International Journal of Advanced Scientific Research and Management, Vol. 3 Issue 3, Mar 2018.
www.ijasrm.com
ISSN 2455-6378

Assessment of Quality Assurance and Quality Control for GNSS Surveying Firms - A case study in Egypt

Samy Ayaad[1], Mohamed H. Elwany[2], Hassan G. El-Ghazouly[3] and Mohamed M. Hosny[4]
[1,3,4] Department of Transportation, Alexandria University, Alexandria, EGYPT
[2] Department of Production, Alexandria University, Alexandria, EGYPT

Abstract
Among currently used Global Navigation Satellite Systems (GNSS), the Global Positioning System (GPS) from the USA and the Russian GLONASS system are the best known, and currently fully operational. Multiple factors can effect on the GNSS technique in surveying such as level of required accuracy, suitability of equipment, time, available budget, type of measurement techniques and satellite availability. Recently, static and Real-Time Kinematic (RTK) surveying using GNSS are the common method used for both cadastral and engineering surveying in Egypt. Despite the benefit of using GPS system, no standard specifications and/or guidelines was performed in surveying firms across Egypt. Thus, an effort was made in the present study to estimate/establish such relationship by applying Quality Assurance (QA) and Quality Control (QC) on the GNSS surveying firms. A closed questionnaire was designed and distributed to different categories of surveying specialists. The questionnaire was designed to cover the main points under investigation in the GNSS surveying.

Keywords: *Global Navigation Satellite Systems, Quality control, Quality assurance, Real-Time Kinematic.*

1. Introduction

Nowadays, Global Navigation Satellite Systems (GNSS) becomes the dominant, fast, and accurate tool specifically in land surveying projects. Among currently used GNSS, the Global Positioning System (GPS) from the USA and the Russian GLONASS system are the best known, and currently fully operational. Essentially, GNSS provides a three-dimensional position *x*, *y*, and *z*. A GNSS survey may be approached with post-processed positioning for static observations related to a single point or network, or involve real-time corrections to provide positioning. Utilizing the GNSS techniques depends on several factors such as the level of required accuracy, suitability of equipment, time, available budget, type of measurement techniques and satellite availability.

Static and Real-Time Kinematic (RTK) surveying using GNSS are the common method used for both cadastral and engineering surveying in Egypt. Despite the fact of high demand in using GPS, no standard and/or guidelines were found to be adopted in surveying firms across Egypt. Actually, there is a lack of information in most surveying firms about site conditions, desired reference system, project planning, practical considerations, project configuration, survey procedures and post processing steps. Therefore, the final produced accuracy even for the same points within the same project may be different. The most common sources of errors may be related to instrument calibration, atmospheric conditions, operative methods, human errors and mistakes, and the unexpected behavior of the reference frame (Maria et al. 2004; Mark et al. 2009; Kumar et al. 2012). As the GNSS becomes a mainstream in the land surveying profession, it is essential to establish guidelines for land surveying using measurements derived from GPS observations positioning (Naudi 2005).

To meet the demands of a modern working environment, commitment from management and coworkers in an empowered organization are needed (Naudi 2005). The concept of quality management is to ensure efforts to achieve the desired quality of the product that is well planned and organized. From the perspective of the surveying company, quality management in surveying projects should mean maintaining the quality of surveying works at the desired level in order to obtain customer satisfaction that will bring long-term competitiveness and survival to businesses (Tan & Abdul-Rahman, 2011). Total quality management is critically required for surveying firms to sustain in current surveying market which is highly challenging and competitive. Tan and Abdul-Rahman (2011) stated that the total quality management has to provide the environment within which related tools, techniques and procedures can be deployed effectively leading to operational success for a surveying firm. The activity of the total quality management for a surveying company is not an isolated activity, but intertwined with all the operational and managerial processes of the firms.

2. Research Significant

The aim of this paper is to apply a quality assurance (QA) and quality control (QC) for GNSS surveying firms in the Arab Republic of Egypt by applying guidelines derived from previous studies in order to address the major challenges of GNSS surveying and set guidelines and recommendations for the optimum field processes and work. Such work can help in reaching high accuracy in GNSS surveying projects which can be used as a guide in the upcoming work.

3. Methodology

A survey questionnaire has been designed in order to collect all possible factors that may affect the GNSS surveying. The survey questionnaire covered the response on what are specialization/job description in the GNSS field, the type of firm sector, the firm location, the guidelines and specifications used in projects firm, the type of receivers according to signal and finally the appropriate observing times of the day to achieve the required accuracy. Schematic diagram for these parameters are shown in Fig. 1. The questionnaire was distributed to three categories of respondents. Category 1 represents the professional staff (project managers with academic background), while category 2 is composed of the technical staff (field surveyors) in Egypt. Finally, category 3 included the project managers and technical staff outside Egypt. To verify the answers of the questions, different specification has been used as a reference such as Canada, Alberta, California, Colombia, Queensland, Connecticut, New York, Washington, South Wales, United Kingdom and National Oceanic specifications for the QA and QC in GNSS surveying.

The questionnaire was divided for two main parts. Part I includes all possible parameters that listed in the previously mentioned specification. The second part (II) includes other questions which may affect the results but not included in the specification. The first draft of the questionnaire was distributed to three professional academics in Egypt and two project managers outside Egypt in the area of GNSS applications and integration for feedback. Furthermore, to assess how the questionnaire stands in international market standard, the questionnaire and cover letter have been personally delivered to this “pilot study” group and have been completed in the presence of the researcher. This has allowed the researcher the opportunity to answer any questions and to receive feedback on the clarity of the questions being asked.

The questionnaire along with a cover letter and return envelope were mailed out to the 62 individuals (sample of study) who were chosen according to the three categories mentioned previously. The sample of study was divided so that there were 16 persons for category 1, 28 for category 2 and 18 for category 3 in land surveying firms. Each questionnaire contains an identification number for mailing purposes only. This identifier has been applied by the researcher to keep a record of the firms which have returned their questionnaire. In addition, the

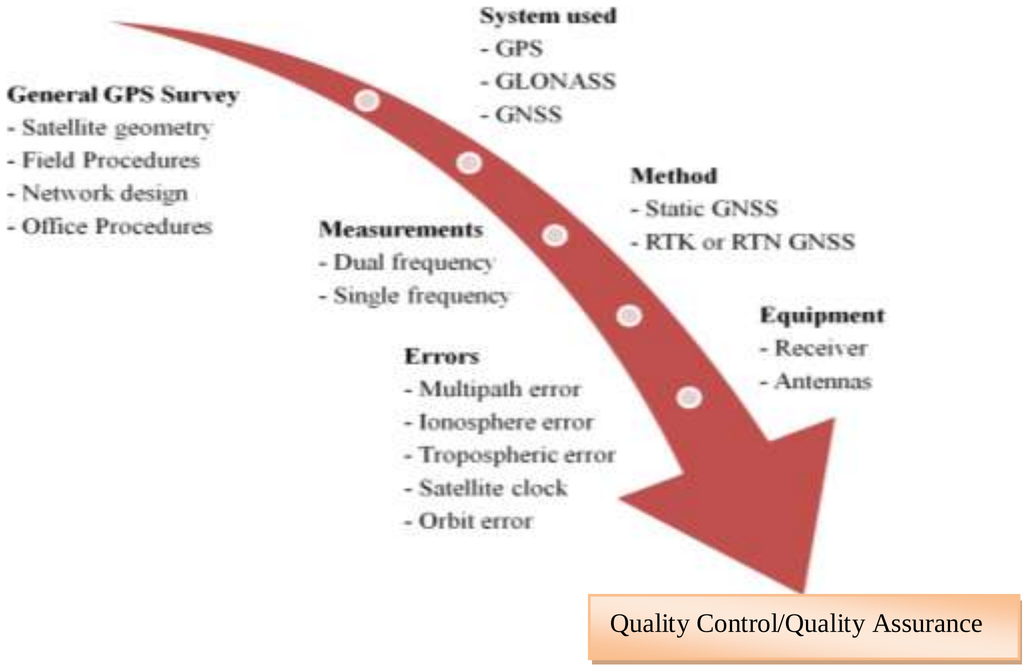

Fig. 1: Schematic diagram for the possible factors that may affect the GNSS surveying.

companies' names have never been attached to the questionnaire in order to ensure complete confidentiality. At this stage the researcher has received much appreciated cooperation from all the interviewees.

4. Questionnaire results

Each question's results and comments in each section of the questionnaire for category 1, category 2 and category 3 are as follows:

Part I:

Question 1: which system is used to determine the positioning?

Fig. 2 shows that 56% and 61% from category 1 and 2 used the GPS, respectively, while category 3 used GNSS only (100%).

Question 2: which receiver is used to collect the signal?

Fig. 3 shows that category 1 used L1 signal, L1&L2 signal and L1&L2&L5 signal by 50%, 37% and 13% respectively. Also, the same trend was observed for category 2 by 53%, 36% and 11%. In contrast, category 3 did not use L1 signal only to collect the signal and apply L1&L2 signal and L1&L2&L5 signal by 89% and 11%, respectively.

Question 3: what is the appropriate observing times of the day?

Question 3 was designed to identify the firms applying the appropriate observing times of the day to achieve a high accuracy in their projects. It can be noticed that the times between 5:00 am to 10:00 am has the greatest frequency, which was 50 and 64% for category 1 and 2, respectively, as shown in Fig. 4. For category 3, the results showed that the description of satellite geometry has the greatest frequency, which accounts for 56 % of the responses.

Question 4: Do you have a ring antenna type in your firm for mitigating the multipath?

Category 1 and 2 shows that 37 and 32%, respectively, of respondents do a ring antenna in their firm while the reset do not (Fig. 5). In contrast, category 3 shows that 100% of respondents do a ring antenna in their firms.

Question 5: Do you perform surveys in unstable weather?

Category 1, 2, and 3 show that 69, 61, 50% respectively (Fig. 6), may perform the survey in an unstable weather, while the reset do not.

Question 6: What is the importance of measuring and recording the antenna height before and after each station occupation?

56 and 64% form category 1 and 2, respectively, claimed that measuring and recording the antenna height before and after each station occupation are not important, while 94% from category 3 reported the essentially for this step, as shown in Fig. 7.

Question 7: What is the importance of collimation and leveling the antenna before and after each station occupation?

Similar for the antenna height, 69 and 64% form category 1 and 2, respectively, claimed that collimation and leveling the antenna before and after each station occupation are not important, while 83% from category 3 reported the essentially for this step

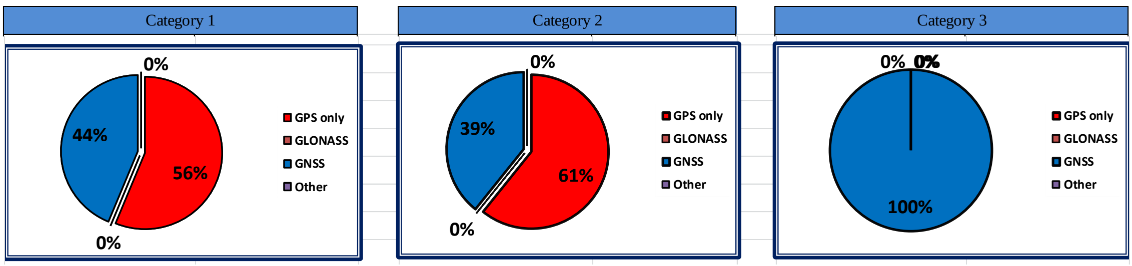

Fig. 2: Response on the used system to determine the positioning.

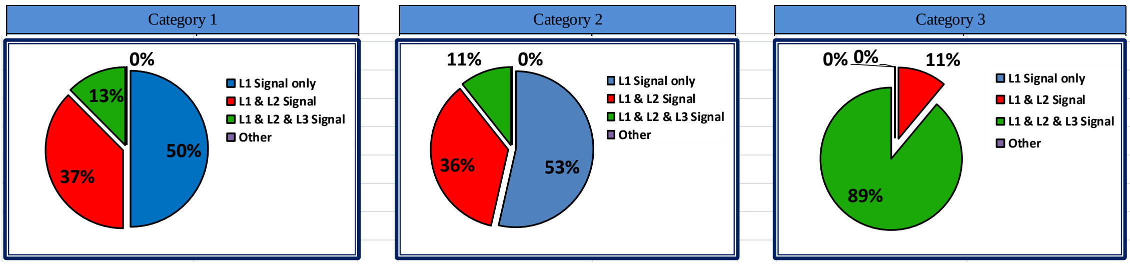

Fig. 3: Response on the used receiver to determine the positioning.

(Fig. 8).

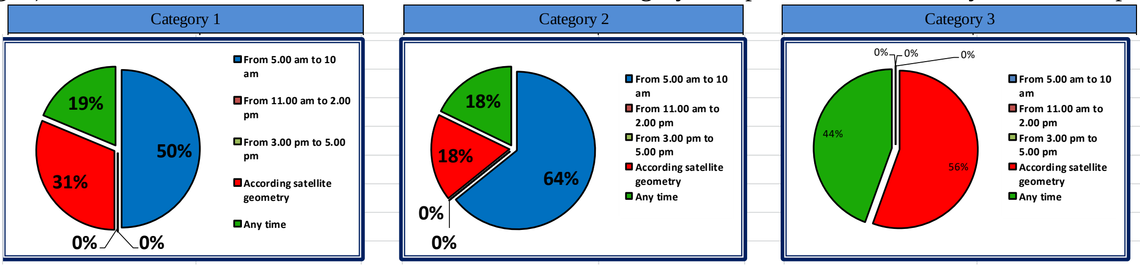

Fig. 4: Response on the appropriate observing times of the day.

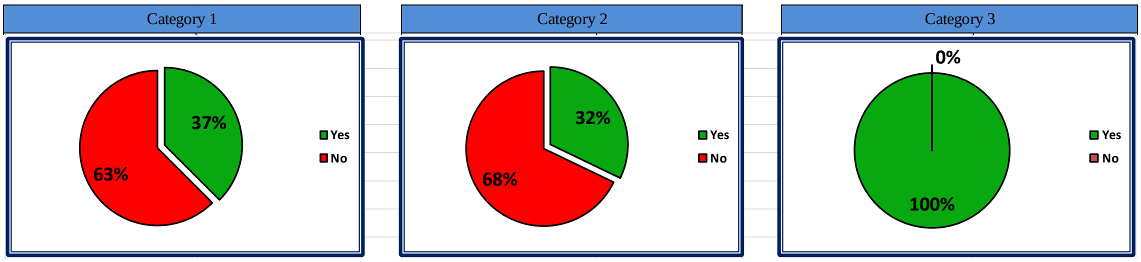

Fig. 5: Response on if the firm containing a ring antenna for mitigating the multipath.

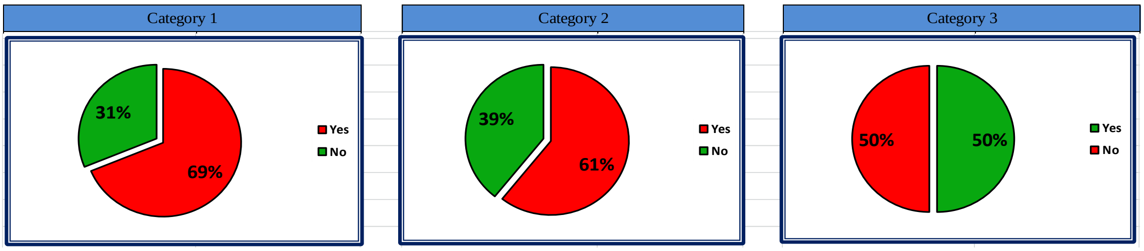

Fig. 6: Response on if the surveys may be performed in unstable weather.

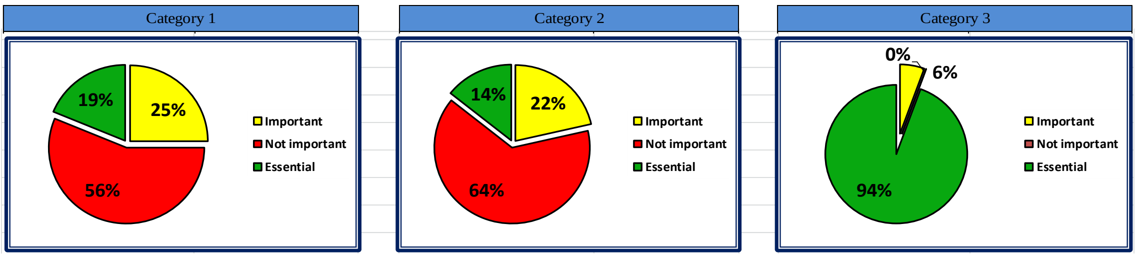

Fig. 7: Response on the importance of measuring and recording the antenna height before and after each station.

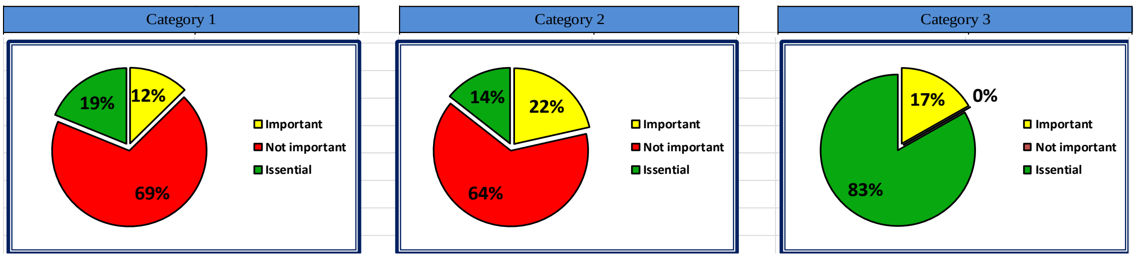

Fig. 8: Response on the importance of collimation and leveling the antenna before and after each station.

Question 8: What is the importance of taking photograph of every station mark in the site?
Fig. 9 shows that 50 and 71% form category 1 and 2, respectively, claimed that taking photograph of every station mark in the site are not important, while

category 3 reported the essentially for this step by 100%.

Question 9: What is the importance of using identical antennas in the site?
62 and 67% form category 1 and 2, respectively, claimed that using identical antennas in the site are not important, while 89% from category 3 reported

the essentially of using identical antennas in the site, as shown in Fig. 10.

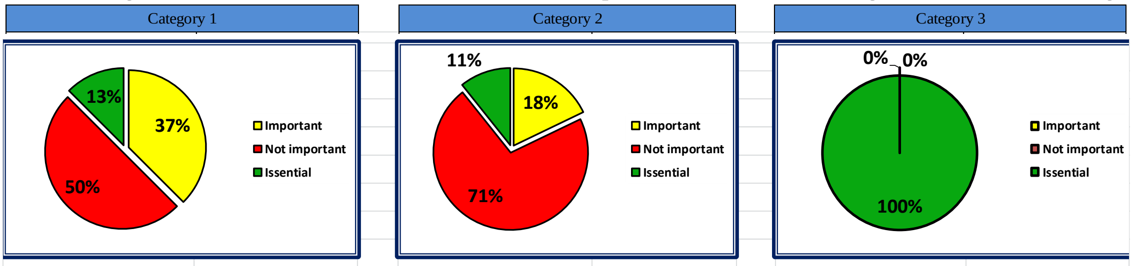

Fig. 9: Response on the importance of taking photograph of every station mark in the site.

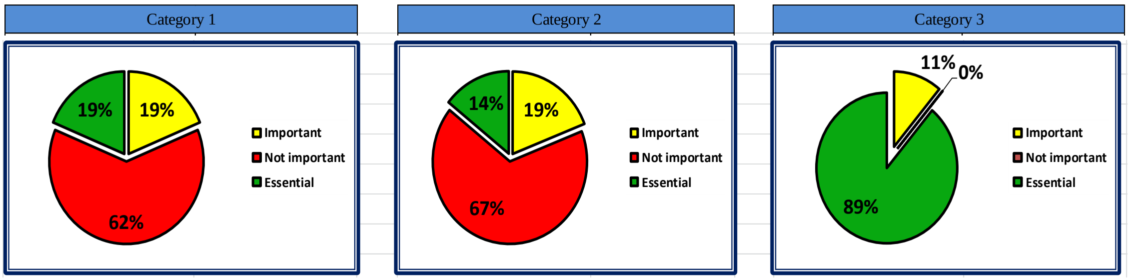

Fig. 10: Response on the importance of using identical antennas in the site.

Question 10: How many times do you calibrate the antennas?
The main part from form category 1 and 2 (56 and 68%, respectively, Fig. 11) calibrates the antennas yearly. Also, the calibration every six months accounts for the second highest observation in these categories (31 and 18%, respectively, Fig. 11). In contrast, the main part in category 3 calibrates the antennas at any stage before the work; in addition, the second main observation in this category did the calibration monthly.

Question 11: Do you have the multipath conditions and obstructions, before starting the work?
Fig. 12 shows that 75% and 82% from category 1 and 2, respectively, have the expected field procedures before starting the work, while category 3 has the expected field procedures before starting the work (100%).

Question 12: Do you have the satellite geometry and field conditions, before starting work?
Fig. 13 illustrates that 69%, 82%, and 100% from category 1, 2, and 3, respectively, have the expected field procedures for satellite geometry before starting the work, while category 3 has the expected field procedures before starting the work (100%).

Question 13: What is the minimum number of reference station for the projects?
Category 1 and 2 shows that two points are the main used trend as a reference station by 56 and 40%, respectively (Fig. 14). In contrast, category 3 shows

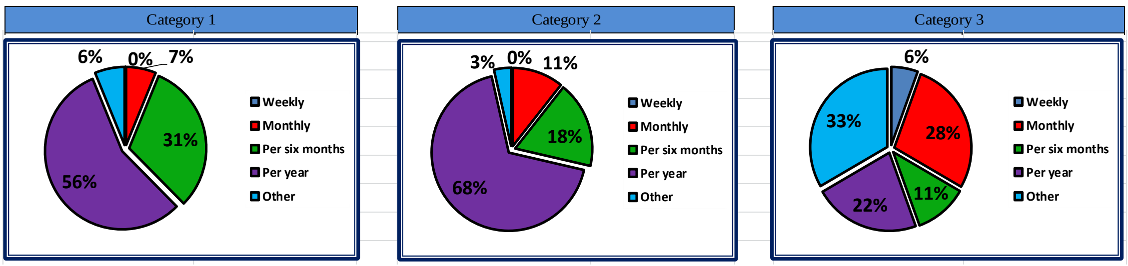

Fig. 11: Response on how many times the antennas were calibrated.

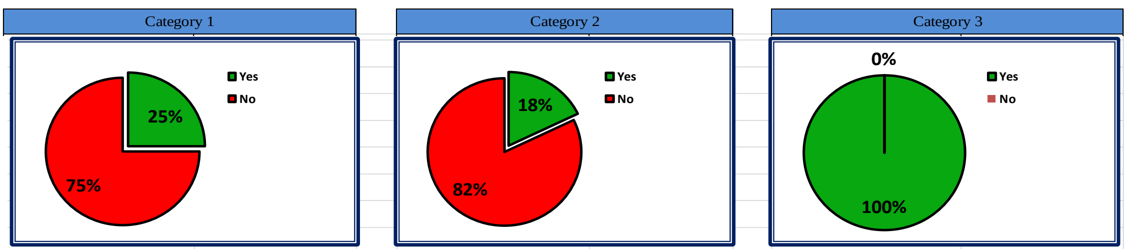

Fig. 12: Response on the expected field procedures in multipath conditions and obstructions, before starting the work.

that more than four points are usually used as a reference station by 44%.

Question 14: What is the minimum number of independent baselines in each loop for the project control network stations?

No main trend was observed for category 1 and 2, as shown in Fig. 15. For example, in category 1, the weight of the observation ranged between 31 to 38% for 2, 3, and 4 independent baselines. In contrast, category 3 shows that two independent baselines are the main trend by 55%.

Question 15: What is the maximum epoch interval for data sampling in the projects?

Fig. 16 shows that 15 second was the main trend by 62, 64, and 83% for categories 1, 2, and 3, respectively.

Question 16: What is the minimum time between repeat station observations?

Fig. 17 illustrates that 60 second was the main trend by 56, 67, and 100% for categories 1, 2, and 3, respectively.

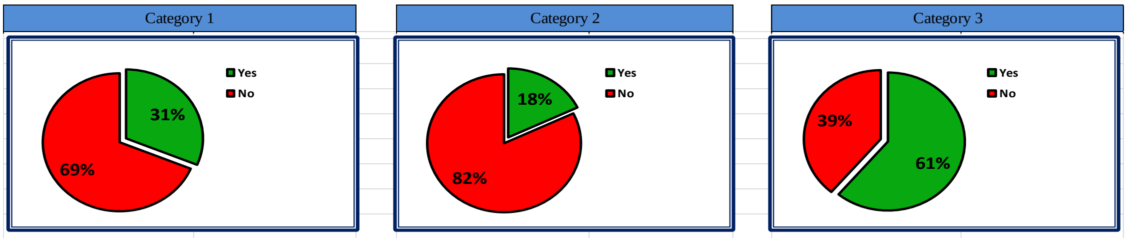

Fig. 13: Response on the satellite geometry and field conditions, before starting work.

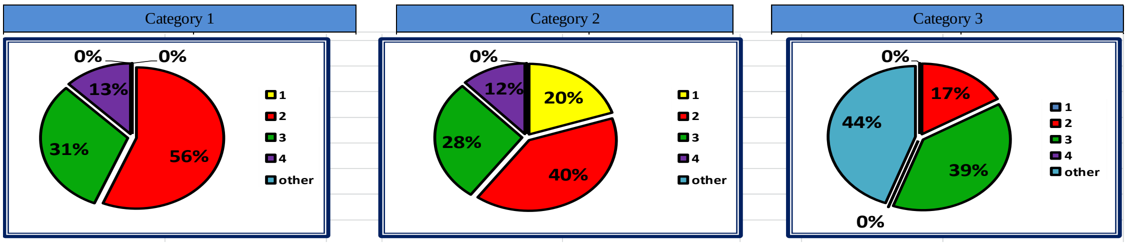

Fig. 14: Response on the minimum number of reference station for the projects.

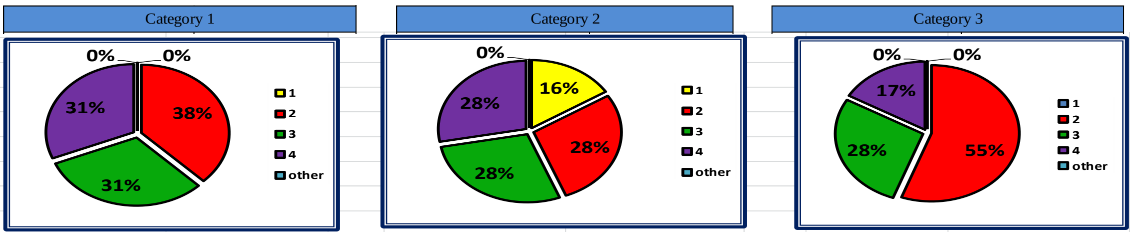

Fig. 15: Response on the minimum number of independent baselines in each loop for the project control network stations.

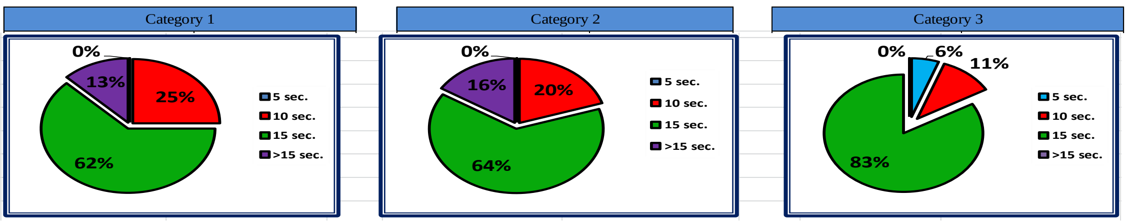

Fig. 16: Response on the minimum number of reference station for the projects.

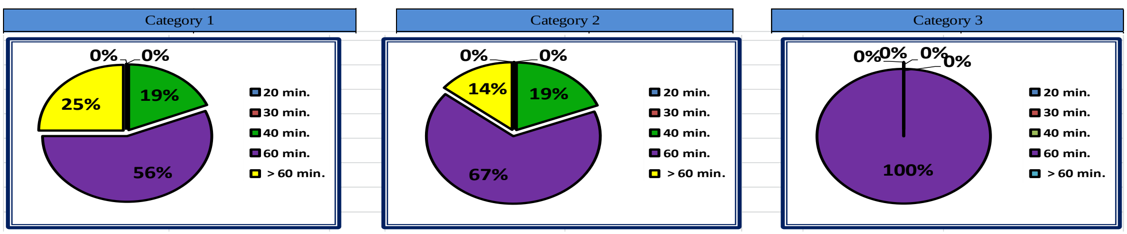

Fig. 17: Response on the minimum time between repeat station observations.

Question 17: What is the solution type used in the projects?
The fixed solution was the main used type in category 1 and 3 (100%, Fig. 18). Also, 93% from category 2 applied the same solution and the rest (7% only) used float solution.

Question 18: Is the antenna height during the surveying fixed or changeable?
Fig. 19 shows that 56%, 46%, and 94% from category 1, 2, and 3 used fixed height during the surveying, while the rest used changeable height.

Question 19: What is the maximum PDOP value used in rover receiver by RTK survey?
Fig. 20 shows that the PDOP values between 4 to 6 were the main values in categories 1, 2, and 3 by 56, 47, and 89%, respectively. Also, the second main values for the PDOP were between 1 to 3 by 44%, 39%, and 11% for categories 1, 2, and 3, respectively.

Question 20: What is the elevation mask angle in rover receiver by RTK survey?
Fig. 21 shows that the elevation mask angles between 10 to 15 degree were the main angels in categories 1, 2, and 3 by 73, 72, and 100%, respectively.

Question 21: What is RTK ambiguity solution type in the projects?
Fig. 22 shows that 81% and 75% from category 1 and 2, respectively, used fixed solution, while the rest used DGPS. In contrast, category 3 applied the fixed solution by 100%.

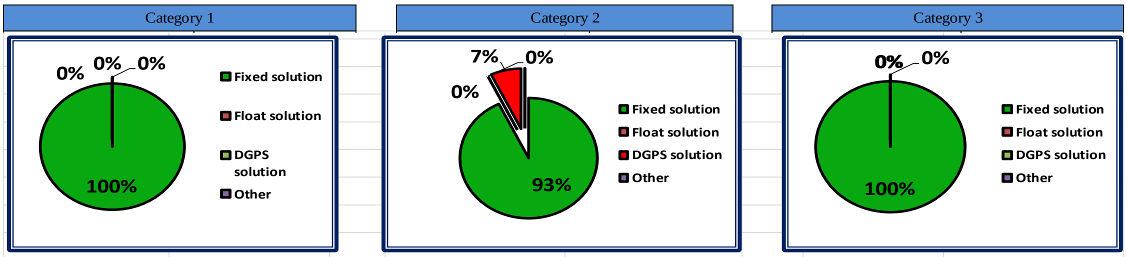

Fig. 18: Response on the solution type used in the projects.

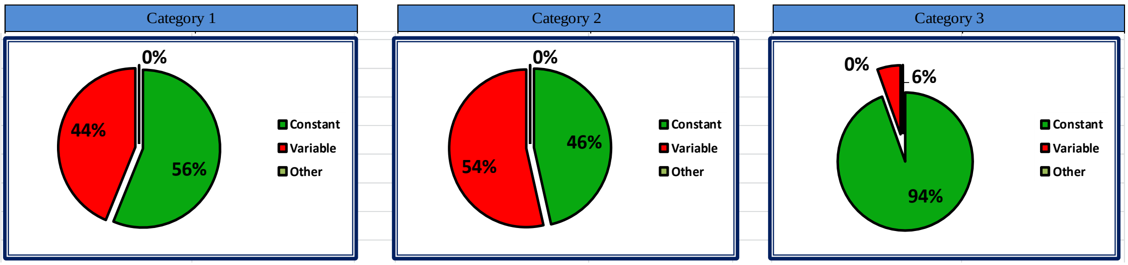

Fig. 19: Response on the type of the antenna height during the surveying.

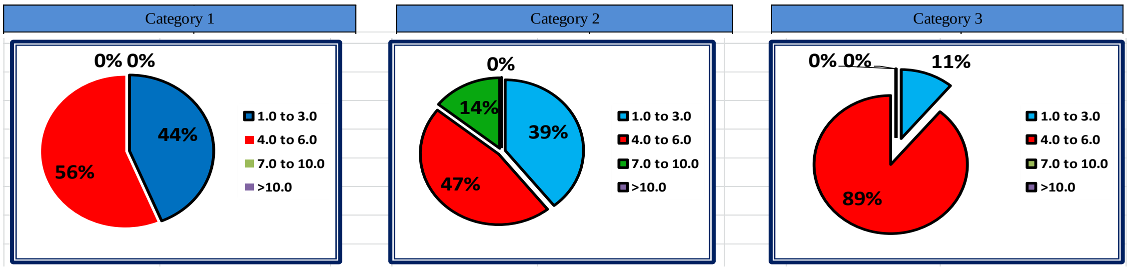

Fig. 20: Response on the maximum PDOP value used in rover receiver by RTK survey.

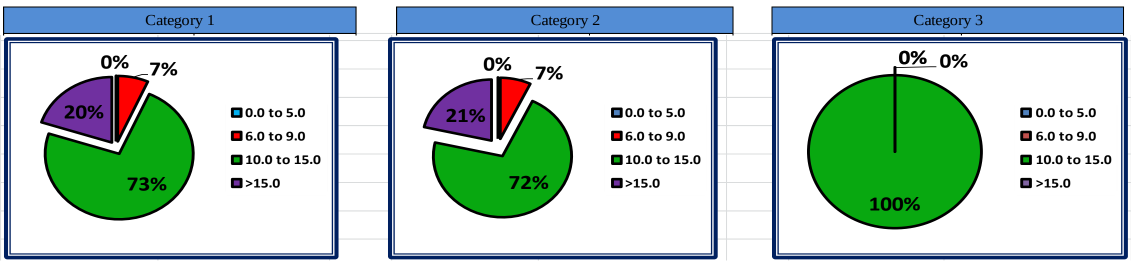

Fig. 21: Response on the elevation mask angle limit used in rover receiver by RTK survey.

IJASRM

International Journal of Advanced Scientific Research and Management, Vol. 3 Issue 3, Mar 2018.

www.ijasrm.com

ISSN 2455-6378

Question 22: What is the most effective error that affects the GNSS surveying?

Multipath error was the main error recorded by all categories (93%, 100%, and 100%, for categories 1, 2, and 3, respectively), as shown in Fig. 23.

Part II:

Question 23: What is the range of observation time in open sky case?

Fig. 24 shows that the observation time between 5 to 30 min. was used by all categories (1, 2, and 3).

Question 24: What is the range of observation time in obstruction from one side?

The results show that the observation time between 31 to 60 min. was the main used time in the surveying if there is an obstruction from one side by 69%, 61%, and 83% for categories 1, 2, and 3, respectively (Fig. 25), while the rest used observation time ranged between 5 to 30 min.

Question 25: What is the range of observation time in obstruction from two sides?

Unlike the one side case, the results show that 61 to 90 min. was the main observation if an obstruction from two sides was existed for categories 1 and 2 by

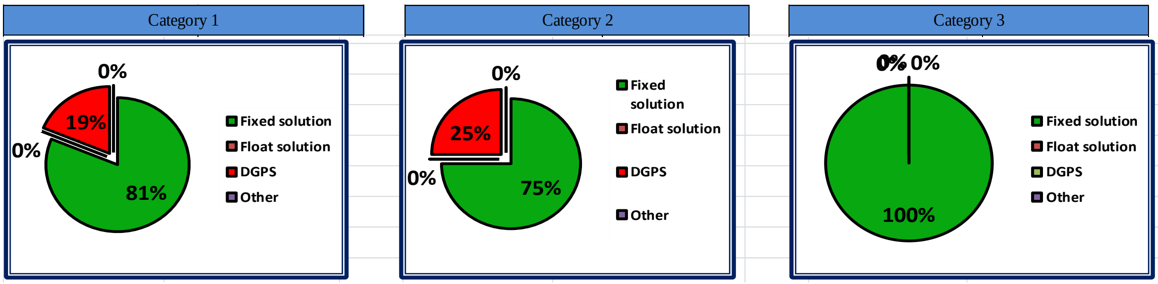

Fig. 22: Response on the RTK ambiguity solution type in the projects.

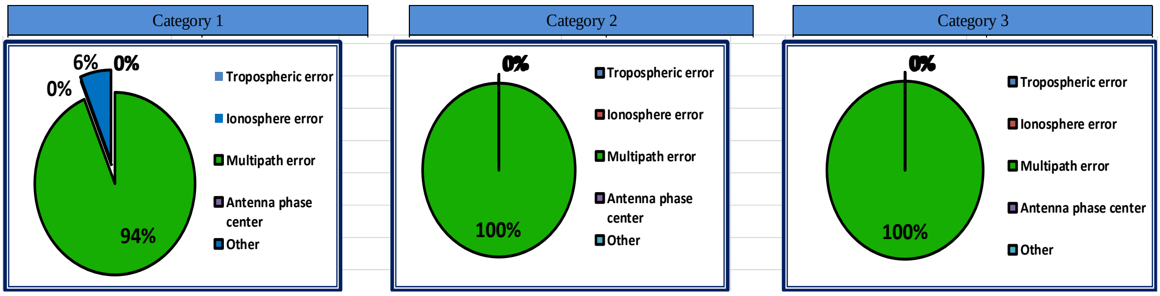

Fig. 23: Response on the most effective error that affects the GNSS surveying.

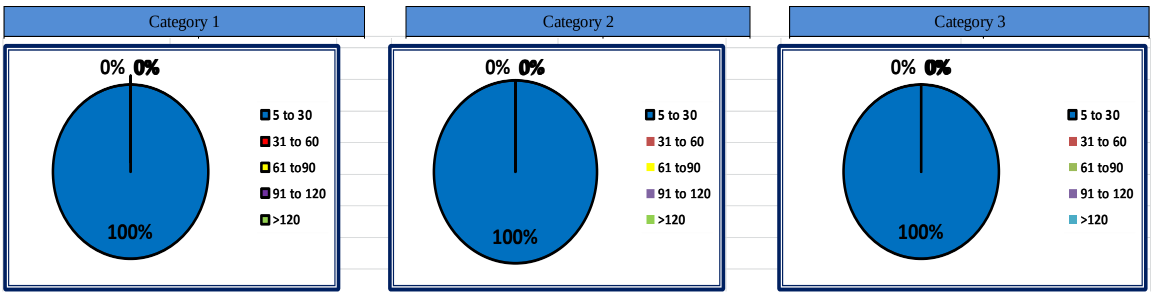

Fig. 24: Response on the range of observation time in open sky case.

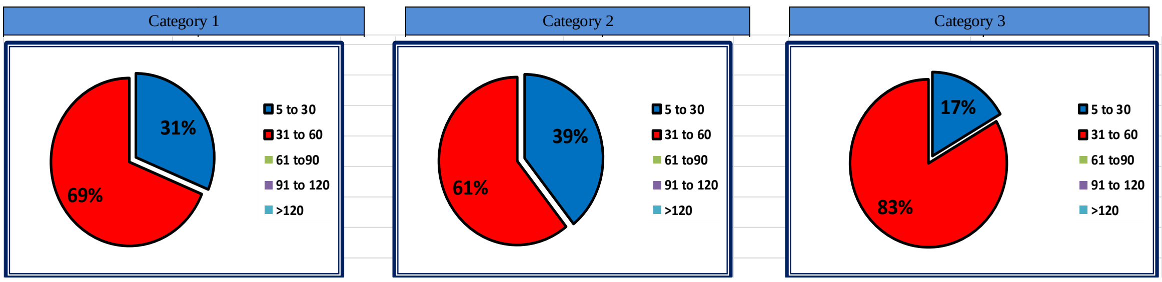

Fig. 25: Response on the range of observation time in obstruction from one side case.

International Journal of Advanced Scientific Research and Management, Vol. 3 Issue 3, Mar 2018.
www.ijasrm.com
ISSN 2455-6378

69% and 61%, respectively, while the rest used observation time ranged between 5 to 30 min. In contrast, category 3 applied 91 to 120 min. as the main observation time by 78%, as shown in Fig. 26.

Question 26: what is the percentage of the re-work in the project?

The results show that the possibility for redoing the work in category 1 and 2 was significantly higher than category 3 as more than 10% was the main response for categories 1 and 2 by 44% and 46%, while 3% to 5% was the main percentage of the re-work in category 3 by 78% (Fig. 27).

5. Discussion

Aforementioned, GNSS surveying depends on several factors such as the number of measurements (single or dual frequency), GNSS errors (multipath, ionosphere, tropospheric, satellite clock and orbit error) and the equipment (receiver and antenna). Furthermore, the GNSS surveying affected by satellite geometry, field procedure, network design and office procedure. These factors should be followed to achieve the required accuracy, as previously shown in Fig. 1. Therefore, the questionnaire's questions were designed based on these procedures.

To verify the results of the questionnaire for each category (1 and 2), different specification (e.g. Canada, Alberta, California, Colombia, Connecticut, New York, Washington, United Kingdom and National Oceanic specifications) were applied. Table 1 shows the allowable limits in these specifications and the main observation from the questionnaire. Also, for better comparison, the highest frequency answer for these questions in all the specifications were used as a reference and compared with the response of all the categories, as shown in Fig. 28. Generally, it can be noticed that the response from category 1 and 2 are close but far from the datum (the highest response according to the specifications) with average ratio 33% for category 1 (project managers staff in Egypt) and 29% for category 2 (technical staff in Egypt). In contrast, category 3 (the project managers and technical staff outside Egypt) matches the highest response according to the specifications with an average ratio 75%.

Part II from the survey was design to cover other aspect which may directly affect the outcomes from the GNSS surveying. The results from this part show that there are similarities between the main trends observed in all categories regarding the observation time and direction. It should be mentioned that a network of GNSS continuously operating reference stations (CORS), which can correct satellite navigation signals in order to provide international standard and high-accuracy positioning, should provide fundamental positioning infrastructure for these countries. These data is streamed to users via a wireless internet connection which apply to all GNSS measurements using CORS. Unlike category 3, these references points are not established/known in Egypt, which may be the main reason behind the inaccurate results for the GNSS surveying (Fig. 29).

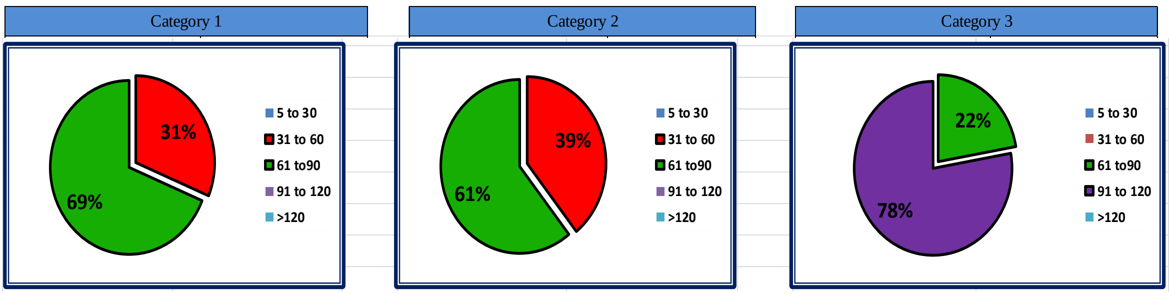

Fig. 26: Response on the range of observation time in obstruction from two sides.

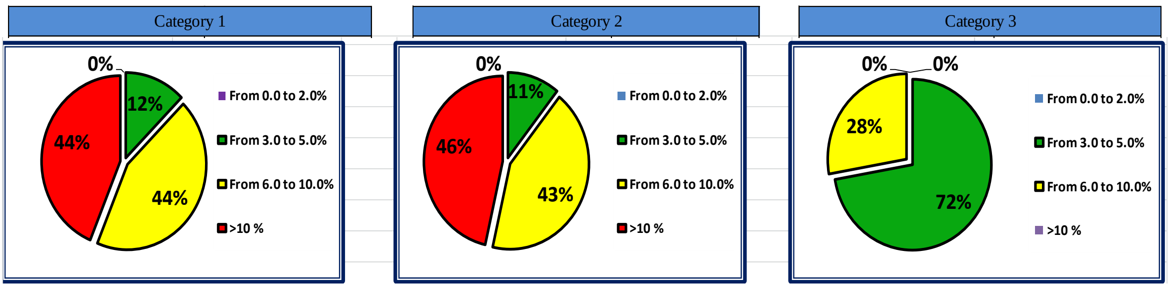

Fig. 27: Response on the percentage of the re-work in each project.

IJASRM

International Journal of Advanced Scientific Research and Management, Vol. 3 Issue 3, Mar 2018.

www.ijasrm.com

ISSN 2455-6378

Table 1: The allowable limits in the specifications and the main observation from the questionnaire.

	Canada	Alberta	California	Australia	Connecticut	New York	UK	Washington	National Oceanic	The reference response*	The main trend in each category		
											1	2	3
Q.1	GNSS	GNSS	GNSS	--	GNSS	………	GNSS	GNSS	GNSS	GNSS	0.44	0.39	1
Q.2	L1, L2, L5 Signal	L1, L2, L5 Signal	L1, L2, L5 Signal	………	L1, L2, L5 Signal	L1, L2, L5 Signal	L1, L2, L5 Signal	L1, L2, L5 Signal	L1, L2, L5 Signal	L1, L2, L5 Signal	0.13	0.11	0.89
Q.3	ST	ST	ST	ST	ST	ST	ST	ST	ST	ST	0.31	0.18	0.56
Q.4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0.37	0.32	1
Q.5	No	No	No	No	No	………	No	No	………	No	0.31	0.39	0.5
Q.6	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	0.19	0.14	0.94
Q.7	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	………	Essential	0.19	0.14	0.83
Q.8	Essential	Essential	Essential	Essential	Essential	Essential	Essential	………	………	Essential	0.13	0.11	1
Q.9	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	0.19	0.14	0.89
Q.10	Weekly	Weekly	monthly	………	………	………	………	Weekly	………	Weekly	0.31	0.18	0.33
Q.11	Yes	Yes	Yes	………	Yes	Yes	Yes	Yes	………	Yes	0.25	0.18	1
Q.12	Yes	Yes	Yes	………	Yes	Yes	Yes	Yes	………	Yes	0.31	0.18	0.61
Q.13	3	3	3	………	3	………	………	3	………	3	0.31	0.28	0.39
Q.14	2	2	2	2	2	2	2	2	2	2	0.38	0.28	0.55
Q.15	………	15 sec	15 sec	15 sec	………	15 sec	15 sec	15 sec	15 sec	15 sec.	0.62	0.64	0.83
Q.16	………	60 min.	60 min.	30 min.	………	60 min.	60 min.	30 min.	60 min.	60 min.	0.56	0.67	1
Q.17	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS	0.81	0.75	1
Q.18	Constant	………	Constant	Constant	Constant	Constant	Constant	Constant	………	Constant	0.56	0.46	0.94
Q.19	1 to 3	3	5	3	3	7	3	4	1 to 3	4 to 6	0.56	0.47	0.89
Q.20	10 to 15	10	15	10	10	10	15	15	10 to 15	10 to 15	0.73	0.72	1
Q.21	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS	1	0.93	1

*The highest frequency response according to the specifications, ST: Satellite geometry, FS: Fixed solution.

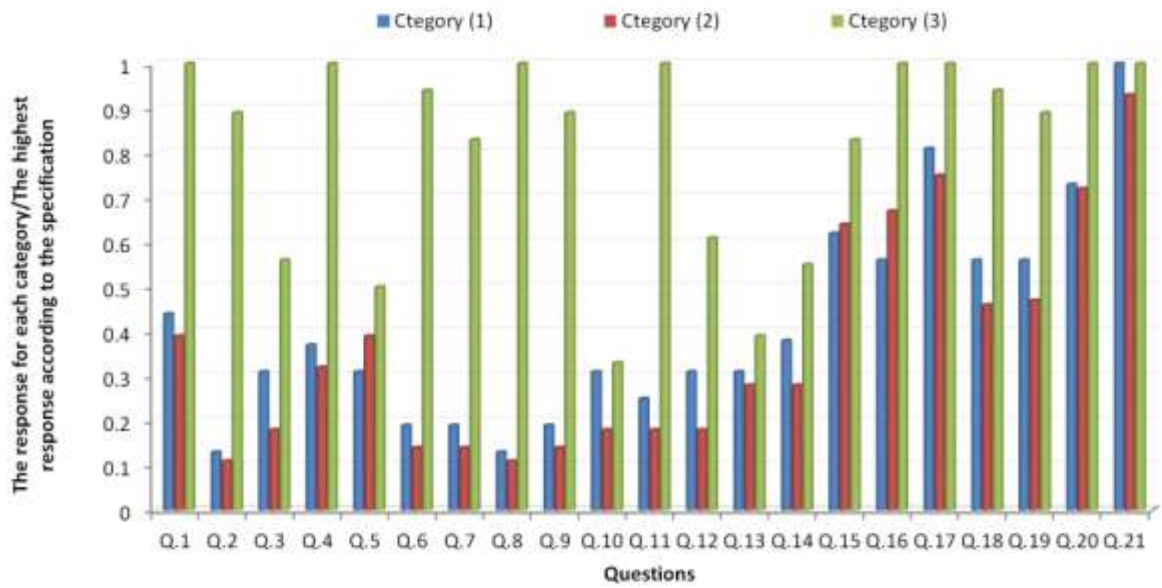

Fig. 28: The main observation from the questionnaire for each category and the highest response according to the specifications.

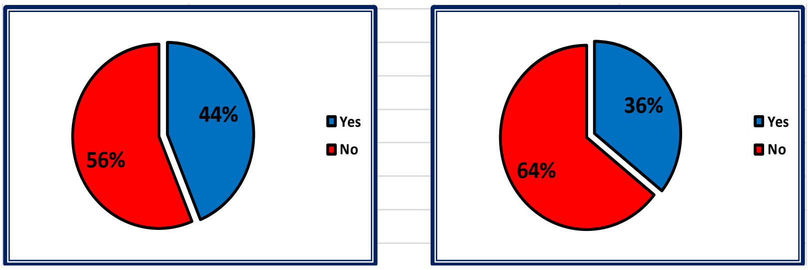

Fig. 29: Response on the existing continuously operating reference stations (CORS)

5. Conclusions

Based on the questionnaire results presented in this paper, the following conclusions can be drawn:

- The general system used to determine the positioning in Egypt is GPS, whereas the GNSS is the main system used worldwide, which might lead to a lack of accuracy quality in the survey works in Egypt.
- The responses on the GNSS surveying from the professional staff and field surveyors in Egypt show some similarity; however, such responses did not follow most of the current specifications.
- The lack of the network of GNSS continuously operating reference stations (CORS) seems to have a direct effect on the inaccurate results in GNSS surveying in Egypt, which needs to further attention.
- The results show that the possibility for redoing the work in Egypt was significantly higher than other countries because a lack of specification and guidelines in Egypt.

References

[1] Antonello Rizzo Naudi "A Quality Assurance System at the Land Survey and Mapping Unit (Malta) ", 2005.

[2] Brian Donahue, Jan Wentzel and Ron Berg, “Guidelines for RTK/RTN GNSS Surveying in Canada”, 2013.

[3] Crown Registry and Geographic Base Branch, “Province of British Columbia Standards, Specifications and Guidelines for Resource Surveys Using (GPS) Technology”, 2008.

[4] Government of Alberta, “Standard, specifications and Guidelines for GPS surveys of Alberta survey control”, 2010.

[5] Government of Ontario, “Ontario Specification for GPS Control Surveys”, 2005.

[6] Maria João HENRIQUES and João CASACA "Quality Control of a Dam Geodetic Surveying System", 2004.

[7] Mark Saunders, Philip Lewis, Adrian Thornhill “Research Method for business students”, 2009.

[8] New York State Department of Transportation "Land surveying standards and procedures manual", 2009.

[9] RICS Practice Standards, UK, “Guidelines for the use of GNSS in land surveying and mapping”, 2010.

[10] S.Senthil Kumar, Arun Kumar Chauhan "Automated Quality Control of Global Navigation Satellite System (GNSS) Data ", 2012.

[11] State of Washington Department of Natural Resources, “Standards and Guidelines for Land Surveying Using Global Positioning System Methods”, 2004.

[12] Tan Chin-Keng, Abdul-Rahman and Hamzah "Study of Quality Management in Construction Projects", 2011.

[13] The California Land Surveyors Association, “GNSS Surveying Standards and Specifications”, 2014.

[14] The Connecticut Association of Land Surveyors,” Guidelines and Specifications for Global Navigation Satellite System Land Surveys in Connecticut”, 2008.

[15] Transport and Main Roads, “GNSS Control Surveys Guideline”, 2016.

[16] Wafeek Ismail “Evaluating the Differences and Accuracies Between GNSS Applications Using PPP ", 2015.

[17] William Henning, “User Guidelines for Single Base Real Time GNSS Positioning”, 2011.