A New Methodology for an Automatic Evaluation Procedure of Cadastral GNSS Measurements According to the Surveyors' Regulations Instruction

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Key words: Cadastral measurements, GPS/GNSS observations, GNSS Regulations' Instructions, automatic validation process, surveyors' regulations.

SUMMARY

Cadastral points' coordinates in the national grid system will play the main role in the future Legal Digital Cadastre (LDC) system. It will be the main legal evidence in the court instead of physical evidence in the current analogical cadastre system. As a result, cadastral survey agency, which is responsible of maintaining the cadastral system, has to be worried about reliable coordinates' values which have to be saved in the cadastral database. Reliable values are those values with accurate properties which meet the instructions and the criteria of the surveyors' regulations.

This paper presents new methodology which is assimilated by software called MAJOR. This software is designed especially for executing an automatic procedure and evaluating the GNSS cadastral measurements via the surveyors' regulations criteria and instructions. The input of the procedure is presented and the patent of the new methodology is as well detailed. An example for GNSS measurements cadastral project is presented for more clarification.

Finally, the paper highlights the role of the MAJOR software in building the LDC database in the near future.

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1. INTRODUCTION

Transforming analogical cadastral system to modern Legal Digital Cadastre – LDC one, has became the ultimate goal for most of the worlds developed countries.

LDC system principles have been firstly summarized by Kaufmann and Steudler in 1998. According to the digital cadastre, every cadastral parcel is defined by closed polygon consisted from boundary points. Every point is defined by grid coordinates of the national projection grid served the country.
The main principle of the LDC concentrate on the fact that the projection grid coordinates of the boundary point will play the main evidence in the court, instead of the physical wedge in the field. The LDC database will be based on those coordinates which are computed from licensed surveyors' cadastral measurements.

Thus, the position accuracy of the cadastral points when marking them in the field, using their coordinates, should be executed in sufficient high level. Accuracy level for LDC purpose has been investigated by several authors over the world. In Israel, Steinberg in 2005 indicated a level of 5 cm as the ultimate level that the Survey of Israel (SOI) is looking for, in all over the country. Reaching this ultimate accuracy level needs a high quality national control network.

At the beginning of 2005 the SOI has been announced basing the two national grids of Israel, the horizontal and the vertical grids, on the Active Permanent GNSS control Network (APN) of Israel. The APN network consists of 19 GNSS points which are illustrated in picture 1, (Steinberg and Even-Tzur, 2005). The new control network projection is similar to the previous Transverse Mercator projection with the same parameters value of the previous "Israel Transverse Mercator" (ITM) control grid. The new grid is called IG2005 grid. Its inner announced accuracy level is 3 mm in 95% confidence level (Steinberg and Even-Tzur, 2005). According to Steinberg and Even-Tzur, 2005, it enables measuring cadastral points in any place in the country with 5 cm better accuracy level in relative to the APN points.

In order to establish the future LDC database with 5 cm accuracy level, the SOI should design the Surveyors' Regulation and their instructions especially for this purpose.
Since the GNSS technology plays the main role for linking any new measured point to the APN control network, modern regulations instructions should concentrate on preserving high quality GNSS observations. GNSS observations' types are vary, for example: static post-processing observations, RTK GNSS observation, Virtual Reference Stations' (VRS), methodology observation etc…
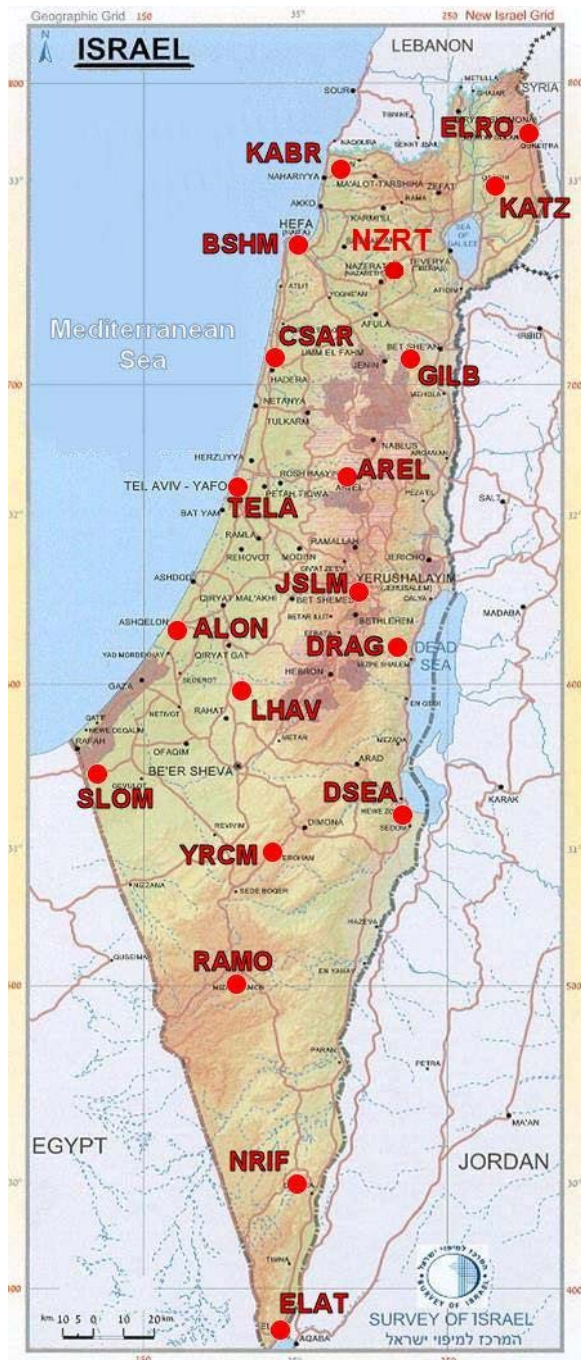
Figure 1: The Active Permanent GNSS Network of Israel consisted of 19 stations

The quality assurance process of the GNSS observations types is a complex one, since the quality observations parameters are varied and related to several situations. The most significant influences are:

- Constellation of the satellites in the sky, position and number.
- Quality of the signals and the noises around the GNSS receivers.

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- The distance between the receivers.
- The place of the receivers whereas there are objects that could affect the visibility to the sky or lead to multi-path phenomenon.

The first two influences are dynamic situations that could not be totally checked during the measurements. Thus, a great responsibility is imposed upon SOI shoulders when writing the future regulations and their instructions related to GNSS observation, for building the LDC database. Therefore, the future regulations' instructions and their quality assurance criteria might be more complicated as well as strict. This fact may affect the validation process of the cadastral measurements via the regulations' instruction and criteria process to become longer and more complex.

2. ISRAELI SURVEYORS' REGULATIONS STUDY CASE

Immediately, at the beginning of 2005, after the entrance of the IGD2005 control grid which is based on the Israeli APN network, the SOI has published a set of instructions which are explaining the measurements' methods for using it Stenberg, 2006). These instructions are published in the website of the SOI in http://www.mapi.gov.il/page.php?id=reg_inst, in Hebrew.

The most important instructions are:
- Instructions num. 1/2005, "Instructions for setting horizontal control points by using active permanent stations and virtual reference stations with formal transformation parameters": http://www.mapi.gov.il/reg_inst/satl_geo.pdf
- Instructions num. 1-9/2007: "Updating and additions for the technical instructions of the manager": http://www.mapi.gov.il/reg_inst/tech-update-98-04-07.pdf.

The main principles of the new instructions are:
- Direct measuring of the point using individual GNSS receiver from APN points or VRS point or VERS RTK Base point. In addition, using known and licensed control points in IGD2005 grid is permitted, taking into consideration more severe validation criteria.
- Checking the Calibration of the GNSS equipments of the surveyor using checkers points.
- Checking the accuracy of the new measured point in relative to the IGD2005 by requiring two independent GNSS measurements and calculating the distance value between them. Distance is computed by the IGD2005 coordinates difference of the points which are derived from every independent measurement session.
- Independent GNSS measurement session is defined as new activation of the GNSS receiver and antenna on the new control point, when the antenna's height is changed more than 5 cm from the last session, and the difference time is more than a specific number of minutes.
- The IGD2005 control points are degraded into several levels in the horizontal positions and the vertical ellipsoidal heights (Steinberg and Even-Tzur, 2006). High levels required: long time of GNSS measurements, longer time difference between independent measurements session as well as small differences distance computed by two sets of coordinates in IGD2005 derived from every measurement session.

-   The new regulation instructions of using GNSS measurements' technology describe the structure of the measurement net. The structure includes a description of the maximum and the minimum distances between the new points and the licensed points. The latter might be VRS, APN points or known as control points. Additionally, the structure includes the maximum and the minimum vectors' length in relative to the accuracy degree level of the new measured control point.

Finally, in order to have high quality GNSS measurements results, the new regulations' instructions require preserving on DOPS values under 5. DOPS or "Dilution of Precision" is GNSS term used in geomatics engineering to describe the geometric strength of satellite configuration on GNSS accuracy (Langley, 1999).

3. DOPS VALUES AS A PROBLEMATIC PARAMETERS FOR VALIDATION

For watching the DOPS parameters values before executing the GNSS measurements, surveyors should plan their measurements time by using planning software which can be found in almost every GPS receiver company and post-processing software. Figure 2 illustrates the Trimble software planning mission.
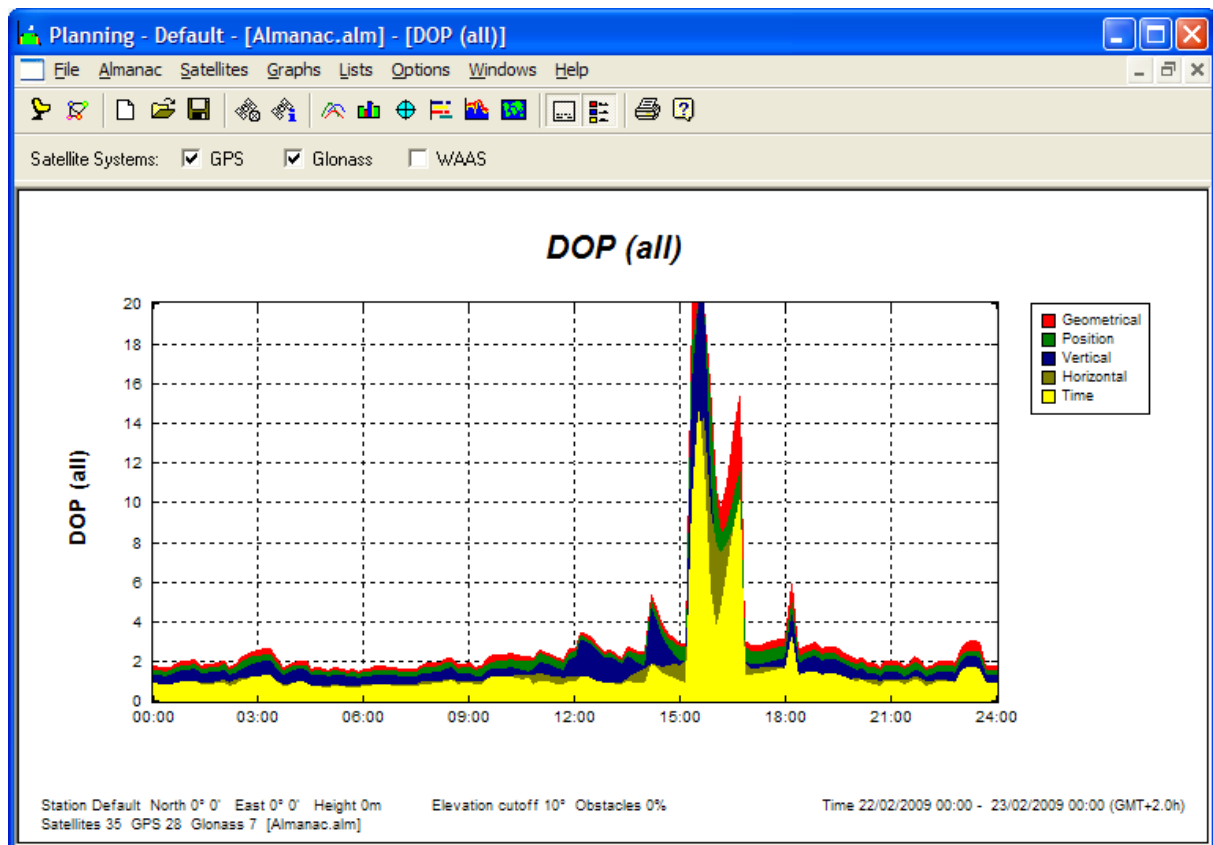

Figure 2: Screen shot of the planning software of Trimble company illustrates the DOPS values during the day…

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Using the planning software may be completely useful for surveyors, especially in non-urban places when the sky is completely opened. The problem appears when the measurements are done in urban places. Measuring in urban places means a possibility of existence high buildings that may hide several satellites from the GNSS receiver. This situation leads to enlarge the DOPS values of the GNSS position solution despite that the software planning mission derives low excellent values.

The new technology of the GNSS receivers is supplied with controllers with small screen that shows the GNSS measurement parameters such as: DOPS values, number of satellites, signal to noise ration that indicates the strength of the satellite signal, the coordinates etc…

These parameters can help surveyors to control their measurements quality during their work in the field. If they meet high values of DOPS, higher than those recommended by the regulations instructions, they can add more time of measurements.

Unfortunately, in a specific situation, especially when trying to measure a GNSS vector by using two receivers, surveyors should meet a situation that the vector they are trying to solve in the office is unsolvable automatically. This despite the existence of these smart controllers, that assist them to watch the DOPS values in the fields and be sure that they are lowest from the critical value recommended by the regulations' instructions.
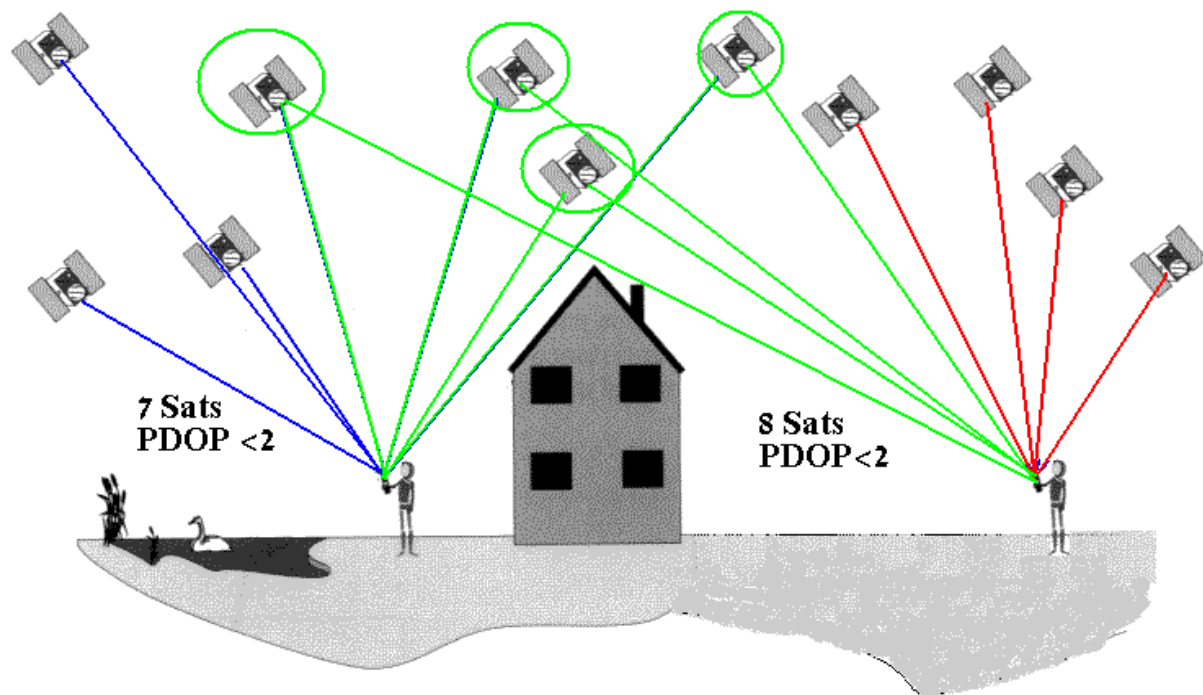

Figure 3: problematic situation of the GNSS measurements, in urban area, that might lead to get high values of the multi-stations DOPS, despite the fact that in the receivers' controller have shown low values in the fields.

Figure 3 illustrates a situation in which the two surveyors see PDOP (Position Dilution of Precision) lower than two because an ideal constellation of GNSS satellite in the sky. The problem which is described clearly by figure 3 is caused because an existence of such a

building blocks some satellites' signals. That leads to achieving a low multi-station PDOP value computed from only four common satellites which are highlighted by circles in figure 3.

This problem might appear when using two receivers for measuring vectors. When using one GNSS receiver against APN station or VRS station, it may not be common problem. Although the VRS or APN Rinex files which are derived from special web-base software, may include the most of the satellites in the sky, it may still have one or more satellites missing caused from different reasons.

4. THE "MAJOR SOFTWARE" AS AN AUTOMATIC EFFECTIVE SOLUTION

The Survey Agency is responsible for building the LDC database. It has to confront all the low quality causes problems by validating all the criteria recommended by the regulations' instructions. Thus, only by validating the cadastral measurements criteria due to those recommended by the regulations instructions, survey agency would build high accurate reliable LDC database.

Task of validating cadastral measurement project has several levels of difficulty. It is related on the amount of points in the projects that need to be validated, the complicated level of the computation methods, number of quality assurance criteria etc…
The period of time which is needed for evaluating the cadastral measurements project is a function of the difficulty level. This average time might reach several hours, especially if the officer of the survey agency, who is responsible for checking and validating the regulations' criteria, is doing his job well. Sometimes, in order to check and evaluate some criteria, a complicated process shall be done. For example, in order to check the quality of the GNSS measurements, instead of checking the multi-station DOPS values which are recommended by the regulations instructions, survey agency officer should try to solve all the GNSS vectors. As long as the regulations instructions' criteria used for validating the solution of the GNSS vectors, survey agency should have checked it before evaluating the post-processing of the vector.

The accelerated construction and the process of transformation the cadastre systems to digital ones, may lead to enlarge the registrations plans numbers. Correspondingly, the number of the validation GNSS measurements according to the regulations' instructions should enlarge also. Thus, as an appropriate solution, this validation process should be executed automatically using computerized applications for saving time and maximizing the resolution of the validation process.

Zeibak & Sabbagh L.T.D Company, by its research and development software department, has developed novel software which is called "MAJOR" which is designated especially for that purpose.

The Major software enables user to build a method according to the regulations' instructions. It includes a library of most of the GNSS surveyors' regulations instructions which have been

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collected from the internet all over the world. The regulations instructions structure have been designated as an object oriented design, especially for defining a regulation method.
A regulation method is composed from:
- Quality assurance criteria of the cadastral measurements net structures.
- Quality assurance criteria of the cadastral measurements.
- The computation method of calculating the coordinates in the national grid. The computation is divided to two steps: computing the geocentric coordinates in the APN datum, and transforming it to the final national projection grid.
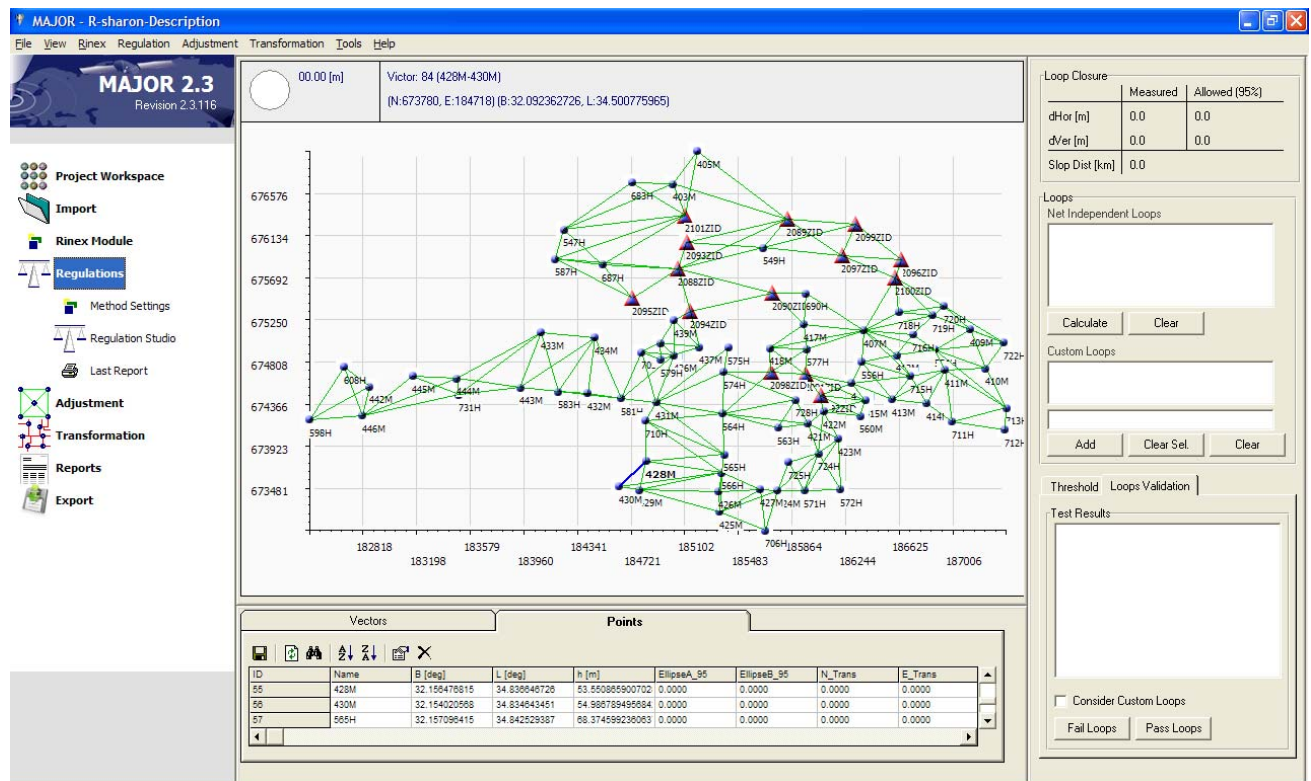- Quality assurance criteria of the computation results.

Figure 4: Screenshot of the main window of MAJOR software.

The process of activating the validation process is relying on: inserting measurements, Rinex GNSS observations and GNSS vectors in different formats, defining the types of the net points, choosing the desired regulations method and finally generating the final computation for the desired detailed report. The final report includes:
- Cadastral project details.
- Cadastral project network scheme.
- Regulations' method details.
- Final coordinates in the national control grid.
- The result of every criterion in the method with "Pass/Fail" evaluation sign.

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In order to perform the whole process above, Major is supplied of control projection grid definitions, least square adjustment engine, loops closure method for eliminating blunders, transformation engine, undulation models, and other tools designated especially for cadastral regulations uses.
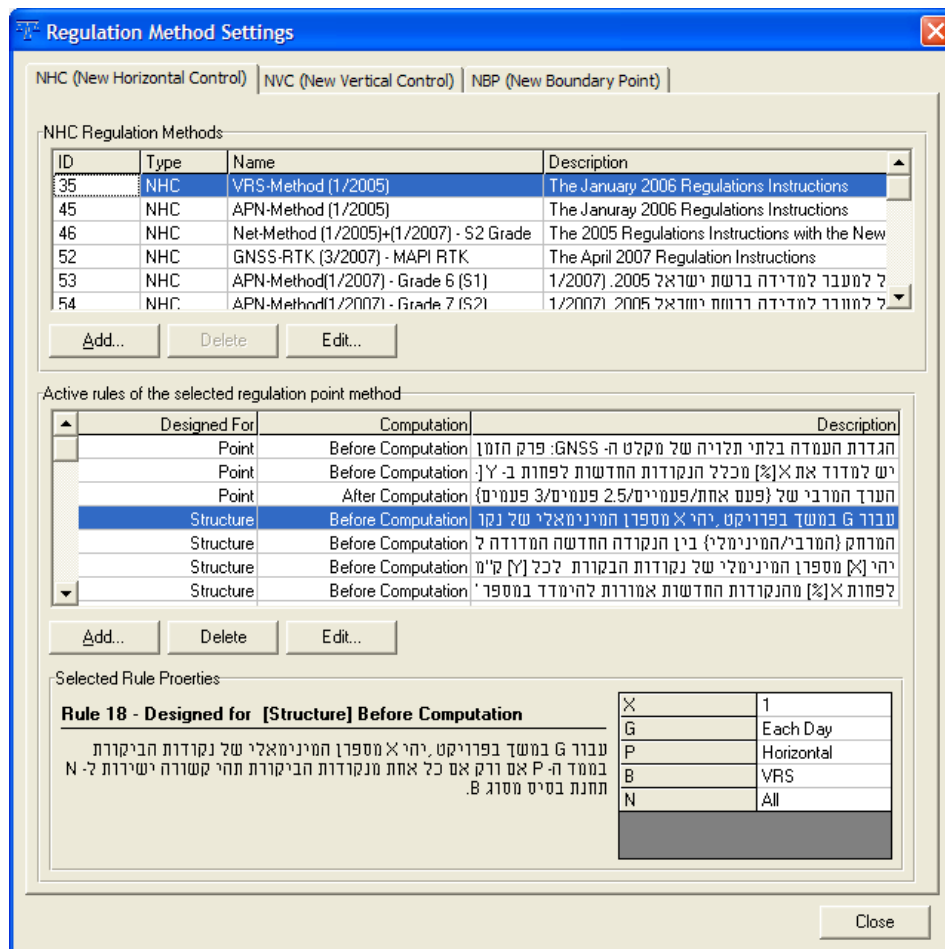

Figure 4: Screenshots from the "Regulation Method Settings" in the Major software that enables user defining a regulation method.

For more details about the whole regulations' method process, the flowchart described in figure 5 illustrates its algorithm. Figure (5) shows that when Major generates the final report, Major has to pass several procedures such like: adjustment computation, datum transformation and finally it describes all the criteria results.
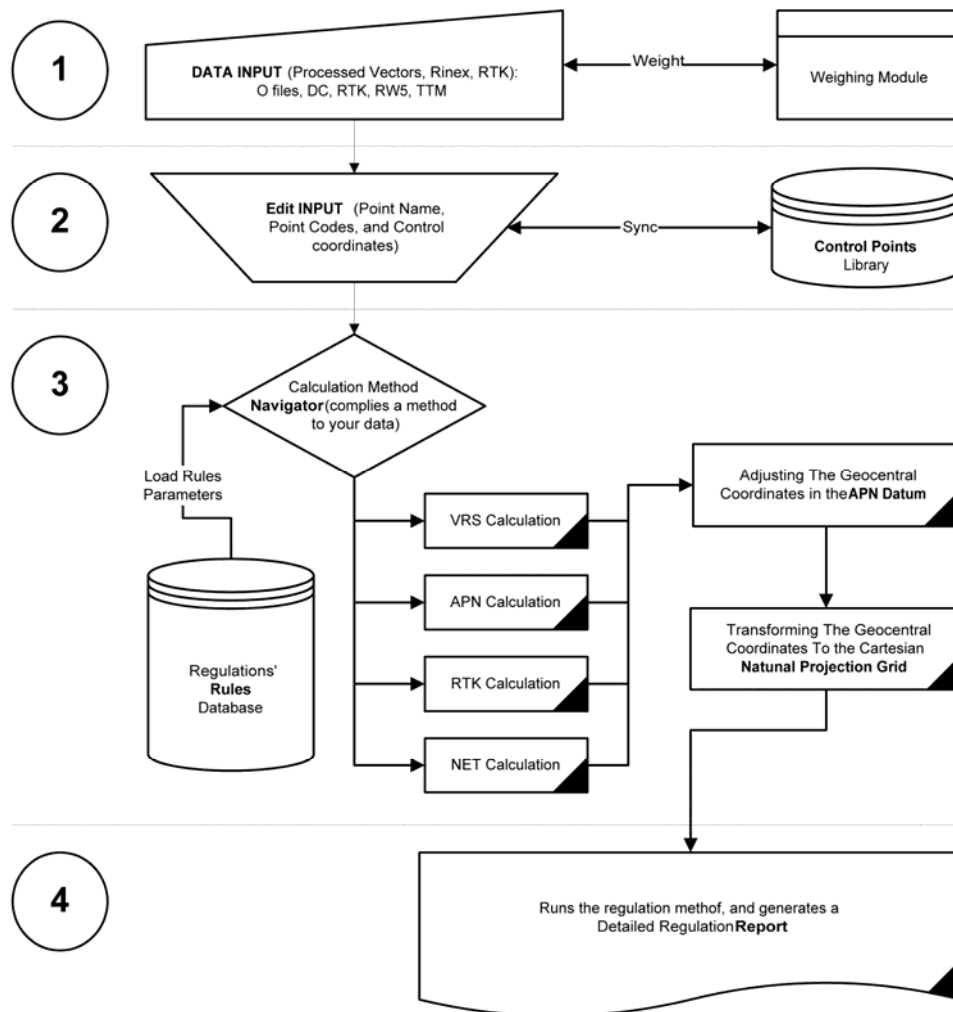
4 Steps In Validating Cadastral Measurements

Figure 5: The four steps of generating the final surveyors' regulations' instructions' module of the Major software.

5. EXAMPLE

5.1 VRS GNSS regulations' instructions' measurements

In order to illustrate the execution process of surveyors' regulation methods in MAJOR software let us define the method of measuring and linking a New Horizontal Control (NHC) point according to regulations' instructions num 1/2007 in Israel degree (S1) to the IGD2005 control grid. The instruction number 1/2007 explains how to measure NHC points and link it to the IGD2005 using the VRS GNSS services supported by the SOI using the Israeli APN. The main instructions of the VRS 1/2007 method are:

1. Every NHC point must be measured against two different VRS independent sessions.
2. The difference between two independent GNSS measurement sessions is 60 minutes with 5 cm difference in the antenna GNSS receiver height.
3. The VRS points must be generated in radius of less than 5 km from each measured point.
4. One licensed control point at the same degree of the (S1) must be measured in the net directly from one VRS. This point is called checker point. The difference between the measured and computed IGD2005 coordinates and its licensed coordinated must not exceed the 4 cm. The distance of the checker point from every point in the net must be less than 10 km.
5. The distance computed from the coordinates' differences between the two independent VRS sessions of every NHC must not exceed the 2.5 cm level.
6. The GNSS PDOP single station measurements values for each point must not exceed the 5 level during minimum 15 continuous minutes.
7. The GNSS PDOP multi-station vector values for each vector in the net must not exceed the 5 level during minimum 15 continuous minutes.

5.2 VRS GNSS cadastral project study case

As a study case, we choose a cadastral project that aims to measure and link 4 new horizontal (NHC) points to the IGD2005 control grid: 880MZI, 881MZI, 882MZI and 883MZI. The project was measured by Zeibak & Sabbagh Company L.T.D in December 2008 according to the VRS 1/2007 regulations' instructions method described in section (5.1). The checker point of the project that was measured from one VRS point is 504U a horizontal licensed control point. Every NHC point was measured twice. Two VRS points were generated by the Geo++ software of the SOI website (http://212.179.112.235/) (see figure 6).

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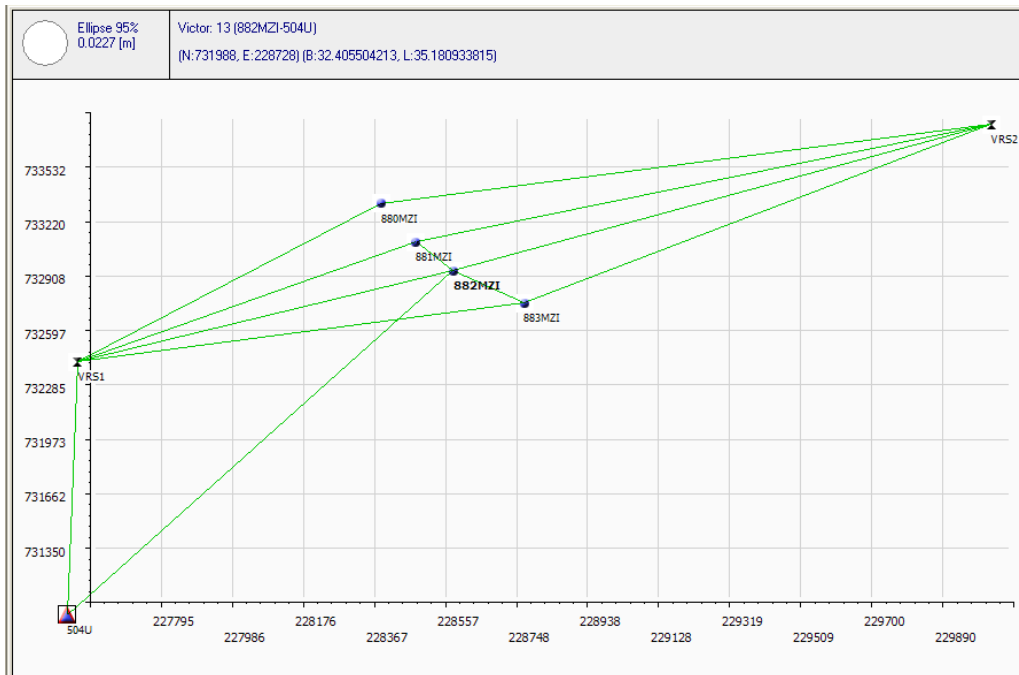Surveyors Key Role in Accelerated Development
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Figure 6: Description of the cadastral example project.

According to the Israeli surveyors' regulations instructions, when surveyors submit their cadastral GNSS measurements project to the SOI for validation the coming data must be attached:

1. The surveyor declaration about: the regulations' method that he has used, the type of the GNSS receivers and antennas as well as the accuracy degree level of the new control points that he requests.
2. A table includes the antenna's heights, the measurement's start time, and the duration time (or the end time) of every GNSS station that was measured in the project.
3. All the GNSS Rinex files of the measurements.
4. IGD2005 coordinates table of the NHC points calculated from every VRS point session. The table must include also the differences between the values of the NHC coordinates calculated from the two VRS sessions.
5. The differences between the values of the checker points measured IGD2005 coordinates from the licensed coordinates which is saved in the LDC database of the SOI.
6. List of the post-processing GNSS vectors includes the post-processing parameters' values such as: The DX, DY and DZ geocentric terrestrial datum components of the vector and their covariances values, the solution type (using L1 and L2 or just L1 GNSS signal), fix or float solution etc…
7. Finally the least square adjustment report for every VRS point. The least squares are activated when every VRS point is set as the only fixed point for the adjustment computation.

After submitting all the above, the SOI officers, which are well qualified to do the best job for executing the validation processing, have to deal with several challenges:

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- Checking the quality of the GNSS observation by trying to solve or process the vectors. This process means that the officers have to perform all the GNSS computations. If the surveyor who submits the project for confirmation had not preserved of the regulation instructions, such as low DOPS for continuous specific time, the officer may have a problematic task, because some vectors could not be solved ideally. This procedure may be time consuming.
- Checking all other criteria according to all the other instructions according to the new post-processed vectors that were done by the SOI.

That means, SOI officers have to do all the job of calculating the GNSS measurements from the beginning till the end. This procedure causes a long queue of projects that have to be validated.

The Major software offers to perform all the regulations procedure automatically. The only input of the software are Rinex files and processed GNSS vectors that may be submitted as OBEN (Ashteck Company vector files format, also called Ofile format) or other post-processing software formats provided by the Major software (Magellan, 2007).
The only steps that the user has to do after inserting the Rinex files and the GNSS vector are:
- To define the points' type, whereas they are NHC, VRS or licensed control point as checker (see figure 7).
- To insert the IGD2005 licensed coordinates of the checker points, or to get it automatically from the Major library database (www.geopioneers.com/Major.html).

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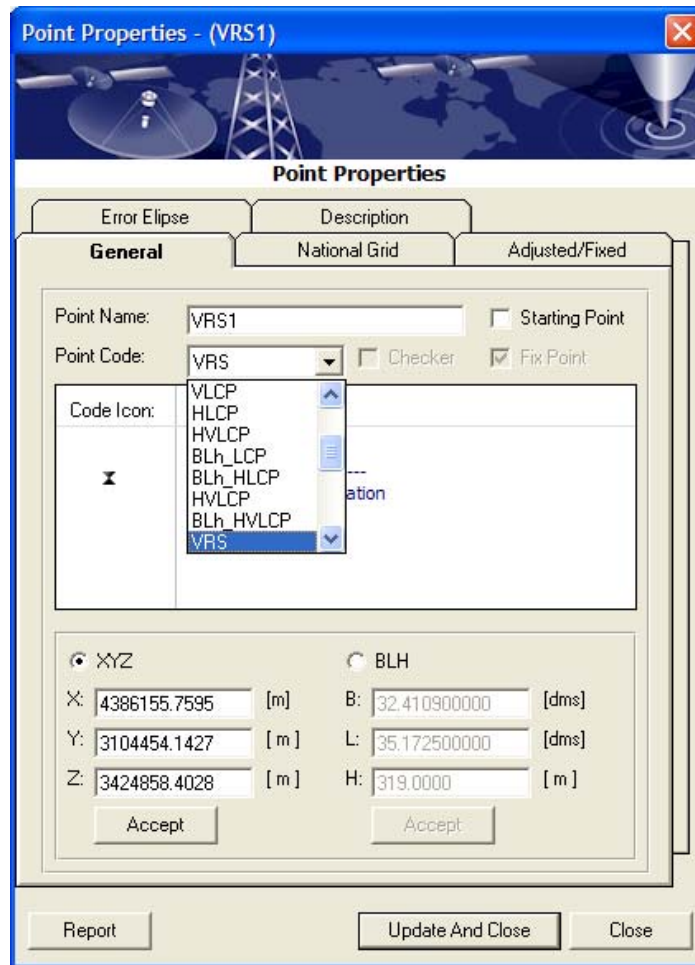Eilat, Israel, 3-8 May 2009

Figure 7: Choosing the type of the points' project in the Major software

- To choose the regulations' method from the Major regulation control panel which includes all the Israeli regulations' instructions' method (see figure 8).
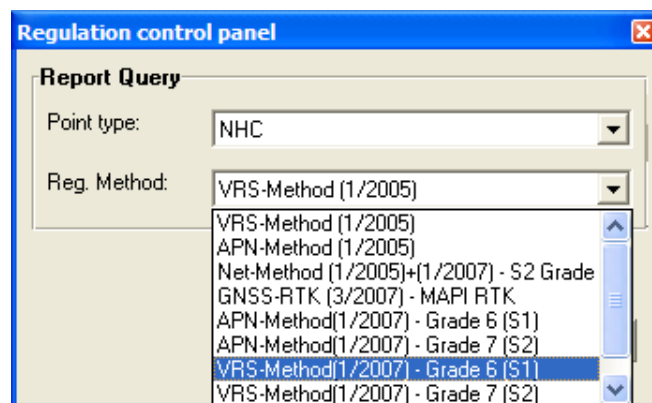

Figure 8: The control panel of the regulation model of the Major

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- Finally, user should run the regulations method for generating full detailed report that includes all the project details, method criteria, final coordinates as well as the result of the criteria with fail or pass sign. Figure 9 illustrates a part of the full detailed report of the regulations module of the Major software.

VRS1		732898.5959		228512.9143

Differences

Fix Points	DN	DE	DL	Test Result
VRS2-VRS1	0.0011	0.0066	0.0067	PASS

881MZI

Fix Point Name	N	E
VRS2	733062.7973	228411.9086
VRS1	733062.7811	228411.9059

Differences

Fix Points	DN	DE	DL	Test Result
VRS2-VRS1	0.0162	0.0027	0.0164	PASS

Regulation Rule ID 30

The difference between the measured horizontal poisition and licensed one of the checker points calculated from IGD2005 coordinates shall not exceed X [m]...

For Structure regulation test After Computation

Regulation Parameters Table

X [m]	EWP	HorV
0.04	Pass	Horizontal

Checkers Reports

504U

Differences

Checker Point Name	Calculated Coordinates			Licensed Coordinates			Rule Results			
	North [m]	East [m]	H [m]	North [m]	East [m]	H [m]	DN	DE	DL	Test Result
504U	730929.8909	227478.7436	147.8374	730929.9100	227478.7500	126.8720	-0.0191	-0.0064	0.0201	PASS

Figure 9: A part of the full detailed report of the regulations' module of the Major software. At upper part of the figure the report shows the coordinates differences between the two VRS sessions. The last part shows the result of the criterion of the 4 cm difference between the measured and the licensed coordinates of the checker point.

6. USING MAJOR FOR OPTIMIZING THE VALIDATION TIME

The Major development staff recommends the survey agency to check the GNSS Rinex observations. While they meet criteria related to the DOPS and the occupation independency, such as number (6) and (7) mentioned above in section 5.2, *immediately* when the cadastral measurements project is submitted for checking. This recommendation might minimize the turn time of the licensing cadastral points process, because the survey agency can immediately return back to the surveyor an automatic report contains initial results. This report is generated by the standalone Rinex module and details all the passed/failed quality criteria related to the Rinex GNSS observations. In this situation, the surveyor can go back immediately to the field to fix his work instead of waiting for several weeks to get them back with negative results. Only the passed reports' projects will be checked in abridge path because in this situation the officers of the survey agency can trust the GNSS processed vectors and use it for computations.
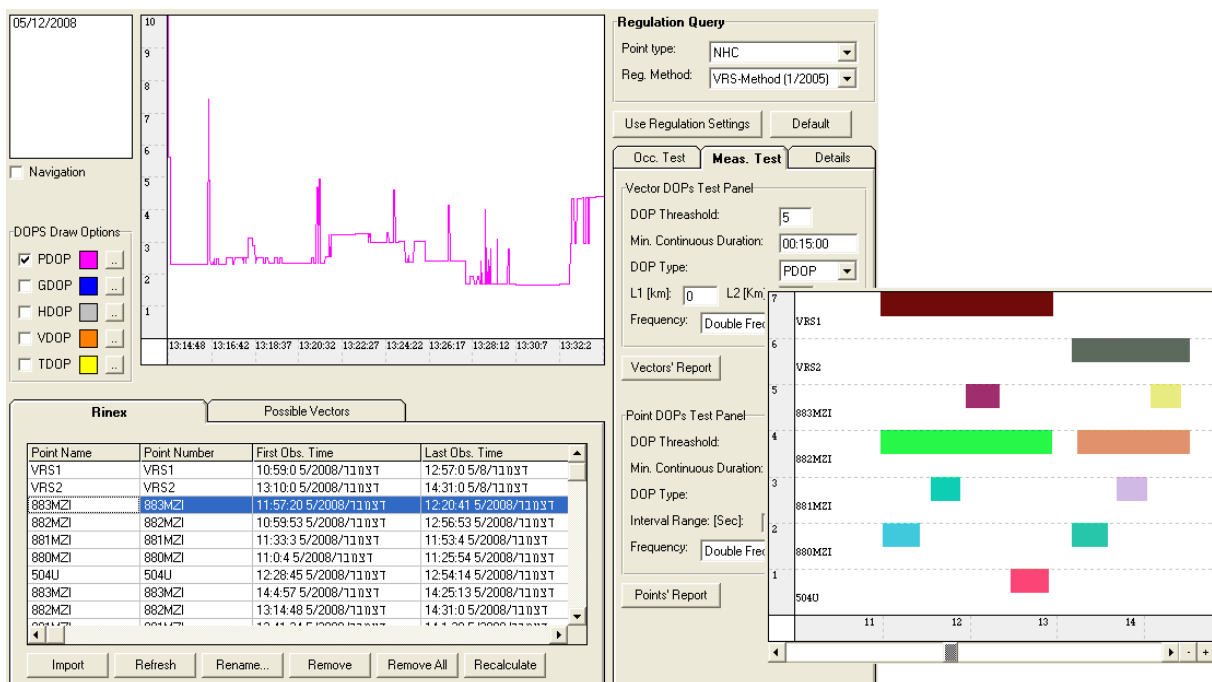

Figure 10: The Major Rinex module that enables user to check his Rinex GNSS observation quality parameters whereas they meet the criteria of the regulations' instructions.

Figure 10 describes screenshots of the Major Rinex module that enables user to check and validate the DOPS values of single and multi-stations observations as a suitable solution for the problem mentioned in section 3 above. The Major generates DOPS reports computed all the DOPS values and their passed or failed results for checking, whereas they meet the regulation criteria (see figures 11).

In addition, the Rinex module checks whether the station observations are independent or not by computing the time between the start and the end of consequence observation whereas they exceed a desired criterion limit of the same stations as well as computes the difference in the

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antenna heights. Finally it lists all station points' occupations with passed or failed sign that indicates if the new point was measured independently according to the regulations' instructions' criteria (see figure 12).

Regulation Criteria

Type of DOP	PDOP
Maximum allowed DOP	5
Minimum passed and continuous epochs	00:15:00
Frequency	Double Frequency

Name	Frequency	Start	Duration	Interval	Epochs	Cont. Found	Result
VRS1-883MZI	Double Frequency	05/12/2008 11:57:20	00:23:21	1	1403	00:23:21	PASS
VRS1-882MZI	Double Frequency	05/12/2008 10:59:53	01:57:00	1	7022	01:57:00	PASS
VRS1-881MZI	Double Frequency	05/12/2008 11:33:03	00:20:01	1	1203	00:20:01	PASS
VRS1-880MZI	Double Frequency	05/12/2008 11:00:04	00:25:50	1	1552	00:25:50	PASS
VRS1-504U	Double Frequency	05/12/2008 12:28:45	00:25:29	1	1531	00:25:29	PASS
VRS2-883MZI	Double Frequency	05/12/2008 14:04:57	00:20:16	1	1218	00:20:16	PASS
VRS2-882MZI	Double Frequency	05/12/2008 13:14:48	01:16:12	1	4574	01:11:40	PASS
VRS2-881MZI	Double Frequency	05/12/2008 13:41:24	00:20:06	1	1208	00:20:06	PASS
VRS2-880MZI	Double Frequency	05/12/2008 13:10:34	00:23:27	1	1409	00:23:27	PASS
883MZI-882MZI	Double Frequency	05/12/2008 11:57:20	00:23:21	1	1403	00:23:21	PASS
882MZI-881MZI	Double Frequency	05/12/2008 11:33:03	00:20:01	1	1203	00:20:01	PASS
882MZI-880MZI	Double Frequency	05/12/2008 11:00:04	00:25:50	1	1552	00:25:50	PASS
882MZI-504U	Double Frequency	05/12/2008 12:28:45	00:25:29	1	1531	00:25:29	PASS
883MZI-882MZI	Double Frequency	05/12/2008 14:04:57	00:20:16	1	1218	00:20:16	PASS
882MZI-881MZI	Double Frequency	05/12/2008 13:41:24	00:20:06	1	1208	00:20:06	PASS
882MZI-880MZI	Double Frequency	05/12/2008 13:14:48	00:19:13	1	1155	00:17:24	PASS

Figure 11: The Major DOPS reports computed all the DOPS values and their passed or failed results for checking, whereas they meet the regulation criteria.

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Figure 12: One of the several reports generated by the Major Rinex module for computing independent occupations for each point in the cadastral GNSS project.

7. SUMMARY

The Major software main principle for executing full automatic computation and validation of the regulations' instructions, and criteria is presented in the paper. The VRS Israeli current regulations method have been shown as an example for working according to well defined method by Major which includes computations and validations all together. Accordingly, several regulations instructions' method exist in the Major library in addition to other that could be defined using the Major library of criteria and computation method as well as the datum and control grid definition module. This makes Major suitable for all other countries, by little effort that could be spent on creating the regulations methods in every country and saving them in the Major regulation control panel database.

At present, the RTK GNSS virtual base technology is being used by most of the surveyors. This technology will institute the "total station" of the future for almost every surveying office. RTK observations are GNSS vectors that could be used as an input for the Major software. Thus, RTK GNSS observations project could also be computed by Major in order to be sure that these observations are meeting the criteria. Since the regulations' RTK methods are being assimilated by Major, it shall have an important role in building the future LDC database.

Finally, the recommendation of the Major staff for start using the regulations' Rinex module in Major might bring a real profit for the survey agency as well as for the surveyors in order to accelerate the licensing process of GNSS work. It will as well, minimize situations in which coordinates have licensed without meeting the criteria for preserving the desired accuracy of the LDC coordinates' database.

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BIOGRAPHICAL NOTES

Jad Jarroush was born in Nazareth in 1977; he received his B.Sc. in Geodetic Engineering in 2000 with honors. In 2002 he received the B.Sc. in Civil Engineering with honors too and the M.Sc. certificate in Geodetic Engineering as well. All are at the Technion. He is currently a graduated student at the faculty of Civil and Environmental Engineering, division of Transportation and Geo-Information Engineering as a Candidate for Ph.D. degree in Mapping and Geo-Information Engineering. Before few month has been passed the final exam of the PhD. He is also head of research and software development of Zeibak and Sabbagh L.T.D Company in Nazareth and the same of Zaid Orniv L.T.D Company in Ramat-Gan.
His main fields of interest include: Cadastre, 3D Cadastre, Dynamic Cadastre, Legal Digital Cadastre, GPS RTK, VRS GPS, VRS RTK GPS and 3D infrastructure presentation models.

Bishara Khell was born in Nazareth 1968, he studied music composition at the Jerusalem academy of music. The relation between music and math leads him to computer science. In 1997 he used to teach software programming in Mar-Elias College in 2001 he worked in Alpha-Omega (solutions for neuroscience and neurosurgery). In 2005 he established AltDoIt

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Software Solutions where He currently works as manager. Bishara was involved in GPS software development since the year 2000. He currently works also in Zeibak & Sabbagh LTD. as a software project leader.

Marwan Zeibak graduated from the Technion Institute since 1979 and received his B.Sc. in Geodetic Engineering. He received the license surveyor in 1981. Participated in constructing the road between Israel and Egypt in 1982. Today he is a CEO general manager of Zeibak & Sabbagh L.T.D that was established since 1980, one of the biggest surveying companies in Israel that includes 33 employees (about ten surveying staffs), GPS department , research department , and Software department.

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