Evaluation Performance Comparison of Surveying and Mapping Systems for Updating the City Geospatial Progress

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1 ABSTRACT

The update of current geospatial data progress at the city scale is utilizing the normal data collection techniques such as GPS, Total Station and level equipments. Due to limitation and complexity of using these techniques on the city scale, where it needs a proper geodetic network to establish a mesh of control points prior to precisely conduct any physical data collection. On the other hand, the needed resources are also huge to run these techniques on the city scale and in daily bases; where the accuracy of the data will be affected and not consistent due to large number of involved resources performing different quality.

The development of new methodologies and using new techniques are needed to facilitate the daily update of the city geospatial development progress to precisely allocate the location of services to significantly enhance the overall maintenance and operation performance.

The technical comparison between the most common surveying technologies provides a more obvious performance understanding for each technology. Each technology has been evaluated based on several efficiency factors; each efficiency factor measure's the technology performance in that particular factor.

2 BACKGROUND

Bernardini et al., (2002) mentioned that in most situations, a single scan will not produce a complete model of the subject. Multiple scans, even hundreds, from many different directions are usually required to obtain information about all sides of the subject. Curless (2000) argues the variety of technologies for smartly acquiring the shape of a 3D object. Schmidt et al., (2007) mentioned that the GNSS-receivers are becoming more and more efficient, smaller in size, weight and price which results in the fact that GNSS-receivers are nowadays a mass product. Wanyun (2010) says as of 2010, the United States NAVSTAR Global Positioning System (GPS) is the only fully operational GNSS.

The Russian GLONASS is a GNSS in the process of being restored to full operation (21 of 24 satellites are operational). Schwarz et al., (2007) discuss a process which was mainly driven by the need of highway infrastructure mapping and transportation corridor inventories. Cameras, along with navigation and positioning sensors, e.g., GPS, and inertial devices such as IMU, were integrated and mounted on a mobile vehicle for mapping purposes. Objects can be directly measured and mapped from images that have been georeferenced using navigation and positioning sensors. Zhang et al., (2003) discuss the latest development and evolution of surveying and mobile mapping technologies that opens new avenues for the acquisition, update, fast and online processing of data. Jeong et al., (2006) provide an effective base for the management of information on construction and repair of highway and its auxiliary facilities. Cracknell et al., (2007) emphasis that the non-metallic objects, such as rain and rocks produce weaker reflections and some materials may produce no detectable reflection at all, meaning some objects or features are effectively invisible at radar frequencies. Ying Cao et al., (2009) investigate an interoperable framework to disseminate earth Science data to different application domains. The proposed framework can manage different Earth science data products and raster snapshots over time through the use of relevant metadata information. Liu Yong et al., (2007) evaluate the effectiveness of radar data processing, it is necessary to have an evaluation System of Radar Emulation. According to the requirement of the real-time, accurate and vivid display of the radar data processing efficiency in modern battle field emulation also discussed. Omar Munyaneza et al., (2009) discussed the required time of satellite radar altimetry in order to measure the time required for a pulse to travel from the satellite antenna to the earth's surface and back to the satellite receiver.

3 INTRODUCTION

The conducted research is oriented to implement one of the smart Geospatial updating for some of the smart city components. The implementation of the research focus on updating of polyethylene city infrastructure networks using laser scanning technologies from the surveying and data collection perspective. The research has investigated a new perspective of the laser scanners which is the mobile (mounted on top of vehicle) scanner integrated with complete navigation and orientation platforms. This chapter is discussing an evaluation of geospatial technical comparison between RTK GPS, Total Station, GNSS reference station, static laser scanning, mobile laser scanning and aerial photographs in terms of collecting the spatial data. The geospatial technology achieved the best evaluation performance is subject to more deep analysis and investigation for developing a mathematical model to detect the daily progress of the polyethylene city infrastructure networks.

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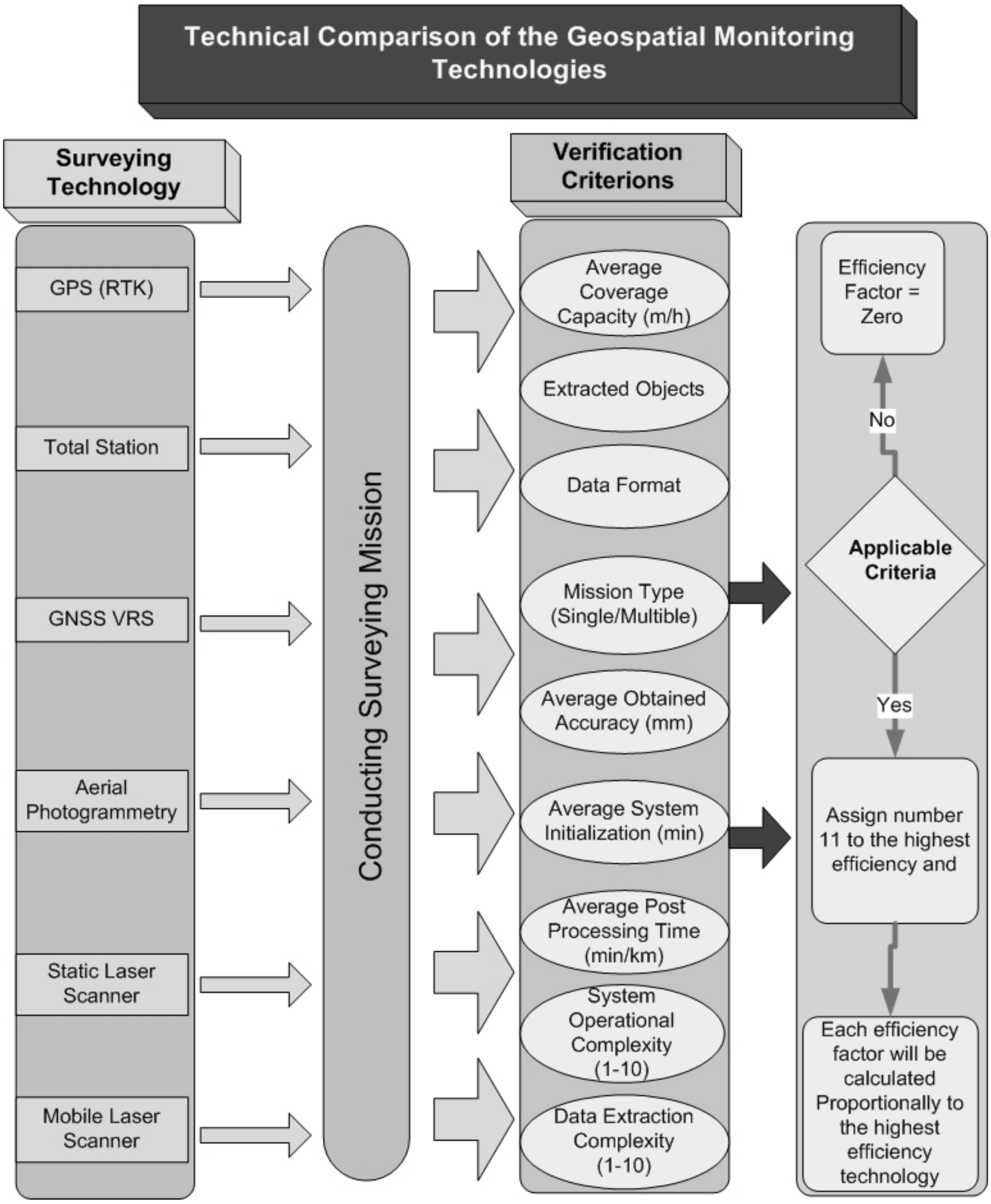

Fig 1: Technical comparison of the geospatial updating technologies.

In the sense of GIS and geospatial applications, the research has conducted two surveyed sites in UAE, Dubai in order to reflect/monitor two kind of utility infrastructure networks. The validation area is about 300 m width and 2 km length, where it is currently in the infrastructure development. Currently the deep utility networks such water transmission, electrical transmission, district cooling; sewer and storm water are still ongoing. The research is to utilize the mobile laser scanning in several missions to survey the several pipe diameters for both distribution and transmission networks in order to check the practicality of implementing the new smart geospatial updating technique.

4 TECHNICAL COMPARISON BETWEEN THE GEOSPATIAL UPDATING TECHNOLOGIES

The research conducted a technical comparison between the common geospatial updating technologies in order to evaluate efficiency factor for each geospatial updating technology. The technical comparison methodology has been designed based on identifying most of functionalities and capabilities adopted in each technology. The average coverage capacity, extracted objects, data format, mission type, average obtained accuracy, average system initialization, average post processing time, system operational complexity, data extraction complexity are the investigated functionalities, where each function has an efficiency factor. Each surveying technology will be subject to mission data collection and data extraction, where some of surveying technologies are not applicable with all efficiency factors. Taking into consideration that some of criterions cannot be precisely measured like measuring the system complexity, accordingly these criterions will be estimated.

5 EVALUATION OF RTK GPS AND MOBILE LASER SCANNING NAVIGATIONAL GPS

A geospatial technical comparison has been conducted between RTK GPS observations and mobile laser scanning navigational GPS observations. The RTK rover antenna has been mounted on top of the car besides the mobile laser scanning GPS unite. The RTK GPS observations have been conciliated with the RTK GPS base station during the post processing. The mobile laser scanning navigational GPS observations have been conciliated with the observations collected from the GNSS reference station. The combination of the navigational GPS and the GNSS reference station observations is generating more enhanced accuracy. In order to compare the obtained accuracy for each technique, the matching in easting and northing is needed, where there is an acceptable tolerance (10 cm) in the horizontal location. The matching in horizontal location is the base for comparing the vertical accuracy, where each technique is measuring the same Z value with respect to technique level of accuracy. Fig 2 shows the matched and directions not matched horizontal locations for both RTK GPS and mobile laser scanning GPS observations. The matched observations (points having the same XY coordinates) used to compare the obtained Z values. Each not matched point has a shift in certain direction, the reference point of the shift directions are the RTK GPS points.

The collected XYZ points from RTK GPS system and mobile laser GPS system having slightly different accuracy level. The RTK GPS points have been adjusted based on the base station, where the mobile laser scanning GPS points have been adjusted based on the combination of GNSS corrections while conducting the post processing. The adjustment of the RTK GPS points implemented on the fly using the radio link. The GNSS reference station is having more observations in less epochs for more satellites (GPS & GLONASS) than collected in the GPS base station. The difference in number of observations between GNSS reference station and GPS base station generates difference in observations accuracy.

The vertical positioning (Z values) is the base of building up an accurate 3D models for the modeling the collected city infrastructure polyethylene pipelines and other features. The research investigates the Z differences and considers it as a base for evaluating the positional accuracy between the RTK GPS observations and the mobile laser scanning GPS observations. Prior conducting the vertical positioning comparison, the horizontal positioning for the two points (RTK GPS point and mobile laser GPS point) must be matched. The points matching cannot be obtained without resolving the accuracy discrepancies; the accuracy discrepancies could be generated in X direction or in Y direction. The elimination of the discrepancies is difficult to be modeled for each direction separately; where it can be combined in one complex number and conduct the linear matching accordingly. The generation of complex number is must be rounded with respect to the accuracy for RTK GPS observations accuracy and mobile laser scanning GPS observations accuracy in order to avoid the improper miss matching. The observations rounding for X direction and Y direction for RTK GPS and mobile laser scanning GPS is 10 cm. The rounding is calculated

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based on the average horizontal positioning RMS generated in the RTK GPS; where the GNSS has 3 cm average RMS accuracy. Due to the tolerance in the horizontal location and the need of conducting a high accuracy assessment; the collected observations needs some filtrations before conducting the matching and rounding activities.

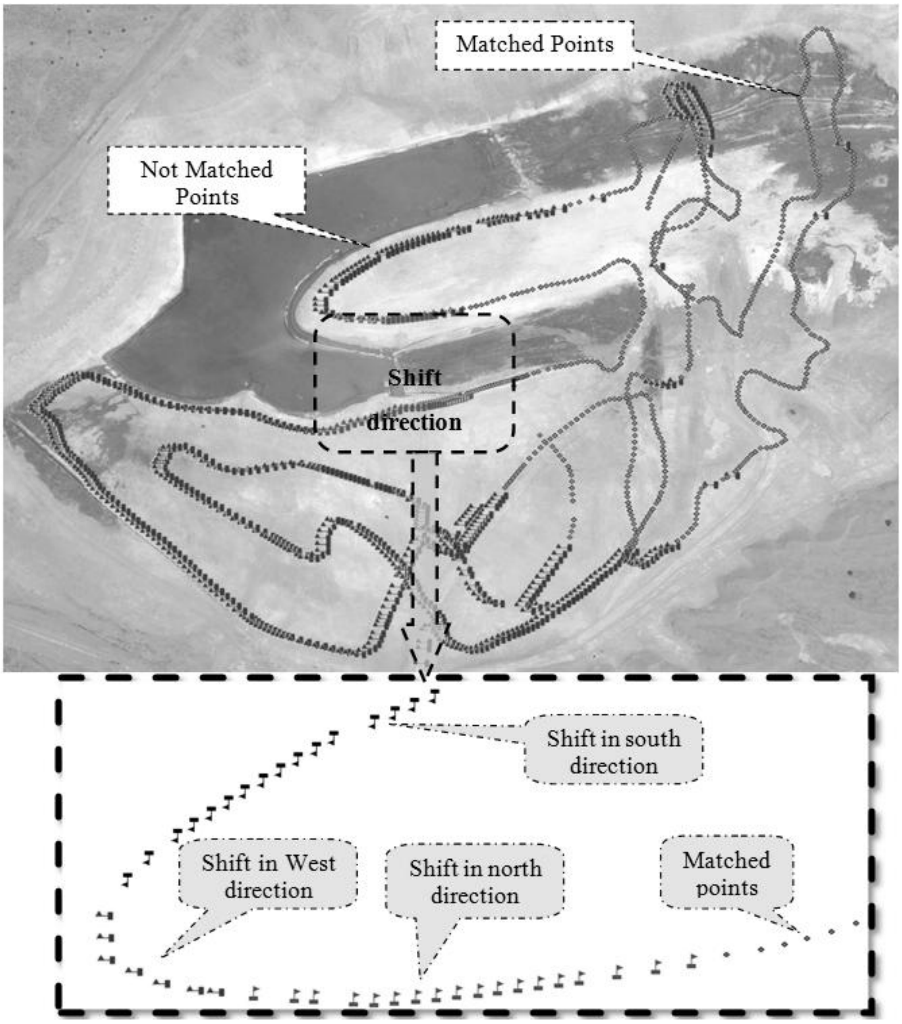
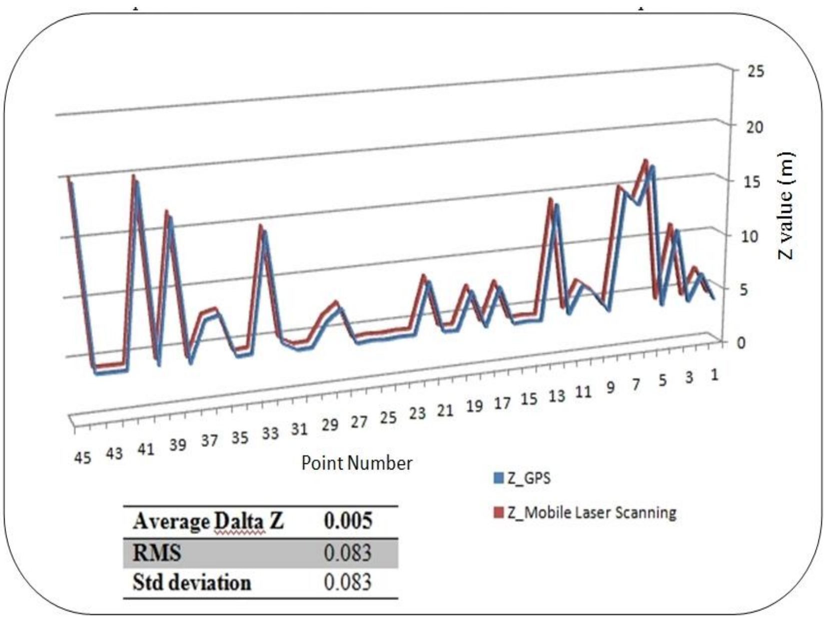


Fig 2: Matched and directions of not matched RTK GPS points with mobile laser scanning GPS.



Average Dalta Z	0.005
RMS	0.083
Std deviation	0.083

Fig 3: RTK GPS and mobile laser scanning accuracy assessment.

The relation between each two points, since each point has approximate matching in XY and Z; then the linear filtering will produce better accuracy assessment. The linear filtering can be achieved by producing complex numbers by concatenating X and Y in one complex number for both RTK GPS points and the mobile laser (GPS points). The complex number is generated based on the rounded XY coordinates (10 cm) for the RTK GPS and mobile laser scanning GPS. The matched horizontal coordinates are subject to compare the Z values; where the horizontal positioning is known and accordingly the variation in vertical positioning for the RTK GPS and mobile laser scanning GPS can be investigated and modeled. After utilizing complex numbers matching, the matched filed observations for both RTK GPS and mobile laser GPS are about 528 matched points where 604 not matched. Fig 3 shows the accuracy assessment of the first 45 points, where the root mean square has been calculated for the all Z values for the matched points.

6 EVALUATION OF STATIC LASER SCANNING

The evaluation of static laser scanning specially in the terms of obtained accuracy, coverage capacity, system initialization, objects extraction, data format and mission type has been concluded based on conduction of two static laser scanning missions. The two static laser scanning missions conducted different type of scanners; one mission using Lieca scan station 2 and the other using Trimble GX standard scanner. The reason of using different types of scanners is to evaluate the capacity of static laser scanning independently. The area of interest is about 0.126586 Sq km, where the best RMS value is 4.8 cm and the lowest operation time is 4 hours; Table 1 presenting the summary of results for each scanner type.

Trimble Scanner (GX Standard)		
	Area	0.126586 Sq km
	RMS	20 cm
	Stations	6
	Points Collected	576,069
	Time (hr)	6
Leica SCAN STATION2		
	Area	0.126586 Sq km
	RMS	4.8 cm
	Stations	4
	Points Collected	4,265,519
	Time (hr)	4

Table 1: Results summary for each type of scanner.

The static laser scanning needs known control point prior conducting the mission in order to georeference the collected point cloud data. The accuracy validation process implemented using known locations inside the scanned areas, while these known locations (sharp angles of some features like stones) are observed using precise GPS surveying technique (2 to 5 cm). After conducting the scanning and post process the observed point cloud data prior generating the 3D surface model, the coordinates of the known points (XYZ) compared with the coordinates extracted from the generated 3D surface. The difference in horizontal and vertical coordinates considered to evaluate the positional accuracy of the static laser scanning. The collected point cloud data using static laser scanning utilized to build up the 3D surface model. In order to have the same area for comparative purposes; the boundary of the area has been identified by set of surrounding known control points.

7 EVALUATION OF AERIAL PHOTOGRAPHS

The evaluation of aerial photogrammetry in the terms of obtained accuracy, coverage capacity, system initialization, objects extraction, data format and mission type has been concluded based on conduction an aerial photogrammetry mission. The mission is conducted in the same area of interest where the static laser scanning missions conducted in order to precisely compare the system initialization, coverage capacity and obtained accuracy among other technologies. Three aerial photogrammetry missions conducted in the same area but in different areas overages in order to conclude better evaluation especially in the sense of coverage capacity, operation time and obtained accuracy. The research conducted short, medium and long term missions for better validation. The area of short term mission is about 12.44 Sq km, where the RMS value is 30 cm; the area of medium term mission is about 43.9 Sq km, where the RMS value is 18 cm. The area of the long term mission is about 27.32 Sq km, where the RMS value is about 28 cm. the average obtained RMS is about 25 cm, where the average area coverage per kilometer is about 10 km/hr, refer to Table 2.

Mission	*Area coverage (km^2)*	*time (hrs)*	*Area (km^2/hr)*	*RMS (cm)*
1	12.44	1.3	10	30
2	43.9	5	9	18
3	27.32	2.5	11	28
		Average	10	25

Table 2: Summary of aerial photogrammetry missions.

The coverage capacity, obtained accuracy, system initialization, objects extraction, data format, post processing time and mission type technical comparisons are based on physical verification and observations. Due to the importance effect of the system operational complexity and data extraction complexity; the evaluation emerged based on qualified surveyors and engineers experience.

8 RESULTS OF THE GEOSPATAIL TECHNICAL COMAPRISON AND OVERALL EVALUATION

The final rating is shows the performance of using the mobile laser scanning technology in general field survey activities especially on the city scale data collection and progress updating. The positive rating of the mobile laser scanning technology is strongly supporting the utilization of this technology in city infrastructure updating; where new methodology and mission planning is required to utilize the best capabilities in the sense of geospatial updating. The research considers the laser scanning technology as a main platform for reflecting the physical geospatial city activities conducted on the city infrastructure networks. The aim of using the city infrastructure as a base of the overall geospatial city updating and surveying is the high interaction between the city infrastructure networks and the overall city operations including the utility services.

The average operational coverage capacity efficiency factor is measuring the technology site data capturing productivity. The coverage capacity is also indicating practicality and usability of the technology from the users. The best average operational coverage capacity efficiency factor was achieved by using aerial photogrammetry; where the efficiency factor is 11 (most efficient utilization). The worst average operational coverage capacity efficiency factor was achieved using total station technique; where the efficiency factor is 0.6 (lowest efficient utilization, only 5.5%). However, dynamic laser scanning efficiency factor was the second best average operational coverage capacity efficiency factor.

The object extraction efficiency factor is also measuring performance of the overall data production. The object extraction is related to the data format and the data completeness within the same mission. The good coverage efficiency drives better data completeness within the same mission and accordingly better data extraction. The best objects extraction efficiency factor was achieved by using dynamic laser scanning and static laser scanning; where the efficiency factor for both techniques are 10 (91% utilization). The aerial photogrammetry is also provides very good efficiency factor. The worst objects extraction efficiency factor was achieved also using total station technique; where the efficiency factor is 1 (9% utilization). However, GNSS VRS and GS RTK techniques are also provide bad objects extraction efficiency factors.

The data formatting efficiency factor is measuring the level of integration between the systems. The vector data format can be easily and more performed in the sense of data integration, import and export functionalities. Raster data format needs more editing and extraction efforts to enhance the data extraction/production activities. The best data formatting efficiency factor was achieved by using all surveying techniques (dynamic laser scanning, static laser scanning, GNSS VRS, total station and GPS RTK) except aerial photogrammetry; where the efficiency factor is 11 (100% utilization). The reason of bad data formatting efficiency factor for aerial photogrammetry is the resulted raster data format; where the efficiency factor is 4 (36.4% utilization).

The mission type (single/multiple) is measuring the capability of the surveying technique in conducting more data capturing planes for different purposes in the same mission. The best mission type efficiency factor was achieved by using dynamic laser scanning and static laser scanning; where the efficiency factor is 11 (100% utilization). Aerial photogrammetry provides very good mission type efficiency factor; where the factor is 7 (36.6% utilization). The worst mission type efficiency factor was achieved using GNSS VRS, total station and GPS RTK techniques; where the efficiency factor is 2 (18% utilization). However, aerial photogrammetry efficiency factor was the second best average operational coverage capacity efficiency factor.

The obtained accuracy efficiency factor is key performance indicator for the overall surveying operations. The accuracy is highly dependent on the surveying application, technique and the expected resulted production. With respect to data capturing and data production for city infrastructure networks; the accuracy level shall be in centimeter level; where the majority of distribution networks are less than 15 cm diameter. The best average operational obtained accuracy efficiency factor was achieved by using dynamic laser scanning, static laser scanning and total station; where the efficiency factor is 11. The worst average operational obtained accuracy efficiency factor was achieved using aerial photogrammetry; where the efficiency factor is 3.3 (30% utilization). However, GNSS VRS and GPS RTK factors were provided an acceptable efficiency.

The system initialization is measuring the time consuming for making the system up and running and ready to surveying. The initialization efficiency factor is affecting the overall system performance. The best average operational system initialization efficiency factor was achieved by using GNSS VRS; where the efficiency factor is 11. The worst average operational system initialization efficiency factor was achieved using aerial photogrammetry, static laser scanning, dynamic laser scanning and GPS RTK techniques; where the efficiency factor is 1.2 (10.9% utilization), 1.8 (16.4% utilization), 2.4 (21.8% utilization) and 2.4 (21.8% utilization) respectively. However, total station efficiency factor provided an acceptable efficiency factor.

The post processing efficiency factor is mainly measuring the geometrical corrections, color balancing (for image production) and overall data production. The post processing can be exempted if the real time correction functionality is available. The research is debating the utilization of post processing correction using the GNSS VRS data. The best average post processing time consumption efficiency factor was achieved by using GNSS VRS and GPS RTK technologies; where the efficiency factor is 11. The worst average post processing efficiency factor was achieved using aerial photogrammetry technique; where the efficiency factor is 1.2 (10.9% utilization). However, total station, dynamic laser scanning and static laser scanning efficiency factors provided very good post processing efficiency factors. The system operational complexity efficiency factor is measuring the usability of the system from the end user and it needs high level of resources qualifications. The high complex system requires more qualified resources; where it needs more operational support, training and cost. The best system operational complexity efficiency factor achieved using dynamic laser scanning and GNSS VRS technologies; where the efficiency factor is 11. The worst system operational complexity efficiency factor was achieved using aerial photogrammetry technique; where the efficiency factor is 6.1 (55.5% utilization). However, GPS RTK, static laser scanning and total station efficiency factors provided high efficiency factors.

The data extraction complexity is very important factor; where it measures the performance of the data production. The data extraction complexity can be recognized for only the multiple mission type; where the single mission type having only single data production which in most cases having automatic or semi-automatic extraction tools. The multiple mission type having varies types of features and each feature is subject to be extracted. The data extraction complexity is mainly related to data format in the sense of vector or raster data format. The best data extraction complexity efficiency factor was achieved by using dynamic laser scanning; where the efficiency factor is 11. The lowest data extraction complexity efficiency factor achieved using aerial photogrammetry technique; where the efficiency factor is 6.1 (55.5% utilization). However, static laser scanning efficiency factor was the second best data extraction complexity efficiency factor. The overall efficiency factors evaluation concluded by gathering and averaging all efficiency factors for each surveying technology. The overall efficiency factors are measuring the each surveying technology from general perspective considering the nine technical factors. The highest efficiency factor achieved using dynamic laser scanning; where the efficiency factor is 7.6 (69.1% utilization). The lowest overall efficiency factor achieved using total station technique; where the efficiency factor is 4.8 (43.6% utilization). However, GNSS VRS, static laser scanning, aerial photogrammetry efficiency factors provide good overall efficiency factors.

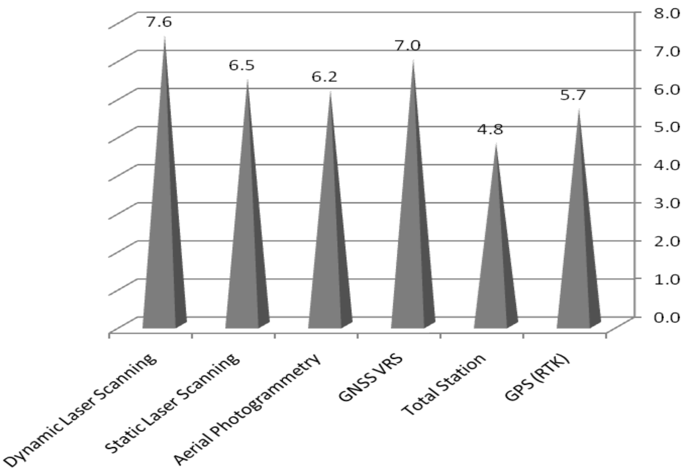


Fig 4: Overall efficiency factors evaluation.

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