune in the east and a coastal area between Marcory and Grand Bassam. Double run leveling was used in the leveling in these areas. (See Figure 9)

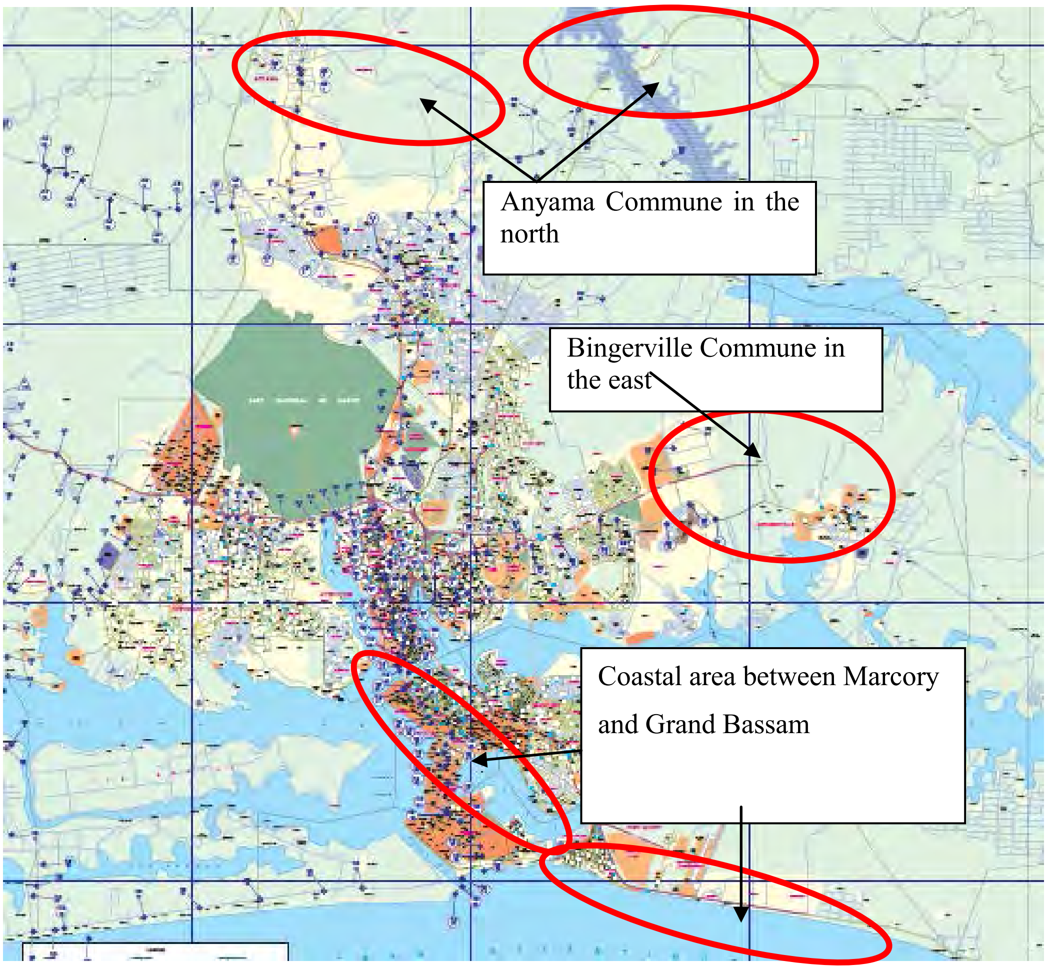
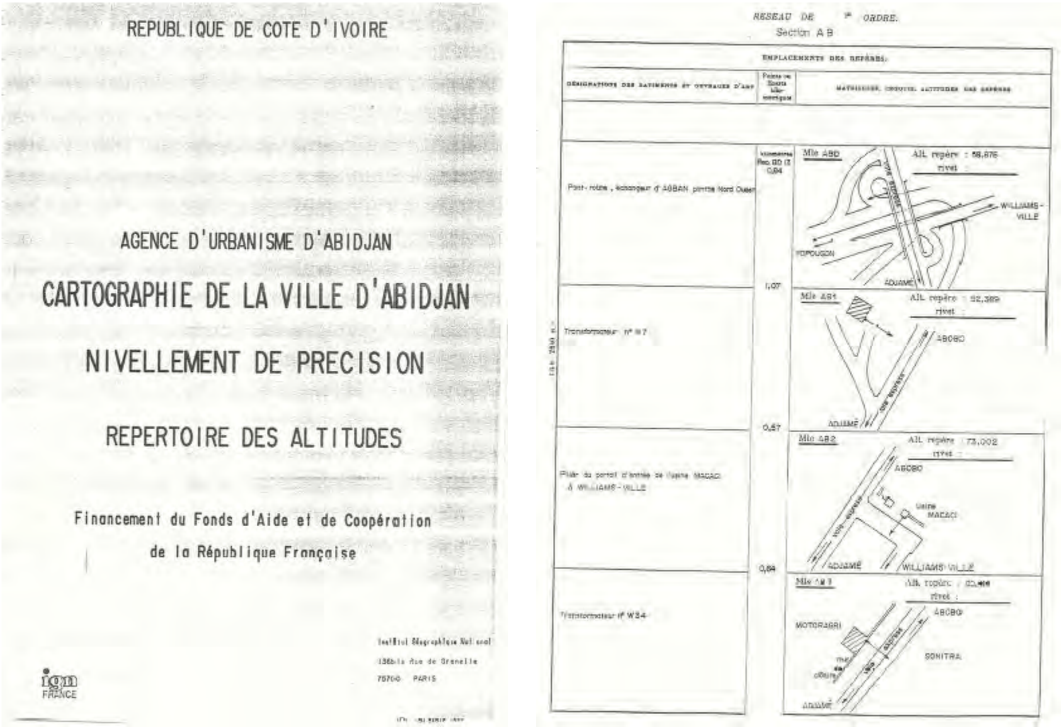


Figure 9 Areas with No Benchmarks
(Source: CCT)

3) Information Gathering before the Leveling

The Study Team obtained the descriptions of benchmark listing the locations of the existing benchmarks from CCT before the leveling. Staff of CCT and Study Team members examined the documents and confirmed that data in them are reliable enough to be used in this Project (See Figure 11)



REPUBLIQUE DE COTE D'IVOIRE

AGENCE D'URBANISME D'ABIDJAN
CARTOGRAPHIE DE LA VILLE D'ABIDJAN
NIVELLEMENT DE PRECISION
REPERTOIRE DES ALTITUDES

Financement du Fonds d'Aide et de Coopération
de la République Française

Institut Géographique National
136bis Rue de Grenelle
75700 PARIS

RESEAU DE 1er ORDRE.
Section A B

EMPLACEMENTS DES REPÈRES.

Pont-route, échangeur d'AGBAN pointe Nord Ouest	0,84	Mle AB0 — AIL repère : 58,876 rivet :
Transformateur n° 87	1,07	Mle AB1 — AIL repère : 52,389 rivet :
Pilier du portail d'entrée de l'usine MACACI à WILLIAMS-VILLE	0,57	Mle AB2 — AIL repère : 73,002 rivet :
Transformateur n° W34	0,84	Mle AB3 — AIL repère : [illegible] rivet :

Figure10 Point Description of an Existing Benchmark Collected from CCT

Urbanism agency of ABIDJAN

ABIDJAN TOWN MAPPING LEVELING OF PRECISION

DIRECTORY OF ELEVATIONS

Financing of the Fund of Help and Cooperation of the Republic of France

(Source: CCT)

4) Inspection and adjustment of the leveling instruments

The leveling instruments to be used in the leveling were inspected on two points, 1) whether they worked normally or not and 2) whether difference in height could be measured at a certain accuracy with them or not. Since it had been confirmed that the collimation errors of the instruments were within the allowable range, no adjustment was made on them.

Table 6 shows the inspection items and the inspection result.

Table 6 Inspection Items and Result of the Inspection of Leveling Instruments

Inspection items	Wild NAK (1)	Wild NAK (2)	Leica SPRINTER (1)	Leica SPRINTER (2)	Leica NA	Leica NA
To confirm whether there is any defect in exterior appearance or performance of the equipment or not	○	○	○	○	○	○
To confirm the levelness of the circular level	○	○	○	○	○	○
To confirm that the collimation error is within an allowable range	2.0mm	1.0mm	0.0mm	1.0mm	2.0mm	2.0mm
To confirm that the automatic correction function is operating properly	○	○	○	○	○	○
To confirm absence of other defects	None	None	None	None	None	None

* Wild NAKs are owned by CCT.

* Leica SPRINTER (1) and (2) were provided by JICA.

* Leica NAs were rented for an additional survey team.

5) Survey/Calculation

Four leveling teams of six members (observer, record keeper, two staff bearers; traffic controllers were added later) were formed for the leveling. The number of the teams was increased to five later. Since the technical capacity of each team was unknown when it was formed, it was evaluated through the practice using the practice sections in CCT and the practice of leveling between existing benchmarks. As the evaluation confirmed that the technical survey capacity of each team was satisfactory, the Study Team instructed each team to conduct leveling along the portion of the leveling route on the leveling plan map assigned to the team and to commence the leveling. The Study Team instructed the leveling team members to wear safety vests and pay sufficient attention to the work safety, because the observation was performed on the road.

The three types of leveling instruments, Wild NAK, Leica SPRINTER (Photo 2) and Leica NA (Photo 3) were used in the observation.

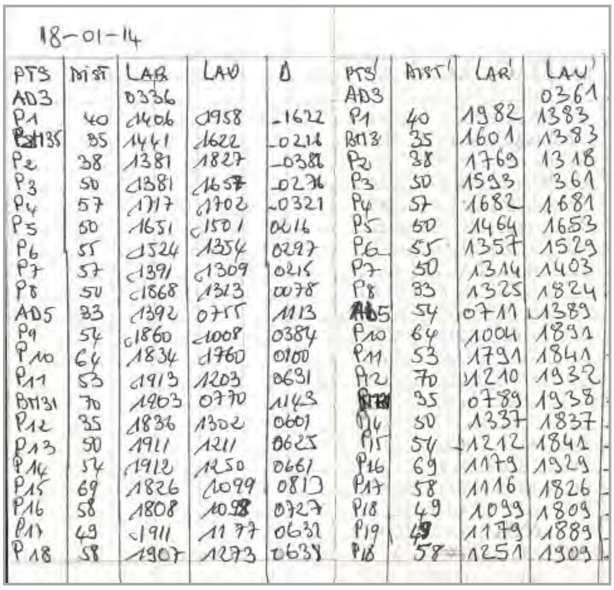
Photo 2 Main Body of Electronic Level and a Staff

Source:Leica Pamphlet

Photo 3 Main Body of Automatic Leveling Instrument and a Staff

The measurements taken by these leveling instruments were recorded on field notes by hand (Table 7), instead of electronic recording with a recorder. At the end of the work of the day, the input data for calculation were created by compiling the records in the field notes of all the groups.

Table 7 Measurements Recorded in a Leveling Field Note



18-01-14

PTS	DIST	LAR	LAU	Δ	PTS'	DIST'	LAR'	LAU'
AD3		0336			AD3			0361
P1	40	1406	1958	-1622	P1	40	1982	1383
BM35	35	1441	1622	-0216	BM3	35	1601	1383
P2	38	1381	1827	-0386	P2	38	1769	1318
P3	50	1381	1657	-0276	P3	50	1593	361
P4	57	1717	1702	-0321	P4	57	1682	1681
P5	60	1651	1501	0216	P5	60	1464	1653
P6	55	1524	1354	0297	P6	55	1357	1529
P7	57	1391	1309	0215	P7	50	1314	1403
P8	50	1868	1313	0078	P8	33	1325	1824
AD5	33	1392	0755	1113	AD5	54	0711	1389
P9	54	1860	1008	0384	P10	64	1004	1891
P10	64	1834	1760	0100	P11	53	1791	1841
P11	53	1913	1203	0631	P12	70	1210	1932
BM31	70	1903	0770	1143	BM31	35	0789	1938
P12	35	1836	1302	0601	P14	50	1337	1837
P13	50	1911	1211	0625	P15	54	1212	1841
P14	54	1912	1250	0661	P16	69	1179	1929
P15	69	1826	1099	0813	P17	58	1116	1826
P16	58	1808	1098	0727	P18	49	1099	1809
P17	49	1911	1177	0631	P19	49	1179	1889
P18	58	1907	1273	0638	P18	58	1251	1909

After field measurements recorded in the field note had been entered into a worksheet of Microsoft Excel (an example of the worksheet shown as Table 8), the calculation and adjustment was carried out using the procedure mentioned below.

6) Elevation calculation before the error correction

a) Calculate comparable elevation difference between each pair of points (A-B, B-C or C-D) from the backward sight (BS) and forward sight (FS) measurements and enter the calculated difference into the cell of "relative elevation" in the form of xx m in the case of rises or - xx m in the case of fall.

b) Calculate the ground elevation of each point by adding/subtracting the calculated elevation difference to/from the elevation of a point of known elevation and enter the calculated elevation into the cell of ground level (m).

c) Calculate the total distance of the leveling route from Point A to Point D.

d) Calculate the total elevation differences of the backward sight and forward sight and calculate the elevation difference between A and D from the total differences.

e) Leave the cells in red blank at this moment.

Table 8 Entry Example of the Calculation Result Using the Measurements

Point name	Distance (m)	Backward sight (m)	Forward sight (m)	Relative elevation (m)	Adjustment (m)	Ground level (m)
A		1.453			No entry	10.000
B	27.5	0.661	0.582	0.871		10.871
C	32.4	1.553	0.749	-0.088		10.783
D	38.8		0.102	1.451		12.234
Total	98.7	3.667	1.433	2.234		12.234

7) Adjustment for the errors

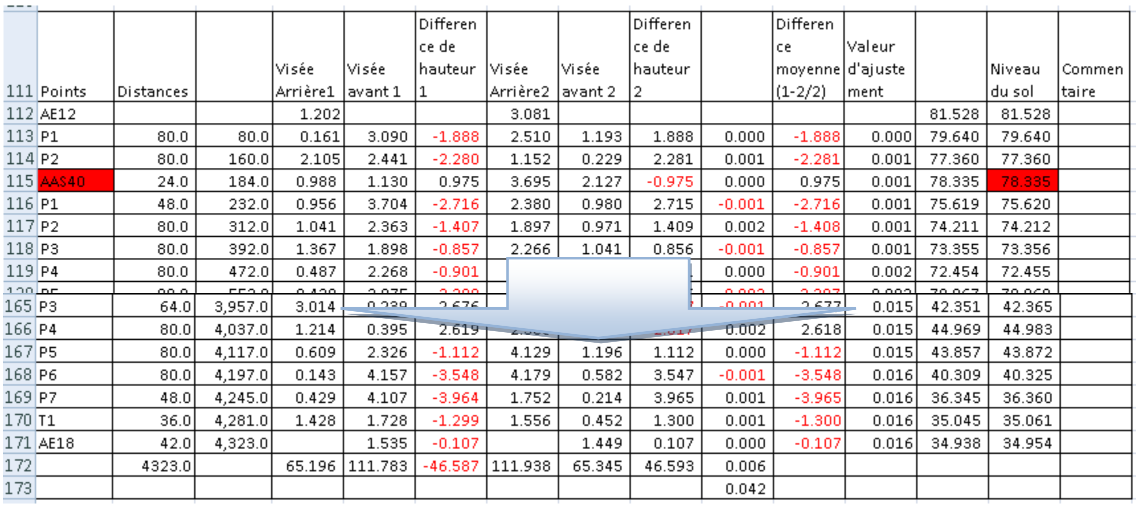
After it had been confirmed that the error (error of connection and error of closure) was within the allowable range after the calculation of the ground level of each point, the error was distributed to the elevation of each point on the basis of the principle that error increases in proportion to the distance on leveling route. Table 9 shows the result of the distribution of the error in Table 9 proportionately to the observation distance.

Table 9 Entry Example of the Result of Leveling with Error Adjustment

Point Name	Distance (m)	Backward sight (m)	Forward sight (m)	Relative elevation (m)	Adjustment (m)	Ground level (m)
A known		1.453				10.000
B	27.5	0.661	0.582	0.871	0.001	10.872
C	32.4	1.553	0.749	-0.088	0.003	10.786
D known	38.8		0.102	1.451	0.005	12.239
Total	98.7	3.667	1.433	2.234		12.239

Table 10 shows a part of the leveling calculation sheet used in this Project.

Table 10 Part of the Leveling Calculation Sheet



111	Points	Distances		Visée Arrière1	Visée avant 1	Differen ce de hauteur 1	Visée Arrière2	Visée avant 2	Differen ce de hauteur 2		Differen ce moyenne (1-2/2)	Valeur d'ajuste ment		Niveau du sol	Commen taire
112	AE12			1.202			3.081						81.528	81.528	
113	P1	80.0	80.0	0.161	3.090	-1.888	2.510	1.193	1.888	0.000	-1.888	0.000	79.640	79.640	
114	P2	80.0	160.0	2.105	2.441	-2.280	1.152	0.229	2.281	0.001	-2.281	0.001	77.360	77.360	
115	AAS40	24.0	184.0	0.988	1.130	0.975	3.695	2.127	-0.975	0.000	0.975	0.001	78.335	78.335	
116	P1	48.0	232.0	0.956	3.704	-2.716	2.380	0.980	2.715	-0.001	-2.716	0.001	75.619	75.620	
117	P2	80.0	312.0	1.041	2.363	-1.407	1.897	0.971	1.409	0.002	-1.408	0.001	74.211	74.212	
118	P3	80.0	392.0	1.367	1.898	-0.857	2.266	1.041	0.856	-0.001	-0.857	0.001	73.355	73.356	
119	P4	80.0	472.0	0.487	2.268	-0.901	[illegible]	[illegible]	[illegible]	0.000	-0.901	0.002	72.454	72.455	
165	P3	64.0	3,957.0	3.014	[illegible]	2.676	[illegible]	[illegible]	[illegible]	-0.001	2.677	0.015	42.351	42.365	
166	P4	80.0	4,037.0	1.214	0.395	2.619	[illegible]	[illegible]	[illegible]	0.002	2.618	0.015	44.969	44.983	
167	P5	80.0	4,117.0	0.609	2.326	-1.112	4.129	1.196	1.112	0.000	-1.112	0.015	43.857	43.872	
168	P6	80.0	4,197.0	0.143	4.157	-3.548	4.179	0.582	3.547	-0.001	-3.548	0.016	40.309	40.325	
169	P7	48.0	4,245.0	0.429	4.107	-3.964	1.752	0.214	3.965	0.001	-3.965	0.016	36.345	36.360	
170	T1	36.0	4,281.0	1.428	1.728	-1.299	1.556	0.452	1.300	0.001	-1.300	0.016	35.045	35.061	
171	AE18	42.0	4,323.0		1.535	-0.107		1.449	0.107	0.000	-0.107	0.016	34.938	34.954	
172		4323.0		65.196	111.783	-46.587	111.938	65.345	46.593	0.006					
173										0.042					

The Study Team performed the calculation and error adjustment shown in Table 10 for the entire distance of the leveling route of approx. 180 km. (See the data list in the supplement.)

8) Quality Control and Inspection

Detailed quality standards for leveling have not been established in Côte d'Ivoire. Therefore, the working criteria for leveling used in Japan (Table 11) were used in the evaluation of the accuracy of the leveling.

However, as the formula of 20mm√S of the error of looped closure of the simple leveling shown in Table 11 is applicable to digital plotting at the scale of 1:2,500, this formula was used in the quality control.

Table 11 Quality Standards of Leveling Used in Japan

Order / Item	First-order leveling	Second-order leveling	Third-order leveling	Fourth-order leveling (simple leveling)
Error of looped closure	2.5mm√S	5mm√S	10mm√S	20mm√S
Discrepancy of double run leveling	15mm√S	15mm√S	15mm√S	25mm√S

S=Length (km)

In the actual evaluation, the result of calculation obtained on each day of leveling was evaluated with the formula of 20mm√S after the result was divided into blocks small enough to allow the evaluation.

The red lines in Figure 11 show the routes on which leveling was repeated because the observed error was larger than the allowable range. The total length of the re-leveled routes was 48.87km out of the total length of the planned route of 180km, or the percentage of the re-leveled route was 25.7%.

This percentage is considered as an extremely high percentage for the re-leveling, which is indicative that the technical level of the CCT personnel in leveling was at a very basic level. It will be essential for CCT to provide its survey engineers with more opportunities to practice leveling to improve their capacity to reduce the percentage of re-leveling to a low level.

Leveling was repeatedly conducted on the routes on which re-leveling was required until the error had become smaller than the standard of 20mm√S and the final result of the leveling was used to obtain the final elevations. The Study Team decided to terminate the leveling because it was confirmed that all the leveling results on the entire leveling route satisfied the quality standards.

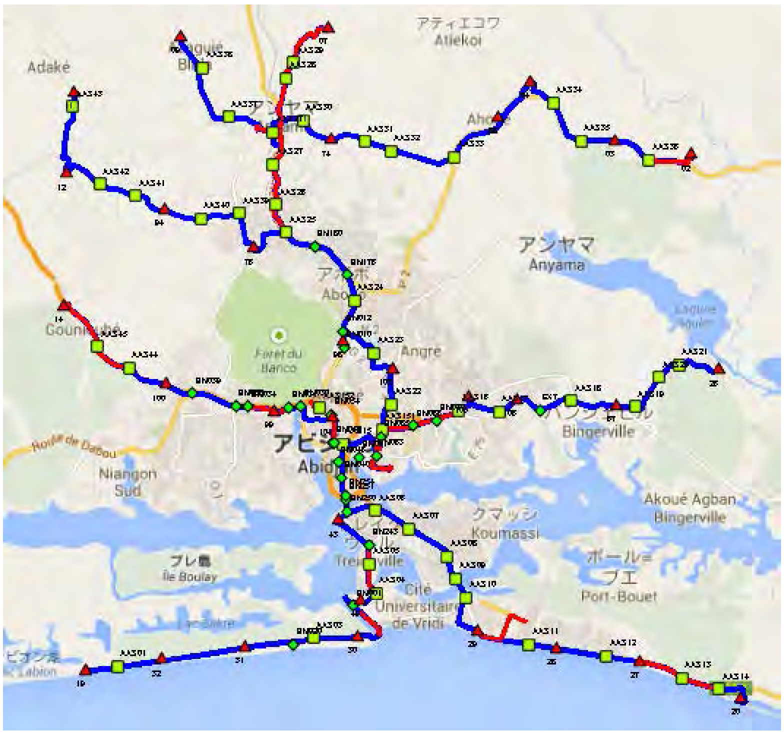


Figure11 Planned Leveling Route and Re-leveled Routes

Blue line: planned leveling route, red line: re-leveled route

(Source: Map data ©2015 Google, Data provided by CCT)

9) Pricking and Preparation of the Point Descriptions

Pricking is an act of marking a location of a point on the ground on the corresponding location on an image. During this Project, the locations of the 73 points which had been surveyed as pricking points were marked on satellite images after the accuracy of the positional data given to the points had been confirmed. In general, it is preferable to use aerial photograph images for pricking when they are used for topographic data creation. However, since the aerial photography and pricking were implemented simultaneously, the satellite images of Google Map were used for the pricking. The point descriptions (Figure 12) containing the information mentioned below, which would make it easy for the engineers in the subsequent aerial triangulation to locate the pricking points, were created as an output of the pricking.

DESCRIPTION DES POINTS DE NIVELLEMENT

NOMS	**BM70**				
EST	391,905.3m	NORD	591,772.5m	ALTITUDE	40.397m

IMAGE GOOGLE

COMMENTAIRE

A Coté de la cite univercitaire
Campus 2 de la rivera 2

IMAGE1

IMAGE2

IMAG

IMAGE4

Figure12 Pricking Point (BM point) Description

(Source: Image ©2015 CNES/Astrium Digital Globe, Study Team)

10) Inspection of the National Benchmark

As part of the mission of the leveling in this Project, a survey for the purposes mentioned below concerning the national benchmark was implemented:

- Evaluation of the relevance of the leveling outputs created by IGN France;
- Inspection survey to determine the elevation values of the national GPS reference points
- Evaluation of the difference between the mean sea levels at Dakar and Abidjan.

a) Evaluation of the Relevance of the Leveling Outputs Created by IGN France

The outputs created by IGN France when it established a network of benchmarks in Côte d'Ivoire have been used in the leveling in Côte d'Ivoire. Since the outputs have not been updated since their creation, a possibility that their locations have been changed by natural deterioration or wear and tear of the structures cannot be ruled out. Therefore, the Study Team conducted the leveling described below to verify whether the outputs were still accurate enough to be used in this Project.

The elevation difference between the existing benchmarks, BE8 and BE10, was measured multiple times and the average of the difference was compared with the corresponding figure in the output of IGN France (Table 12). It was concluded from the result of the comparison that the output of IGN France was still sufficiently accurate.

Table 12 Comparison of the Elevation Difference between the Existing Benchmarks, BE8 and BE10

	Elevation difference	Evaluation
Output of IGN France	11.533m	—
First leveling	11.533m	◎
Second leveling	11.547m	○

Then the leveling was continued to the benchmark in CCT and its elevation was measured at 29.483m. (See Photo 4)

Benchmark (H = 29.483m)

Photo 4 Benchmark in CCT

b) Inspection Survey for the Determination of the Elevations of the National GPS Reference Points

The geodetic origin in CCT (RGIR-001) and RGIO-019 in Anyama town are national GPS reference points. However, since they have been used only as the reference points of horizontal position, they have not had elevation data.

In order to make these points national control points with three-dimensional coordinate values, the elevations of RGIR-001 and RGIO-019 were determined with direct leveling from the benchmark in CCT to RGIR-001 and the leveling output of EE2.

- RGIR-001: 32.569m
- RGIO-019: 88.772m

It is officially approved that the elevations values thus obtained were to be used as the elevations of the national GPS reference points by CCT.

c) Study on the Difference between the Mean Sea Levels at Dakar and Abidjan

The leveling outputs created by IGN France are used in Côte d'Ivoire. IGN France used the original benchmark in Dakar in Senegal to create those outputs. The mean sea level at Abidjan is different from that at Dakar. Therefore, the elevation data in the outputs do not necessarily give actual elevations above the sea level at benchmarks. Continued use of such data in port and urban development may create confusion.

The possibility of this confusion was to be eliminated by obtaining the offset for the correction of elevations.

The following was obtained from the currently available information.

- IGN (0m) = Port (0m) +(-1.140m)
- IGN (0m): The leveling outputs developed by IGN France (with the original benchmark in Dakar)
- Port (0m): The output created with the Abidjan mean sea level.

2.3 Aerial Photography (B-3)

Since the aerial photography was conducted by the subcontractor, the details of the conclusion of the subcontract, management of the photography and receipt of the outputs are described as Work in Côte d'Ivoire in the following. It is the process of capturing the photograph images necessary for conducting stereo aerial photogrammetry by taking continuous photographs of overlapping aerial photographs.

(1) Conclusion of the Contract on the Aerial Photography

The representatives of the Study Team and FUGRO, the company awarded the preferential negotiating right in the tender, concluded a contract on the aerial photography by putting their signatures on the contract after negotiation on October 26, 2013 at the office of the Study Team in CCT in the presence of Mr. Timite Ibrahima of JICA Côte d'Ivoire Office.

(2) Local Subcontractor of the Aerial Photography

FUGRO GEOSPATIAL B.V.
Dillenburgsingej 69, 2263 HW, Leidschendam, The Netherlands.

(3) Details of the Subcontracted Work and Photographed Area

The following is the description of the aerial photography conducted by the subcontractor:

(i) Photographed area: 1,380 km^2

(ii) Details of the Work: Transport of the equipment required for the photography in and out of Côte d'Ivoire, acquisition of various permits required for the photography, the aerial photography, GPS observation at the base station simultaneously with the photography and inspection, reporting and delivery of outputs of the photography.

(4) Technical Specifications

A DMC, a digital aerial camera of ZI Imaging (equipped with a GPS receiver and an inertial measurement unit), shown in Photo 5, was used in the aerial photography. Digital images with a ground resolution of 16 cm were taken in the aerial photography so that they could be used for the topographic mapping at the scale of 1:2,500. (See the Specifications for the Aerial Photography attached hereto as a supplement for details.)

Photo 5 Digital Aerial Camera

(5) Work Implemented in the Period between the Tender/Conclusion of the Contract and the Delivery of Outputs

The outline of the process of the aerial photography from the tender/conclusion of the contract, through the management of photography and to the receipt of outputs was as follows:

(i) October 28, 2013: Sending of the invitation to tender and tender documents for the work to be subcontracted
(ii) November 8, 2013: Evaluation of the bid documents, notification of the evaluation result to JICA and the bidders
(iii) November 26, 2013: Conclusion of the contract (in Abidjan in the presence of a representative of JICA)
(iv) November 27, 2013: Submission of various applications including those for the landing and photography permits, tax exemption and visas
(v) December 26, 2013: Arrival in Abidjan of the aircraft and photography crew
(vi) December 30, 2013: Approval of the aircraft by the National Civil Aviation Authority (ANAC) and issuance of the photography permit
(vii) December 31, 2013: Commencement of the aerial photography
(viii) January 23, 2014 :First photography from four strips on Day 24
(ix) February 3, 2014: Approx. 80% of the photography completed by Day 35
(x) March 9, 2014: Completion of the photography on Day 69
(xi) March 15, 2014: Completion of the verification of photography data quality, departure of the photography crew from Côte d'Ivoire

(xii) March 24, 2014: Completion of the secondary photography data processing and delivery of the accessory outputs

(6) Progress Management of the Photography (a sample of the photography progress management chart)

In principle, the Study Team made a daily report on the progress of the photography to JICA. At the same time, the team used progress management charts to show the progress of the entire process in the progress management. The figure below shows a sample of the progress management chart showing the progress of the photography as of February 12, 2014. (See Figure 13)

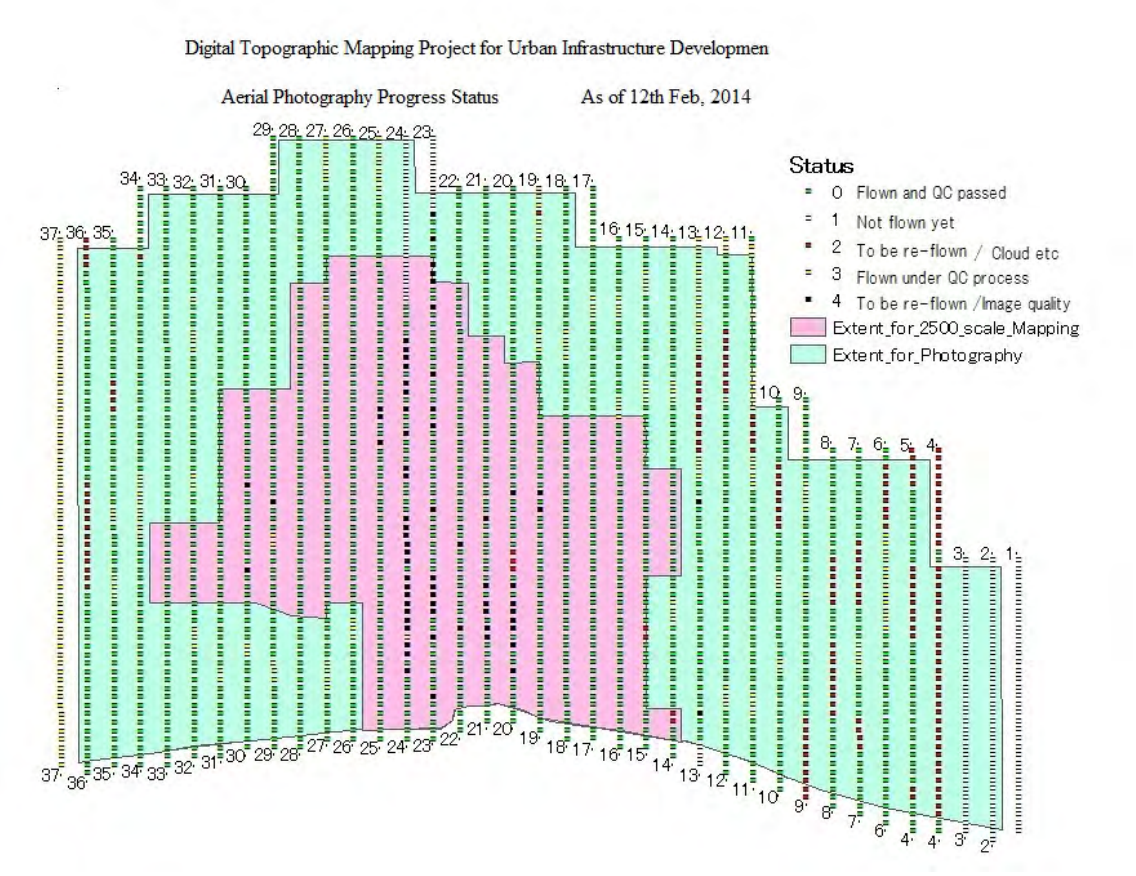


Figure13 Photography Progress Management Chart

(7) Problems Faced during the aerial Photography and measures Taken

Since the aerial photography was the most likely bottleneck of the progress of this Project, sufficient time was set aside for it in the schedule and the work was closely supervised. The following were the problems faced during the photography and the countermeasures taken against them.

(i) It took a long time to obtain the photography permit despite the assistance from CCT. Therefore, the subcontractor used its connections to facilitate the application process.

(ii) The number of days with the meteorological conditions suitable for aerial photography (no cloud or mist below the elevation of photography of 1,500m) was very small. In fact, the subcontractor had to wait until Day 24 to take the first photographs.

(iii) The analysis of the photographs of clouds taken from the ground every day revealed the characteristics of the weather that temporary gaps appeared in the cloud cover in a two-hour period in the late afternoon. The time required for the aerial photography was shortened by using this time period for it.

(iv) Meanwhile, a large proportion of the area in the north and the east of the study area remained not photographed even in the latter half of the work period, since gaps in the cloud cover were rarely observed throughout the day. The Study Team advised FUGRO to employ cloud watchers in the area concerned so that FUGRO could acquire real-time knowledge of the cloud condition. FUGRO took a photograph of a specific area where a gap in the cloud over had been reported by a cloud watcher.

(v) A workflow of the secondary processing consisting of photography, quality inspection of photographs on the day of photography, verification by a supervisor and delivery to the data center was established. The use of this workflow enabled efficient creation of high-quality outputs.

(8) Result of the Aerial Photography

The result of the aerial photography is described below. While the number of aerial photographs (digital data files) to be taken was 2,221 in the plan, the actual number of the aerial photographs taken was 2,382 (Table 13). In principle, a flight strip for aerial photography is in the east-west direction. However, the existence of the lagoon stretching in the east-west direction in the coastal area would have made it impossible to locate the aerial photographs of the area if they had been taken from ordinary east-west flight strips, because the principal points of the photographs taken from such courses would have been located at points in the image of the lagoon on the photographs. Therefore, 37 flight strips in the north-south direction were used in the aerial photography of this area. Table 13 shows the number of photographs taken and Figure 14 shows the flight strip index map.

Table 13 Number of Photographs Taken

Flight strip	Q’ty	Flight strip	Q’ty	Flight strip	Q’ty	Flight strip	Q’ty
1	33	11	66	21	79	31	69
2	34	12	68	22	79	32	68
3	33	13	62	23	100	33	69
4	50	14	62	24	92	34	78
5	46	15	61	25	96	35	63
6	45	16	61	26	72	36	64
7	44	17	66	27	74	37	63
8	43	18	65	28	74		
9	53	19	66	29	79	—	—
10,44	58	20	72	30	75	—	—
Total							2,382

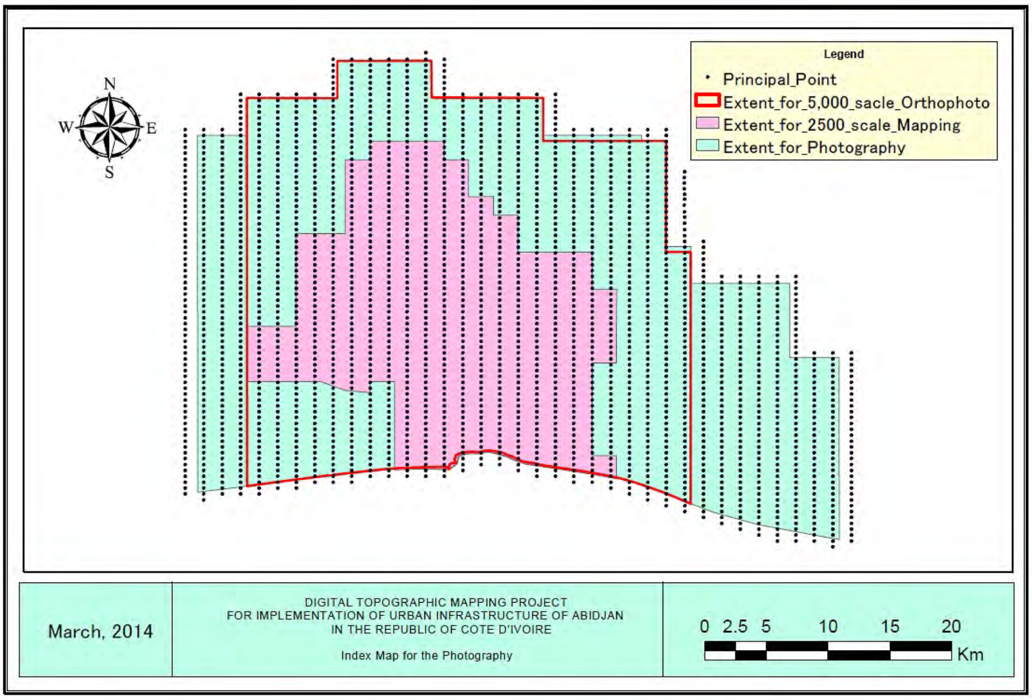


Figure14 Flight Strip Index Map of the Aerial Photography

(9) Photographs

The photographs taken at the time of pre-flight inspection are shown below. (See Photo 6, 7, 8, and 9)

Photo 6 Inspection of the Aircraft by ANAC

Photo 7 Aircraft for Aerial Photography to which a Photography Permit was Issued

Photo 8 Pre-flight Inspection 1

Photo 9 Pre-flight Inspection 2

2.4 Field Identification Survey (B-4(1)) and Field Completion Survey(B4-(2))

Field identification survey is the process of identifying the features which could not be interpreted clearly on aerial photographs and solving the questions raised in the interpretation in the field on aerial photographs taken to the field so that features to be represented on the final topographic maps can be captured in the digital plotting. Field completion survey is the process of making the final confirmation of questions raised, administrative boundaries and annotations in the field on edited maps taken to the field so that they can be represented correctly on the final topographic maps.

(1) Outline of Field Identification Survey

Table 14 shows the number of feature data types (97 items) identified in the field identification. After the feature data concerning their feature codes, names and types collected from the aerial photographs and existing geographic data were scrutinized in the office, the features concerned were identified and examined in the field in the field identification of names, shapes and types of facility-related features.

Table 14 Targeted map features in the field identification survey

Data theme	Data type					
	point	line	polygon	text	attribute1	attribute 2
Traffic related facilitis	1	3	9		Name	
Building related facilities	25	0	2			Abbreviation
Genenral facilities	2	8	3		Name	
Hydrography	0	2	8		Name	
Land use	0	0	10			
Morphology	0	3	0			
Limits	0	6	0		Name	
Annotation	4					Abbreviation
			11		Name	

(2) Procedures

The field identification survey was conducted during five month period between 9th of May 2014 and 15th of September 2014 based on workflow as showed in Figure 15.

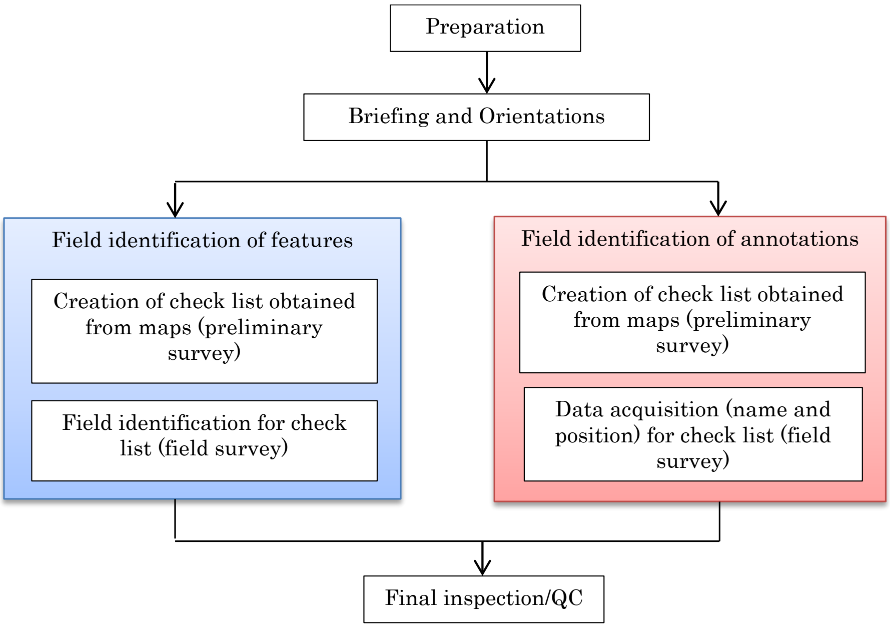


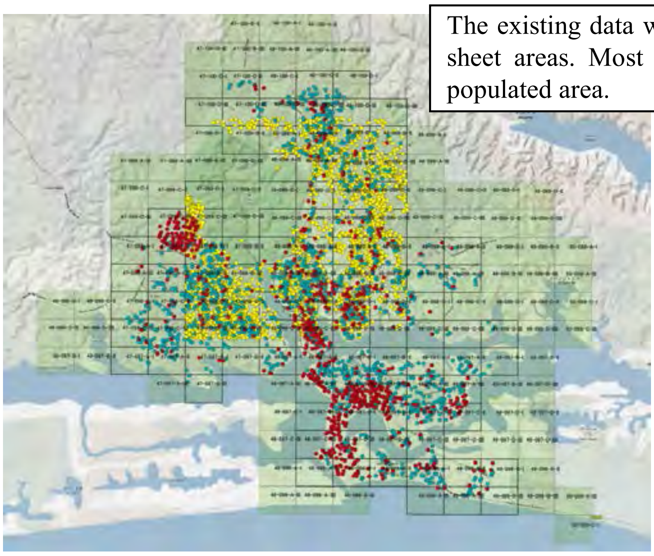
Figure15 Workflow

1) Identification with Images Using the Existing Data (Office work)

The feature data (at the scale of 1:5,000) which had been created by CCT were used in this project to develop a sense of ownership of the project in CCT. In practice, a method of reducing the time and cost by scrutinizing the details of the data and updating them was used in the project.

CCT owned the feature data (toponymy data) captured from 104 map sheet areas out of the total of the 172 map sheet areas (Figure 16). These data were examined carefully to identify those usable in the project. In the examination, the existing data were plotted on pieces of tracing paper and these pieces were placed on the printouts of the aerial photographs. The existing data were classified into the four groups mentioned below by comparing the data on the tracing paper and the aerial photographs.

- Feature data with correct positional information and contents: usable data
- Feature data with either questionable positional information or contents: data requiring verification
- Feature data clearly incorrect: data to be excluded
- Feature data unclassifiable in the system used in this Project: data to be excluded



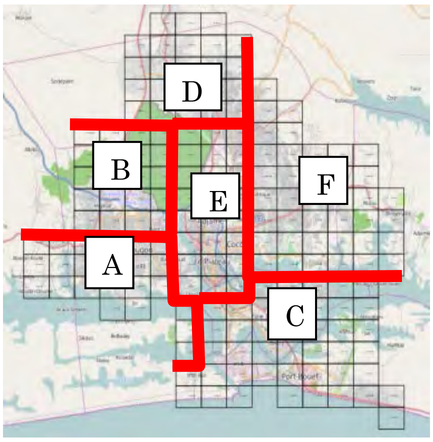
The existing data were captured from 104 map sheet areas. Most of them are located in the populated area.

Figure16 Map Sheet Areas from Which the Existing Data Owned by CCT were Captured

(Source: Map data ©2015 Google, Study Team)

2) Field Identification

The field identification was implemented by six work groups each consisting of three members. One of the six areas shown in Figure 17 was assigned to each group. The members of each group walked all the roads in the assigned area and collected required data using the method of identification that they had learned in the orientation. The figure on the right shows the areas assigned to the six work groups for the field identification. (A total of 172 map sheet areas.)



(Source: Map data ©2015 Google, Study Team)

Figure17 Division of the Study Area for the Field Identification

3) Data Management/Accuracy Control

After the fieldwork in the field identification had been completed, the coordinate and identification data entered in the field notes in the field were compiled in a spreadsheet of Microsoft Excel and the compiled data were entered in the GIS software with the data measured by the handheld GPS devices. The accuracy of the positional data and attribute data in the entered data were evaluated by comparing the result of the field identification described on aerial photo images (Figure 18) and the photographs taken in the field (see Photo 10) and field identification data to be referred to in the subsequent process of digital plotting and editing were created.

Figure18 Results of the Field Identification Described on a Simplified Orthophoto

(Source: Study Team)

Photo 10 Evaluation of the Result of the Field Identification (left) and Management of the Field Identification Data with GIS software (right)

(3) Outline of the Field Completion

Six work groups of Japanese experts and staff members of CCT jointly conducted the field completion from March to May 2015. The field completion in this Project was composed of the following three major components: 1) data capture at the locations of questionable data, 2) verification of administrative boundaries and annotations of major buildings and 3) identification of the names of the roads, beginnings and ends of roads, as shown in Figure 19.

In order to complete the topographic map data, maps and a list on which the questions raised in the digital plotting and digital editing were described were prepared in Japan and a field survey was conducted at the locations indicated on the maps, the list and those where data in the collected reference materials were suspected of not representing the actual conditions correctly. Then, administrative boundaries, annotations including names of major buildings and features represented on topographic maps were inspected for the compliance with the map specifications in the field and, if non-compliance was found, data to be corrected were identified and described on the topographic maps (1:2,500) for the field completion. The names, beginnings and ends of the roads which were to be represented on maps with annotations were identified. Then, the field completion data which described the locations where correction of data was required were created.

Before the implementation of the field completion, the University Center for Research and Application of Remote Sensing (CURAT) where the Study Team had conducted an interview survey on the data utilization plan requested participation of their graduate students in the project as interns. The project accepted a total of 28 graduate and foreign students during the period of field completion.

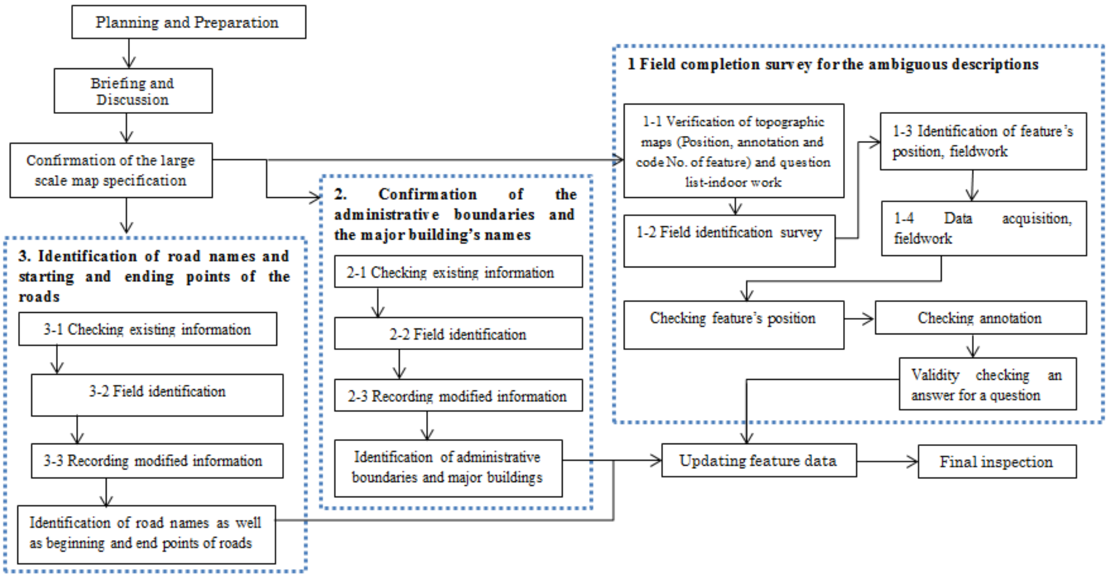


Figure19 Workflow of the Field Completion

(4) Result of the Field Completion on the Questionable Data (at the Locations with Ambiguities)

In order to solve the ambiguities in the shapes, locations and names of features in the data generated in this Project in the entire study area of this Project consisting of a total of 172 map sheet areas, six survey groups conducted the final survey for the field completion. (See Photo 11)

The major checkpoints in the field completion were as follows:

(a) Identification of the unverified data (locations, names and code numbers of features)

(b) Capture of the data of the major structures and features which had had not been captured previously

(c) Identification and capture of data concerning vegetation and land use

Photo 11Scenes in the Workshop on Field Completion

Since the field completion was conducted one year after the photography, the work groups identified changes in land use at several locations. Large-scale development found in illegal residential areas was particularly noted. It is therefore, necessary for CCT firstly, to obtain a formal update request with a budget backing from other relevant government organizations, then, to identify change over time of features in the field and revise data accordingly using the technologies transferred in this Project.

1) Correction of Administrative Boundaries

After the consultation with the staff members concerned of CCT, the existing data on administrative boundaries owned by CCT was revised by placing topographic map data on 1:2,500-scale orthophotos on ArcGIS. (See Figure 20)

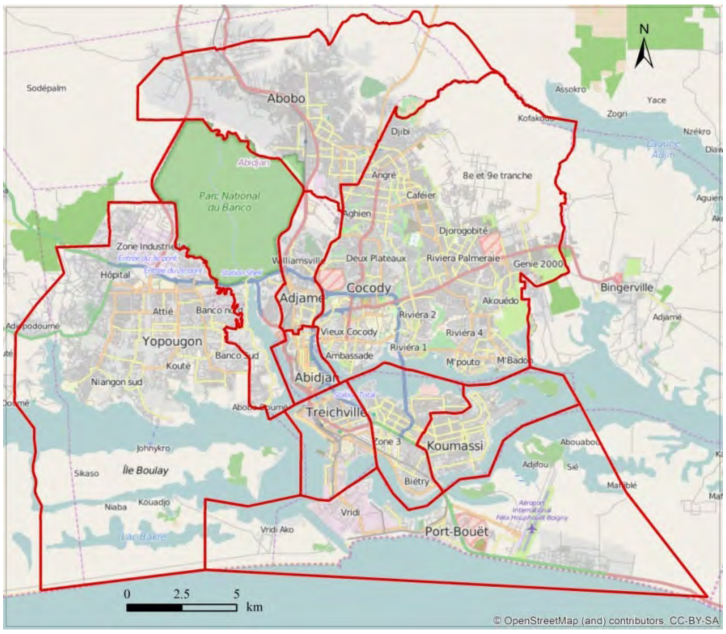
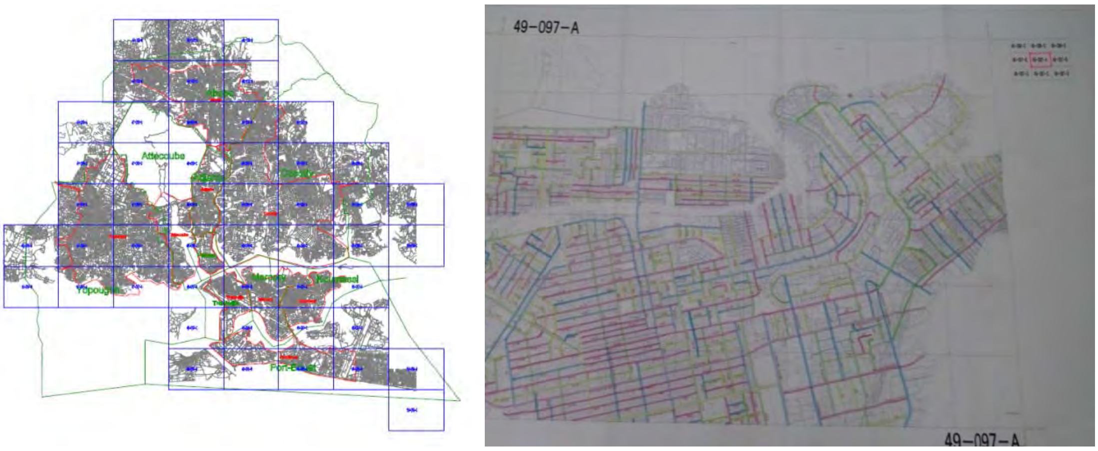


Figure20 Result of the Survey, Verification and Correction of the Administrative Boundaries (Source: © OpenStreetMap contributors、Study Team)

2) Identification of Road Annotations

Road annotation data were sorted (into the names, beginnings and ends of roads) using the road annotation data created in advance in the project and the road name data owned by the Urban Development and Local Development Department (DAUDL/BNETD), an organization responsible for the road administration, and described in different colors (blue, red and green, respectively,) on maps. (See Figure 21) SRCPT/CCT examined the data carefully and gave a final approval of the data.



(Source:CCT,StudyTeam)

Figure21 Result of the Classification of the Annotations of Roads

3. Work Related to the Topographic Mapping (in Japan)

The work related to the topographic mapping conducted in Japan is described in the following.

3.1 Aerial Triangulation (C-1)

Aerial triangulation of the 1050km^2 area of the aerial photography was implemented in Japan. Orientation parameters required for the subsequent digital plotting were analytically deduced from the aerial photography data which were considered the best on the basis the result of the quality inspection of the images taken in the aerial photography and the date and time of the photography for the implementation of the aerial triangulation.

(1) Data Used in the Aerial Triangulation

The equipment installed on the aircraft which was used for the acquisition of the photograph and photography data of the aerial photography which were to be used in the aerial triangulation is as follows:

- GNSS (Global Navigation Satellite System) receiver
- IMU (Inertial Measurement Unit); and
- POS (Position and Orientation System)

The calibration data of the above-mentioned systems and the results of the fieldwork mentioned below were used in the aerial triangulation.

- Approximate external orientation parameters (POS-EO)
- Field surveying outputs (of benchmarks and GCPs)

(2) Workflow

The flowchart of the aerial triangulation is as follows:

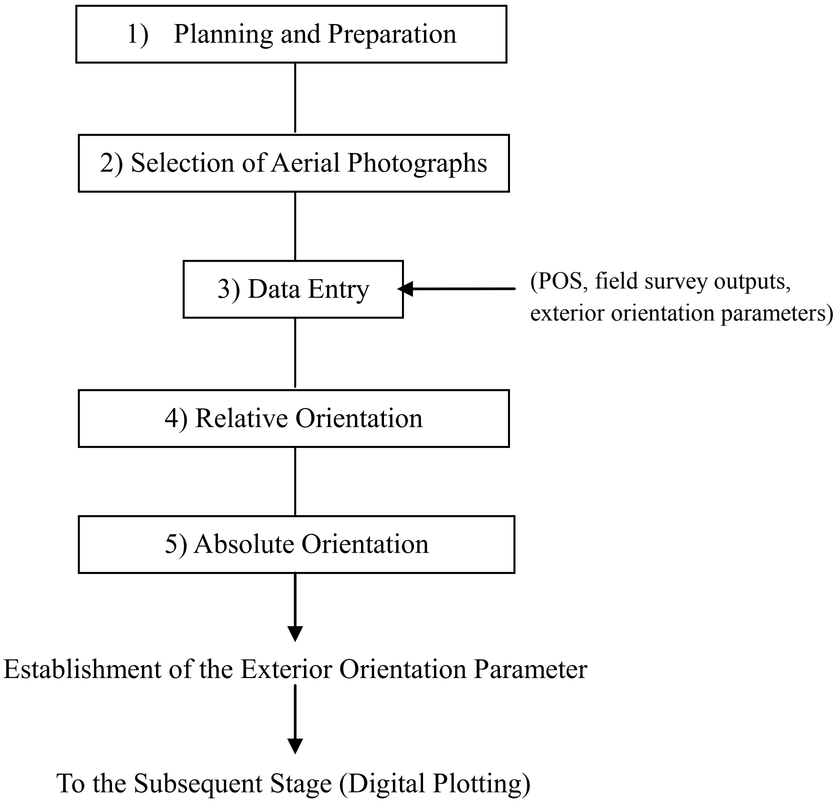


Figure22 Workflow of the Aerial Triangulation

1) Planning and preparation

The aerial photographic data required for the aerial triangulation and the data processing software and hardware mentioned below, which were required for large-scale aerial triangulation, were procured for the aerial triangulation. The total quantity of analyzed data was 2,382 pieces of aerial photographic data in 27 strips.

2) Selection of aerial photographic data

The latest aerial photographs most suited for interpreting features clearly in the digital plotting were selected among the 2,382 photographs taken in a three-month period. The criteria mentioned below were used in the selection.

- A stereo photograph with the latest day of photography
- A clear stereo photograph (a photograph on which the view of objects on the ground is not obstructed by cloud, fog or smoke)
- A stereo image with little wet ground surface or few puddles on the ground surface

created by rain

- A stereo photograph which will not create an incomplete model
- A photograph with POS-EO data

3) Data entry

The state of the camera ((X,Y,Z) and (ω,φ,κ)) at the time of photography was re-created on a PC with the analysis of the aerial photograph data, POS-EO data and the focal length of the aerial camera at the time of photography with digital photogrammetric system. Incomplete models result from photographs which contain large areas of water bodies were excluded from the data to be analzed because it is impossible to perform orientation of such photographs. As a quality control of the entered data, they were inspected visually whether they could be re-created into a stereo model correctly on the screen of PC or not.

a) Specifications of the aerial camera

The specifications of the aerial camera used in the aerial photography were as follows;

- Model: DMC01-0049
- Image size: 7680, 13824 (H,W Pixel)
- CCD size: 0.012, 0.012 (mm)
- Focal length: 120.0 (mm)

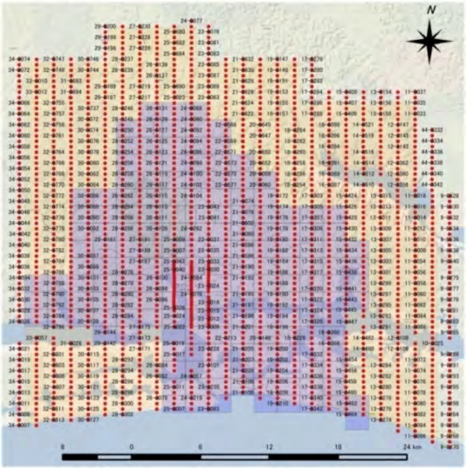
b) Aerial photograph data

1,816 aerial photographs in the 27 strips shown in Table 15 below were selected from a total of 2,382 photographs in 27 strips for use in the photogrammetry. (See Figure 23 "Index Map of the Aerial Triangulation")

Table 15 Number of Photographs Used in the Aerial Triangulation by Flight Strip

Line No.	Photo No.	~	Photo No.	Quantity	Line No.	Photo No.	~	Photo No.	Quantity
C-9	9-0260	~	9-0543	51	C-23	23-0006	~	23-0230	96
C-10	10-0007	~	10-0052	46	C-24	24-0063	~	24-9063	91
C-11	11-0006	~	11-0086	64	C-25	25-0022	~	25-0019	91
C-12	12-0089	~	12-0366	68	C-26	26-0091	~	26-0089	70
C-13	13-0154	~	13-0317	60	C-27	27-0160	~	27-0230	73
C-14	14-0468	~	14-0527	59	C-28	28-0231	~	28-0302	73
C-15	15-0405	~	15-0464	59	C-29	29-0129	~	29-0154	77
C-16	16-0346	~	16-0404	59	C-30	30-0072	~	30-0127	73

C-17	17-0278	~	17-0342	65	C-31	31-0029	~	31-0026	66
C-18	18-0214	~	18-0277	64	C-32	32-0747	~	32-0813	66
C-19	19-0147	~	19-0210	65	C-33	33-0006	~	33-0073	66
C-20	20-0058	~	20-9038	73	C-34	34-0026	~	34-0022	74
C-21	21-9073	~	21-0209	78	C-44	44-0332	~	44-0343	12
C-22	22-0053	~	22-0079	77				Total	928
			Total	88					
					27strips			Ground Total	1816

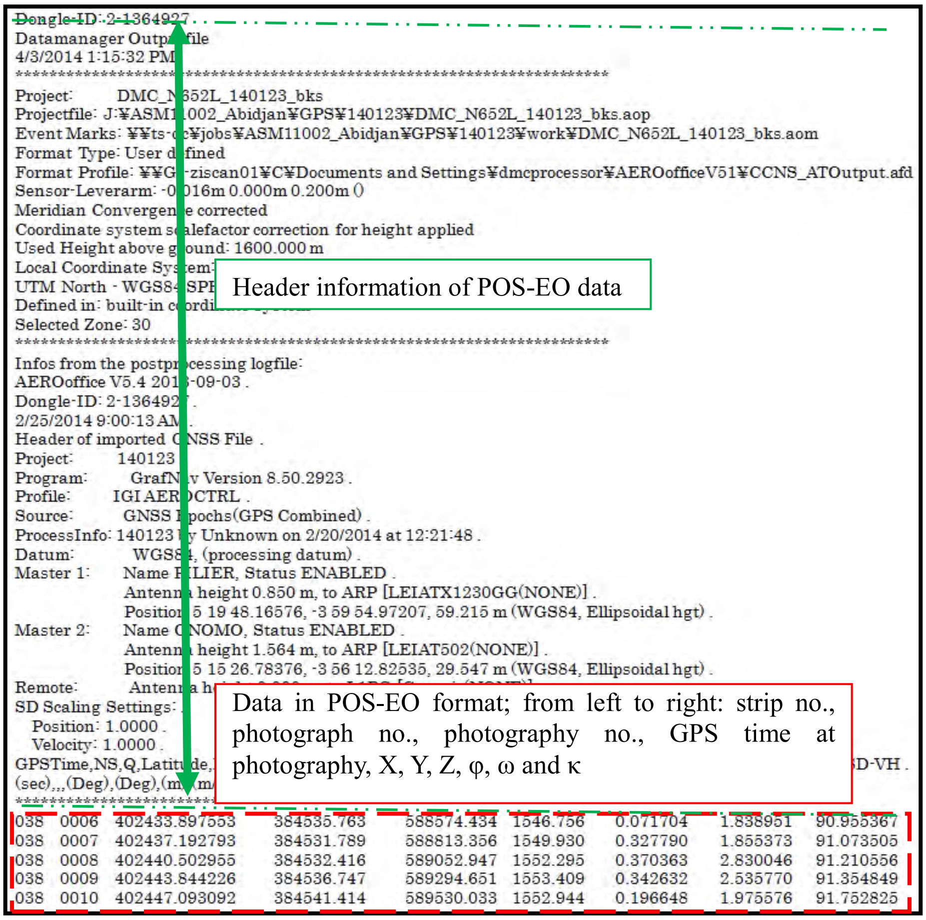


(Source: Map data ©2015 Google, Study Team)

Figure23 Index Map of the Aerial Triangulation

c) POS-EO data

Estimates of the exterior orientation parameters were calculated from the data recorded with the POS unit on the aircraft and the data of continuous GPS observation on the ground at the time of aerial photography. The outputs of these estimated exterior orientation parameters in the POS-EO format were used in the aerial triangulation. Figure 24 below shows an example of the POS-EO output.



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Dongle-ID: 2-1364927 .
Datamanager Outp  file
4/3/2014 1:15:32 PM
**********************************************************************
Project:        DMC_N 652L_140123_bks
Projectfile: J:¥ASM1 002_Abidjan¥GPS¥140123¥DMC_N652L_140123_bks.aop
Event Marks: ¥¥ts- c¥jobs¥ASM11002_Abidjan¥GPS¥140123¥work¥DMC_N652L_140123_bks.aom
Format Type: User d fined
Format Profile: ¥¥G -ziscan01¥C¥Documents and Settings¥dmcprocessor¥AEROofficeV51¥CCNS_ATOutput.afd
Sensor-Leverarm: -0 016m 0.000m 0.200m ()
Meridian Convergen e corrected
Coordinate system s alefactor correction for height applied
Used Height above g ound: 1600.000 m
Local Coordinate Sys em:
UTM North - WGS84 SPE
Defined in: built-in c ordi
Selected Zone: 30
**********************************************************************
Infos from the postpr cessing logfile:
AEROoffice V5.4 201 -09-03 .
Dongle-ID: 2-136492  .
2/25/2014 9:00:13 AM .
Header of imported  NSS File .
Project:        140123
Program:         GrafN v Version 8.50.2923 .
Profile:        IGI AER CTRL .
Source:         GNSS  pochs(GPS Combined) .
ProcessInfo: 140123  y Unknown on 2/20/2014 at 12:21:48 .
Datum:           WGS8 , (processing datum) .
Master 1:       Name  LIER, Status ENABLED .
                Antenn  height 0.850 m, to ARP [LEIATX1230GG(NONE)] .
                Positio  5 19 48.16576, -3 59 54.97207, 59.215 m (WGS84, Ellipsoidal hgt) .
Master 2:       Name  NOMO, Status ENABLED .
                Antenn  height 1.564 m, to ARP [LEIAT502(NONE)] .
                Positio  5 15 26.78376, -3 56 12.82535, 29.547 m (WGS84, Ellipsoidal hgt) .
Remote:          Antenn a h
SD Scaling Settings:
   Position: 1.0000 .
   Velocity: 1.0000 .
GPSTime,NS,Q,Latit de,                                                          D-VH .
(sec),,,(Deg),(Deg),(m (m
************************
038   0006   402433.897553      384535.763      588574.434   1546.756    0.071704    1.838951    90.955367
038   0007   402437.192793      384531.789      588813.356   1549.930    0.327790    1.855373    91.073505
038   0008   402440.502955      384532.416      589052.947   1552.295    0.370363    2.830046    91.210556
038   0009   402443.844226      384536.747      589294.651   1553.409    0.342632    2.535770    91.354849
038   0010   402447.093092      384541.414      589530.033   1552.944    0.196648    1.975576    91.752825
```

Header information of POS-EO data

Data in POS-EO format; from left to right: strip no., photograph no., photography no., GPS time at photography, X, Y, Z, φ, ω and κ

Figure24 Example of POS-EO Output

4) Relative orientation

Automatic stereo image matching was used to capture the pass points and tie points to be used for the relative orientation. The standards of capturing five pass points per model and at least one tie point per photograph were used. A total of 10,761 matching points were captured.

5) Absolute Orientation

Absolute orientation was performed by obtaining the conversion coefficient between the model coordinates given to the pass points, tie points, points of aerial signal marking installation and benchmarks in the relative orientation and the coordinates of pass points obtained from the outputs of the control point survey (outputs of the ground control point survey and leveling) and aerial triangulation. Consequently, the final exterior orientation parameters of each photograph were collected.

(3) Quality Inspection

The criteria of the quality inspection of the output of the aerial triangulation was to inspect whether the vertical parallax of pass points and tie points and the residual of the outputs of the control point survey and leveling obtained in the ground survey are within the respective standard ranges or not. Also, the non-existence of vertical parallax in the models was visually confirmed.

The limiting values at the time of POS-EO adjustment calculation were obtained with bundle adjustment calculation with the parameters in Table 16.

Table 16 Limiting Values at the Time of POS Adjustment

Limiting value of each parameter		Coefficient	Unit
Exterior orientation parameters	X	0.05	m
	Y	0.05	m
	Z	0.08	m
	Ω	0.005	deg
	Φ	0.005	deg
	K	0.008	deg
Control point	Standard deviation	0.02	%×(flight height)
	Maximum value	0.04	%×(flight height)
Pass points/ tie points	Standard deviation	0.015	mm
	Maximum value	0.03	mm

(4) Calculation Result

Adjustment calculation with the initial values of POS-EO data produced large residuals at the control points and benchmarks and, if the limiting values of the exterior orientation parameters within the standard range were used, the calculation of aerial triangulation did not converge. Therefore, the exterior orientation parameters were determined with the adjustment calculation without using the POS-EO outputs in this Project.

If the adjustment calculation is to be performed without using the POS-EO outputs, as mentioned above, the calculation is to be performed assuming that the 105 ground control points are reference points (known points). Table 17 shows the result of the adjustment calculation performed with this assumption. Each residual in the table is smaller than the limiting value. In this way, the exterior orientation parameters required in the subsequent process of digital plotting were determined.

Table 17 Limiting Values and Calculated Values of Aerial Triangulation

Limit of each parameter		Limiting value	Calculated value
Exterior orientation parameter	X (m)	0.05	-
	Y (m)	0.05	-
	Z (m)	0.08	-
	ω (deg)	0.005	-
	φ (deg)	0.005	-
	κ (deg)	0.008	-
Reference point	Standard deviation (%)	0.02	0.011
	Maximum (%)	0.04	0.020
Tie points /pass points	Standard deviation (mm)	0.015	0.003
	Maximum (mm)	0.03	0.012
Elevation of the photography (m)	1,590		

A total number of the photo models to be utilized for the aerial triangulation is 1789. Some of POS/EO data of the photo models were utilized the orientation as the most part of the photo models fall on lagoons.

The absolute orientation in the aerial triangulation produced good results of the standard deviation of the reference points (x,y,z) = (0.124m, 0.132m, 0.104m) and that of the benchmarks of (H) = 0.109m. (See Supplement for the table of residuals of each reference point)

3.2 Orthophoto Creation (C-2-1)

An orthophoto used in the field identification is hereinafter referred to as a "simplified orthophoto" in order to distinguish it from an orthophoto in the strict sense created using breaklines obtained in the subsequent process of DEM and plotting. Simplified orthophoto was created before implementing field identification.

Simplified orthophotos are the outputs of the process of converting photographic images, which are outputs of the perspective projection, into orthographic images with a simplified method. Therefore, the output of aerial triangulation and elevation data (digital elevation model, DEM) are required for creation of simplified orthophotos. Since the study area of this Project is flat, DEM density is low. Creation of simplified orthophotos in such an area does not require absolute elevation. It requires an elevation resolution of 10m. Therefore, SRTM (shuttle radar topography mission) data were used for creation of simplified orthophotos.

Figure 25 shows the area for simplified map creation.

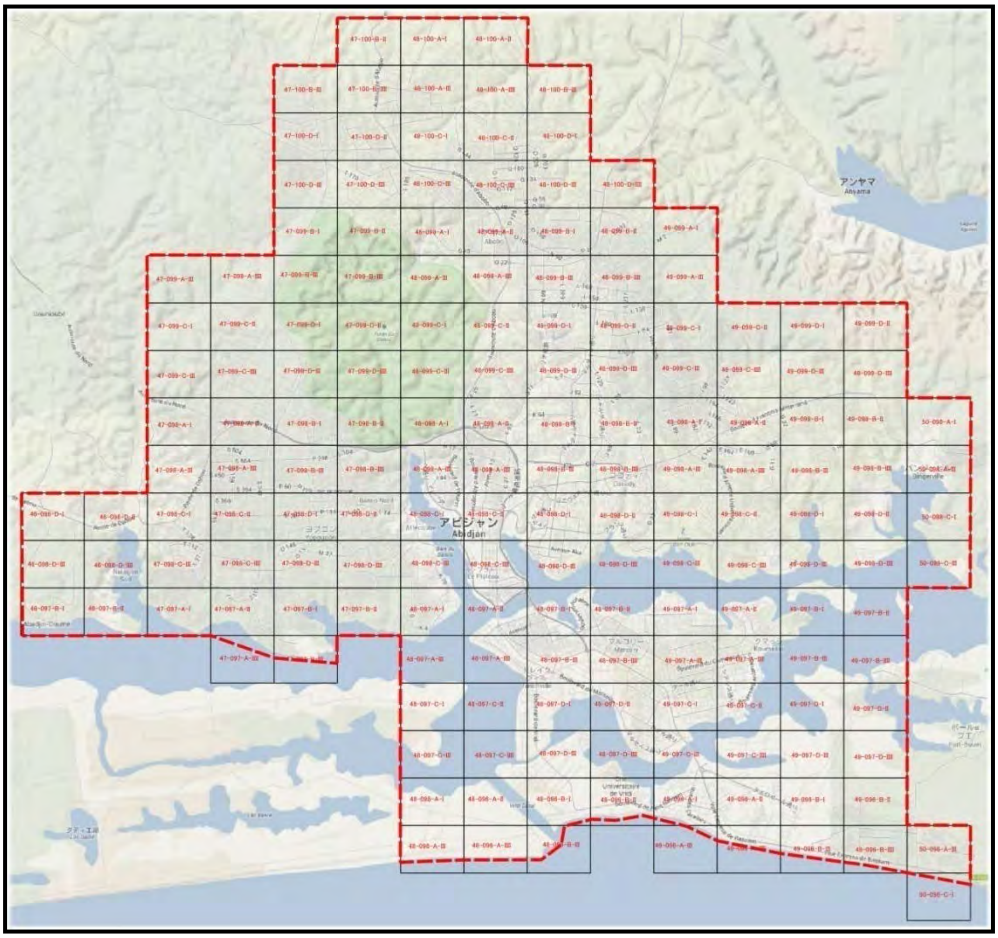


Figure25 Area for the Simplified Map Creation

（Source：Map data ©2015 Google、Study Team）

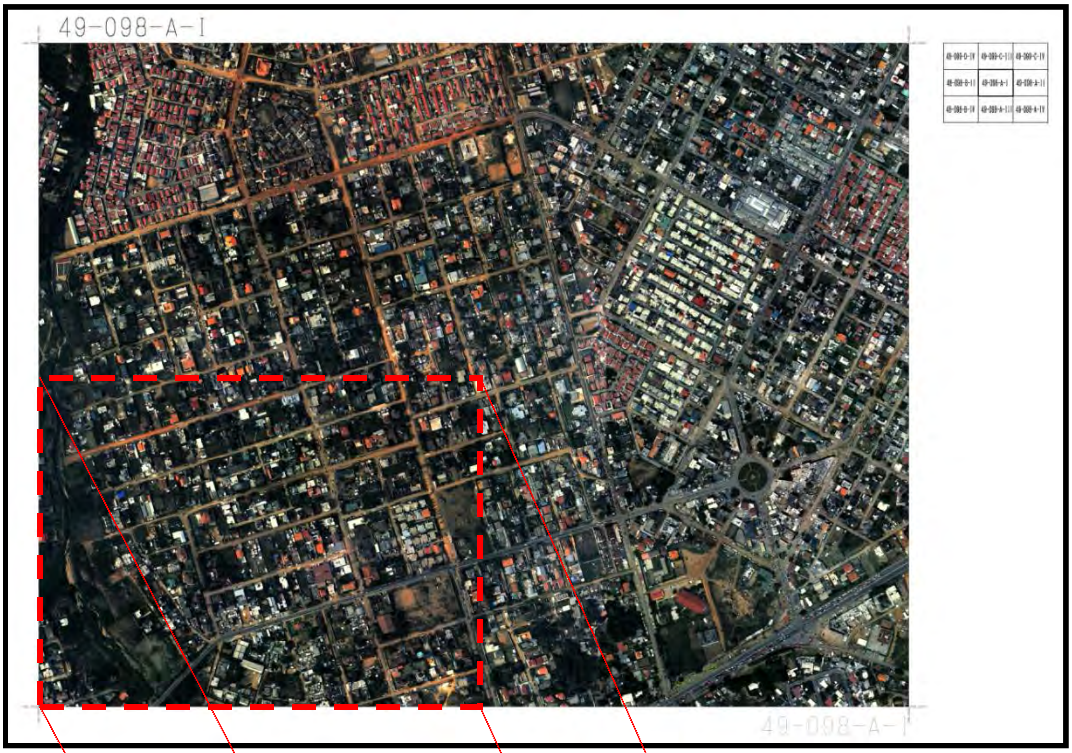


Figure26 Printout of a Simplified Orthophoto (1:2,500) on A0 Paper

Figure27 Printout of a Simplified Orthophoto on A1 Paper (1:4 image)

(Surce: Study Team)

Two types of printouts of the simplified orthophotos were created for their use in the field identification, as mentioned below. The full-sized ones on pieces of A0 paper (Figure 26) were to be used for sorting and compilation of the data in the office and the 1:4-sized ones on pieces of A1 paper (Figure 27) were portable ones for recording the findings in the field identification in the field.

- Area for the creation of simplified orthographic data : 500 km^2
- Simplified orthophotos on A0 pape : 172 pieces
- Simplified orthophotos on A1 paper : 664 pieces

3.3 Digital Plotting (C-3)

Of the entire aerially photographed area of 1,050 km^2, a 500 km^2 area, consisting of 172 (2.0 km x 1.5 km) map sheet areas, including the central area of Abidjan, was selected for the digital plotting in this Project.

Map Information Level 2500 (1:2,500-scale equivalent) accuracy was followed in the digital plotting as stipulated in the “Mapping spec rules.” (See Figure 28) Digital plotting is the process of capturing features as point, line and polygon data and giving them appropriate layer numbers in accordance with the map specifications using a digital plotter.

🟩 : Digital plotting area

（Source：Map data ©2015 Google、Study Team）

Figure28 Area for Creation of Digital Plotting Data

(1) Workflow

Figure 29 shows the workflow for digital plotting.

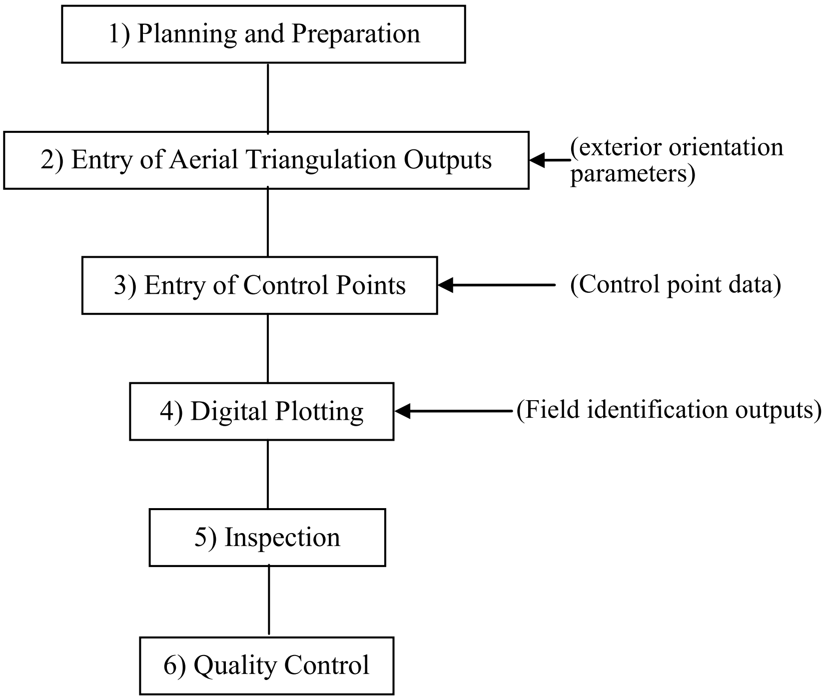


Figure29 Workflow of Digital Plotting

1) Planning and preparation

   An environment for the digital plotting was constructed on the software for digital plotting by importing the aerial photograph images and the outputs of the aerial triangulation required for the digital plotting in the system and creating a map symbol table in accordance with the approved “Map Specifications” on the system.

2) Entry of aerial triangulation outputs

   The exterior orientation parameters obtained in the aerial triangulation were loaded in the digital plotting instrument and the stereo models to be used in the digital plotting were created with the software. The created stereo models were tied to the geographic coordinate system. A total of 1,789 stereo model images, including the overlapping parts of the strips, were created.

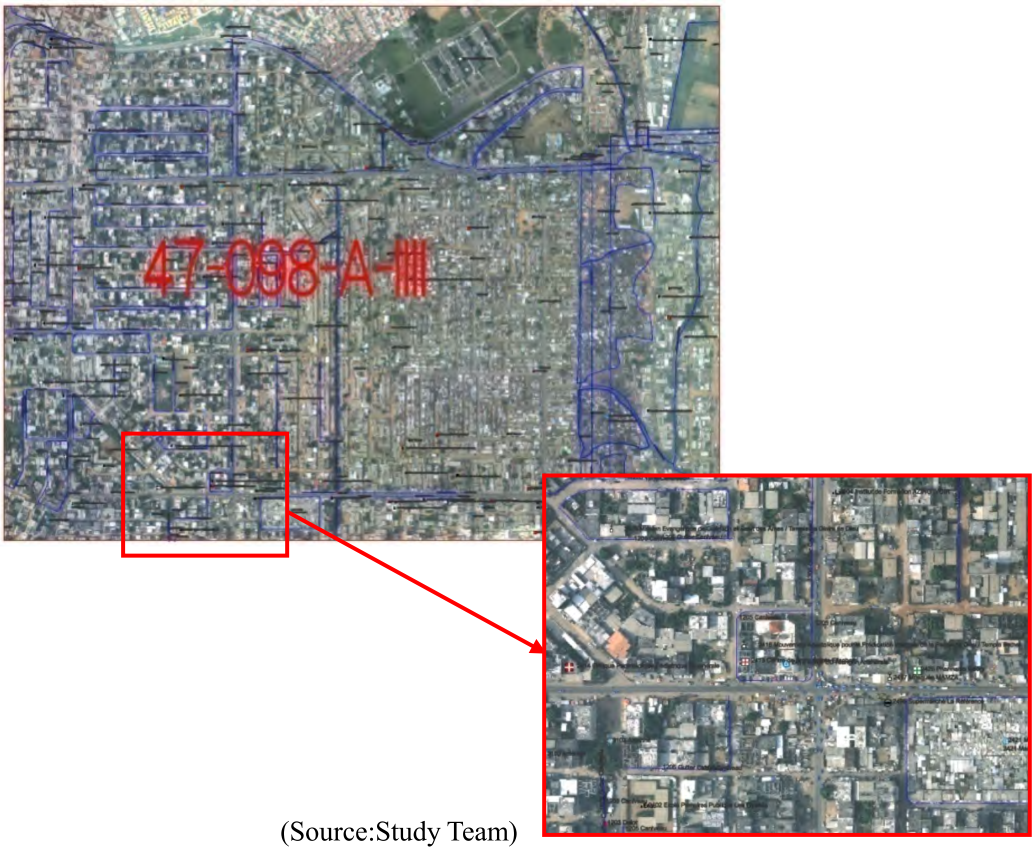
3) Entry of the control points

   The control point data (of RGIR, RGIO, DCF and NRGAE) provided by CCT were entered into the digital plotting system. These control points were expanded on stereo models and the conformity of the expanded coordinate and elevation values with the plotting environment constructed in the system was confirmed.

4) Digital plotting

The digital plotting began with photo-interpretation. In the photo-interpretation, the data (of roads, buildings, boundary walls and fences, contours, etc.) were captured with the layer numbers specified in the map specifications attached to them. The draft plotting data created in the photo-interpretation were used in the field identification at the locations of ambiguous data (See Figure 30). The data captured in the field identification including those of attributes, locations and shapes of features were sorted and the detailed digital plotting data were created with the sorted data.

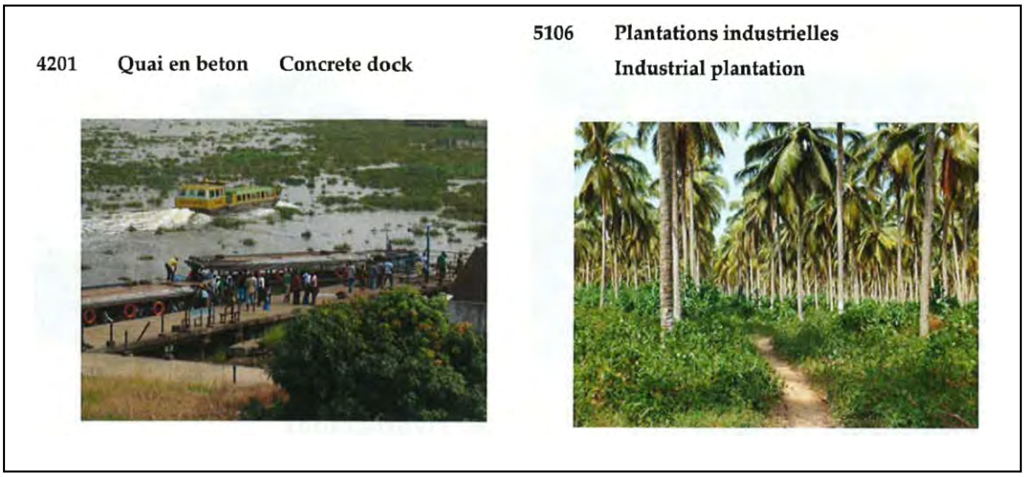
The operators of the digital plotting prepared a checklist and used it in the self-inspection of the details of the captured data as part of the quality control.



(Source:Study Team)

Figure30 Field Identification Data

Photographs taken in the field were also used in the digital plotting as reference material to facilitate interpretation of the characteristics of the target areas and classification of features. (See Photo 12)

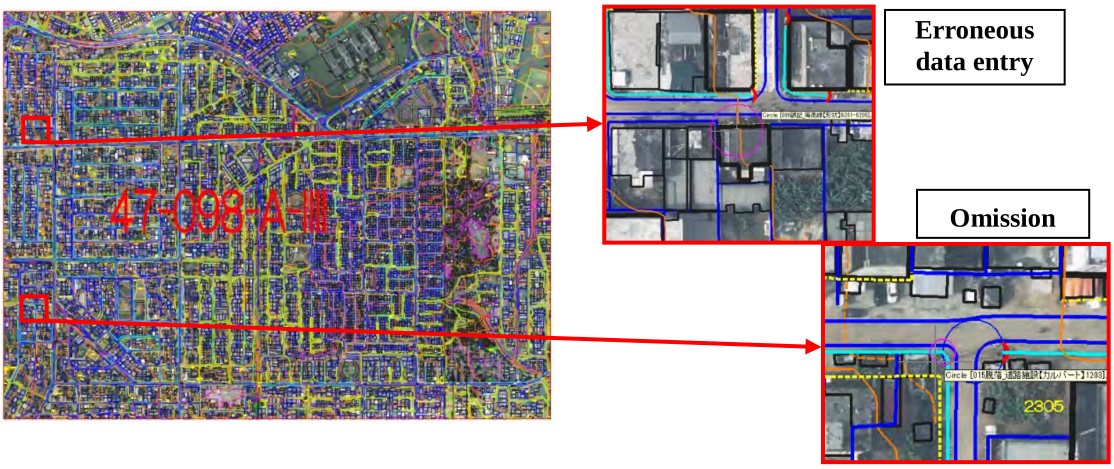


(Source:Study Team)

Photo 12 Reference Photographs Taken in the Field

5) Inspection

The various types of captured features were inspected by map sheet for omission or duplication in data capture, conformity with the specifications for data capture and the locations and shapes of the captured data by comparing the outputs of the digital plotting with the orthophoto images and stereo models on the screen. Areas where omissions or errors in data capture were identified in the inspection were marked on the outputs (See Figure 31) and data addition or correction was made in the marked areas on the outputs. Each operator was informed of the results of the inspection to improve his/her capacity in data capture.



(Source:Study Team)

Figure31 Example of Digital Plotting Output with Error and Omission in Data Capture Marked

6) Quality control

The standards for positional accuracy and elevation accuracy mentioned in the table below were used in the inspection in 5) above.

Table 18 Accuracy Standards

Map Information Level (Represented with the denominator of the scale fraction)	Standard deviation of horizontal location	Standard deviation of elevation point	Standard deviation of contour
2500	Less than 1.75 m	Less than 0.66 m	Less than 1.0 m

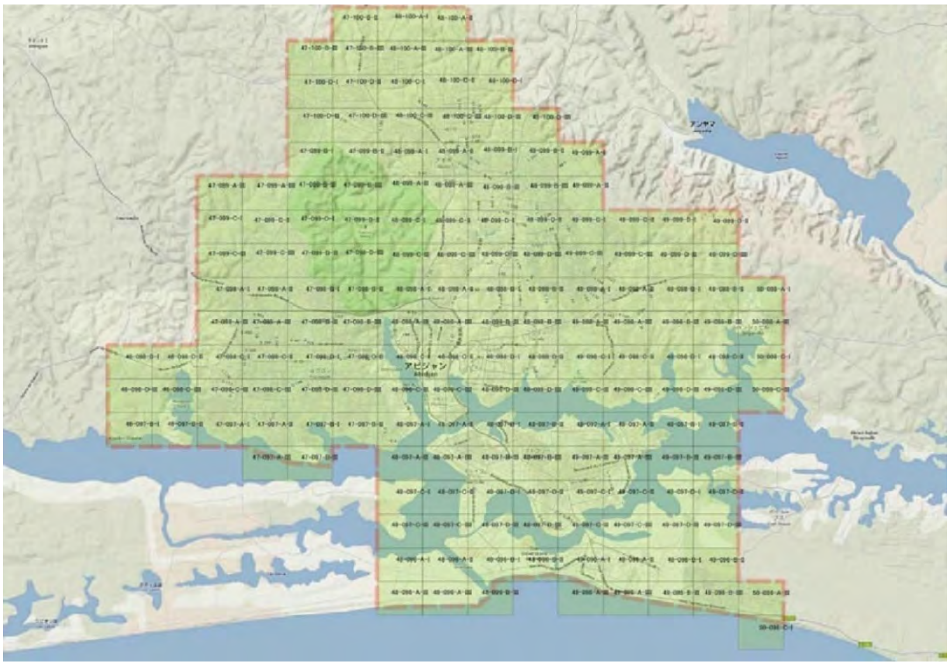
(Source: Japan Public Survey Work Regulations)

In this case, “Map Information Level” in this table means the accuracy of the representation of the digital topographic map data on the map and is an indicator of the average overall accuracy of the data in the digital topographic map sheet area.

3.4 Digital editing (C-3) and Symbolization (C-5)

The same 500 km^2 area, consisting of 172 (2.0 km x 1.5 km) map sheet areas, including the central area of Abidjan, selected for the digital plotting was used for the digital editing and symbolization. (See Figure 32)

Digital editing is the process of arranging and editing shapes of the data created in the digital plotting in accordance with the “map specifications.” The accuracy standards of the Map Information Level 2500 were followed in the process. Symbolization editing is the process of completing the topographic map data from the output data of the digital editing by placing marginal information data, annotations and symbols, creating symbols and line types and adjusting color for the final outputs in accordance with the map specifications, as in the digital editing.



🟩 : Area for digital editing/symbolization

（Source：Map data ©2015 Google、Study Team）

Figure32 Area for Creation of Digital editing

(1) Workflow

Workflow for digital editing is shown as below.

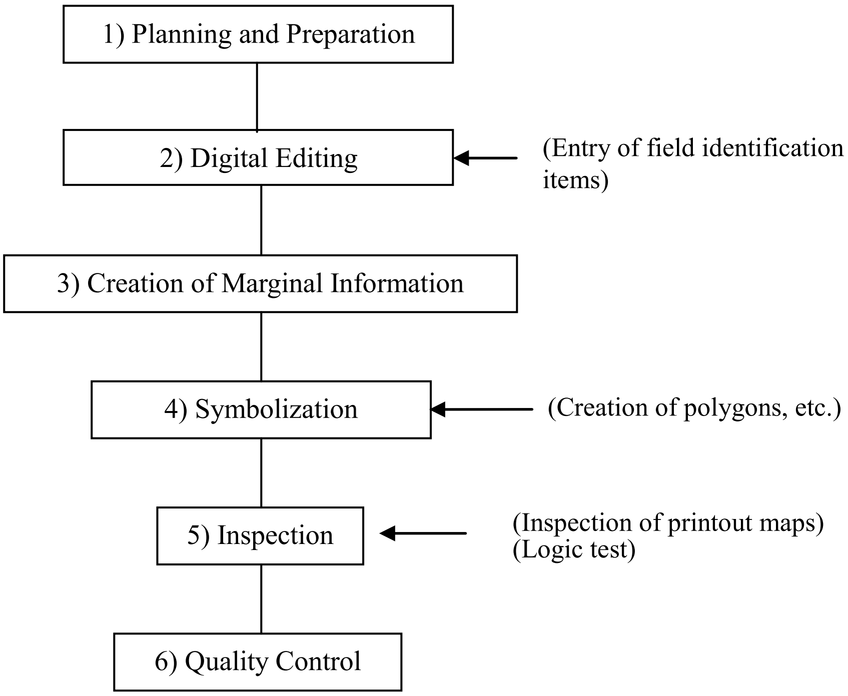


Figure33 Workflow of Digital editing

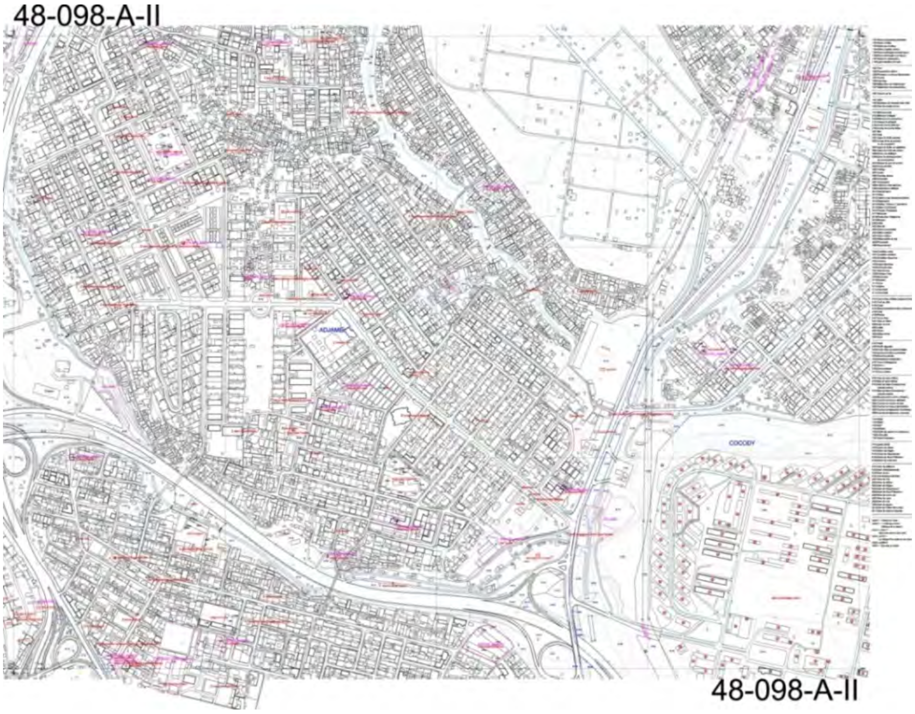
1) Planning and preparation

The output data files of the digital plotting created from the data captured on individual stereo photograph models in the previous process were loaded on the digital editing system. The loaded data were clipped by the area of the 1:2,500-scale map sheet and stored in the data files on the system. These data files were used in the digital editing.

2) Digital editing

In the digital editing, the data captured in the digital plotting were inspected for the continuity and the direction of input of the feature data, attribute data were added to the captured feature data and the data of names of locations and names and symbols of facilities were entered into the data files as specified in the "Map Specifications." (See Figure 34)

The ambiguities in and lack of data detected in the digital editing were recorded on the field completion reference maps to be used in the subsequent process.



(Source :Study Team)

Figure34 Result of Digital editing

3) Creation of marginal information

The name of the 1:2,500 map sheet, grid coordinate values, map sheet numbers of adjacent map sheets and index map were entered in the margin of each of the required 172 map sheets together with the legend and the provided logo types of BNETD/CCT and JICA. (See Figure 35)

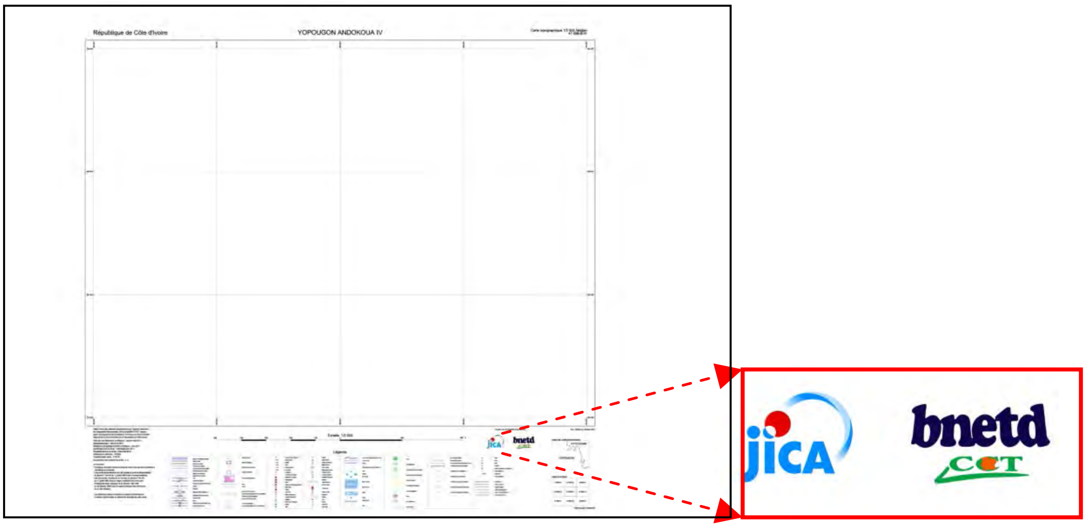
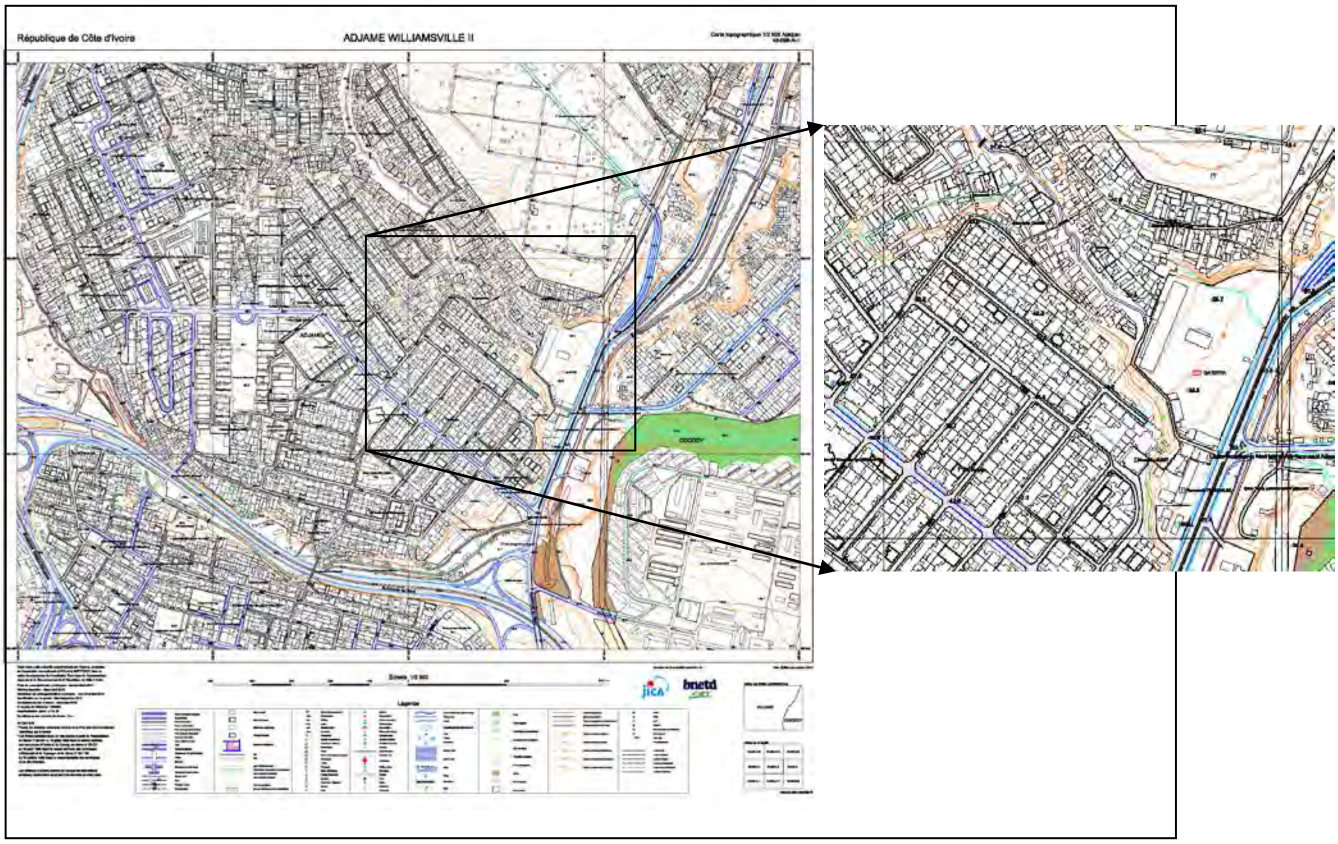


Figure35 Marginal Information

4) Data Editting for Symbolization

In the data editting for symbolization, output files were created by entering polygon data required for representing data created in the digital editting on maps, generating map symbols for the captured features and making adjustment on the data so that they can be represented with the colors of polygons or map symbols provided in the "Map Specifications."



(Source :Study Team)

Figure36 Output of the Data Created in the Data Editting for Symbolization

5) Inspection

The output data were inspected visually for data omissions and erroneous data entries at each stage using the method most appropriate for the stage. (See Figure 37)

Two methods were mainly used in the visual inspection. One was the inspection on the consistency and density of contours and spot heights on printout maps. The other was the comparison between the rasterized output of the printed images of the CAD data created in the data editting for symbolization combined with the marginal information data and the rasterized field completion maps, road name instruction maps and digitally editted vector data. (Seee Figure 38)

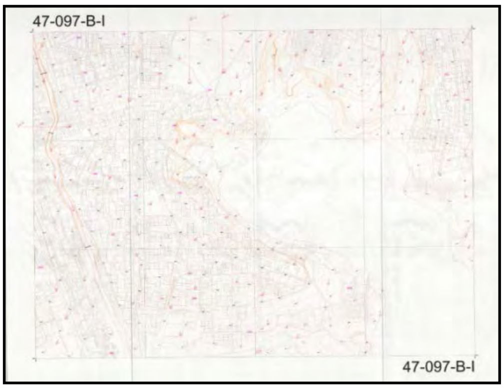
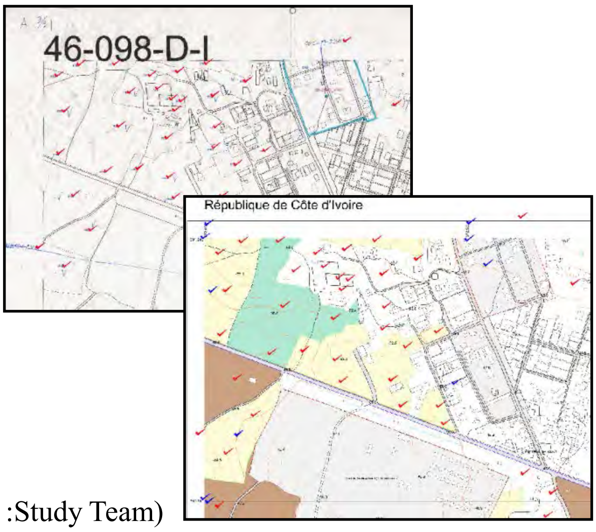


Figure37 Printout Map Inspection



(Source :Study Team)

Figure38 Comparative Inspection

A program in the digital editting system was used in the logical test for the data processing for the correction of errors in the type classification, structure and topology of data.

6) Quality Control

The data omissions and erroneous entries detected in the visual inspection and the logical test were compiled in the quality control sheet for the digital editting. The data entered into the sheet confirm that there was no omission or error.

3.5 True Orthophoto Creation (C-2(2))

The aerially photographed 1,050 km^2 area was divided into two parts for the creation of true orthophotos. 172 true orthophotos on a scale of 1:2,500 (an area 2.0 km x 1.5 km) were created of the digitally plotted 500 km^2 area, while 65 orthophotos on a scale of 1:5,000 (an area 4.0 km x 3.0 km) were created of the remaining 550 km^2 area. (See Figure 39) True orthophoto creation is the process of creating orthographic projection images which represent features captured on aerial photographs, which are outputs of the perspective projection, at the correct locations and scale using DEMs and break lines. The created true orthophotos are orthographic images like topographic maps, which can be used to measure areas and lengths of features on the images.

Figure39 Area for True Orthophoto Creation

(1) Workflow

Workflow for true orthophoto creation is shown as below.

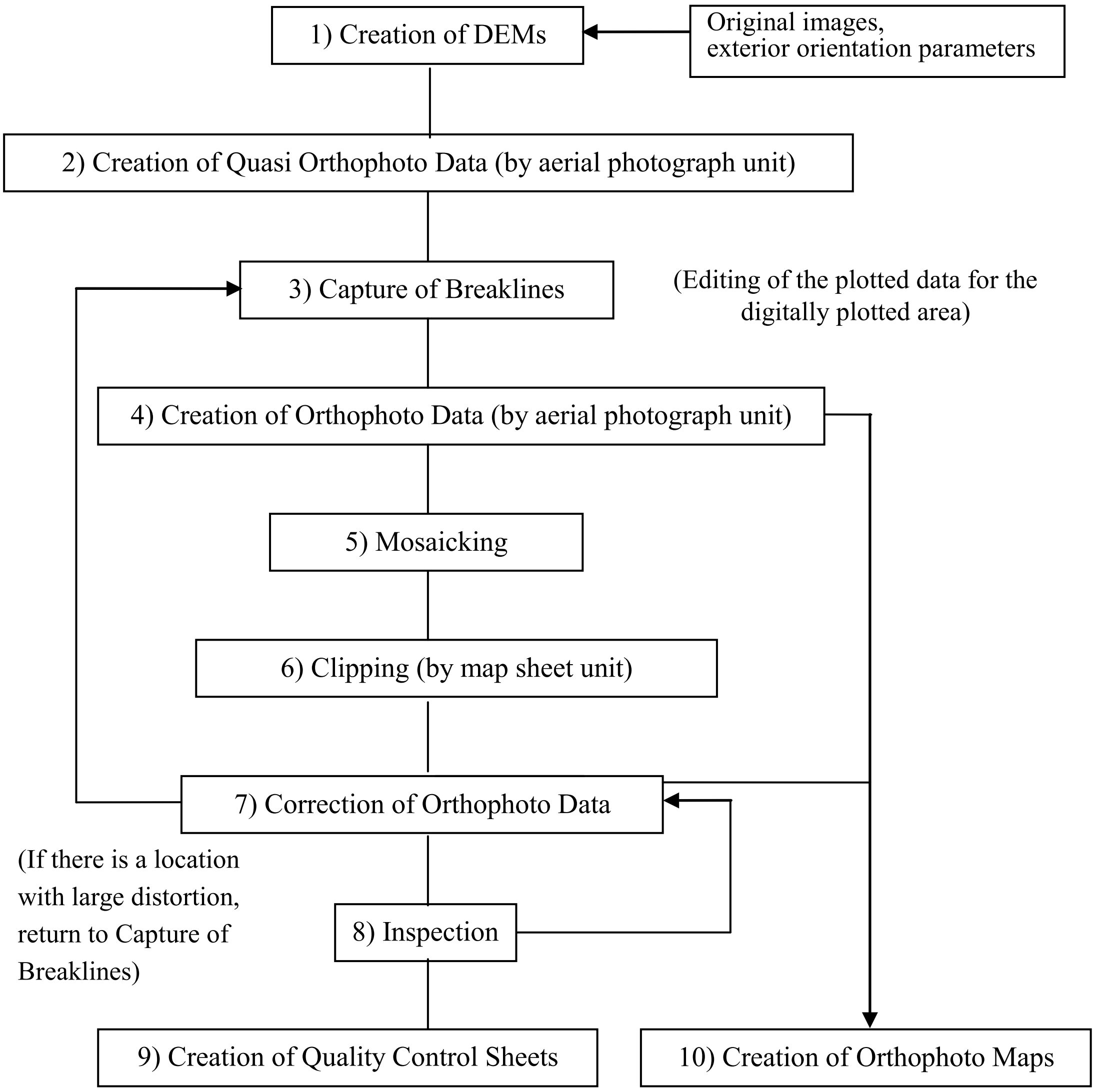
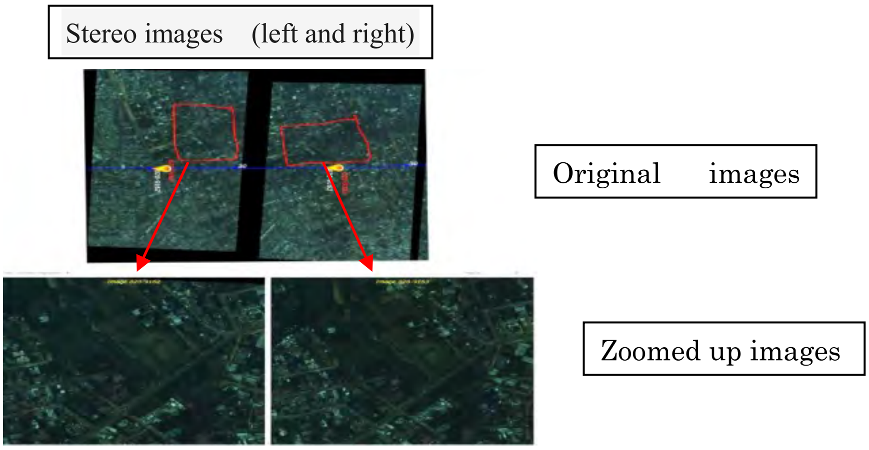


Figure40 Flowchart of True Orthophoto Creation

1) Creation of DEMs

DEM data were created from the aerial photograph data (original images) and the outputs of the aerial triangulation (exterior orientation parameters) by automatic stereo matching technology.

DEM data of the locations where automatic matching had failed were created by correcting the model manually. (See Photo 13)

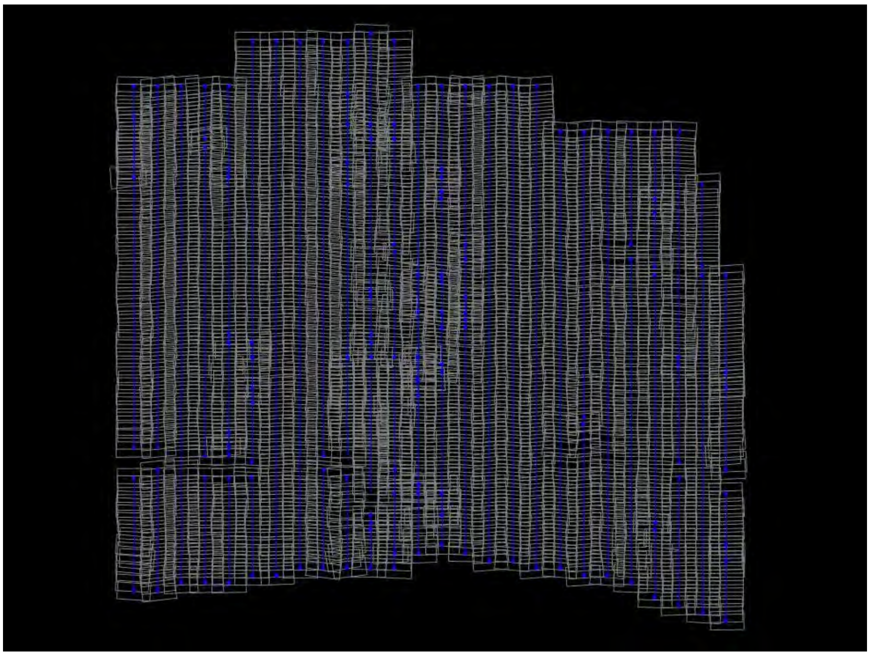


(Source:Study Team)

Photo 13 Images Used for Automatic Matching for DEM Creation

2) Creation of Orthophotos of Individual Aerial Photographs

Orthophoto data were created by aerial photograph unit using the data acquired in the DEM creation. (See Figure 41)



(Source:Study Team)

Figure41 Area for Orthophoto Creation

3) Capture of breaklines (editing of digital plotting data)

Breakline data were captured from stereo models where distortion of roads, etc. was identified with the quasi-orthophoto data.

In the digitally plotted area, plotted data requiring editing such as roads and contours were edited.

4) Creation of orthophoto data by aerial photograph unit

Orthophoto data were created by aerial photograph unit using the DEM data and breakline data (compiled plotted data). (See Figure 42)

(Source:Study Team)

Figure42 Original Image (left) and Orthophoto Data (right)

5) Mosaicking

All the orthophoto data created by aerial photography unit were loaded in the software and seamline data were created using the software's automatic mosaicking function. (See Figure 43)

The orthophoto data created by aerial photography unit were clipped by map sheet unit using the seamline data.

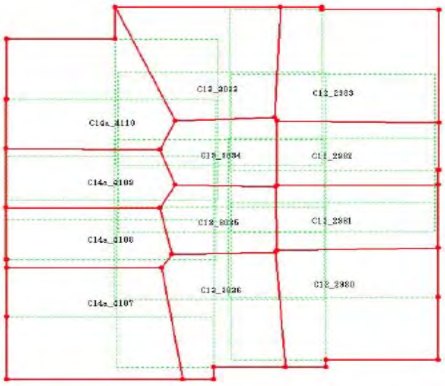


Figure43 Mosaicking (seamline)

6) Correction of orthophoto data

The clipped orthophoto data were inspected and corrected for overall edge mismatching, distortion of features and inconsistency in color tone.

Where significant distortion of features was identified, additional breaklines were captured (recaptured) and orthophoto data were created again with the recaptured breaklines. (See Figure 44) As the aerial photographs were taken on different days, it took a long time to match the color tone of the photographs.

(Source:Study Team)

Figure44 Orthophoto data before correction (left) and Orthophoto data after correction (right)

7) Inspection

The areas in the orthophotos where image was obscure were identified and marked while they were corrected. After the correction, the marked areas on the corrected orthophotos were inspected intensively.

If the data at an error flag location were found to be uncorrected, they were corrected.

The inspected and corrected orthophoto data were regarded as the final orthophoto data.

8) Creation of quality control sheets

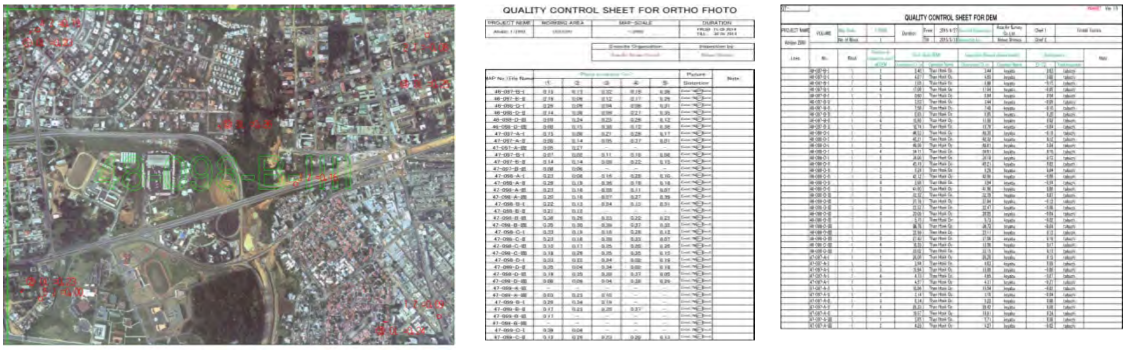
The standards for the accuracy of the orthophoto data positions and the elevation of the DEM mentioned in the table below were used for inspection of the outputs and the results of the inspection were compiled in the quality control sheet.

Table 19 Accuracy Standards for the Positional Data

Map Information Level	Standard deviation of the horizontal position	Standard deviation of the elevation point
2500	Less than 2.5 m	Less than 1.0 m
5000	Less than 5.0 m	Less than 2.5 m

Source: Public Survey Work Regulation - provisionally abbreviated as "PSWR," the Ministry of Land, Infrastructure, Transport and Tourism of the GOJ

The coordinate values of the same location measured with the topographic map data and the final orthophoto data were compared in the inspection of the accuracy of the horizontal position data. The residues between the elevation values on the DEMs and those measured by the plotter were used for the quality control of the elevation data. (See Figure 45)



QUALITY CONTROL SHEET FOR ORTHO PHOTO

QUALITY CONTROL SHEET FOR DEM

(Source:Study Team)

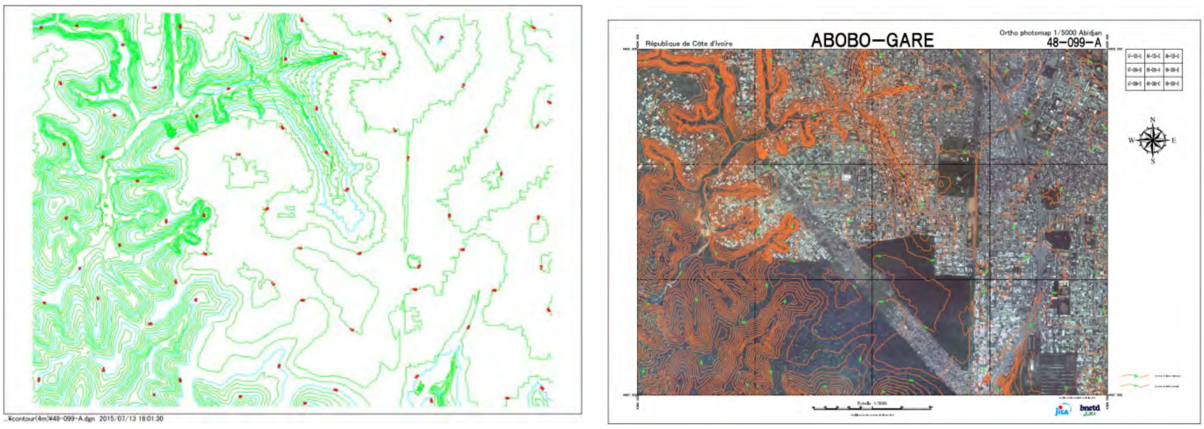
Figure45 Output Map from Quality Control Sheets (left) and Quality Control Sheets (right)

9) Creation of orthophoto maps

To create orthophoto maps of the area outside the digitally plotted area, areas where distortion of roads etc. was found on the orthophoto data were identified and breakline data in the areas were captured from the stereo models. Contour lines were automatically generated from the DEMs used in the creation of orthophoto data and the created contour lines were corrected with additional breakline data of roads and valley lines.

Meanwhile, the contour data for orthophoto maps of the digitally plotted area were created by editting the contours in the digitally editted data.

One-to-five thousand-scale orthophoto maps (with contour data and marginal information data) were developed by creating the marginal information for the orthophoto maps and adding the contour data and the orthophoto data to the created marginal information. (See Figure 46)



(Source:Study Team)

Figure46 Contour Map (left) and Orthophoto Map (right)

3.6 Digital Editing after Field Completion (C-3)

Digital editing after field completion is the process of verifying the created topographic maps and solving questions concerning the maps in the field for the last time. In the digital editing after field completion, field completion maps indicating the locations where data omissions or ambiguities had been detected in the outputs of the field identification were printed and taken to the field completion, the results of the field completion were recorded in the field on the field completion maps and the recorded data were used to add new data and correct data in the compiled data.

Digital editing after field completion was conducted based on the field completion survey map (see Figure 47) in the 500 km^2 areas, consisting of 172 (2.0 km x 1.5 km) map sheet areas, including the central area of Abidjan.

🟩 : Area of digital editing after field completion

（Source：Map data ©2015 Google、Study Team）

Figure47 Area for Data Creation in Digital Editing after Field Completion

Workflow

Workflow for digital editing after field completion is shown as below.

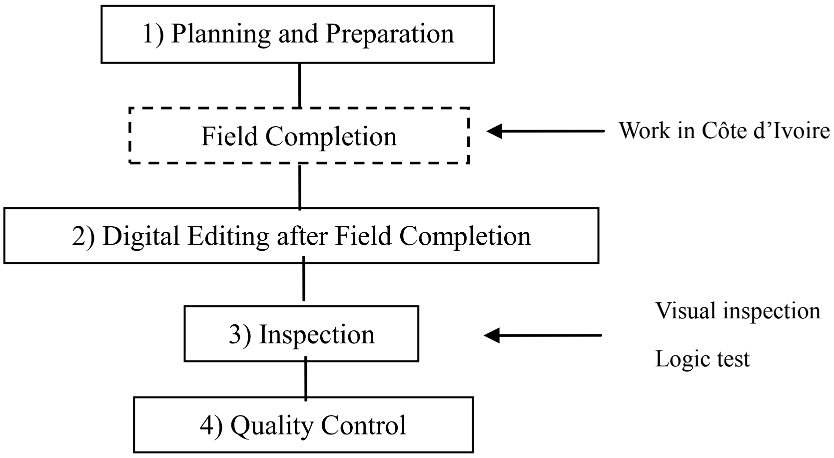


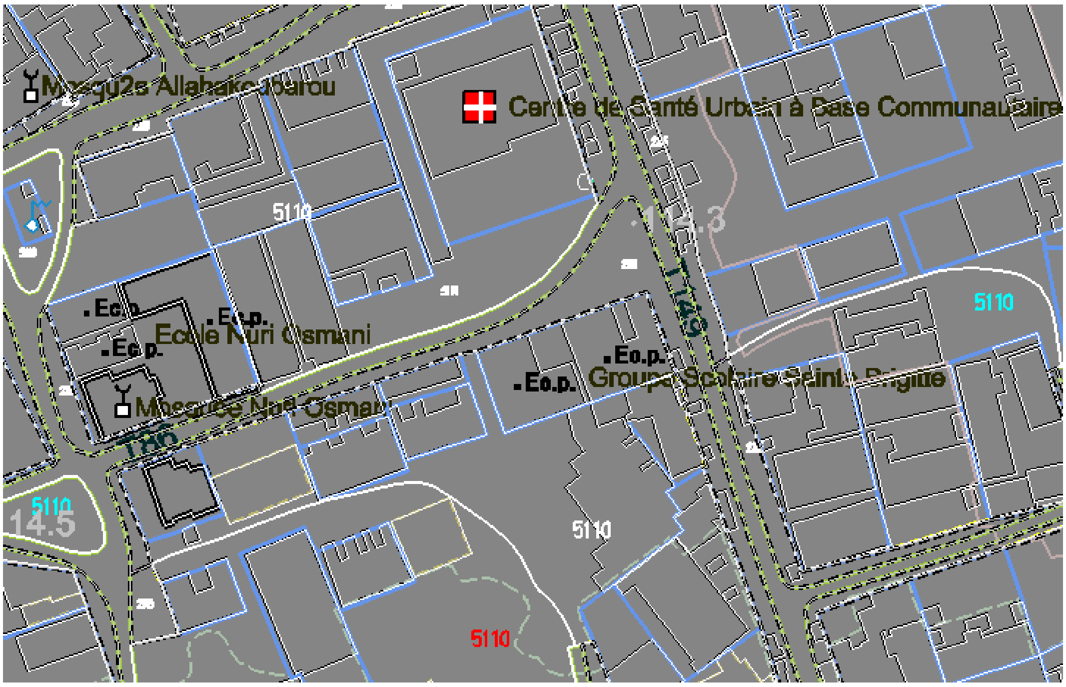
Figure48 Workflow of Digital editing after Field Completion

1) Planning and preparation

   The digital editing for field completion was conducted for the verification in the field of the feature data which had failed to be captured and erroneously captured in the field identification for digital editing and for the clarification of the feature data which had been found to be ambiguous in the digital editing. Field completion maps which indicated the locations at which the feature data should be verified in the field were printed and used in the field completion. In the preparation for the field completion, the instruction for the field completion was inspected for omissions and errors.

2) Digital editing after field completion

   The digital editing after field completion was completed by obtaining field completion data and supplementary GIS data and by adding and correcting them in the CAD data created in the digital editing. (See Figure 49)



(Source:Study Team)

Figure49 Output Data of Digital editing after Field Completion

3) Inspection

In order to inspect the data visually, the data editing for symbolization of the data created as the final output of the digital editing after field completion was conducted as in the field editing. The data created in the data editing for symbolization were combined with the marginal information data and the rasterized output of the printed images of the combined data was created. Rasterized field completion maps and road name maps and the output vector data of the digital editing were overlaid using the digital editing system. The two types of maps were compared by visual inspection.

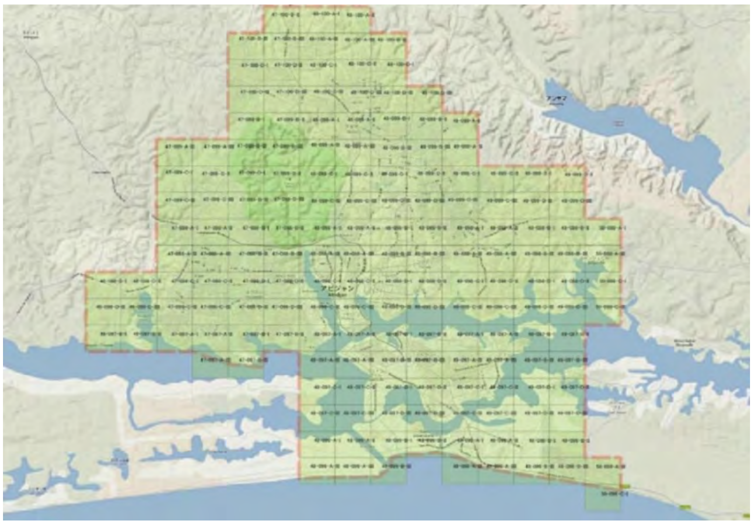
4) Quality control

Data omissions and erroneous data entries identified in the visual inspection and logic test were compiled in the quality control sheets for the digital editing after field completion. (The quality control sheet was recorded as digital data.)

3.7 GIS Basic Data Structurization (C-4)

GIS basic data structurization is the process of sorting the captured shapes into the point, line and polygon data and adding attribution data to them to create GIS basic data. In the data structurization, data on the centerlines of roads and the auxiliary lines on administrative boundaries and land use were added to the output data of the digital editing after field completion so that they were structured into data to which attribute data could be attached as data from which points, lines, and polygons could be created.

Data in the 500 km^2 area, consisting of 172 (2.0 km x 1.5 km) map sheet areas, including the central area of Abidjan, were structured. (See Figure 50)



🟩 : Structurization area

（Source：Map data ©2015 Google、Study Team）

Figure50 Area for Data Structurization

(1) Workflow

Workflow for entry of centerlines of roads is shown as below.

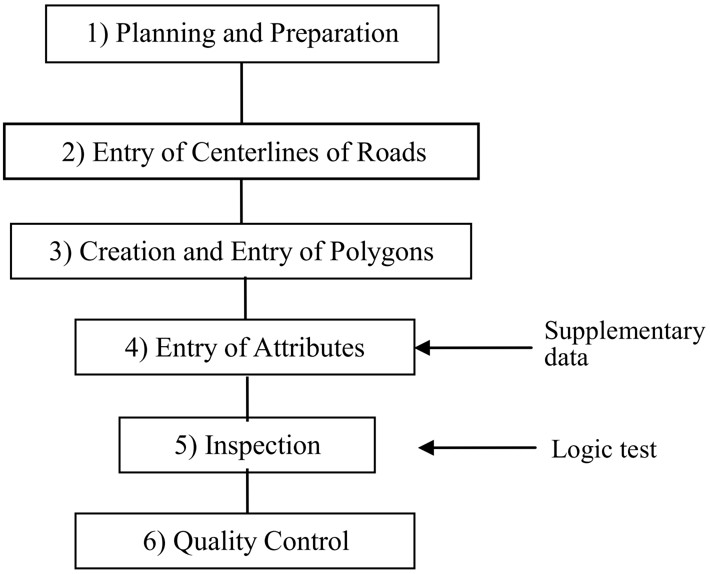


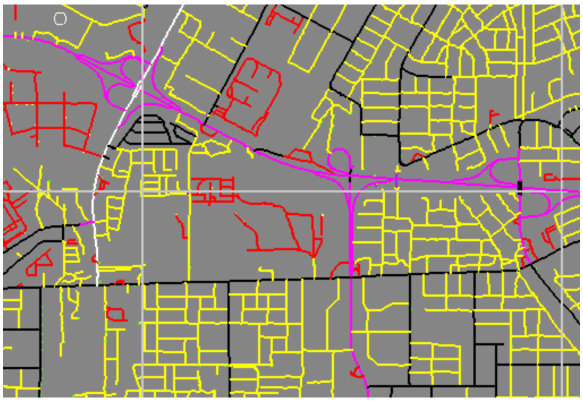
Figure51 Workflow of Entry of Centerlines of Roads

1) Planning and preparation

The GIS attribute data obtained in the field were converted and integrated with the CAD data, and reference data obtained in the field completion were printed on paper for the data structurization.

2) Entry of the centerlines of roads

After completion of the editing of the field completion data, for roads compiled in true width of more than 2.5 meters, edge matching for roads with single lines symbolizing the narrower roads was carried out by entry of the data on the centerlines of the roads. When road network data were compiled, an auxiliary input of a line was made to connect a line representing a road symbolized by a single line and the centerline of a road represented with the true width at each intersection between them (See Figure 52).



(Source:Study Team)

Figure52 Road Centerline Input Data

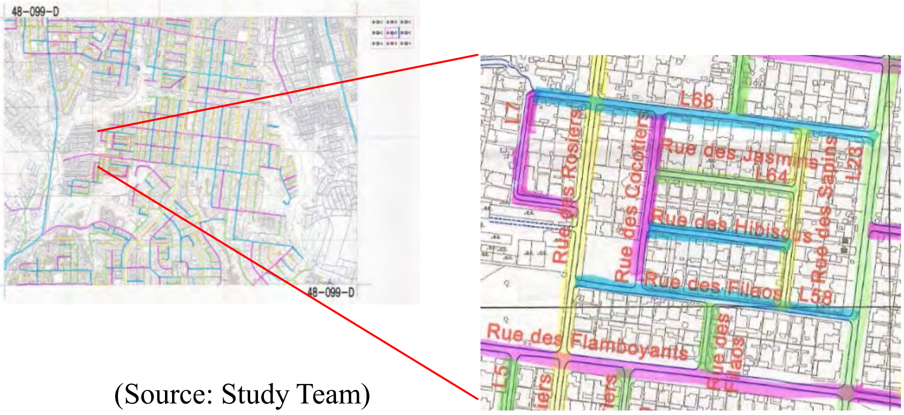
3) Creation and entry of polygons

Houses and buildings, including those located on neat lines and requiring edge matching, were entered as polygons up to the edge matching lines so that attribute data could be attached to their data.

Additional entry of auxiliary lines was carried out to enable creation of different polygons for different types of land use, etc.

4) Entry of attributes

The required attributes were attached to features (*e.g.* road names to the centerlines of the roads and annotations of buildings to the locations of the building symbols) using the reference materials created in the field completion. (See Figure 53)



(Source: Study Team)

Figure53 Reference Material for Entry of Road Names

5) Inspection

A computer program was used for data processing for the correction of errors in type classification, structure and topology of data in the inspection.

6) Quality control

In the quality control, the calculated quantity of errors detected in the logic test and the details of the data correction were compiled in the quality control sheets.

The logical test confirmed the absence of error in the final output of the data editing for structurization.

3.8 GIS Data Structuralization (C-4-2)

GIS data structuralization is the process of specifying the rules for the structuralization of topographic map data for their utilization as geographic information and storing the structuralized data.

3.8.1 Introduction

Geographic information system (GIS) data is important for urban infrastructure development. However, successful use of GIS data for urban infrastructure development depends on its quality as well as an efficient geographic information database management system. In this project, GIS data structuralization refers to the organization of various GIS datasets and the design of an efficient geographic information database management using geospatial data acquired during the project implementation. The specific objectives of the geodatabase model is to efficiently migrate computer aided design (CAD) data into geodatabase format as well as efficiently store, manage and process GIS data.

3.8.2 Abidjan Urban Geodatabase Model

The GIS data structuralization (hereafter referred to as the Abidjan urban geodatabase model) is based on ESRI’s single-user file geodatabase model. A geodatabase is a container of geospatial and attribute data. The geodatabase, which is a native data structure of ArcGIS (ESRI 2012), organizes vector data sets into feature datasets and feature classes. Feature classes store spatial features of the same geometry type (e.g., point, line and polygon), while the feature dataset stores feature classes that share the same coordinate system and area extent (Chang, 2010; ESRI, 2012). Raster data can also be stored in a geodatabase. Below is a brief outline of the design process, which involves conceptual, logical, and physical design phases. For definition geodatabase terms and concepts, refer to the geodatabase design technical specifications and training manual.

(1)Conceptual Model

The conceptual model comprise seven feature datasets, which were compiled from 134 feature layers that include spatial features and annotations. The 134 feature layers were derived from the “1:2,500 scale map symbol specifications and rules” document (version 5.1). In addition, the conceptual model includes the Digital Elevation Mode (DEM) raster dataset. Note that the “1:2,500 scale map symbol specifications and rules” were designed and prepared by BNETD/CCT and the JICA study team. Table 20 shows the main feature datasets, which are described in the subsections below.

Table 20 Main feature datasets compiled from the 1:2,500 scale map symbol specifications

Feature Dataset	Map use	Data Source	Representation
Administrative	Administrative and legal boundaries	CCT	Line and polygons
BuildingInfrastructure	Represents buildings,cultural,landmark features and building related facilities	CCT/JICA	Mainly polygons includes annotations
Hydrography	Represents surface water and features for moving, storing, and managing water	CCT/JICA	Points,lines and polygons
Hypsography	Represents terrain	CCT/JICA	Spot height contour lines, DEM includes annotations
PublicFacilities	Represents government buildings, banks, schools, religious institutions e.t.c.	CCT/JICA	Points includes annotations
SurfaceOverlays	Represents land use/cover such as urban areas, bareland, forest	CCT/JICA	Polygons
Transportation	Represents roads, rail way,and the associated infrastructure	CCT/JICA	Lines and points includes annotations
DEM	Digital elevation model	CCT/JICA	Elevation

(2) Logical Model

The Abidjan urban geodatabase logical model comprise seven feature datasets and the digital elevation model (DEM) raster dataset as well as annotations (Figure 54). The subsection below describes feature classes in each feature dataset, and DEM raster dataset.

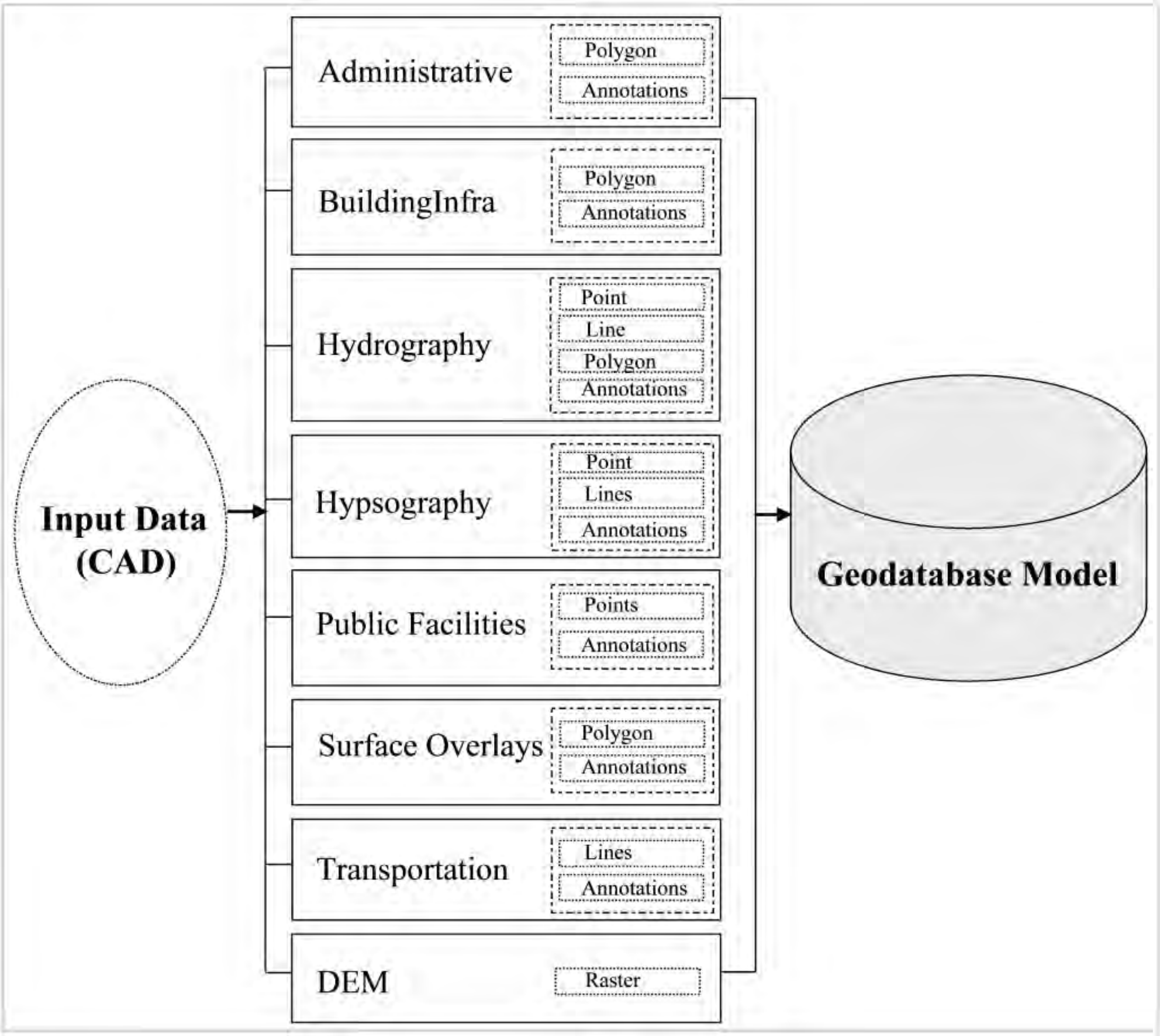


Figure54 Abidjan urban geodatabase logical model.

1)Administrative Feature Dataset

The “Administrative” feature dataset comprise the administrative boundary feature class. In addition, the administrative feature class consist of sub-prefecture and commune subtypes.

2)Building and Infrastructure Feature Dataset

The building and infrastructure (BuildingInfra) feature dataset comprises buildings, delimitation zones and enclosures delimitation line feature classes.

Buildings

The “Buildings and Infrasstructure” feature class consists of the single (independent) building, multistory building, building under construction, hangar (warehouse), high density areas, and other artificial areas subtypes.

Delimitation Zones

The Delimitation Zones feature class includes the development zones and unspecified zones subtypes.

Enclosures Delimitation Line

The Enclosures Delimitation Line feature class comprises the special limit line, hedge, wall, cultivation limit line, vegetation limit line and parcel limit line.

3)Hydrography Feature Dataset

The “Hydrography” feature dataset comprises the hydropoint, hydroareas and hydrolines feature classes.

HydroPoint

The HydroPoint feature class comprises the well, reservoir tank and lighthouse subtypes.

HydroAreas

The HydroAreafeature class includes water course, canal, pond, basin or reservoir, and pool subtypes.

HdroLines

The hydroline feature class consist of gutter and shoreline subtypes.

4)Hypsography Feature Dataset

The “Hypsography” feature dataset comprises the morphology, contour and ground control points feature classes.

Morphology

The Morphology feature class includes crest slope, bottom slope (concrete), convex creep slope, colluvial foot slope, and rock cliff subtypes.

Contour

The Contour feature class comprises index contour line, intermediate contour line, normal contour line, depression contour line (normal) and depression contour line (intermediate) subtypes.

Ground Control Points

The Ground Control Points feature class consist of NRGAE control point, spot height and aerial photography point subtypes.

5)Public Service Feature Dataset

The “Public Service” feature dataset comprises commercial areas, governmental organizations, education, health, non-governmental administration, religion, general services, cemetery, line facilities and other facilities feature classes.

Commercial Areas

The Commercial Areas feature class consist of bank, hotel, market and shopping centres subtypes.

Governmental Organizations

The Governmental Organizations feature class consist of government office, military facilities, and gendarmerie, police and fire stations subtypes.

Education

The Education feature class consist of comprise primary school, secondary school, high school, colleges and university subtypes.

Health

The Health feature class consist of dispensary, hospital and pharmacy subtypes.

Non-Governmental Administration

The Non-Governmental Administration feature class consist of embassy and international organisation subtypes.

Religion

The Religion feature class comprise Catholic Church, Protestant church and Mosque subtypes.

General Services

The General Services feature class consist of filling station, bus terminal and ferry landing subtypes).

Cemetery

The Cemetery feature class comprise mixed cemetery, Christian cemetery and Muslim cemetery subtypes.

Line Facilities

The Line Facilities feature class consist of power line, water conduit and pipeline subtypes.

Other Facilities

The Other Facilities feature class include antenna, airport, water tower, monument, tank (oil and gas) and pylon subtypes.

6)Surface Overlays Feature Dataset

The “Surface Overlays” feature dataset comprises the land use/cover feature class. In addition, the land use/cover feature class consist of the forest, degraded forest, woodland/ savanna woodland, shrub savanna, culture area, industrial plantation, marshy area, bare land, sand areas and urban areas subtypes.

7)Transportation Feature Dataset

The "Transportation" feature dataset comprises road and railway feature classes.

Road

The Road feature class consist of divided highway, paved road, unpaved road, trail and footpath, road on premises (double line), road on premises (double line) road under construction subtypes e.t.c.

Railway Line

The Railway feature class consist of railroad crossing, rail bridge and railway line subtypes.

8)Digital Elevation Model (DEM) Raster Dataset

DEM is a raster dataset that represents elevation.

(3) Physical Model

In this project, the physical geodatabase model was implemented in ArcGIS 10.2 (Advanced) software platform. The process of implementing follows a number of steps that involves creating a prototype, pilot, and the final geodatabase. The GIS datasets from sample base map index 47_098BIV were used to create a prototype geodatabase model. Following that, all the base map indices were used to develop a pilot geodatabase. After testing the pilot geodatabase, the final provisional geodatabase was created.

3.8.3 Summary

The design and implementation of a geographic database management system is a highly iterative process, which starts with the conceptual and logical models and ends with the actual physical model. Therefore, this geographic database management system based on the geodatabase model is provisional since it provides the base on which to build a robust geodatabase management system for BNETD/CCT.

3.9 Creation of Data File (C-6)

After the creation of all the data had been completed, they were classified into CAD data of the topographic map data, symbolized PDF data for printing, orthophoto data and GIS basic data and the classified data were stored in separate files. As all the GIS basic data were stored in a single file, metadata explaining the contents of the geospatial information in the file (including the date of creation and creator of the data, data format, title and annotations) were added in the beginning of the data file when it was stored on a recording medium.

(1) Creation and Recording of digital Data

The output data of the digital editing after field completion were edited for symbolization in accordance with the “Map Specifications” and the edited data and the marginal information file were integrated in CAD data files. Then, the CAD data files were stored on a HDD as an output to be submitted.

Data is in DGN format, total of 172 files (in map sheet unit).

(2) Creation and Record of PDF Data

The topographic map data in the PDF file format were created as PDF data output created from the output data of the data editing for symbolization using a pen table (the specifications for types, colors and widths of lines) which was prepared in accordance with the “Map Specifications.” The files of created PDF data were stored on a HDD as an output to be submitted.

Data is is in PDF format, total of 172 files (in map sheet unit).

(3) Creation and Recording of the Orthophoto Data

A file of 1:5,000-scale orthophoto data of each map sheet area with contour data was recorded on a storage medium.

The data were stored as PDF data. The orthophoto data (of the (550 + 500) km^2 area) were stored in a total of 100 files.

Original 1:5,000-scale orthophoto data without contour data of the entire study area were integrated into a single seamless data set and the data set was stored in a file on a recording medium.

The integrated data were stored in the file in the GeoTIFF data format.

(4) Creation and Recording of the GIS Basic Data

The GIS basic data were created by converting the shape and attribute data in the CAD data created in the editing for structurization into the data in the SHAPE file format of ArcGIS.

The data files of the created data were stored on a HDD as an output to be submitted.

Data is in SHP format.

Similar to data structurization, GIS basic data file of seamless data of the 500 km^2 area shown below, consisting of 172 (2.0 km x 1.5 km) map sheet units, which included the central area of Abidjan was created.

The figure below shows the workflow of the GIS basic data creation.

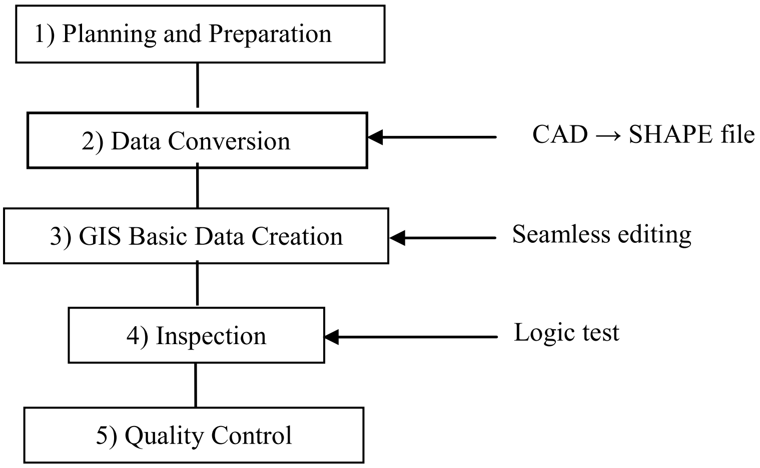


Figure55 Workflow of Creation of GIS Basic Data

1) Planning and preparation

The attribute and annotation data in the structured DGN (CAD) data of the 172 map sheet units were verified in preparation for the creation of GIS basic data.

2) Data conversion

ArcGIS of ESRI was used for the conversion of the data verified in the planning and preparation stage to those of the SHAPE file format.

3) GIS basic data creation

Seamless editing of the converted SHAPE file data including removal of dangles, overlapping and intersecting of polygon data and donut polygon creation was performed for the GIS basic data creation.

The created data were inspected whether they had structures and attributes as specified in “Mapping spec rules” developed in this project.

4) Inspection

The created GIS data were inspected to see whether they had the structures, shapes and attribute data specified in the “Mapping spec rules” without errors or omissions using the ArcGIS outputs.

5) Quality control

As quality control, logic tests were conducted until no errors were detected.

(5) Metadata (of the GIS basic data)

The table below shows the contents of the metadata of the GIS basic data. They are the data required for their utilization.

Table 21 Metadata Input Items

Metadata input item		
1	Brief description of the data (purpose of the project)	Digital Topographic Data (CAD, GIS, PDF)
2	Language used in the data	French
3	Title of the spatial data (project name)	Digital Topographic Mapping Project for Urban Infrastructure Development in The Republic of Côte d'Ivoire
4	Data creation date (delivery date)	September 2015
5	Data encoding	UTF 8
6	Data classification	Positional (001)
7	Executing organization	Japan International Cooperation Agency
8	Metadata name	ABJ_Digital_Mapping
9	Metadata format	JMP
10	Metadata version	2.0
11	Metadata creation date	Date of delivery
12	Language used in metadat	English
13	Metadata encoding	UTF 8
Meta data contents		
1.Data		
1.1	Purpose	Digital Topographic Data (CAD, GIS, PDF)
1.2	Language	French
1.3	Project name	Digital Topographic Mapping Project for Urban Infrastructure Development
1.4	Date of delivery	September 2015
1.5	Encoding	UTF 8
1.6	Data classification	Position (001)
1.7	Executing organization	Japan International Cooperation Agency (JICA), Asia Air Survey Co., Ltd. (AAS)
2.Meta data		
2.1	Name	ABJ_Digital_Mapping
2.2	Format	JMP
2.3	Version	2.0
2.4	Creation date	August_2015
2.5	Language	English
2.6	Encoding	UTF 8
2.7	Aerial photography date	January 2014 to March 2014
2.8	Total volume	??????Mb
2.9	Coordinates system	WGS 84, UTM 30N
2.1	Height reference	Original benchmark at Dakar port
2.2	Copyright	Le Centre de Cartographie et de Télédétection (CCT), Japan International Cooperation Agency (JICA)

3.10 Result of the Overall Quality Control

The quality control sheets of all the processes were compiled into a report on the quality control.

3.11 Preparation and Printing of the Publicity Material

Publicity material with French text printed on both sides of A3 paper in color was prepared. The outline of the activities in the project, implementation procedures, project area, general condition of the project area and output, result, conclusion and recommendations of the project were described on the material. Two hundred copies of the publicity material were printed and 150 of them were distributed in the seminar.

3.12 Creation of Digital Image

Photographs depicting the activities in the project office and at the project sites and documentary photographs of the project taken from the commencement until the completion of this Project were compiled in a collection of digital images with simple captions in the Microsoft Word format attached to them. Two copies of the collection on DVDs were created.

4. Work related to the Technology Transfer

The policy for the technology transfer in this Project is to transfer "technologies that CCT does not have" and "technologies required by CCT" identified after an analysis of the technological gap in photogrammetry in general in CCT through lectures and demonstration of theories and new technologies and a practical approach, *i.e.* OJT, as mentioned in the Inception Report. The policy was implemented for the purpose of improving the technical capacity of CCT to the level at which they could create and revise topographic maps unassisted after the completion of this Project.

4.1 Results of and Discussions on the Technology Transfer

As the geospatial data are to be provided to users involved in public works, a data supplier has to ensure a supply system, product liability and technical reliability of the data based on certain accuracy standards and inspection standards. This Project was commenced with the understanding that, even if geospatial data were produced in this Project, it could not produce an effective outcome with far-reaching effect unless CCT, as a public organization in the information administration, clearly understood the purposes of creating such data and its responsibilities in supplying the data independently and maintaining the data independently and sustainably.

Therefore, in order to develop a sense of ownership of the outputs of this Project in CCT, the Study Team had sufficient discussion and exchange of views with CCT on the project from its beginning. The team and CCT clarified the role and purpose of this Project in the city planning sector and the practical ways to utilize the outputs in the field in the early stage of the project and expanded the common understanding of the project in the discussion. Against this background, the technology transfer was carried out with the concept that the underlying output of this Project was the human resource development and strengthening of the data supply system in CCT to facilitate the city administration associated with the city planning in the Greater Abidjan Area which is expected to expand and the land use including cadastral management.

The focus of the technology transfer in this Project was not on the practical procedures in the digital topographic mapping, because the staff members of CCT had been recognized to have sufficient level of technical capacity and knowledge, but on the establishment of a data management system with the main purpose of the improvement in the capacity concerning the accuracy control to be implemented in each process in a specific technical area and the quality control of the outputs. In practice, the Study Team had intensive discussion with the people in charge of this Project in CCT after they conducted a baseline survey on the technical skills of staff members of CCT. The team requested full-time assignment of staff members of CCT to the project in the discussion. Then, the team decided the actual contents of the technology transfer in each technical area with the full understanding of the request of CCT. The table below summarizes the outputs of the technology transfer.

Table 22 Outputs of the Technology Transfer

Technical area	Subject of technology transfer	Baseline technical level	Level of achievement
Aerial photography	Goal to be achieved: To be able to prepare a photography plan appropriate for a purpose of photography with the time of photography and meteorological conditions taken into consideration and to manage a schedule of photography	-	○
	Planning of photography	△	○
	Direct orientation measurement (GNSS・IMU)	×	○
	Inspection of photography data	○	◎
	Accuracy control	△	○
Ground control point survey	Goal to be achieved: To be able to control the quality of the survey results using a quality control sheet with the understanding of the basic concept of the quality control	-	◎
	Planning for point selection	○	◎
	Installation of aerial signal markings	△	◎
	Pricking	△	○
	GNSS observation	○	◎
	Leveling	△	○
	Accuracy control	△	○
Field identification and field completion	Goal to be achieved: To be able to prepare a survey plan appropriate for a pre-determined scale (Map Information Level) and implement field identification and field completion with the understanding of the basic concept	-	◎
	Understanding of the difference in the mapping at different scales	○	○
	Understanding of the specifications, map symbols and rules on the use of the symbols	△	○
	Understanding of the contents of the survey (data to be captured)	△	◎
	Understanding of the difference between the field survey with photographs (field identification) and that with maps (field completion)	○	◎
	Implementation of the field identification and field completion	△	◎
	Compilation of the survey results	△	○
Aerial triangulation	Goal to be achieved: To be able to understand the entire process of aerial triangulation and perform it independently	-	◎
	To be able to understand the basic preparatory work	○	◎
	To be able to perform 3-D observation	○	◎
	Determination of the interior orientation	○	◎
	Determination of the exterior orientation	○	◎
	Accuracy control	△	○
Creation of DEMs and orthophotos	Goal to be achieved: To be able to understand the basic concepts of the DEMs and orthophotos and learn the method to create them with their quality controlled	-	◎
	Acquisition of the method to create DEMs	○	◎

	Understanding of the method to edit DEMs	△	◎
	Understanding of the process of orthophoto creation and the method to use them	△	○
	Understanding of the relationship between the pixel size and accuracy	△	○
	Creation of orthophotos	○	○
	Image adjustment and mosaicking	△	○
	Understanding of the accuracy control	△	○
Digital plotting	Goal to be achieved: To be able to interpret digital data from 3-D stereo models composed of stereo aerial photographs and control the accuracy of captured data with the understanding of the specifications and the Map Specifications	-	◎
	Acquisition of elevation measurements (single point measurements)	○	◎
	Acquisition of the accuracy of feature interpretation (feature classification)	○	◎
	Understanding of the contents of the digital data for large-scale mapping	△	○
	Understanding of the specifications and the Map Specifications	○	◎
	Learning of the preparatory work for digital plotting (environment setting and compilation of various outputs)	△	○
	Drawing of features, feature measurements, elevation points and contours	○	◎
	Understanding of the quality control (method of the accuracy control and recording of its result)	△	○
Digital editing	Goal to be achieved: To be able to edit digital data and control the accuracy of the edited data with the understanding of the specifications, map symbols and rules on the use of map symbols	-	◎
	Understanding of the matching of coordinates at the edges of adjacent map sheets	△	○
	Understanding of the feature data type and classification of captured feature data	○	◎
	Learning of the editing of plotted data	○	◎
	Understanding of topology structure	○	◎
	Understanding of the appropriate method to enter the data captured in the field identification and field completion	○	◎
	Understanding of the appropriate method to enter data in collected materials	○	◎
	Understanding of the basic concept of the quality and schedule control	△	○
Structurization of digital data	Goal to be achieved: To be able to perform the GIS structurization and control the accuracy of the created GIS basic data with the understanding of the specifications, map symbols and rules on the use of map symbols	-	○
	Understanding of the structure of point data	○	○
	Understanding of the structure of line data	○	○
	Understanding of the structure of polygon data	○	○
	Understanding of the structure of attribute data	○	○
	Learning of the basic operation of the GIS software	△	◎
	Understanding of metadata	△	○
	Quality and accuracy control	△	○
Discussion on Specifications	Goal to be achieved: To be able to prepare and understand the details of new specifications for 1:2,500-scale maps and the rules on the use	-	◎

	of map symbols and collect them when required.		
	Understanding of the details of the rules for the use of map symbols	△	◎
	Understanding and use of the rules on annotations	△	○
	Understanding and use of the map sheet numbering system	△	◎
	Understanding of the marginal information	△	◎
Map symbolization of digital data	Goal to be achieved: To be able to perform map symbolization and control the accuracy of the created symbolized data with the understanding of the specifications, map symbols and rules on the use of map symbols	-	◎
	Understanding of the map symbols and rules on the use of map symbols	○	◎
	Creation of the map symbols, line types and patterns to be used	○	◎
	Understanding of the representation of map symbols with the image of the final printout maps taken into consideration	○	◎
	Learning of the method to create the marginal information and legend	○	○
	Learning of the method to make correction for changes over time	△	△
	Understanding of the accuracy control	△	○

×:No Knowledge and no.experience, △:have knowledge but no experience,
○:have some konwkedge and experience, ◎:Necessary level to work

In addition, the problems on the existing geospatial data raised by their users were analyzed and, after the consultation with CCT, the data of administrative boundaries and road classification, the data which are extremely important in the city planning, were updated using the data owned by the competent authorities of the boundaries and roads, *i.e.* the Ministry of Home Affairs and DAUDL/BNETD, respectively.

Topographic map data had been created without elevation data in Côte d'Ivoire until this Project. In the seminar held near the completion of the project, a 3-D model of a selected pilot site, an area expected to have high developmental needs, was developed with the elevation data created in this Project as a demonstration to promote and extend the use of the outputs of this Project including 3-D data to their potential users.

4.2 Contents of the Implemented Technology Transfer in each Technical Area

At the commencement of this Project, CCT submitted a request for the technology transfer on the all the processes in the mapping. The outcome of the technology transfer implemented in this Project is described in detail in the following.

4.2.1 Implementation of a Seminar/Workshop at the commencement of this Project (D-1(1))

Organizations that intended to use the outputs of this Project effectively were invited to attend the seminar/workshop. In the seminar/workshop, the Study Team explained the purposes of the Project, a plan for the utilization of data to be created in the Project, details of the tangible outputs (counterpart organization, project area, data accuracy, technology transfer and equipment to be provided) which would become available for infrastructure development in the Abidjan Metropolitan Area in future, sample topographic maps and the entire process of the digital topographic mapping. There was also a demonstration of the data use with WebGIS, a question-and-answer session and a free discussion session with potential users in various sectors in the seminar/workshop. The details of the seminar/workshop are as follows. (See Attachment for more details.)

As this seminar was co-sponsored by JICA and CCT, CCT took the initiative in the reservation of the venue, selection of the guests and delivery of the letters of invitation.

- Date and time : December 4, 2013, from 10:00 to 14:00
- Venue : Conference Hall, Ministry of Foreign Affairs

4.2.2 Seminar/Workshop for the Extension of the Data Utilization (D-1(2))

The overall plan and the outline of the expected outputs of the project were explained in the Kick-off Seminar held in December 2013. As the creation of all the outputs had been completed by the time of the Final Seminar, it was decided to introduce those outputs, explain the state of their utilization and simulate the utilization of the outputs in the Final Seminar. Therefore, the stakeholders who were expected to utilize these data and representatives of the relevant government ministries and agencies, international organizations and JICA projects were invited to the Final Seminar. The summary of the seminar is described below. (See the Report of the Final Report for the details.)

CCT helped the Study team in the preparation and delivery of the letters of invitation and the setting of the venue of the seminar as it was co-sponsored by CCT and JICA.

- Date and time : 25 September 2015, 09:00 - 14:30
- Venue : Salle de fêtes , Hotel Ivoire

The table below shows the outline of the seminar.

Table 23 Outline of the Seminar

Title of Seminar	Date and time	Number of participants	Contents	Key participants
Kick-off Seminar	December 4th, 2013 10:00-14:00	87: Breakdown Organizations concerned: 40 BNETD/CCT: 36 Japanese Side: 9 Others: 2	Introduction of the project (scale of the budget, work schedule and expected outputs)	Director of the Department of Bilateral Cooperation, for the Minister of Foreign Affairs Chief Secretary of the Ministry of Construction, Housing, Hygiene and Urban Development First Secretary of the Embassy of Japan in Côte d'Ivoire Director of the Department of Asia, the Ministry of Foreign Affairs Chief Representative of JICA Côte d'Ivoire Office Representative of the Director General of BNETD Representatives of the Directorate of Transport, communes, the Directorate of Urban Development and Planning, the National Police Directorate, etc.
Final Seminar (on the data utilization)	September 25th, 2015 9:00-14:30	153 Breakdown Organizations concerned: 52 BNETD/CCT: 80 Japanese Side: 12 Others: 9	Annoucement of the completion of the project, speeches and the handover ceremony (of the outputs and the atlases) Study Team: Explanation of the outputs and presentation on WebGIS Presentations by the CPs: Aerial photogrammetry, map specifications, ground control point survey and sales of the outputs, Exhibition booth: explanation on the data utilization	Chief Cabinet Secretary for the Minister of Foreign Affairs Ambassador of Japan to Côte d'Ivoire Chief Representative of JICA Côte d'Ivoire Office Director General of BNETD Representatives of the Directorate of Transport, communes, the Directorate of Urban Development and Planning, the National Police Directorate, the Directorate of Statistics, the National Office of Potable Water, etc.

4.2.3 Ground Control Point Survey and Installation of Aerial Signal Markings (D-2 (1))

Staff members of CCT involved in GPS survey had experience in conducting surveys commissioned by the Government and private companies and had a certain level of technical capacity in GPS observation. The Study Team prepared a plan for the technology transfer appropriate for their level of technical capacity and transferred the following technologies in accordance with the plan in OJT.

- Technologies required for acquisition of observation data at the resolution required for the creation of 1:2,500 topographic maps;
- Technologies required for quality control of the acquired observation data

(1) Details of the Technology Transfer

The Japanese expert in charge of the subject gave the trainees a lecture on arrangement planning of ground control points, personnel planning, specifications of aerial signal markings and standards for GPS observation so that they could learn the technologies to acquire observation data of a resolution required for the creation of 1:2,500 topographic maps. The expert also gave them a lecture on quality control so that they could learn the technologies to control the quality of observation data.

1) Ground Control Point Arrangement Planning

The Japanese expert explained the conditions to be considered with emphasis on the natural conditions specific to Côte d’Ivoire, to the trainees using the draft ground control point arrangement plan.

2) Specifications of Aerial Signal Markings

The Japanese expert explained the shapes, colors, locations of installation and sizes of signals which could make them interpretable on aerial photographs. He explained that quality of interpretation could be improved by using two types of color schemes on the ground of different colors around the installation sites. (See Photo 14)

It was decided to use three types of aerial signal markings in this Project. The one best suited to the conditions at a site was to be used at each site. The expert also explained that the use of different types of aerial signal markings improved the quality of the work. (See Photo 15)

Photo 14 Lecture on Criteria for Selection of Aerial Signal Markings (left) and Training on Installation of Aerial Signal Markings (right)

Photo 15 Three Types of Aerial Signal Markings (Types A, B and C)

3) Standards for GPS Observation

The standards of the parameters of GPS observation required for high-precision measurement of positions with GPS observation are mentioned below. The trainees practiced GPS observation outdoors in advance.

a) PDOP
b) Angle of the antenna
c) Observation time and reception intervals
d) Network

A lecture was given on the characteristics of GPS, an example of observation shown in the figure below and the methods of two-hour simultaneous observation. After the lecture, the trainees practiced the observation outdoors. (See Photo 16 and 17)

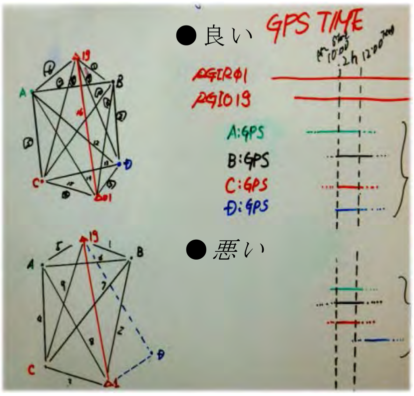


Figure56 Conceptual Drawing of Simultaneous Observation Method (lecture in classroom)

Photo 16 Outdoor Practice

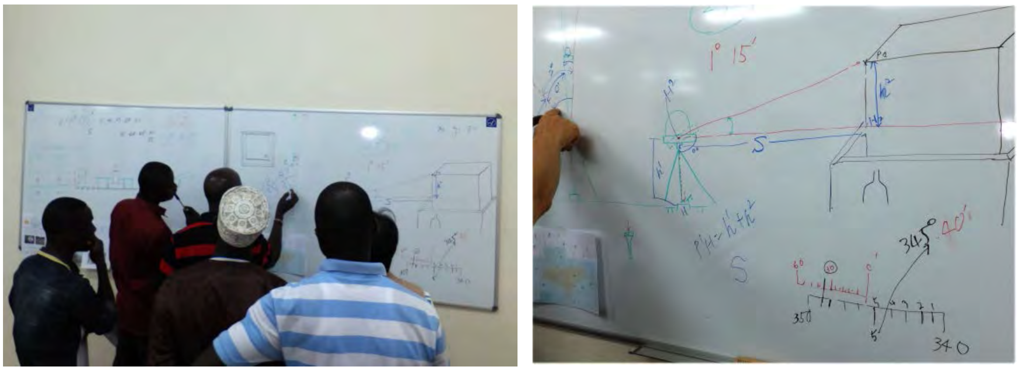


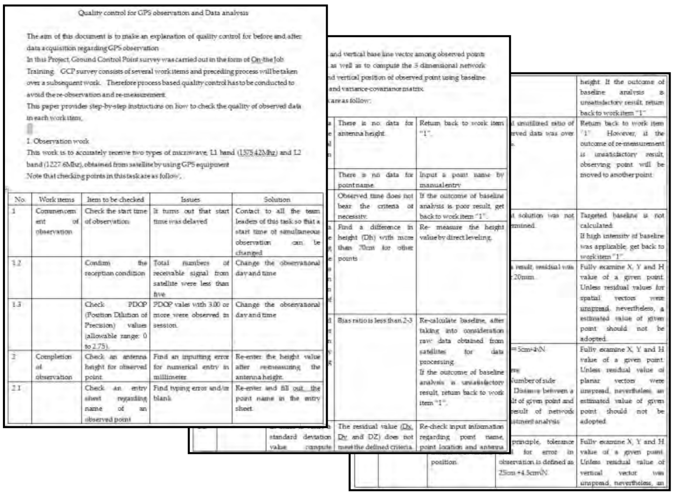
Photo 17 Lecture on Observation Standards

4) Quality Control

As a significant number of unsatisfactory results were found in the quality control of the observation data and the result of the baseline analysis, the expert prepared a quality control check sheet for each work step and gave a brush-up lecture to the trainees after they had completed the observation and analysis. In the lecture, the trainees reviewed the details of the quality and accuracy control items at each step. A lecture on the quality control required for the ground control point survey was given to them.

The details of the quality control check sheet is as follows.

- GPS devices to be used : Enable to receive multiple frequencies
- Items to be recorded/checked at the time of observation
  - Observation point name/No., time, Observer
  - Number of satellite acquired (5 or more)
  - PDOP value (0 to 2.75 : Practical, 3.0 or more : Unacceptable)
  - Antenna height to be measured to mm
  - Bias value (less than 2.3)
  - Coordinate residual (within the value specified by the regulations)
- Check items at the calculation
  - Availability of comparable height by leveling survey
  - Results of base line analysis (if it is within the tolerable range)
  - Results of 3D network analysis (25 cm ±4.5cm√N)



Quality control for GPS observation and Data analysis

The aim of this document is to make an explanation of quality control for before and after data acquisition regarding GPS observation.
In this Project, Ground Control Point survey was carried out in the form of On-the Job Training. GCP survey consists of several work items and preceding process will be taken over a subsequent work. Therefore process based quality control has to be conducted to avoid the re-observation and re-measurement.
This paper provides step-by-step instructions on how to check the quality of observed data in each work item.

1. Observation work
This work is to accurately receive two types of microwave, L1 band (1575.42Mhz) and L2 band (1227.6Mhz), obtained from satellite by using GPS equipment.
Note that checking points in this task are as follow'.

No.	Work items	Item to be checked	Issues	Solution
1	Commencement of observation	Check the start time of observation	It turns out that start time was delayed	Contact to all the team leaders of this task so that a start time of simultaneous observation can be changed
1.2		Confirm the reception condition	Total numbers of receivable signal from satellite were less than five	Change the observational day and time
1.3		Check PDOP (Position Dilution of Precision) values (allowable range: 0 to 2.75).	PDOP vales with 3.00 or more were observed in session.	Change the observational day and time
2	Completion of observation	Check an antenna height for observed point.	Find an inputting error for numerical entry in millimeter.	Re-enter the height value after re-measuring the antenna height.
2.1		Check an entry sheet regarding name of an observed point	Find typing error and/or blank	Re-enter and fill out the point name in the entry sheet.

Figure57 Quality Control Check Sheets for Ground Control Point Survey

(2) Problems in and Evaluation of Each Step

In the following, the problems found in the technology transfer on the ground control point survey and the evaluation of the technology transfer are described by work step.

1) Ground Control Point Arrangement Planning

The technology transfer on the planning of arrangement of ground control points was implemented using the draft arrangement plan for this Project prepared in advance. It is considered that the trainees have understood the arrangement planning required for standard photogrammetry (aerial triangulation) sufficiently.

The direct orientation measurement with GPS/IMU is mostly used in the photography with latest digital camera, because of its better efficiency than the conventional method.

It is assumed necessary for CCT to acquire not only the knowledge to prepare a ground control point arrangement plan appropriate for this surveying method, but also technical capacity to use the above-mentioned knowledge to prepare an arrangement plan with the environment characterized by the lagoons with complicated shapes in Abidjan taken into consideration, as strongly recommended in this Project.

Among the aerial photographs newly taken in this project, those of the area surrounding the plotted area, *i.e.* those taken on Strips 1-9 and Strips 34-37, have not been used for the mapping (Figure 64). The Study Team assumes that CCT should practice and utilize the technologies acquired in this Project for the creation of 1:2,500 or 1:5,000-equivalent topographic maps of the unmapped area mentioned above without external assistance. Therefore, the Study Team shall provide maximum support to CCT upon their request for the mapping until the completion of the Project.

2) Installation of Aerial Signal Markings

The trainees learned the specifications, such as shapes and colors, of aerial signal markings and how to find a site appropriate for installation. Since they had prior experience in the work for the creation of small scale topographic maps, it did not take long for them to acquire the technologies for large-scale maps.

However, as the trainees of CCT had little experience in selecting a spare point for the installation of the marking required when an aerial signal marking at the original point had been destroyed, they still have the problems mentioned below in the eccentricity measurement and calculation required for positioning the spare point from the original point and making field sketches.

- The trainees have failed to indicate the direction of north on the sketches.
- The trainees have made many errors in the eccentricity measurement and calculation.
- The final results of the eccentricity calculation have not confirmed by the inspector and trainees failed to correct them.

3) GPS Observation of Ground Control Points

Since the trainees had sufficient experience in general GPS survey, their knowledge of the theory and experience in the practical work in GPS survey were considered sufficient.

As equipment has to be installed in different ways in the GPS observation performed in the ground control point survey, certain rules are required to ensure the accuracy of the observation. Therefore, the technology transfer focused on the standards for the GPS observation was implemented to improve the technical capacity of the individual trainees.

As a result, while various problems mentioned below emerged in the project, the trainees acquired the technical capacity at a satisfactory level both in the observation and analysis at the end of the project.

a) Lesson Learned in the Technology Transfer on GPS Observation

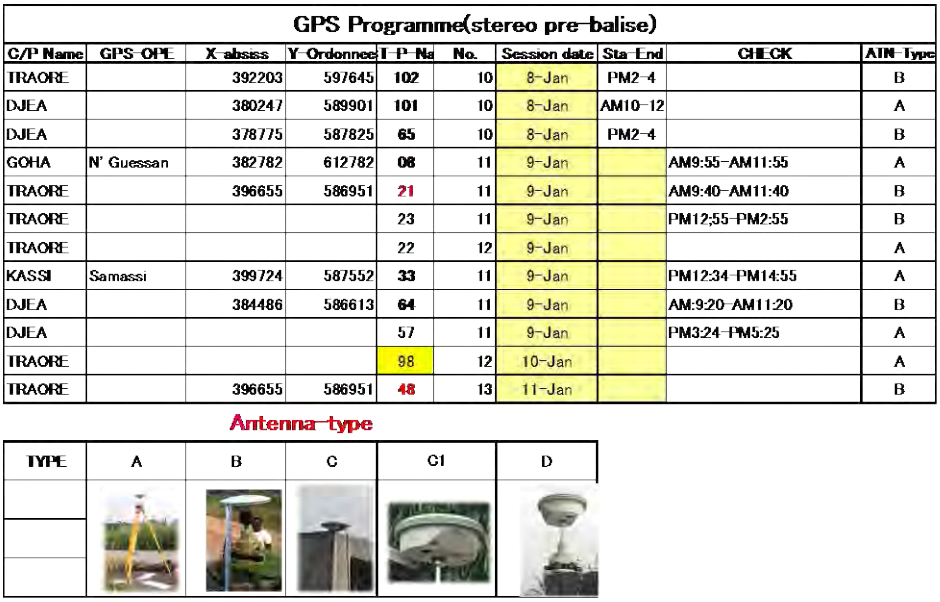
In the beginning of the Project, there were cases where correct observation result had not been obtained at observation points where the GPS antenna was installed directly on the ground.

The trainees were constantly reminded of the need to record the antenna height when GPS devices are installed on a ground control point for the GPS observation and the need to inform the person in charge of the subsequent process (GPS data analysis) of the height.

A person who has carried out GPS observation has to measure the elevation difference between the electrical center point (location of GPS radio wave reception) of an antenna and the ground with a tape measure, keep a record and inform a person who will conduct the subsequent work of this measurement correctly when the observation has been conducted with an antenna detached from a tripod and installed directly on the ground, unlike the cases where GPS observation has been carried out in the ordinary way with an antenna installed on a tripod.

As a measure to address this issue, the antenna type classification table shown below was prepared using the point descriptions and photographs which recorded the conditions of the observation as a reference and used in this Project. In addition, in order to prevent malfunction caused by the entry of a wrong point name to the GPS receiver, the session numbers and observation date were also recorded in this table so that it could be used as a tool to transmit information to the subsequent work.

Table 24 GPS Observation Antenna Type Classification Table



GPS Programme(stereo pre-balise)

C/P Name	GPS-OPE	X-absiss	Y-Ordonnee	T-P-No	No.	Session date	Sta-End	CHECK	ATN-Type
TRAORE		392203	597645	102	10	8-Jan	PM2-4		B
DJEA		380247	589901	101	10	8-Jan	AM10-12		A
DJEA		378775	587825	65	10	8-Jan	PM2-4		B
GOHA	N' Guessan	382782	612782	08	11	9-Jan		AM9:55-AM11:55	A
TRAORE		396655	586951	21	11	9-Jan		AM9:40-AM11:40	B
TRAORE				23	11	9-Jan		PM12;55-PM2:55	B
TRAORE				22	12	9-Jan			A
KASSI	Samassi	399724	587552	33	11	9-Jan		PM12:34-PM14:55	A
DJEA		384486	586613	64	11	9-Jan		AM:9:20-AM11:20	B
DJEA				57	11	9-Jan		PM3:24-PM5:25	A
TRAORE				98	12	10-Jan			A
TRAORE		396655	586951	48	13	11-Jan			B

Antenna-type

TYPE	A	B	C	C1	D

(3) Training Photographs

Photographs of the scenes at the OJT on the verification of the accuracy, a lecture and a brush-up lecture. (See Photos 18 and 19)

Photo 18 Accuracy Verification of GPS Device Installation (left) and Accuracy Verification of Eccentricity Measurement (right)

Photo 19 Lecture on Verification of the Data Obtained with GPS (left) and Brush-up Lecture on Quality Control (right)

4.2.4 Leveling/Pricking (D-2 (1))

CCT already had a certain level of technical capacity in the observation and calculation in the direct leveling as in the GPS observation. Evaluation of their improvement in skills by practice was the only subject in the technology transfer of the general technologies. The focus of the technology transfer was on the following subjects:

- Level adjustment of the optical axis of a level
- Evaluation of the observation accuracy of leveling
- Error distribution method

(1) Details of the OJT

The details of the OJT provided to the trainees of CCT are described in the following.

1) Level Adjustment of the Optical Axis of a Level

Correct leveling result cannot be obtained however accurately the graduation on a staff is read, if the horizontality of the instrument is not been maintained. The trainees learned that a leveling instrument needs to be inspected for horizontality before implementing leveling to acquire a correct elevation as pointed out below.

a) Install the staffs vertically at points A and B which should be separated by a distance between 30 and 50m.
b) Install a leveling instrument at the midpoint between Points A and B and measure the elevations A1 and B1.
c) Move and install the instrument 2m from Point A and measure the elevations A2 and B2.
d) Calculate (A1-B1) and (A2-B2) using the measurements to confirm the difference between the two is very small.

2) Observation Accuracy of Leveling

Management of leveling involves not only management of daily leveling work but also evaluation of observation result and provision of appropriate instruction for re-leveling.

Since the standards for positional accuracy in leveling have not been established in Côte d'Ivoire, the trainees learned allowable errors at the different levels of leveling (Table 11) and an equation to calculate the error using the Japanese standards.

The equation mentioned below gives an allowable range of discrepancy in the direct leveling:

$m = \pm k\sqrt{S}$ ………………….Equation 1

Where m is an allowable range of discrepancy, k is allowable value of discrepancy per km and S is the length of the leveling route (in km, one-way)

3) Error Distribution Method

An elevation determined as a result of repeated measurement of elevation difference between two points always has a certain degree of error. The error distribution method is an important technology because it gives a statistically optimal solution in the leveling by evenly distributing an error when it is within an allowable range. The trainees learned the following calculation using the sample data shown below in the technology transfer.

a) Calculate the error to be distributed per 1 m distance in this sample case with the overall error of 5 mm.

5.0mm÷98.7m=0.0507mm/m

b) Calculate the error adjustment proportional to the leveling distance

Error adjustment at B = (0.0507mm/m) × (27.5m) = (1.39mm) Use the value of 1mm by rounding 1.39mm

Error adjustment at C = (0.0507mm/m) × (32.4m) = (1.64mm) Use the value of 2mm by rounding 1.64mm

c) Calculate the final adjustment and confirm that the result of the final adjustment is equal to the known elevation of point D.

Table 25 Data Used in the Training on Error Adjustment

Point Name	Distance (m)	Backward site (m)	Forward site (m)	+ (m)	- (m)	Adjusted value (m)	Determined Height (m)
A (known point)		1.453					10.000
B	27.5	0.661	0.582	0.871		0.001	10.872
C	32.4	1.553	0.749		0.088	0.003	10.786
D (known point)	38.8		0.102	1.451		0.005	12.239
Total	98.7	3.667	1.433	2.234			12.239

(2) Lessons Learned and Problems Observed in the Leveling

The problems observed in the technology transfer are described in the following.

1) Level Adjustment of the Optical Axis of a Level

The trainees were able to understand the methods of level adjustment of the optical axis of a level and the analysis of inspection results by practicing them. However, since all the instruments had maintained the horizontality, they were unable to practice adjustment. They will have to acquire process and skills to adjust them for the time when one of them will require the adjustment.

2) Evaluation of the Observation Accuracy of Leveling

It is assumed that the trainees understood the necessity for controlling the accuracy in accordance with the level of leveling by implementing the re-leveling. While the Japanese standards are being used in this Project, CCT will have to establish the standards of Côte d'Ivoire to evaluate the accuracy of leveling in other projects. The Study Team recommends that the accuracy standards shall be kept in writing for future re ference.

3) Error Distribution Method

The error distribution method is part of the method to calculate the elevation difference with leveling. Therefore, the trainees fully understood the method. Thus, no problem has been found in the technology transfer of this method.

4) Evaluation

The counterparts already had skills to implement leveling observation and calculation at the commencement of this Project. Therefore, it is certain that they were able to acquire the advanced technologies in the practical work in OJT.

However, the problems of slow progress of the work and high ratio of re-leveling derived from the lack of sufficient practical work experience have remained.

The Study Team hopes that counterparts will have opportunities to review and use the technologies transferred in this Project in actual projects.

(3) Training Photographs

Scenes at the explanation of digital leveling instrument and test observation. (Photos 20 and 21)

Photo 20 Explanation of a New Leveling Instrument (left) and Practice of Leveling within the premises of CCT (right)

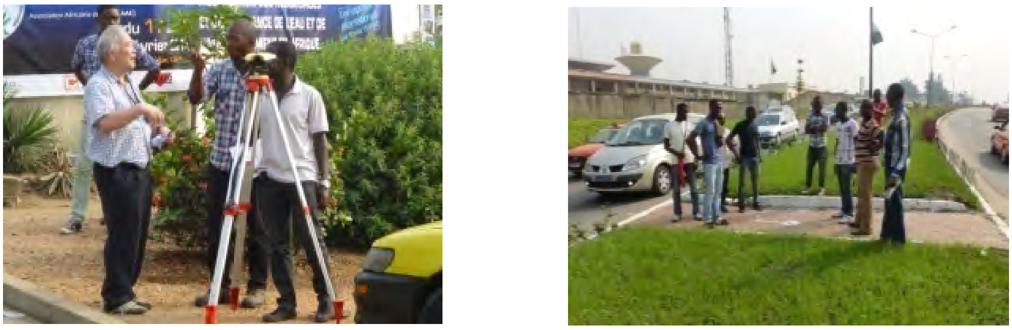


Photo 21 Practice of Leveling on a road (left) and Practice of Establishing a Pricking Point for Leveling (right)

4.2.5 Aerial Triangulation （D-2(2)）

The digital aerial photographs of the study area taken in this Project were used in the photogrammetry to create 1:2,500-scale digital topographic maps and 1:5,000-scale digital orthophoto maps.

CCT owns an aircraft (currently being repaired) and an analog aerial camera (RC10 of Wild of Switzerland, manufactured in the 1970's) and has experience in using them. Therefore, CCT have general organizational knowledge of the basic principles of photogrammetry.

However, because CCT has not used the equipment for aerial photography for a long period of time and because of the instability in the country including civil war, CCT almost has no knowledge of the latest trend in the technologies driven by the rapid advancement of digital technologies.

(1) Understanding of the Current State and Technical Level of CCT

The technological transition from analog to digital cameras has been completed in the market of aerial cameras and the production of films for aerial photography has been terminated. CCT is discussing the replacement of aerial cameras. The technology transfer implemented in this Project focused on the technological difference between aerial photography with analog cameras and that with digital cameras.

The technology transfer focused on “understanding of the latest trend in technologies” and “acquisition of the technologies for flight planning for aerial photography with digital camera” was implemented to help the counterparts acquire capacity to plan and manage implementation of aerial photography without having their own equipment.

(2) Outline of the Technical Training

The technical training on the technical services required in photogrammetry in this Project consisted of the components mentioned below. The focus of the training was on the gap between the analog and current technologies created by the innovation in the photographic technology. Table 26 summarizes the implementation of the technology transfer program on aerial photography and Table 27 shows the manuals (draft) provided to the counterparts in the program (Attachment).

Table 26 Summary of Technology Transfer Program on Aerial Photography

No.	Items	Style	Place	Hour	D,/M./Y.	Participants
Opening lecture			CCT		21/1/2014	1,2,3,4
1.	Latest technology introduction 1 as digital approach	Lecture	CCT	2.5 hours	30/1/2014	1,2,3,4
2.	Latest technology introduction 2 as digital approach	Observation	Air port	2.5 hours	22/1/2014	1,2
3.	Flight planning	*Lecture*	CCT	2 hours	29/1/2014	1,2
4.	Practical planning	Practical work,self study	CCT	2 hours	29/1/2014	1,2
5.	Data processing/quality control	Lecture	Hotel Meeting1.2 room	2.5 hours	4/2/2014	1,2
6	Question and answer	Lecture	Hotelm meeting room	2.5 hours	4/2/2014	1.2
Closing lecture					4/2/2014	1.2
Participants 1:N’Guessan Kouakou Privat (Navigator) Participants 2:Ouattara Baba Danouma (Pilot) Participants 3Coulibaly Gogninniga (Chief of Aerial photogrammetry Participants 4 Kamelan Aka Eugene (Technician of aerial photogrammetry)			Hotel Onomo			1.2

Table 27 List of Manuals for Technology Transfer on Aerial Photography

No.	Subject	Title	Language
A1	Digital Aerial Photography	Digital Aerial Photography_Eng	English
A2		Digital Aerial Photography_Fr	French
B1	Flight Planning	QGIS Flight Planning-Eng	English
B2		Plan de vol QGIS-Fra	French
C1	Data Management and in field QC	Data Management and in field QC_Eng	English
C2		Data Management and in field QC-Fr	French

(3) Evaluation by Subject

The counterparts were introduced to new technologies with a presentation in a lecture and given an opportunity to see the aircraft and digital camera which were being used in the aerial photography at an airport in the practice in Introduction to the Latest Technological Trend.

Explanation on the methods of various data processing and quality control of the processed data after the photography was provided in the form of lecture using actual data.

Software created specifically for a camera provided by its manufacturer is usually used for flight planning for aerial photography, an important subject of the technology transfer, in addition to the understanding of the latest technological trend.

In this Project, because it was impossible to provide a software license to CCT, it was decided to evaluate the result of the practice by the trainees in the following way.

a) Provision of a software license for a limited period of time (one month)
b) Loan of software which is designed to prepare flight plans on Microsoft Excel using the specifications of a digital camera as a reference
c) Preparation of a flight plan for the aerial photography of the capital of Côte d'Ivoire, Yamoussoukro

The photographer and the pilot of CCT were selected as the trainees in the consultation with CCT. In addition, the photogrammetry engineers recommended by CCT participated in the lectures. Since most of the questions which they raised were concerning the difference between film and digital cameras, it was considered that they had understood the lectures.

This was because all the trainees had prior experience in topographic mapping with film camera and, therefore, had knowledge of the basic principles.

Explanation on how to use and time to practice a) the software with a one-month limited license and b) the software which worked on Microsoft Excel were provided to the trainees in the lecture in the technology transfer on the digital flight planning.

Then the trainees were to practice preparation of flight plans for photography with the software a), and the prepared flight plans were to be evaluated in a week-period specifically reserved for the preparation and evaluation. Figure 58 shows a screen display and a worksheet of Microsoft Excel of the software b).


Required GSD: 10 cm
Camera: DMC-II_250
Fwd. overlap [%]: 60
Sidelap [%]: 30
Camera cycle @ 160 kts GS =
Film scan: 20 µm
Photo scale: 1: 5000 = 1" : 417'
Area Dimensions [km]: 10 km x 25 km =
Distance: 100 km (one way)
Street width [m]: 10

Figure 58 GSD Calculator-1 and GSD Calculator-2

(4) Quality Control

Since the method of the quality control in digital aerial photography is basically the same as that in analog aerial photography, the trainees had a lecture and practical training with sample images of digital photographs. They were able to understand the method without problems.

(5) Lessons Learned in the Aerial Photography

In this Project, the technologies used in a series of work in which digital equipment was used, except for aerial photography, were transferred. Meanwhile, because of the use of digital equipment, all the outputs to be processed are in digital formats. Therefore, the entire work is to be processed on computer. In order to utilize the learned technologies fully, the trainees will have to improve their understanding of the latest technologies including those for GPS data applications and their capacity on IT technology for the maximum use of the digitized data on the basis of the analog technologies in photogrammetry they have.

(6) Training Photographs

The following are photographs taken at the practice of flight planning for photography with digital camera, observation of the inspection of the photography equipment, photography data processing and the practice on quality control. (See Photos 22, 23, and 24)

Photo 22 Lecture on Digital Aerial Photography (left) and Lecture on Flight Planning for Digital Photography (right)

Photo 23 Observation of Inspection of a Digital Aerial Camera (left) and Inside of the aircraft equipped with the camera for the aerial photography (right)

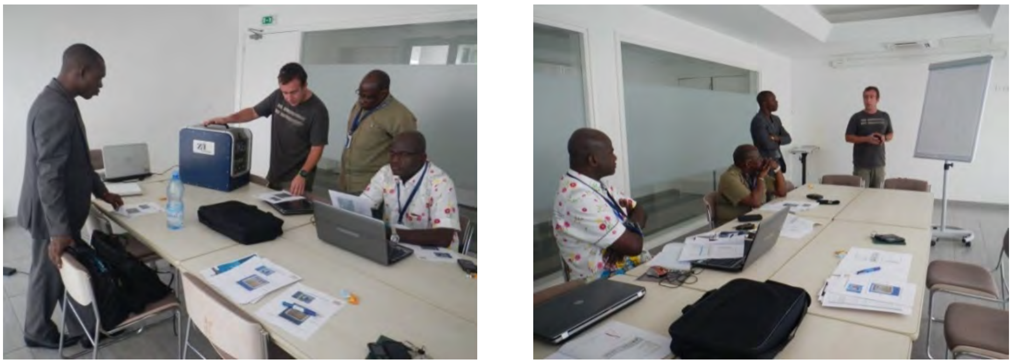


Photo 24 Lecture on Processing of Photography Data (left) and Lecture on Data Quality Control (right)

4.2.6 Promotion of the Data Utilization (D-3(1)(2)(3))

The topographic map data at a scale of 1:2,500 are an output of this Project. In order to promote the use of such large-scale and high-resolution data, the Study Team held the Kick-off Seminar at the beginning of the project and explained the outline of the project and showed geospatial data outputs to various stakeholders and donor organizations in the seminar. In order to make the data available to the general public, the team procured and installed a server to which the output data of this Project were to be uploaded and developed a WebGIS[*1] system on the server. The team created an environment for the publicity activities and service provision to topographic map users and general internet users by saving the output data of this Project on the system.

Various simulation data created from the outputs of this Project (digital topographic maps and orthophoto maps) were presented at the Final Seminar.

[*1] WebGIS : The GIS data stored in the server of CCT can be browsed by the general pulic through the internet network, to be available to this function, it is necessary for the data viewer to install Q-GIS, a free software to their computers in advance.

4.2.6.1 Installation of and Technology Transfer on the Server System

CCT and the Study Team constructed the WebGIS system in order to achieve provision of an opportunity to visualize the 1:2,500 topographic map data of Central Abidjan and its environs to the potential users and sharing of the data with them.

The construction of this system in this Project has the following two purposes:

- Dissemination of the information on this Project and its outputs to the general public at the national and local levels
- Enforcement of cooperation with relevant stakeholder organizations

(1)Server purchase and configuration

An HP ProLiant ML350p server, including a CISCO 24 ports Switch and an Infosec 2000 VA X1 UPS have been purchased in the framework of the Project.

The physical installation and the basic configuration executed. The server has a dual role, data storage and WebGIS server displaying.

A fixed IP has been initially defined to access the WebGIS server displaying. Secondarily the url http://websig.bnetd.ci has been defined as official address of the WebGIS displaying.

(2)Installation and configuration of WebGIS server

Virtual Box was used to install a customized version of Debian containing the WebGIS LizMap system. The complete kit of installation was supplied to CCT as back up.

(3)Creation and configuration of user interface

The three stages planned to configure the system were executed:

- Preparation of the sample data by using QGIS
- Configuration and publication of map by using LizMap plunging of QGIS
- Data display on internet

(4)Technology Transfer

An official training of 3 days was given according to the following program:

24 June 2014 – Introduction to QGIS (Installation, visualization and data editing)
25 June 2014 – Introduction to QGIS (Editing and layout of map printing)
27 June 2014 – Configuration and publication of data by using the plugin LizMap, and discussion.

On the 26th June 2014, a training was given to CCT cartographic Team about the advanced data shaping by using QGIS.

On September 11th and 14th, 2015 a special session was given to CCT cartographic team about the shaping and the downloading of CCT 1:200.000 scale data into WebGIS server.

(5)Creation of a web site access

A web site was created with the aim of recapitulating the principal points of the Digital Topographic Mapping Project for Urban Infrastructure Development of Abidjan. The Interface of the site appears as follows:

On the website the user can reach WebGIS display, which already offers the possibility of displaying the 1:2.500 map scale data produced in this Project as well as the 1:200.000 map scale data produced by CCT. The website and especially the

WebGIS server have the purpose of sharing the data created in this Project as well as the data created by CCT. This tool will be accessible on the international level. The images on the WebGIS are protected. Although unauthorized users may browse the images, they are not allowed to download the images. CCT intends to conclude contracts which specify the conditions on the data utilization with individual users and charge for the data provision. Please see 4.4 for the details.

(6)Preparation and shaping of the final data and download into the WebGIS server.

The final data produced in this Project (digital topographic maps and orthophoto maps) were relieved to allow a faster Internet browsing after the shaping and the addition of metadata; the data were downloaded into WebGIS server.

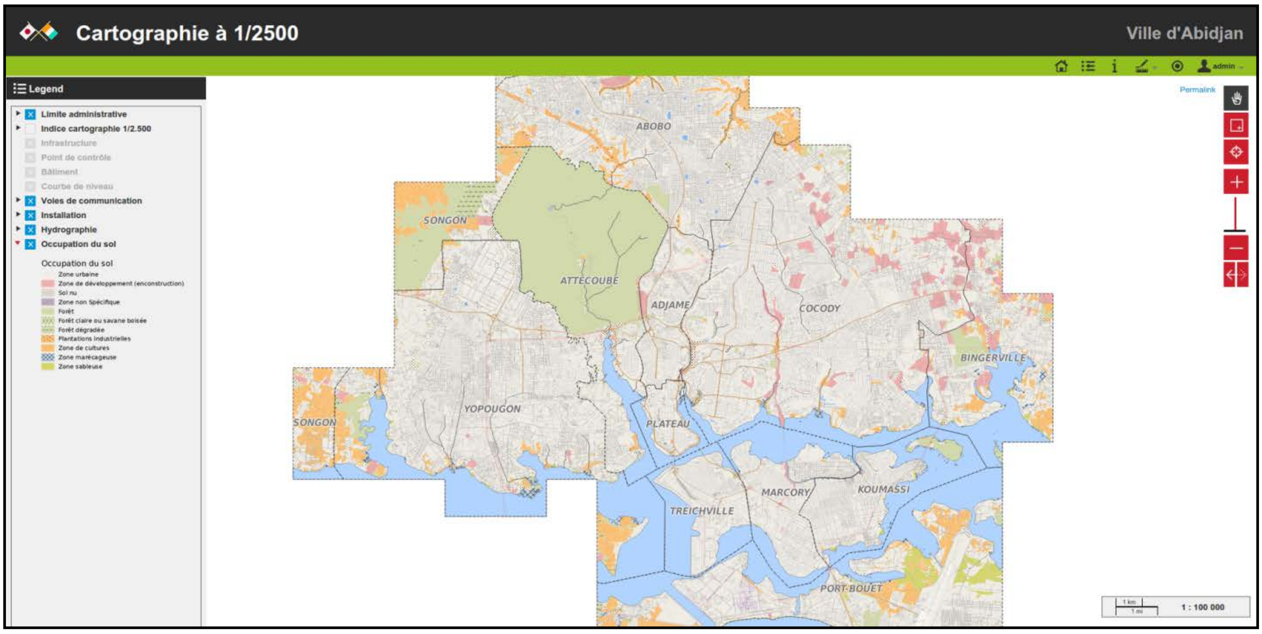


Figure 59 Final image of WebGIS

(7) Installation and system administration of the data

All the geospatial information data (the digital topographic map data and the ortho photo data) which were created by this project was installed in BNETD/CCT's servers in September, 2015. The password enabling the access to the system was delivered to the person in charge of BNETD/CCT after completing a training on data and server management. Before the end of the project the system operation and management authority of the WebGIS system has been transferred to the BNETD/CCT

4.2.6.2 Cases of the Data Utilization

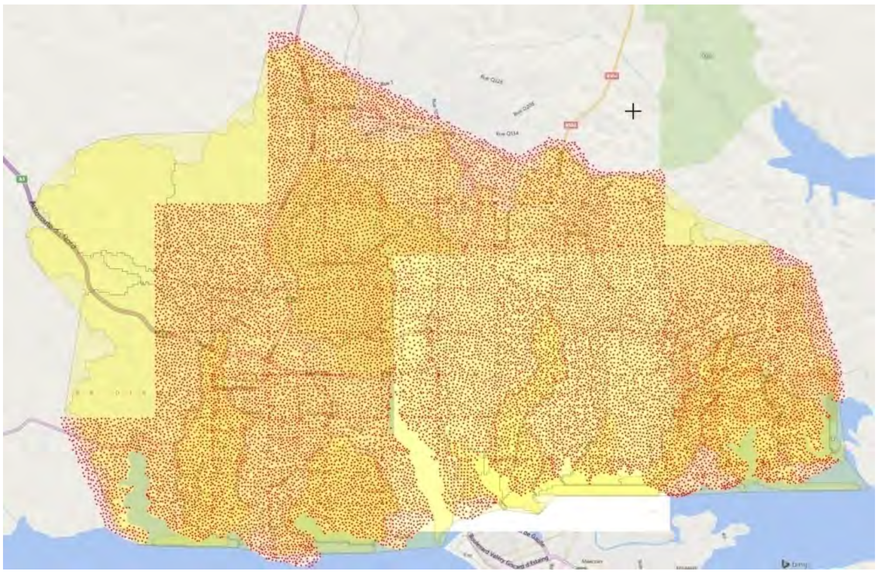
The Study team received several requests for the use of intermediate output data during the project period. The team provided the applicants with the requested data through JICA Côte d'Ivoire Office with the permission of CCT. The details of the provided data and purposes of their use are described below.

(1) JICA - Construction of a Flyover at the Intersection of Solibra (aerial photographs of Solibra), April 2014

The provided aerial photographs were used in the topographic mapping and boring, geological and geotechnical surveys for the planning of the construction of a flyover at the Intersection of Solibra in Marcory Borough in Abidjan by JICA. A 3-D aerial photograph created in this project was used as a general topographic map of the project site. A local subcontractor carried out the ground surveys including the ground control point survey, leveling and boring and geological surveys. The data created in those surveys were used for the preparation of the interim report.

(2) A project of WB (a sewerage system development project, provision of the ground level data), August 2014

A person in charge of the project of WB requested the provision of the DEM (XYZ) data created from stereo aerial photographs using the stereo matching technology for flood control. The DEM data of the area shown in the figure below (Figure 60) were provided to the WB project free of charge. Permission of the Director of CCT had been obtained for the provision of the data for their effective use.



（Source：Map data ©2015 Google、Study Team）

Figure60 Target Area of the Flood Control Measures (in yellow) and Area Covered by the Provided DEM (XYZ) Data (in orange)

(3) Request for the Provision of Aerial Photograph data for a Project to Improve Water Resource of AfDB, December 2014

The Study Team received a request for the use of stereo photographs of Bassin du Gourou area shown in the figure below among the latest aerial photographs taken in this Project for the Cocody Bay Water Resource Improvement Project (provisional) of the African Development Bank (AfDB) in early November 2014. As the aerial photograph data were in use in the technology transfer on aerial triangulation at the time of request, CCT sent the digital data of the requested area to the person in charge of the project of AfDB in early December with the permission of JICA office and CCT. The 3-D elevation data of the project area of the AfDB project except for the northern part were sent to AfDB through JICA Côte d'Ivoire Office. The JICA Office transferred the report of AfDB that they had found the aerial photograph data very useful for their project because they reflected seasons

Asia Air Survey Co., Ltd. quantified the data of the target area of the AfDB project as follows:

Area: approx. 26.5 km^2 (Northern part of the target area of the AfDB project is outside the study area of this Project)

Number of aerial photographs: 70

Number of stereo models: 66

Number of flight strips: 3

Provided data: 3-D elevation data (extracted from the topographic map data)

(Source :AfDB)

Figure61 Bassin du Gourou Area

(4) JICA - Four Locations in Abobo and Yopougon Communes, March 2015

Settlements of the urban poor have been developed in Abobo and Yopougon Communes in the Autonomous District of Abidjan. The basic infrastructure including school facilities, health facilities, roads and drainage has been underdeveloped and the unemployment rate among the youth is very high in these settlements. Therefore, JICA implemented a project on the reinforcement of community in those communes. The intermediate 3-D field completion data of the road outline and contour lines in the four locations were provided to the consultant in charge of the project with the permission of JICA and CCT.

(5) CCT - Updating of Cadastral Data (updating of the 1:5,000 cadastral maps), July 2015

CCT is updating the 1:5,000 cadastral maps of Abidjan at the request of the Directorate of Cadastre, Ministry of Economy and Finance. The Director of CCT requested the orthophotos created in this project for the use in the updating. The Directorate of Cadastre is expected to use the 1:5,000 topographic maps to be created to control cadastral data. A hard disk copy of the requested data was provided to CCT.

4.2.7 Field Identification (D-2(3))

Understanding of a theory is not required for the implementation of field identification, unlike the other subjects of the technology transfer. Instead, it requires understanding of the specifications of maps at different scales and the technology to take correct records at the field. Therefore, it is important to practice it repeatedly in the OJT and evaluate and manage the output of the field identification.

Therefore, the field identification in this Project was implemented in the form of OJT so that the field identification could be implemented in collaboration with CCT. The focus of the OJT was on the following subjects:

- Technologies to interpret aerial photographs
- Field identification survey with aerial photographs
- Practice of the field identification in accordance with the map specifications for the large-scale topographic maps
- Evaluation and maintenance of the output of the identification

Before implementing the field identification with multiple work groups, the group members received two weeks of orientation in the conference room of CCT. The purpose of the orientation was to share the correct understanding of the subjects of the field identification and to ensure consistency of the output. The following are the subjects of the orientation. (See Photo 25.)

(1) Outline of the field identification and explanation on the work procedure
(2) Close inspection and verification of the existing data (1:5,000-scale spatial data)
(3) Data capturing method
(4) Method to record captured data on aerial photographs
(5) Method to record field notes
(6) Basic operation of the handheld GPS devices and method of photography
(7) Compilation of the data at the end of the day's work

Photo 25 Scenes in the Orientation

In the technical guidance on the evaluation and management of the output of the field identification, the trainees seem to have been able to not only use the same evaluation standards and the same data management method to transfer data to the subsequent process, but also to learn how to manipulate the captured data on the GIS software, because they used the GIS software in the work. (See Photo 26.)

Photo 26 Lecture on the Evaluation Standards and Data Management (left) and Practice of the Operation of the GIS Software (right)

All the staff members of CCT were considered to have understood the map specifications for the large-scale maps defined in this Project well and learned the methods to record data correctly in the field through the repeated practice in a five-month period. Because they created large-scale topographic maps for the first time in this project, they made errors in the interpretation and judgment and their output was inconsistent in the first half of the field identification. However, the examination of their output near the completion proved that the variation in the quality of the output between the groups was within the allowable range and that the standardization and consistency of the captured data had been achieved.

4.2.8 Aerial Triangulation and Creation of DEMs and Orthophotos (D-2(4-1),(4-2))

The schedule and different categories of the technology transfer on aerial triangulation and creation of DEMs and orthophotos are mentioned below. The Study Team conducted a baseline survey of the trainees' capacities at the beginning of this Project and used its result to decide to place the focus of this technology transfer on 1) accurate 3-D measurement and 2) knowledge and techniques concerning the environment setting for aerial triangulation, to make "To understand the entire work processes of the aerial triangulation and be able to carry out it independently" and "To understand the basic concepts of DEM and orthophoto and learn the method to create them with their accuracy controlled" the purposes and to decide the training contents and schedule of the technology transfer to the staff members of CCT .

The staff members of CCT selected by Mr. COULIBALY Gogninniga of the Department of Aerospatial Data Processing (STDA) participated in this technology transfer.

(1) Implementation Schedule

- Aerial triangulation : for 10 days from October 24th, 2014 until November 6th, 2014
- DEM and orthophoto creation : for 6 days from November 7th, 2014 until November 14th, 2014

(2) Participants

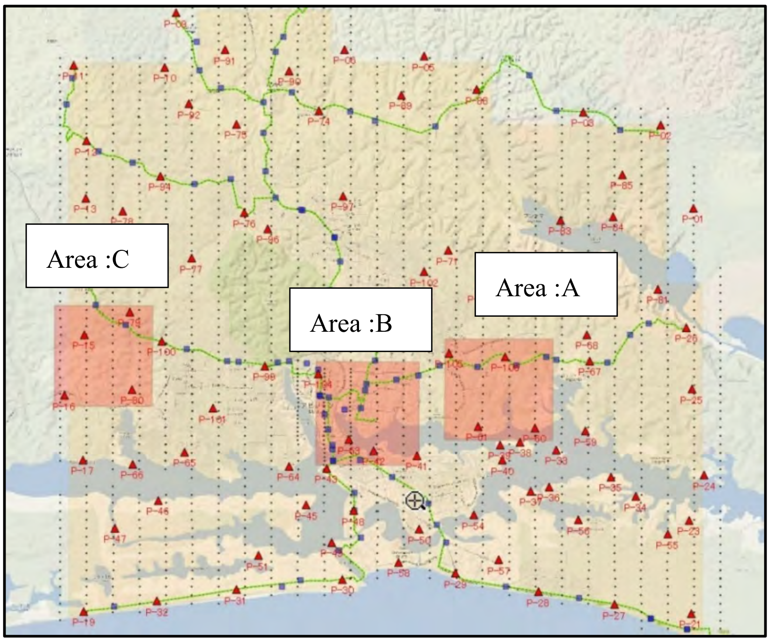
The three CCT staff members with prior experience in aerial triangulation were selected to participate in the technology transfer. The prior experience was required because the participants had to learn the advanced technologies and methods and accumulate experience in a short period of time.

(i) OUATTARA SEYDOU: Senior Engineer, STDA
(ii) KAMELAN AKA EUGENE: Senior Engineer, STDA
(iii) KONE GNIGUEFOLOMA OLIVIER: Engineer, STDA

(3) Training Areas

Since the trainees had to learn the 3-D measuring technology in a short period of time, the Study Team decided to include the measurement of various topographic patterns in the training plan as a wide variety of topographic environments were found in Abidjan. In the end, the team selected three training areas (Figure 62: Training Areas) in the area of the aerial triangulation. The three areas are characterized as a mountainous area, an incompletely modeled area and an area including an urban area and a plain (See Figure 63). As data, one hundred and sixty-five aerial photographs of an area of 124 km^2 were used in the technology transfer.

Figure62 Training Areas: urban area and plain (A: right), incompletely modeled area (B: middle), mountainous area (C: left)



（Source：Map data ©2015 Google、Study Team）

Figure63 Locations of the Three Selected Areas

(4) Subjects of the Technology Transfer

The trainees had lectures and practical training in accordance with the schedule mentioned below.

- October 24th, 2014 : Outline of aerial triangulation and basic operation of LPS
- October 27th, 2014 : Starting ORIMA and initial value entry, practice of the observation (Area A)
- October 28th, 2014 : Practice of the observation (Area B)
- October 29th, 2014 : Practice of the observation (Area C)
- October 30th, 2014 : Entry of ground control points, starting the software for the automatic observation
- October 31st, 2014 : Result and the method of evaluation of the bundle block adjustment and quality control of the aerial triangulation
- November 3rd, 2014 : Tie point measurement and method to correct the measurements (Areas A and B)
- November 4th, 2014 : Implementation of CAP-A and repeated practice
- November 5th, 2014 : Final analytical aerial triangulation (a series of work)
- November 6th, 2014 : Practice of the preparation of quality control sheets
- November 7th, 2014 : Generation and presentation of DEMs
- November 10th, 2014 : Quality control of DEMs, Creation of orthophotos
- November 11th, 2014 : Mosaicking
- November 12th, 2014 : Color tone adjustment and quality control of orthophotos
- November 13th, 2014 : Determination of the exterior orientation parameters and creation of orthophotos with QGIS, Question-and-answer session
- November 14th, 2014 : Evaluation of the training output

(5) Baseline Survey of the Technical Level

A questionnaire survey of the participants to measure the technical capacity and proficiency of the participants in the technical field was conducted before the training. The details of the survey are as follows:

The capacity of the participants was evaluated on three items on basic knowledge, five on technical knowledge, three on technical skills, two on special technology and two on quality control (See Table 28).

Table 28 Details of the Questionnaire Survey

Survey subject	Training content
Basic knowledge	1) Understanding of the work process of the digital topographic mapping
	2) Understanding of the work process of the aerial triangulation
	3) Understanding of the work process of the DEM/orthophoto creation
Technical knowledge	1) Capacity in the stereopsis of aerial photographs
	2) Capacity to interpret features with stereopsis
	3) Capacity to measure ground control points and tie points
	4) Knowledge of DEM data editing
	5) 5Knowledge of orthophoto creation
Technical skill	1) Understanding of the initial setting of LPS
	2) Understanding of the number of ground control points when output of the POS/IMU are to be used
	3) Knowledge of the connecting lines of orthophotos
Special technology	1) Knowledge of the bundle block adjustment calculation
	2) Knowledge of the method to adjust the color tones of images
Quality control	1) Knowledge of the quality control of the output of the aerial triangulation
	2) Knowledge of the quality control of the output of the DEM/orthophoto creation

(6) Training Contents

In the training, the trainees had lectures on the work processes in the aerial triangulation and creation of DEMs and orthophotos and the basic concepts of photogrammetry. After the lectures, they practiced aerial triangulation and creation of DEMs and orthophotos of the training areas using the digital 3-D plotter procured in this project.

The trainees practiced the methods of accuracy control in the aerial triangulation, DEM creation and orthophoto creation using the aerial photographs taken in this Project (see Photo 27).

In particular, in order to improve the proficiency, the staff members of CCT repeated the practice (see Photo 28) in the training on quality control, special technologies and technical skills.

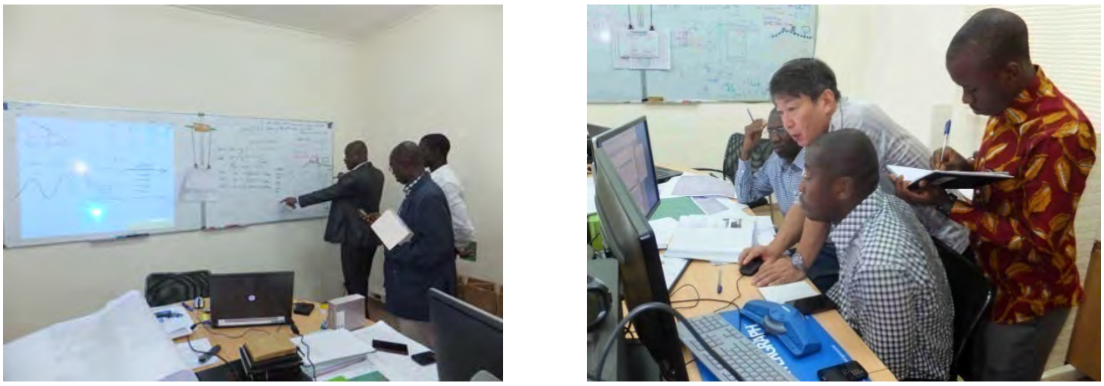


Photo 27 Review of the Accuracy Control in the Lecture on the Aerial Triangulation (left) and Practice of the Aerial Triangulation (right)

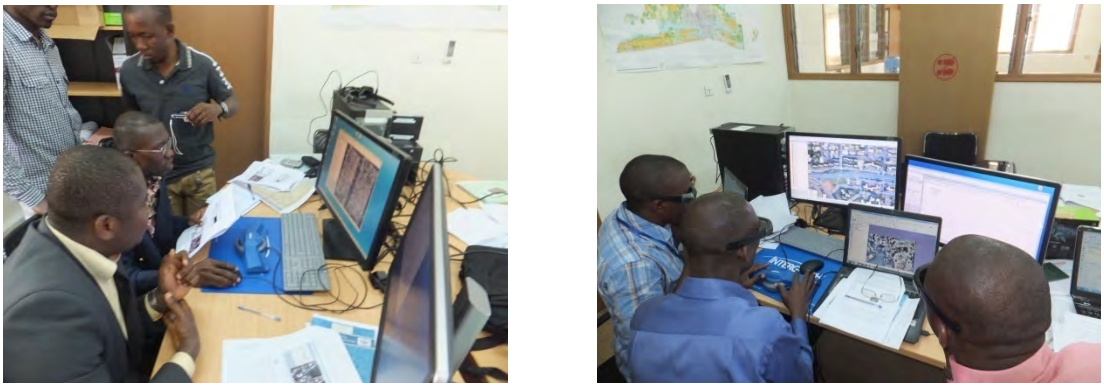


Photo 28 Correction and Accuracy Control of DEM data (left) and Creation and Quality Control of the Orthophoto Images (right)

(7) Evaluation of the Training

The achievement of the trainees in each training content used in the baseline survey was evaluated by the output created by them after the training.

1) Aerial Photogrammetry

Aerial triangulation consists of preparation, interior orientation, exterior orientation (relative and absolute) and accuracy control. The trainees had lectures and practical training on each work process separately. The output of the practical training on each work process was evaluated to identify the technical skills and special technologies that they were not good at and the trainees repeated the practice of the identified skills and technologies. The trainees created output of the aerial triangulation using a digital plotting system (LPS) in the practical training. The transfer of a series of technologies was successfully completed with the evaluation of the output and recording of the result of the quality control on a quality control sheet.

As the trainees had been using a plotting system with the same function before the training, they showed excellent performance in the training on the basic and technical knowledge and completed the scheduled training. As a consequence, they improved the level of knowledge. The trainees clearly showed that they had improved the technical skills and special technologies to certain levels by repeating the practice.

2) DEMs and Orthophotos

The trainees learned how to create and use DEMs and orthophotos. They received the instruction on the principle of elevation models (DTM: digital terrain model and DSM: digital surface model), the definition of orthophoto (orthographic conversion) and the difference between the analog and digital creation methods. They also learned how to use the digital 3-D plotting system (hardware and software). The trainees understood the basic concept of DEMs and digital orthophotos and became able to create them at a certain accuracy level.

3) Lessons Learned in the Training

The trainer evaluated the technical capacity and proficiency of the trainees on a scale of one to five in the 15 training contents in the questionnaire used in the baseline survey of the trainees, after the training. The trainees also evaluated their own technical capacity and proficiency (see Table 29). The result of the evaluation indicates that the capacity of the trainees was improved to the level at which they could conduct the aerial triangulation, create DEMs and orthophotos, and control the quality of the output data independently.

Table 29 Table and Radar Charts of the Result of the Survey and Evaluation of the Technical Level of the Three CCT Staff Members before and after the Training

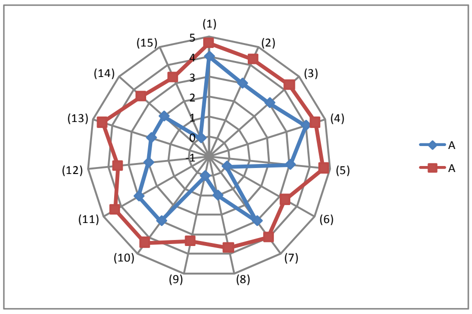
Technical level survey of the CCT staff

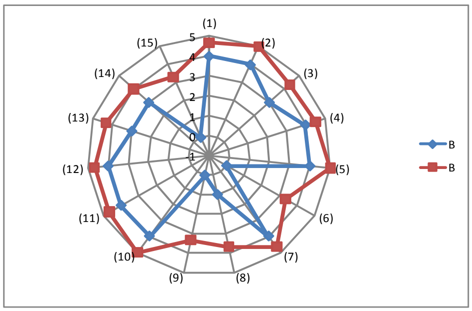
14-Nov

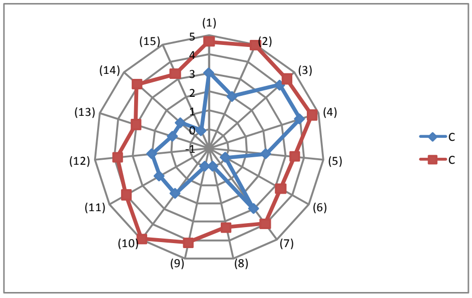
Item No,	Research item	Examination before the training (Present situation level) 24/11/2014			Examination after the training (The later level) 13/11/2014		
		A	B	C	A	B	C
(1)	1.Knowledge of the work production process of the digital topographic map	4	4	3	4.7	4.7	4.7
(2)	2.Knowledge of the work production process of the Aerial triangulation	3	4	2	4.3	5.0	5.0
(3)	3.Possibility of the Aerial photography	3	3	4	4.3	4.3	4.5
(4)	4.Possibility of interpretationand measurement of field features in stereovision	4	4	4	4.5	4.5	4.7
(5)	5.Initial setting of the LPS is possible：Input of the exterior orientation,camera, Aerial photography image	3	4	2	4.7	5.0	3.5
(6)	6.Amount of a control point necessary to a minimum of the Aerial triangulation using POS/IMU	0	0	0	3.3	3.3	3.3
(7)	7.The measurement of the control point /Tie point is possible (control of the APM function)	3	4	3	4.0	4.7	4.0
(8)	8.Possibility of the operation of the bundle adjustment computation (CAP-A)	1	1	0	3.7	3.7	3.3
(9)	9.Possibility in accuracy management of the quality control	0	0	0	3.3	3.3	4.2
(10)	10. Possibility of the work production process of the DEM/ ortho photo	3	4	2	4.3	5.0	5.0
(11)	10.1 Possibility of the editing method of DEM	3	4	2	4.3	4.7	4.0
(12)	10.2 Possibility of the preparation method of the ortho photo	2	4	2	3.5	4.7	3.8
(13)	10.3 Possibility of editing and the setting method of the ortho connection line	2	3	1	4.5	4.3	3.0
(14)	10.4 Possibility of the tone collection of ortho photoimage	2	3	1	3.5	4.0	4.1
(15)	10.5 Possibility of the accuracy management method of the DEM/ ortho photoimage	0	0	0	3.3	3.3	3.3

:Before
:After

Unaware 0 1 2 Know the basics 3 4 Well known 5





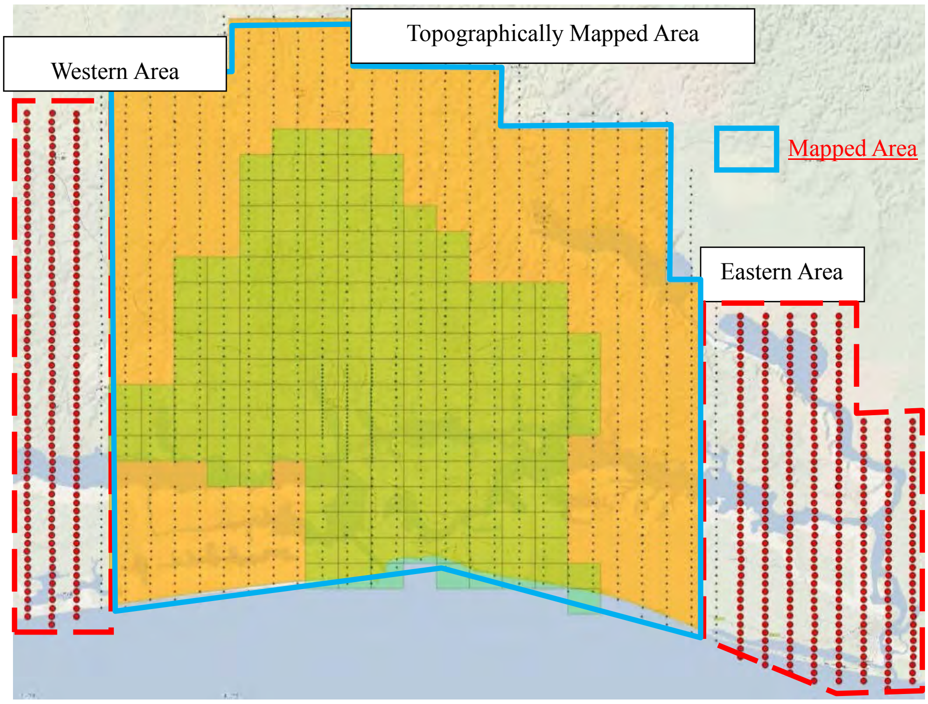


4) Plan for the Future

The staff members of CCT have begun the to produce maps starting by the ground survey (GPS observation), aerial triangulation and creation of DEMs and orthophotos in the two areas (Approx. 330 km²) in the eastern and western parts of the area photographed in this Project using the technologies transferred to them in this training (see Figure 64).

As the changes have already been observed in the study area of this Project, as mentioned above, they will have to make partial updatings of the topographic maps created in this Project, in addition to the urgently-required creation of DEMs and orthophotos mentioned above.

The implementation of the project of CCT staff members will complete the aerial triangulation and creation of DEMs and orthophotos of the entire 1,380 km^2 area photographed in this Project. The created DEMs and orthophotos are expected to be used as basic data in a wide area including city development, disaster mitigation planning based on high accuracy elevation data, updating of the cadastral maps and community development in the Republic of Côte d'Ivoire.



（Source：Map data ©2015 Google、Study Team）

Figure64 Map of the Areas where the Aerial Triangulation Has not Been Implemented

4.2.9 Digital Plotting Editing and (Map Symbolization) (D-2(5))

The Study Team implemented the technology transfer to the selected CCT staff members using the three digital photogrammetry systems (for digital plotting, digital editing and GIS structurization) provided by JICA.

The team conducted a baseline survey to measure the technical level of the CCT staff members before the implementation of the technology transfer.

(1) Outline of the Technology Transfer

The staff members of CCT mentioned below received the technology transfer on digital plotting and digital editing for the creation of 1:2,500-scale digital topographic maps.

1) Technical transfer on the digital editing and map symbolization and quality control of the output data: February 6th, 2015 - February 27th, 2015 to Deni KOFFI and Lamine SORO
2) Technical transfer on the digital plotting and quality control of the output data: March 2nd, 2015 - April 1st, 2015 to OUATTARA Seydou, NOBI Awo Marthe and TABIO Bernard

One map sheet area in the 1:2,500-scale topographic mapping area was selected as a sample area and used in the technology transfer. The outline of the topographic mapping was explained and the lectures and practical training on the details of the work procedures in the digital plotting, editing, map symbolization and printing and the quality and accuracy control of the output data were provided in the technology transfer.

(2) Baseline Survey of the Technical Level

The study team conducted a questionnaire survey on digital plotting and digital editing to measure the technical capacity and proficiency of the participants in the technical field before the training. The details of the survey were as follows.

Table 30 Details of the Questionnaire Survey on Digital Plotting and Digital Editing

Item	Training Content
Basic knowledge	・ Understanding of the work process in the digital topographic mapping
Technical knowledge	・ Understanding of the work process in the digital plotting and digital editing ・ Understanding of the data structure of the plotted and edited data
Technical skill	・ Interpretation of topography and features on aerial photographs ・ Conversion of plotting data to editing data ・ Entry of map symbols and line types specified in the Map Specifications ・ Understanding of digital plotting and digital editing for the creation of general topographic maps
Special technology	・ Stereopsis of stereo aerial photographs ・ Interpretation of geography and features with stereopsis ・ Understanding of 3-D editing of contours and elevation points
Quality control	・ Understanding of the quality and accuracy control

(3) Workflow of the Technology Transfer

The figure below shows the flowchart of the technology transfer on digital plotting and digital editing.

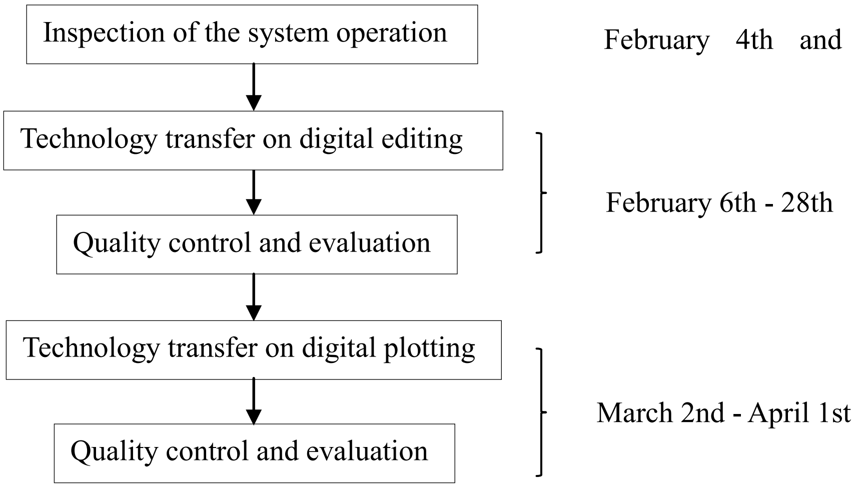


Figure65 Flowchart of the Training on Digital Editing and Digital Plotting

(4) Contents of the Training on Digital Plotting

The trainees received an explanation on 3-D digital plotting with a digital plotting system (IMAGINE PHOTOGRAMMETRY PRO600) and the digital data structure and lectures and practical training on the standards for the data capturing for the creation of 1:2,500-scale topographic maps to improve their technical level. They learned the method of the quality control using the output of the practical training.

1) The four activities mentioned below were the major components of the technology transfer.
   - Explanation of the plan for the technology transfer on digital plotting
   - Explanation on the data capture procedures in digital plotting and the outline of the map specifications
   - Practical training of the digital plotting (of an approx. 0.18 km^2 area)
   - Quality control and preparation of the quality control sheets

The trainees had lectures on the work processes in the digital topographic mapping and the contents of various data created in each process in the training on basic knowledge. (See photos 29,30)

They had lectures on the output created and the contents of the information referred to in the process of digital plotting in the training on technical knowledge.

They had lectures and practical training for the understanding of the provisions in the Map

Specifications for 1:2,500-scale maps and on the basic setting of the digital plotting system in the training on technical skills,

They had training on data capture with the 3-D interpretation of topography and features on stereo aerial photographs in the training on special technologies.

They had learned the method of quality control and the method to fill in the quality control sheet using the data captured in the digital plotting in the training on the quality control.

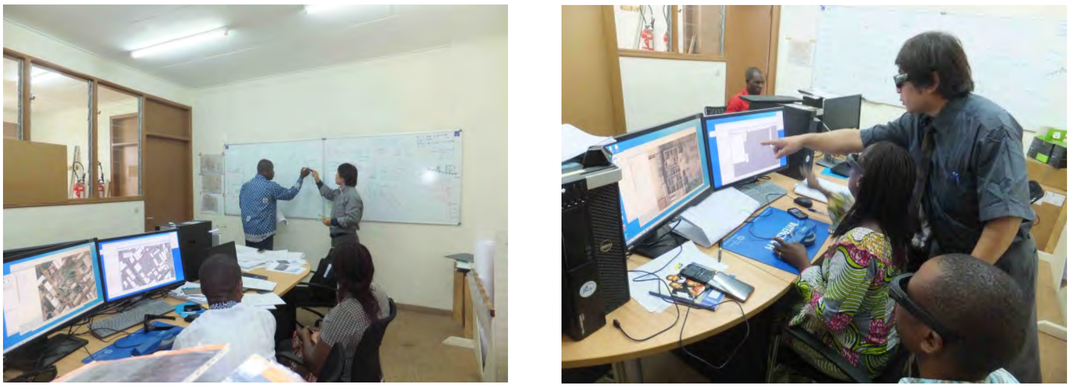


Photo 29 Explanation on the Work Process in the Digital Plotting (left) and Measurement of Features and Elevation with a 3-D Monitor (right)

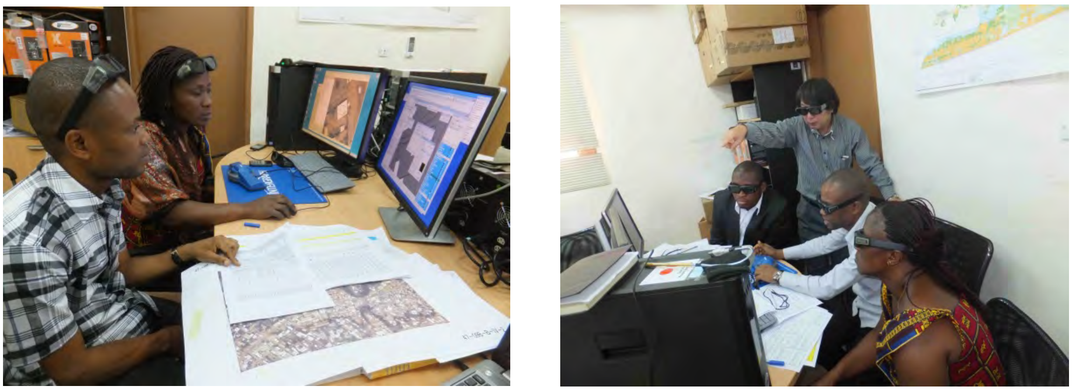


Photo 30 Construction of an Environment for the Digital Plotting (left) and Explanation on Data Inspection and Quality Control (right)

(5) Output and Evaluation of the Training on Digital Plotting

The lectures and practical training on digital plotting were provided using PRO600 (Software for data capture with CAD software for MicroStation).

The level of the basic knowledge of the three staff members of CCT was very high and they were able to understand the contents of the lectures.

As they had experience only in creating analog maps, they needed some time to understand the data structure which formed the basis of digital maps in the training on technical knowledge.

Therefore, the Study Team provided them with additional explanation on the structure in the practical training and they acquired a certain level of understanding of it.

In the practical training on capturing topographic and feature data in the training on technical skills and special technologies, one of the trainees who had experience in analog plotting taught the other trainees how to capture those data. In this way, they acquired the technical capacity at a practically sufficient level in a short period of time. Meanwhile, as none of them had experience in drawing contour lines, which was considered as a special technology, they repeated the practical training on it. With the repeated training, they acquired a certain level of capacity in drawing contours.

The trainees were able to complete the transfer of a series of technologies by evaluating the quality of the data generated in the digital plotting and recording the result of the evaluation in the quality control sheet in the training on the quality control.

The staff members of CCT required a long time to measure elevation points because they had little experience in the stereopsis of 3-D stereo images. The time required for the accurate elevation measurement can be reduced as they accumulate practical experience in digital plotting. The quality of the data had been controlled by a person in charge of the quality control in the previous quality control system. However, the information on the level of the quality of generated output had not been available in this system because the record of the quality control had not been kept. Therefore, the system of recording the result of quality evaluation in quality control sheets used in Japan was introduced. The Study Team recommends that CCT will revise the quality control sheets used in this Project to make them suited to the surveying system in Côte d'Ivoire and continue utilizing them.

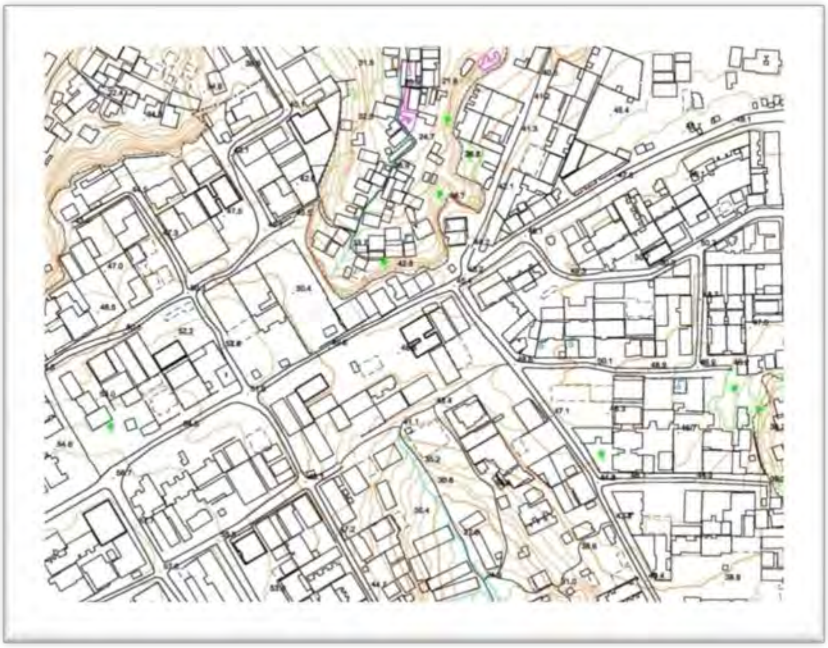
The Study Team conducted another questionnaire survey of the three staff members of CCT to measure the improvement in the level of their technical capacity with the technology transfer. As shown in Figures 66 and 67, the improvement has been confirmed. The nine subjects mentioned below were evaluated.

- Plotting 1: Level of understanding of the work processes in the digital topographic mapping
- Plotting 2: Level of understanding of the work processes in the 3-D digital plotting
- Plotting 3: Capacity to interpret locations of features on orthophotos
- Plotting 4: Capacity in the 3-D photointerpretation of aerial photographs
- Plotting 5: Capacity to perform the initial setting of LPS
- Plotting 6: Capacity to operate PRO600
- Plotting 7: Level of understanding of the technical manual of PRO600

- Plotting 8: Capacity in the 3-D interpretation and measurement of features
- Plotting 9: Level of understanding of the accuracy and quality control in the digital plotting

(6) Output of the Digital Plotting ("PRO600-Microstation MAP V8i")

The figure below shows the printout of the digital plotting data created by the staff members of CCT. When compared with the digital plotting data of the same area created in Japan by the Japanese expert, the accuracy of the data of the horizontal measurement of features created by them was satisfactory in general. While a slight difference was observed in the measurement of contours and single points on flat terrain, the quality of the contour line data in the hilly areas created by them was considered to be almost equivalent to the quality of those created by the Japanese expert.



(Source:Study Team)

Figure66 Output of the Technology Transfer on Digital Plotting

(7) Result of the Evaluation of the Technical Level in Digital Plotting (See Figure 66)

The trainees evaluated their own technical levels in the digital plotting on the nine subjects on a scale of one to five before and after the training. The result of the evaluation is shown in the figure below.

It is worth mentioning that the figure below reveals that all three trainees acquired a level of technical capacity above the average (3 points) in the 3-D measurement with application software of a digital plotting system, PRO600, in the training despite having almost no prior experience in using it. Thus, the improvement in the level of their technical capacities has been confirmed.

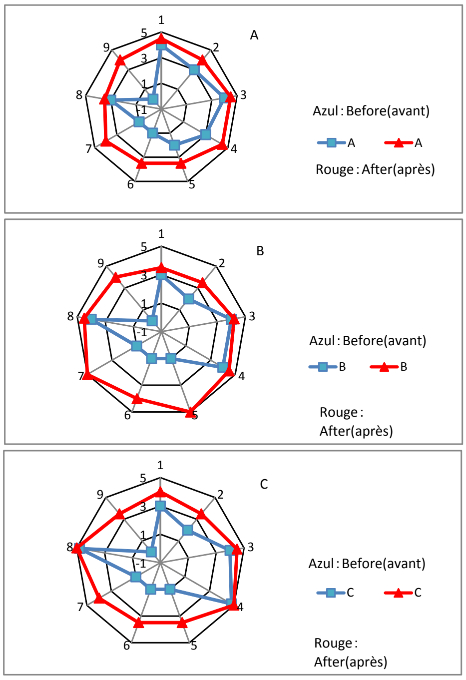
The figure also suggests that all the trainees acquired full understanding of the quality control in the training despite having no prior experience in performing it.

Technical level survey of the CCT staff

Restitution numérique

3/4/2015

Item No	Research item	Examination before the training (Present situation level) 2015/3/6			Examination after the training (The later level)2015/4/1		
		A	B	C	A	B	C
1	Degré de compréhension sur le processus des travaux de la cartographie	4	3	3	4.5	3.5	4
2	Degré de compréhension sur le processus des travaux de l'aé	3	2	2	4	3.5	3.5
3	Capable d'interpréter la disposition du terrain et des objets terrestres sur une orthophoto	4	4	4	4.5	4.2	4.5
4	Capable d'interpréter des objets terrestres tridimentionnellement sur deux photos aériennes	3	4	4.8	4.5	4.5	5
5	Capable de configurer et modifier un ficher bloc du LPS (Configuration pour le démmarage de la restitution numé	2	1	1	3.5	5	3.5
6	Capable de configurer l'environnement du PRO600 (Ficher de projet, Paramè tres Tolérance etc)	1	1	1	3.5	4	3.5
7	Connaissance sur la configuration de la bibiliothéque du PRO600	1	1	1	4	5	4
8	Capable de mesurer des reliefs terrestres et des objets terrestres sur une image en 3D (Degré d'expérience de la technique de l'interprétation en 3D)	3	4	4.8	3.5	4.5	5
9	Connaissance sur le contrôle de qualité et de précision.	0	0	0	4	4	3.5



🟦 :Before(avant)
🟥 :After(après)

médiocre Unaware			moyenne Know the basics		élevé Well known
0	1	2	3	4	5

Figure67 Evaluation of the Technology Transfer on Digital Plotting

(8) Contents of the Training on Digital Editing

The trainees received instruction on editing of topographic maps, map symbolization and printing of topographic maps with "MicroStation MAP V8i" and "LorikSoftware V5." They improved their technical level with the lectures and practical training on the structurization of topographic map data and the quality control of the structured topographic map data.

The trainees received lectures on the work processes in the digital topographic mapping and the contents of various data generated in each process in the training on basic knowledge.

They received lectures on the output created in the processes of digital editing and the contents of the information referred to in the training on technical knowledge.

They learned the contents of the specifications for 1:2,500-scale topographic maps, received lectures on the map symbols and line types used in the editing system and practiced the creation of map symbols in the training on technical skills.

They learned and practiced data editing with 3-D interpretation of topography and features on stereo aerial photographs in the training on special technologies.

They learned and practiced the method of quality control of the data corrected and supplemented with annotation data from the digital editing and the method to fill in the quality control sheet in the training on the quality control.

(9) Outline of the Technology Transfer on Digital Editing

The trainees had lectures and practical training on editing of topographic maps, map symbolization and topographic map data structure with “MicroStation MAP V8i” and “LorikSoftware V5.” The technologies for the quality control were transferred to the trainees.

1) Subjects of the Technology Transfer
   - Explanation of the outline of the work process of the digital editing and map specifications
   - Lectures and practical training on digital editing
   - Printing of symbolized data
   - Quality control and preparation of the quality control sheet
2) Output and Evaluation of the Training on Digital Editing

   The trainees practiced the digital editing using the output data of the digital plotting. Questionnaire surveys of the two CCT staff members were conducted before and after the technology transfer to measure the improvement in the level of their technical capacity. The survey result shown in Photos 31 and 32 confirmed the improvement. The nine subjects mentioned below were used in the evaluation.

- Editing 1: Level of understanding of the work processes in the digital topographic mapping
- Editing 2: Level of understanding of the work processes in the 3-D digital plotting
- Editing 3: Capacity to interpret locations of features on orthophotos
- Editing 4: Capacity in the 3-D editing of contours and single points
- Editing 5: Capacity to convert from plotted data to digital editing data
- Editing 6: Capacity to design and enter map symbols
- Editing 7: Level of understanding of the general digital editing
- Editing 8: Level of understanding of data structure of digital topographic map data
- Editing 9: Level of understanding of the accuracy and quality control in the digital editing

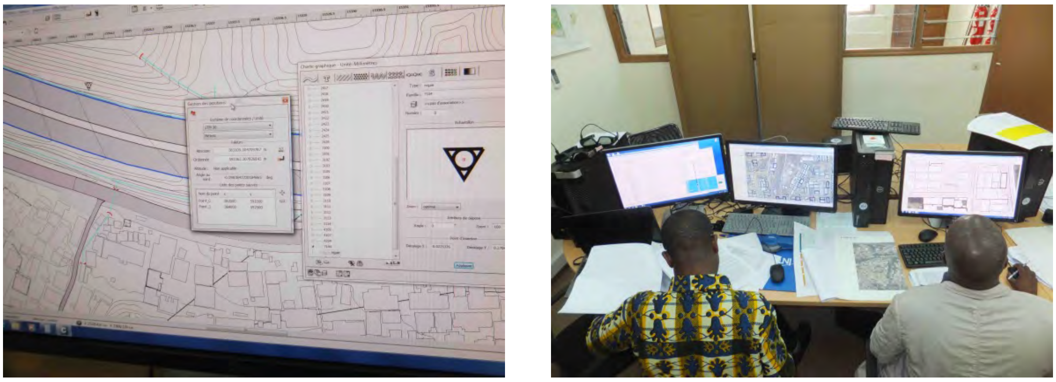


Photo 31 Import of Map Symbols into the Editing System (with MicroStation: left, and Lorik: right)

Photo 32 Lecture on the 3-D Editing of Contours (left) and Explanation on the Data Name and Quality Control (right)

3) Output of the Digital Editing (“LorikSoftware V5”)

The trainees practiced the digital editing of the output data of the digital plotting in accordance with the Map Specifications.

As in the case of the digital plotting mentioned above, the output data of the trainees was evaluated by comparing them with the output data of the digital editing of the same area performed by the Japanese expert in Japan.

(Source:Study Team)

Figure68 Output of the Technology Transfer on Digital Editing

(5) Evaluation of the Training on Digital Editing

Lectures and practical training on digital editing were provided to the trainees using the output data of the digital plotting. Since the two CCT staff members who participated in the technology transfer had practical experience in digital editing, they understood the training contents in a short period of time.

The latest software, “MicroStation MAP V8i” and “LorikSoftware V5,” was used in the training. As CCT staff members had been using software for digital editing, map symbolization and printing released five to eight years ago, the trainees seemed to be uncomfortable with the latest software with new functions and a new operation menu at the beginning of the training. However, their technical level in the operation of the software had improved to a satisfactory level by the end of the training.

The two staff members had the basic knowledge at a level high enough to understand the contents of the training in a short period of time.
Since they had experience in digital editing, they needed only a short period of time to understand the data structure of the digital maps in the training on technical knowledge.
SHP data created by converting the output data of the digital plotting with ArcGIS software were used in the training on technical skills, because the data conversion tool in “LorikSoftware V5” for the transfer of the output data of digital plotting was inapplicable. As one of the trainees

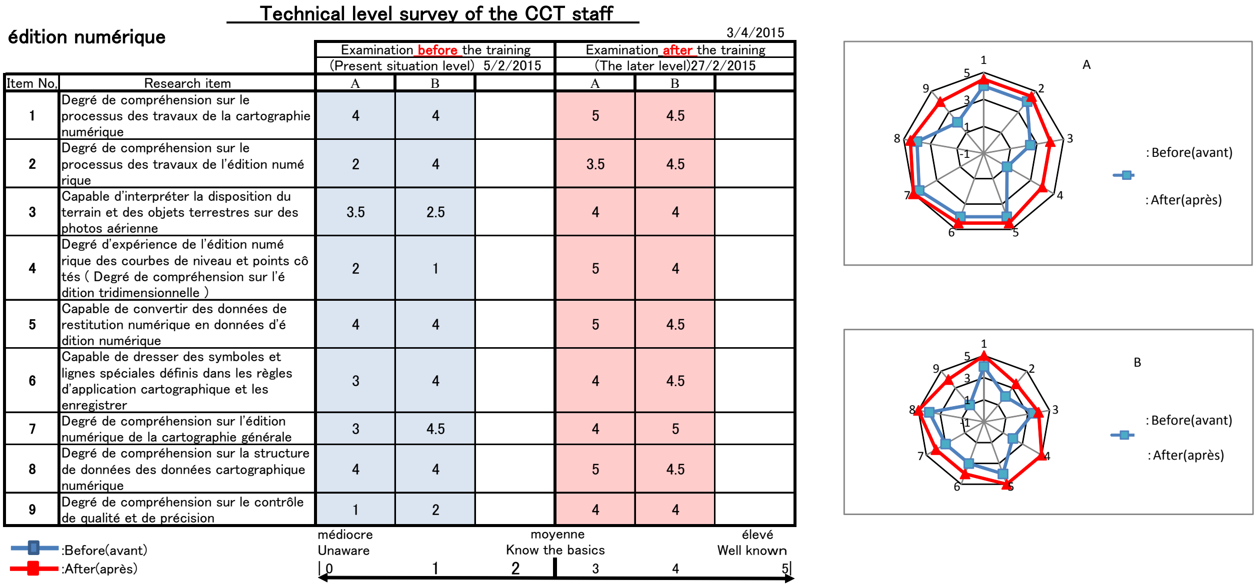
showed the capacity for the improvisation, he is expected to contribute greatly to the digital topographic mapping by CCT.

The trainees practiced 3-D data editing with "MicroStation MAP V8i" in the training on special technologies. Although the trainees could not even understand the meaning of the 3-D data editing at the beginning of the training, they understood the importance of storing 3-D information in the form of edited data as the training progressed and improved the quality of created 3-D data with repeated practice.

1) Result of the Evaluation of the Technical Level in Digital Editing

The trainees evaluated the level of their capacity in the digital editing on the nine subjects on a scale of one to five before and after the training. As the staff members of CCT had experience in the digital editing with LorikSoftware before the training, they gave relatively high scores to their capacity in the baseline survey before the training.

The radar charts in the figure below show the result of the self-evaluation. The blue and red lines indicate the evaluation before and after the training, respectively. The scores of both trainees were at or above the pass marks on all the subjects. It is worth a special mention that their scores on 4) 3-D editing of contours and single points and 9) quality control improved to the standard marks.



Technical level survey of the CCT staff

édition numérique

3/4/2015

		Examination **before** the training (Present situation level) 5/2/2015			Examination **after** the training (The later level)27/2/2015		
Item No.	Research item	A	B		A	B	
1	Degré de compréhension sur le processus des travaux de la cartographie numérique	4	4		5	4.5	
2	Degré de compréhension sur le processus des travaux de l'édition numé rique	2	4		3.5	4.5	
3	Capable d'interpréter la disposition du terrain et des objets terrestres sur des photos aérienne	3.5	2.5		4	4	
4	Degré d'expérience de l'édition numé rique des courbes de niveau et points cô tés (Degré de compréhension sur l'é dition tridimensionnelle)	2	1		5	4	
5	Capable de convertir des données de restitution numérique en données d'é dition numérique	4	4		5	4.5	
6	Capable de dresser des symboles et lignes spéciales définis dans les règles d'application cartographique et les enregistrer	3	4		4	4.5	
7	Degré de compréhension sur l'édition numérique de la cartographie générale	3	4.5		4	5	
8	Degré de compréhension sur la structure de données des données cartographique numérique	4	4		5	4.5	
9	Degré de compréhension sur le contrôle de qualité et de précision	1	2		4	4	

Figure69 Evaluation of the Technology Transfer on Digital Editing

4.2.10 Field Completion (D-2(6))

The purpose of field completion is to examine the questions and ambiguities found in the output of the digital plotting and field identification in the field for the last time to solve them. The field survey in the field completion was implemented as an OJT focused on the following subjects, in accordance with the rules used in the field identification.

1) Technologies to interpret topographic maps
2) Field verification survey with topographic maps
3) Practice of the field survey in accordance with the specifications for large-scale topographic maps

(1) Contents

In order to maintain consistency of the survey result as in the field identification, the Study Team held a 3-day explanation meeting and orientation before the field completion. The subjects of the meeting and orientations were as follows:

1) Outline of the field completion and explanation of the work procedures
2) Careful examination and inspection of field completion maps on which the result of the field identification was entered
3) Data capture method
4) Method to enter data on the completion maps
5) Method to enter data in a field note
6) Data compilation at the completion of the survey
7) Correction of administrative boundaries using GIS
8) Method to enter data on the road annotation maps

(2) Theories and Suggestion

The field completion was implemented in collaboration with CCT in the form of OJT, in the same way as the field identification. As mentioned above, the staff members of CCT conducted field survey while giving instruction to the interns of CURAT. In the field completion, topographic maps on which the output of the field identification is described are interpreted and verified in the field for the last time. The CCT staff members are considered to have understood the following correctly in the field completion.

1) Recognition of the difference from the analog field survey which had been implemented by CCT before the training
2) Acquisition of the expertise including identification of points to be noted required for

large-scale digital topographic mapping

3) Method to capture data in the field
4) Method to manage captured data

As mentioned above, the Study Team suggests that the landscape in Abidjan has changed significantly since the aerial photographs were taken in this Project because of the progress in large-scale development projects in the City. (See Photo 33)

As the conditions at the time of the aerial photography are depicted on the topographic maps created in this Project, the implementation of field identification survey as the one shown in Photo 34 is urgently required to identify locations where changes have taken place since the aerial photography.

Photo 33 Orthophoto Image (left) and Copy of a Google Earth Image (right)

(Source: Image ©2015 CNES/Astrium Digital Globe)

Photo 34 Change in the Landscape Caused by a Large-scale Development Project

4.2.11 Structurization of Digital Data (D-2(7))

The selected CCT staff members participated in the technology transfer on structurization of digital data with the GIS system procured in this Project (ArcGIS software).

4.2.11.1 Introduction to GIS

The purpose of this technology transfer (on GIS data structurization, map symbolization and database management) was to facilitate the understanding of the staff members of the departments responsible for the work mentioned above on the design and management of geodatabases*. The focus of the technical training in the technology transfer was on the following.

(1) Understanding of the geodatabase design concept
(2) Designing of efficient models and a geodatabase schema in which data can be stored with ease
(3) Creation of a geodatabase and correction of existing data in accordance with the map specifications
(4) Efficient transport of data in the data structurization and conversion of the format of the existing basic GIS data to the geodatabase format.

*Geodatabase: The Geodatabase means “Geographic Database”. This “Geographic Database can be stored as vector data, raster data and other GIS data in the Data base Management System (DBMS). This is the standard format of ESRI GIS software. (Source: Google)

Four-week-long technical training was provided in the technology transfer program. Approximately 10 % of the training time was used for the lectures and the rest was used for the practical training with the output data of this Project and the ArcGIS 10.2 provided in this Project. Four CCT staff members (two each from the Information and Database Service (SIBD) and GIS Application and Geospatial Information Service (SASIG)) participated in the program. (See Table 31) A graduate student in the doctorate course of the Cocody University was accepted in the program as an intern.

Table 31 List of the Participants

Name	Affiliation	Profession
Mr. Charles SABENIN	SASIG/CCT	GIS engineer
Mr. Mamadou KONE	SASIG/CCT	GIS engineer
Mr. Tetchi Boris Armel KENA	SIBD/CCT	Database engineer
Mr. Amu BINATE	SIBD/CCT	Database engineer

4.2.11.2 GIS Structurization/ Geodatabase

(1) Preliminary Questionnaire Survey

A questionnaire survey was conducted before the implementation of the technology transfer program on the geodatabase design and management. The responses to the questionnaire of the participants were used to establish a baseline to measure their technical capacity and experience in GIS and database management. The result of the preliminary questionnaire survey is summarized in the following:

1) All the participants had practical experience in using Quantum GIS. Some of them had experience in using ArcGIS and MapInfo.
2) All the participants were proficient in the basic software for statistical data processing, Microsoft Access, PostgreSQL and MySQL.
   They recognized the urgent need for the training on the geodatabase management for the improvement of the management of GIS basic databases in their work in CCT.

(2) Training on Designing and Management of Geodatabases

In the training on the geodatabase management, practical training focused on the six main subjects mentioned below was provided to the participants.

1) Designing a simple geodatabase schema
2) Building and populating a geodatabase
3) Creating subtypes
4) Working with annotations
5) Importing raster dataset into a geodatabase
6) Creating topology

The output of the practice and training was used for the evaluation of the capacity of the participants. The participants evaluated their performance in the technology transfer. The result of their evaluation was used to identify the subjects which they had not fully understood and the knowledge that they had acquired. Figure 70 shows the evaluation of the performance of a participant from SASIG in the training. The figure shows that the training was very effective in improving the capacity of the participant. The figure suggests that the level of understanding of the participant concerned in 1) designing a simple geodatabase schema, 2) creating and populating a geodatabase 3) creating subtypes and 4) working with annotations had improved significantly.

As the participants from SASIG had basic knowledge of subjects 1) to 4), had read the manual and did self-study voluntarily before the training, their capacity improved significantly during the training. However, the result of the evaluation on the subjects 5) and 6), the subjects of an intermediate to high technical level, was at the average level. This finding revealed that the participants concerned had been performing the work without the knowledge of the concepts in geospatial data editing such as topology before the training.

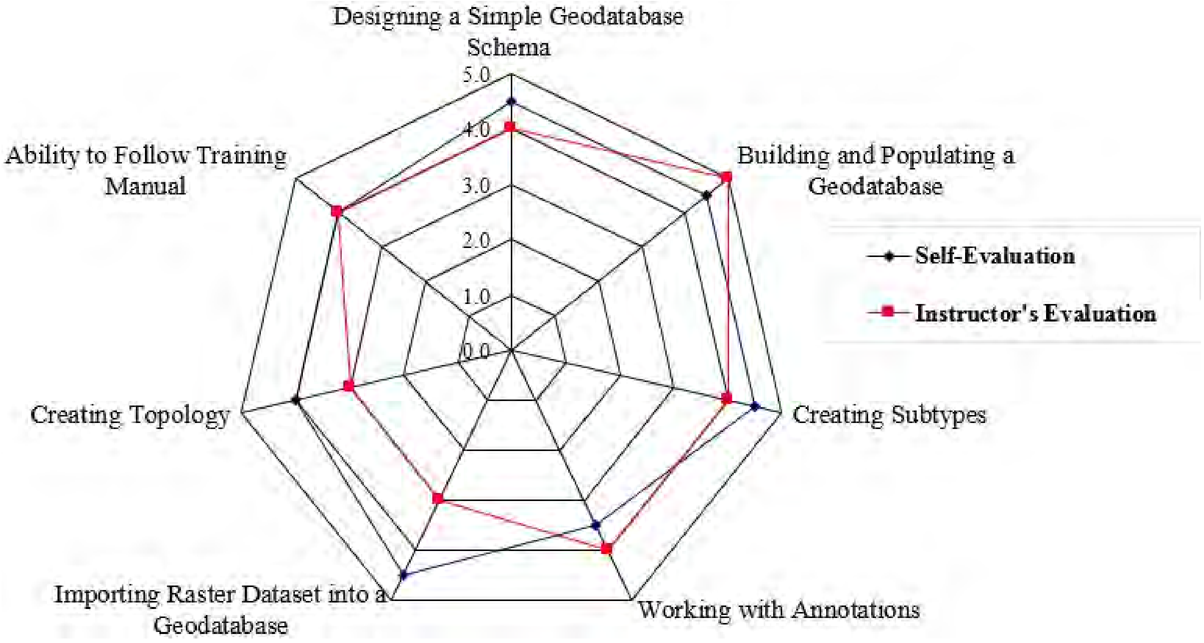


Figure 70 Results of the Self-evaluation and Evaluation by the Instructor of the Performance of Participants from SASIG

Figure 71 shows the result of the evaluation of the performance in the training of a participant from SIBD. The figure shows that the understanding of the participant concerned in 1) designing a simple geodatabase schema, 2) creating and populating a geodatabase 3) creating subtypes and 4) working with annotations had improved to a relatively high level. The participants also had practical training on the subjects 1) to 4) using the training manual.

As was the case with the participants from SASIG mentioned above, the participants from SIBD had a problem in understanding the subjects 5) and 6) concerning the raster data management and topology, the concepts required in geospatial data editing. In order to solve this problem, the instructor explained the basics of the concepts of the database management with GIS and topology repeatedly to improve the level of understanding of the participants.

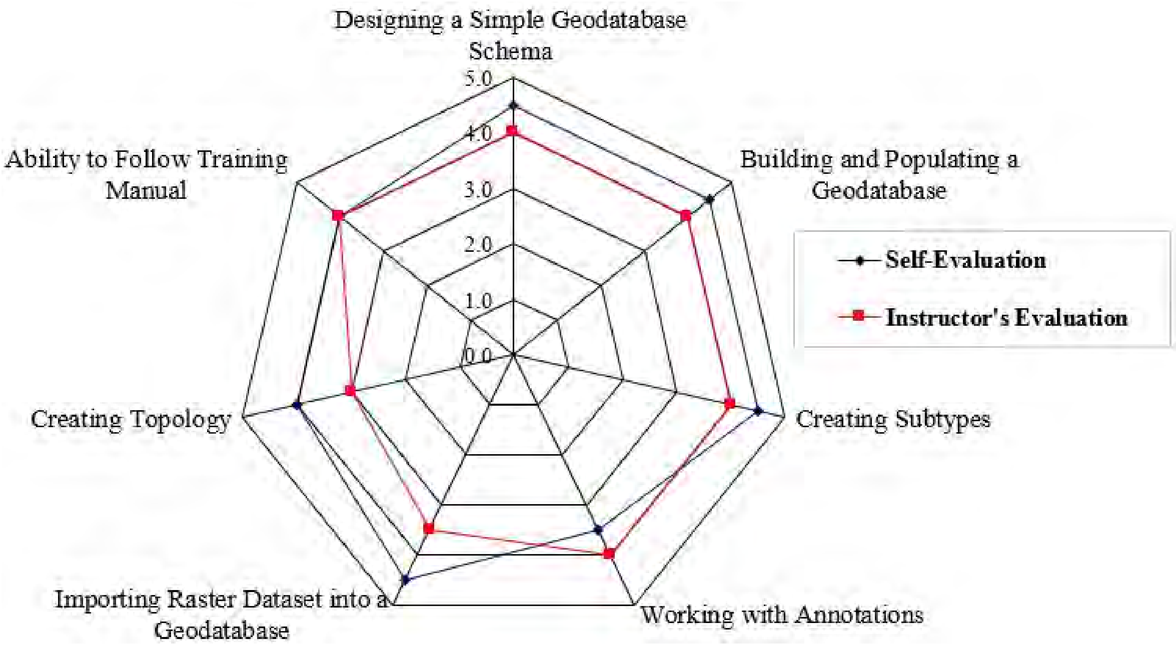


Figure71 Results of the Self-evaluation and Evaluation by the Instructor of the Performance of Participants from SIBD

Meanwhile, as CCT did not have an appropriate geodatabase management system or rules or regulations to manage GIS basic data, the participants requested practical instruction on appropriate operation of a geodatabase management system in the last stage of this program. In response, the instructor provided them with additional training on the designing and management of a geodatabase with the GIS basic data owned by CCT.

(3) Evaluation at the Completion of the Program

When this program was completed, the instructor asked the participants to fill in a questionnaire. This questionnaire survey was conducted to measure the contribution of the program to the improvement of the attitude of the participants, who were the staff members in charge of the database and GIS in CCT, to the management of databases of GIS basic data. The main findings of the survey were as follows:

1) All the participants were satisfied with the contents of the geodatabase training program.
2) All the participants recognized the direct relevance of the geodatabase to their daily work and the need for the geodatabase management for the improvement in the management of the GIS basic databases in CCT in future.
3) They recognized the need for the training on geodatabase management at a higher

level.

4) In response to CCT's requests on the use of GIS in daily work as well as the advanced data utilization by GIS, some utilization examples such as 3D modering, Cadastral data management and flood risk area zooning simulation by Q-GIS, a free software were presented not only at the work shop but also at the final seminar as well.

4.2.11.3 Conclusions and Recommendations on GIS Structurization and Training on Geodatabases

Although each participant has a certain problem in understanding the topology and importing raster datasets for the designing and management of geodatabases, all the participants have improved the level of understanding of the geodatabase designing and management. The participants, who had knowledge of GIS before the technology transfer, gave relatively high marks to their own performance in the training (Figures 70 and 71). This observation suggests that CCT already has high potential in the geodatabase designing and management. The Study Team prepared the recommendations mentioned below as strategies to be adopted by CCT for the further development towards its potential.

1) All the participants have to improve their technical capacity in the geodatabase management further. Therefore, CCT has to continue implementing the technical training program to improve the knowledge and technical capacity concerning geodatabases of its staff members.
2) CCT has to develop an environment in which it can build close relationships with the organizations concerned with geospatial data in order to implement more sophisticated GIS training (training on ArcSDE and ArcGIS Server, in particular).
3) CCT has to establish a place to discuss GIS and standardization of geospatial data at the national level or carry out mutual evaluation of geospatial data with other existing groups of creators of geospatial data.
4) CCT is advised to take a coordinated approach with universities in Côte d'Ivoire for the improvement of the quality of the training contents.

4.3 Summary on the Technology Transfer and Expectation in Future

The gap analysis revealed that CCT had lost outputs of various surveys and manuals in the unfortunate events and turmoil in the country in the past. In many cases, the remaining analog data were found to be managed, not in organized ways, but by individual staff members. These data are not only important data for CCT, but also national assets. With the common understanding of the importance of the data within the organization, CCT digitized these analog data urgently to centralize the data management by the completion of the project.

(1) The ground control point survey was implemented as collaboration between CCT and the Study Team in the form of OJT. The focus of the instruction provided in the ground control point survey was on the importance of accuracy control. The team recommends CCT to establish survey standards urgently to ensure the accuracy of the data and maintain reproducibility of the survey results. Meanwhile, the focus of the instruction in the technology transfer on field identification was on efficient and consistent data capture for the large-scale topographic mapping. The interim outputs of the digital topographic mapping in this project were created as the outputs of the above-mentioned activities and they were utilized effectively in the subsequent processes.

(2) The technology transfer on aerial triangulation, digital mapping and GIS structurization was implemented as theoretical and practical training. As complicated procedures are used in these processes, repeated practice is recommended in the technology transfer on these subjects. The transferred technologies are not those which can be mastered in a day. The staff members of CCT has already begun their own project of creating topographic maps after the completion of the training utilizing the equipment provided and manuals prepared in the project. Improvement of their technical capacity is expected from this voluntary and independent activity. The Study Team explained the importance of these work manuals to the staff members of CCT in the technology transfer. The team hopes that the counterparts will revise the manuals prepared by the team into manuals which are easy-to-use for them, and share them with the other staff members of CCT.

The Study Team explained the importance of these work manuals to the staff members of CCT in the technology transfer. The team hopes that the counterparts will revise the manuals prepared by the team into manuals which are easy-to-use for them, and share them with the other staff members of CCT.

(3) The head of the Geodesy Department submitted the compiled manuals for the GPS observation, installation of aerial signal markings, leveling, pricking and aerial photography to the Study Team. The team hopes that these manuals will be utilized for the transfer of the technologies to young engineers.

(4) The team designed the plan of the technology transfer in such a way that the participants would strongly feel the necessity of coordination and cooperation between and within organizations and teams and that the experienced and young engineers in the Project Team work together in cooperation in the technology transfer. Then, the team gave the responsibility of the work to the trainees in the technology transfer.

This strategy for the technology transfer was adopted in this Project because it was important for the staff members of CCT to perform their duties in cooperation with the other members of their group and with the philosophy that one must create reliable output in each work process and hand it over to the subsequent process in order to achieve a goal of a project.

(5) The quality control of completed output can be ensured by establishing a system in which both the creator of the output and the leader of the groups to which the creator belongs inspect the quality and accuracy of the output. As this system allows production of output which satisfies clients, it will contribute to the revitalization of the organization and improvement of its function.

(6) The Study Team performed public relations activities to create awareness and facilitate utilization of the outputs of this Project for various stakeholders and actors in development who were assumed to be potential users of the output. As a result, the team received various requests during the project implementation period.

4.4 Provision of data to the public

A discussion on the provision of data to the public (customer) was led between the Team of JICA and BNETD/CCT. Both parties agreed on the fact that the produced data will be made available to public for a price. This price, which will be fixed by BNETD/CCT will take into account the following aspects:

1. Updating of data
2. Site maintenance
3. Printing cost (paper + toner)

However, BNETD/CCT sells 1/5 000 topographic map scale of Abidjan and some towns in the interior of the country. In addition, the new available prices of 1/5 000 topographic map scale are going to take into account this offer.

For information, the 1/5000 maps scale are sold in FCFA excluding VAT for the prices in the table below.

Table 32 Price list

SCALE	PAPER	RASTER	VECTOR
1/ 5 000	8 500FCFA	25 500FCFA	78 178FCFA
1/ 2 500			

BNETD/CCT will do a deep study to suggest very early the sale prices of the products of the Project.

4.5 Future Prospects and Recommendation to CCT

CCT implemented practical work in the quality control, establishment of the specifications and holding of seminars and workshops as a public relations activity, as an administrator of geospatial data, in cooperation with the Study Team.

(1) The Study Team recommends that the CCT staff members should continue creating the latest topographic map data of the area surrounding the study area of this Project with their self-help effort, utilizing the new photogrammetric technologies learned in this Project and the aerial photographs of the area concerned taken in this Project effectively. The team believes that repeated practice of these transferred technologies by the staff members will lead to the establishment of these technologies in CCT.

(2) It is important for CCT to improve its services by establishing a Metadata Department for the operation and maintenance of WebGIS created in this Project, making publicly available both the geospatial data created in the past and digitized in this Project and the latest data created in this Project, establishing a geospatial data search system, sharing with geospatial data sales department located on the first floor and launching the operation on provision of assistance in the use of the GIS technologies.

The Study Team also suggests that it will become necessary to reinforce the communication infrastructure (for high-speed large-volume data processing and data security) for the WebGIS for the improvement in the efficiency of the service provision at the WebGIS because the volumes of the digital topographic map data and geographic information to be provided are extremely large.

(3) The Study Team considers that it will be a particularly important duty of CCT to assist governmental organizations in development planning by creating tourist maps, hazard maps, road management data and the data for the development of airports and harbors on the basis of the geospatial information data created in this Project (stereo aerial photograph data, topographic map data, DEM data, orthophoto data, the data of the ground control points and GIS basic data).

The team also recommends that, as data users in various sectors are expected to send inquiries on the development and management of the GIS data to CCT, CCT shall perform an important role of organizing and providing technical training and seminars for individual sectors in cooperation with those sectors using the technical capacity acquired in this Project and developing a new strategy for the GIS data creation which will respond to requests from various sectors.

(4) The table below shows the data utilization plan including the expected data utilization in various sectors deduced from the requests and inquiries received. The Study Team recommends CCT to maintain close contact with the ministries and agencies concerned and disseminate the information actively on the utilization of geographic information.

Table 33 Data Utilization Plan

Geospatial information output	Utilization method	Area of the data utilization in future	Sector concerned
Stereo digital aerial photographs	3-D measurements, 3-D modeling	Urban and rural development, development of ports and harbors	DAUDL PAA
1:2,500-scale digital topographic map data in the CAD format	Sales of basic city map data	Surveys on changes over time, management of the administrative boundaries, management of public transport infrastructure, system for address management	Communes concerned DIT AGEROUTE DGI Private companies
Printed 1:2,500-scale digital topographic map data	Sales of printed basic city maps	Background map of tourist maps and maps of government offices	Directorate of Tourism Ministries and agencies concerned Private companies
1:2,500-scale GIS basic data	Utilization of point, line, polygon and attribute data	Road management plan, house survey, cadastral management plan, zoning (of mining and manufacturing, agricultural, forest and protected areas), traffic navigation data, management of power transmission and distribution facilities and management of communication infrastructure	DAUDL AGEROUTE DGI Police Nationale DAFR DIT DIEM DTIC Donor countries concerned, private companies
DEMs, 1:5,000-scale orthophoto maps	Digitized 2-D data	Cadastral management plan, water resource management, flood mitigation measures, management of waterworks and sewerage	DGI DEAH Directorate of Waterworks and Sewerage
1:5,000-scale orthophoto data of the entire study area	WTIFF file (images with coordinate values)	Road management, background of land use maps and background of landscape simulation	DAUDL Private companies

⑸ The Study Team instructed the CPs to perform the accuracy control in each process in the technology transfer of this Project. The team recommends staff members of CCT to perform accuracy control appropriately also in other ordinary work within CCT, create their own accuracy control sheet by revising the sample created in this Project and use it in the control and management of the geographic information performed by CCT.

⑹ The Study Team has disseminated information on the outputs of this Project (topographic maps and orthophotos) and their utilization to various stakeholders and actors in the development and the expected potential users. In response, the team has received various requests from them during the project period. The team recommends CCT to actively revise the data of Abidjan where significant change has taken place over time using the equipment provided in this Project, with the requests from the users involved in the development of Abidjan and developmental activities in progress in Abidjan taken into consideration.

5. Work Related to Procurement of Equipment

The equipment procured in this Project consisted of that procured by the consultant and that procured by JICA. All the equipment has already been procured. The lists below are the equipment management lists describing the current state of the procured equipment.

5.1 Procurement of Materials and Equipment by the Contractor (E-1, E-2)

The equipment (to be) procured in Japan, Côte d'Ivoire and in third countries in accordance with the contract on this Project, (planned) time of procurement and its current state are reported in the following: The Study Team requested CCT to issue a receipt whenever the team had handed over equipment to CCT.

(1) Equipment procured in Japan

4) Levels: 2 sets (handed over to CCT in February 2014)
5) Handheld GPS devices : 6 sets (handed over to CCT in April 2015)
6) Handheld digital cameras : 6 sets (handed over to CCT in April 2015)

(2) Equipment (to be) procured in Côte d'Ivoire and in third countries

7) Laptop PCs : 2 sets (handed over to CCT in April 2015)
8) Printing equipment (Color laser printer) : 1 set (handed over to CCT in September 2015)
9) Printing equipment (A3-size color copier) : 1 set(handed over to CCT in September 2015)
10) Equipment for data sharing (server, WebGIS) : 1 set (handed over to CCT in September 2015)
11) Printing equipment (A0-size plotter with scanner) : 1 set (handed over to CCT in October 2014)
12) Equipment for the editing and GIS (plotting, editing and GIS structurization) : 1 set each (handed over to CCT in April 2015)

Table 34 List of Equipment Procured by the Consultant

Name of equipment	Specification/Type number	Currency	Purchased place	Utilized organization	Purpose of goods	Installation place	Purchased date	Procured organization	Note
Leveling equipment	Leica Sprinter with measuring rod*2 sets	JPY	Asia	CCT	Project	CCT	20-Nov-13	Aasu Shoji (Japan) M. Nishida Tel: +81 3 3701 5473 Fax.:+81 3 3703 5226	Delivered to CCT (one unit applied for repair by insurance) on 24 February 2014
Accessory	Tripod * 2 sets		Asia	CCT	Project	CCT	20-Nov-13	Ditto	Delivered to CCT on 24 February 2014
Accessory	Rod base*2*2sets		Asia	CCT	Project	CCT	22-Nov-13	Ditto	Delivered to CCT on 24 February 2014
Laptop PC (leveling/Field identification)	Laptop HP 4540S 15.6"*1 set	FCFA	Africa	CCT	Project	CCT	22-Nov-13	Papici- Top Buro (CI) Email: papici@aviso.ci Tel: +225 21 28 20 78/79 Fax: +225 21 28 20 81	Delivered to CCT on 29 April 2015 (with Office)
Laptop PC (GPS/Field identification)	Laptop HP 4540S 15.6"*1 set	FCFA	Africa	CCT	Project	CCT	22-Nov-13	Ditto	Delivered to CCT on 29 April 2015(with Office)
Handy GPS	Magellan GRS MAP*6 sets	JPY	Asia	CCT	Project	CCT	05-Nov-13	Aasu Shoji (Japan) M. Nishida Tel: +81 3 3701 5473 Fax.:+81 3 3703 5226	Delivered to CCT on 29 April 2015
Handy GPS camera	TB-2 Tough * 6 sets	JPY	Asia	CCT	Project	CCT	05-Nov-13	Ditto	Delivered to CCT on 29 April 2015
Data output equipment	Imprimante grand format: HP Designjet Z5400 ePrinter PostScript (A0)	FCFA	Africa	CCT	Project	CCT	01-Aug-14	GLOBESPACE globespace.ci@gmail.com Tel: +225 20 21 60 67 Fax: +225 20 21 60 57	Delivered to CCT on 28 October 2014 (with Cartridge for 6 colors*3 sets)
	Taskalfa 2551C1A3/A4*1 set	FCFA	Europe	CCT	Project	Study Team office	18-Jan-14	Papici- Top Buro (CI) Email: papici@aviso.ci Tel: +225 21 28 20 78/79 Fax: +225 21 28 20 81	Used in JICA Study Team office by the end of this Project. Delivered on 28 Septmber 2015
	Printer officejet HP 7610*1 set	FCFA	Europe	CCT	Project	Study Team office	25-Nov-13	Ditto	Used in JICA Study Team office by the end of this Project. Delivered on 28 Septmber 2015
Data sharing equipmen	Server HP ProLiant ML350p + UPS, 1set Switch 24 ports CISCO	FCFA	Africa	CCT	Project	CCT	13-Jun-14	Ditto	Installed at CCT main building on 30 June 2014 Installed at CCT main building on 30 June 2014
	WebGIS Lizmap	EUR	Europe	CCT	Project	CCT	30-Jun-14	Faunalia (IT) <http://www.faunalia.it> M. PaoloCavallini Tel:+39 348 3801953	Installed at CCT main building on 30 June 2014
Workstation for photogrammetry	DELL Precision T3610/WS/E-5-1607/16GB RAM 2TB DDUR WIN 7PRO 64BIT +Monitor: DELL s2440L Screen+ UPS 2000VA, 1set	FCFA	Africa	CCT	Project	CCT	22-Jul-14	Papici- Top Buro (CI) Email: papici@aviso.ci Tel: +225 21 28 20 78/79 Fax: +225 21 28 20 81	Delivered to CCT on 28 April 2015(with Graphic Board)
	3D monitor*1set, 3D glasses* 3 sets	JPY	Asia	CCT	Project	CCT	05-Jul-14	Geospatial Intergraph Japan M. Hirata Tel: +81 3 5428 5946 Fax: +81 3 5428 5971	Delivered to CCT (Parts of photogrammetric system) on 28 April 2015
	Topo mouse 3D*1 set	EUR	Europe	CCT	Project	CCT	26-Jun-14	GeoSystems France SARL <http://www.leica-geosystems.com>	Delivered to CCT (Parts of photogrammetric system) on 28 April 2015
	Bentley Enterprise V8i* 1set	EUR	Europe	CCT	Project	CCT	23-Jul-14	Ditto	Delivered to CCT (Parts of photogrammetric system) on 28 April 2015
Data editing equipment	DELL Precision T5610/WS/E5-2609/16GB RAM 2 TB DDUR WIN 7 PRO 64BIT,Monitor:DELL S2440L Screen, UPS 2000VA, 1set	FCFA	Africa	CCT	Project	CCT	22-Jul-14	Papici- Top Buro (CI) Email: papici@aviso.ci Tel: +225 21 28 20 78/79 Fax: +225 21 28 20 81	Delivered to CCT on 28 April 2015 (with Graphic Board)
	Adobe Photoshop* 1set	FCFA	Africa	CCT	Project	CCT	01-Aug-14	Inges-CI(CI) Email: ingesci14@gmail.com Tel: +225 22 50 24 80 Fax: +225 22 50 52 53 Mob: +225 05 74 08 73	Delivered to CCT(Parts of Editing system) on 28 April 2015
Equipment for GIS	DELL Precision T5610/WS/E5-2609/16GB RAM 2 TB DDUR WIN 7 PRO 64BIT,Monitor:DELL S2440L Screen, UPS 2000VA, 1set	FCFA	Africa	CCT	Project	CCT	22-Jul-14	Papici- Top Buro (CI) Email: papici@aviso.ci Tel: +225 21 28 20 78/79 Fax: +225 21 28 20 81	Delivered to CCT on 28 April 2015 (with Graphic Board)
	Adobe Acrobat Pro*1 set	FCFA	Africa	CCT	Project	CCT	01-Aug-14	Inges-CI(CI) Email: ingesci14@gmail.com Tel: +225 22 50 24 80 Fax: +225 22 50 52 53 Mob: +225 05 74 08 73	Delivered to CCT(Parts of Editing system) on 28 April 2015
	ArcGIS Desktop Advanced*1 set	EUR	Africa	CCT	Project	CCT	29-Jul-14	Comafrique Technologies Email: daouda.meite@comafrique-telecom.ci M. MEITE Daouda Tel:+225 21 75 07 80 Fax:+225 07 27 71 57	Delivered to CCT(Parts of GIS system) on 28 April 2015

5.2 Procurement of Materials and Equipment by JICA (E-3)

The equipment procured in third countries and Côte d'Ivoire in this Project is described in the following:

(1) Equipment procured in Japan

None

(2) Equipment procured in Côte d'Ivoire and in third countries

1) GPS observation system : 3 sets (handed over to CCT in August 2014)
2) Software for editing and printing (Dry) : 1 set (handed over to CCT in April 2015)
3) Software for the digital plotting system : 1 set (handed over to CCT in March 2015)

Table 35 List of Equipment Procured by JICA

Dual frequency GPS receiver	Leica GS15 with accessories*3 gets /Geoffice software*1 set	FCFA	Africa	CCT	Project	CCT	25-Aug-14	GLOBESPACE globespace.ci@gmail.com Tel: +225 20 21 60 67 Fax: +225 20 21 60 57	Purchase by JICA Côte D'Ivoire office
Software for photogrammetry	LPS0014 package Desktop Mapping:incluis Imagine photogrammetry, Imagine Auto DEM, Imagine Terrain Editor	EURO	Europe	CCT	Project	CCT	21-Jul-14	GeoSystems France SARL <http://www.leica-geosystems.com>	Purchase by JICA Côte D'Ivoire office
	LPS0012 ORIMA DP-TE/GPS	EURO	Europe	CCT	Project	CCT	21-Jul-14	Geospatial France <http://geospatial.intergraph.com>	Purchase by JICA Côte D'Ivoire office
	LPS0028 PRO600CART	EURO	Europe	CCT	Project	CCT	21-Jul-14	Ditto	Purchase by JICA Côte D'Ivoire office
	LPS0028 PRO600DTM	EURO	Europe	CCT	Project	CCT	21-Jul-14	Ditto	Purchase by JICA Côte D'Ivoire office
	MAT0015 DVD+Products installation+Frais de Port)	EURO	Europe	CCT	Project	CCT	21-Jul-14	Ditto	Purchase by JICA Côte D'Ivoire office
Software for data editing and plotting	Dry(LorikCartographer)*1 set	EUR	Europe	CCT	Project	CCT	21-Jul-14	Lorienne S.A (FR) <http://www.lorienne.com> Tel: +33 1 48 51 12 12 Fax: +33 1 48 59 58 49	Purchase by JICA Cote d'Ivoire office including installation and operation check

5.3 Outputs

The outputs described in this report are mentioned below.

The outputs will be recorded on memory media (hard disks and DVDs) in appropriate data formats and delivered. All the outputs are kept as supplements to this report except for the data of the aerial photographs on hard disk because the data size is big.

Outputs of the Topographic Mapping

(1) Field surveying result (printouts) : 1 set (handed over to CCT)
(2) Point descriptions of the GPS observation points and benchmarks: 1 set (handed over to CCT)
(3) Data of the aerial photographs (on hard disk) : 1 set (handed over to CCT)
(4) Report on aerial photography (printouts) : 1 set (handed over to CCT)
(5) Output of the aerial triangulation (printouts) : 1 set (handed over to CCT)
(6) Report on the kick-off seminar (printouts) : 1 set (handed over to CCT)
(7) Final Report in the PDF format (on DVD) : 2 sets (to CCT and JICA)

(8) Report on the quality control : 2 sets (to CCT and JICA)
(9) Work manuals (on DVD) : 2 sets (to CCT and JICA)
(10) 1:2,500-scale digital topographic map data (in a DGN file) : 2 sets (to CCT and JICA)
(11) 1:2,500-scale digital topographic map data (in a PDF file) : 2 sets (to CCT and JICA)
(12) 1:2,500-scale GIS basic data (in a SHP file) : 2 sets (to CCT and JICA)
(13) 1:5,000-scale orthophoto map data (in a PDF file) : 2 sets (to CCT and JICA)
(14) 1:2,500-scale orthophoto data (in TIFF and TFW files) : 2 sets (to CCT and JICA)
(15) 1:5,000-scale orthophoto data (in TIFF and TFW files) : 2 sets (to CCT and JICA)

Other Reports (submitted with the Final Report)

(16) Project Implementation Report (in Japanese, simple binding) : 3 sets (to JICA)
(17) Public relations material (in French, distributed at the Final Seminar): 200 copies (150 to CCT and 50 to JICA)
(18) Public relations material (in French, electronic data) : 1 set (to JICA)
(19) Collection of digital images (in the JPEG format on 20 CD-Rs) : 1 set (to JICA)