The Reasons to Succeed and to Fail a GNSS RTK Positioning Infrastructure Project

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SUMMARY

Most of the GNSS Network RTK projects have been developed by the economical justification that an active geodetic network would reduce the cost of maintaining a traditional geodetic network where the maintenance of the benchmarks and the control survey were a significant part of the owner's budget.

A GNSS Network RTK can also be justified where there was no geodetic network to assist the creation and the maintenance of a Spatial Data Infrastructure to support land governance and cadastre operations. We also have seen the decision to deploy such technology as part of prestige from governmental organizations but without a clear analysis of user's need and business plan leaving such positioning infrastructure with only few users and a request to re-engineer the approach.

The authors have been in charge of both the development of the technology and also on the promotion, the design and the implementation of numerous GNSS Network RTK positioning infrastructures worldwide. That paper is dealing with the reasons the authors have indentified to make such project a success or a failure.

Is there still a future for such infrastructure and what would be the conditions to make them sustainable? What is the real economy? Is selling corrections the only product and how the users are prepared to pay for a service that could be still delivered by setting up their own local GNSS Base Station? How to deal with the security that most countries are concerned with in term of releasing precise coordinates? Will we be able to cope with the new constellations signals? Is Precise Point Positioning the technology that will make the GNSS Network RTK obsolete? Where are the hidden costs and how much the communication infrastructure is affecting the operation expensive?

Most of those questions are open and must be reviewed to conclude about the possible changes needed to consider an investment in a GNSS Network RTK of a great value and how optimizing and re-engineering an existing GNSS Network RTK can be carried out and beneficial for the owners of such positioning infrastructure.

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1. INTRODUCTION

A continuously operating GNSS reference station - or permanent reference station as it is often called - comprises a GNSS receiver and antenna set up in a stable manner at a safe location with a reliable power supply. The receiver operates continuously, logging raw data, perhaps also streaming (continuously outputting) raw data, and often outputting RTCM and DGPS data for transmission to RTK, GIS and GPS and GNSS navigation devices. The receiver is usually controlled by a computer that can be located remotely if necessary. The PC will usually download data files at regular intervals and pass them to a bulletin board or web site for access by the GPS user community.

One or more single reference stations supplying GNSS services in the immediate surrounding areas may be all that is required by some organizations. Other authorities, however, may need to establish networks of reference stations - perhaps, 5, 10, 20, 50, or even more - to provide complete GNSS services over entire regions and even countries. A single server running a GNSS reference station software and communicating by telephone, LAN, WAN or Internet can control all the stations in the network (PC's are not required at the receivers). *If required, the entire network can be computed automatically to determine the positions of the antennas and even to derive ionosphere-free area corrections for enhanced RTK performance.*

This brief introduction illustrates that reference stations and networks can vary considerably in extent and complexity.

Organizations that are studying the establishment of reference stations should consider carefully what they will be used for, what services they will have to provide, and what will be the appropriate levels of sophistication and cost.

2. WHAT ARE GNSS REFERENCE STATIONS USED FOR?

The first reference stations, in the days when GPS was in its infancy, were set up along coastlines to transmit DGPS corrections to improve the accuracy of ship navigation.

Today, with the widespread acceptance of high-precision GNSS measurement techniques, GNSS reference stations are being established all over the world in ever increasing numbers to monitor the earth's crust, to provide geodetic control, to support surveying, engineering, GIS and precise positioning, as well as to monitor natural and man-made structures and to support machine guidance systems in agriculture and construction sites.

Geodetic control for surveying, engineering and GIS

A network of continuously operating GNSS reference stations can easily replace a traditional triangulation/traverse network. The stations can be set up at convenient locations in areas where they are needed (rather than on remote hilltops). Network geometry is not as critical as with traditional networks, and the accuracy is higher and more consistent. Users set up their field receivers in the areas in which they are working, download reference station data via the Internet, and compute their positions. The stations can also transmit RTK and DGPS data for direct use by RTK and GIS field rover equipment.

Such a network can be of almost any size. Whilst one or two stand-alone reference stations may be all that is required for a local area, town and municipality, opencast mine or engineering site, a multi-station network will usually be needed to provide full GNSS service coverage for a large county, region or entire country.

Endless permutations

GNSS reference stations and networks can be used in many ways for many applications. Stations and networks can be set up and configured for just one particular application and one user group. Or they can be designed to be multi-functional to support a wide range of applications and a multitude of users.

A single reference station may be perfectly sufficient for a small locality. A multi-station, multi-purpose network will often be preferred for an entire region.

The permutations are endless.

3. POINTS TO TAKE INTO ACCOUNT WHEN DECIDING WHAT TYPE OF STATIONS AND NETWORK ARE NEEDED

GPS reference stations and networks are readily scalable. They can be easily enhanced and upgraded as requirements change and the number of users increases. Thus, initially, it will often be quite sufficient to establish only the stations and services that are really needed.

Afterwards, as the requirements increase, the number of users grows and additional funds are available, new stations and features can be added and the services that are provided can be improved and enlarged.

The initial investment is never lost.

- What is required?
- What applications have to be supported?
- What will the stations and/or network be used for?
- What is needed today?
- What will be needed in future?
- The area to be covered
- Where to establish the stations?
- What can be the separation distance between stations?
- The need for suitable sites with an open view of the sky
- Power, communication, security
- The infrastructure that is readily available and can be used
- The new infrastructure that has to be added
- The type of users that have to be supported
- The number of users that have to be supported
- Is it sufficient simply to log data and provide RINEX files?
- Is it also required to transmit RTK/DGPS data?
- The most suitable methods of communication between the receivers and the server
- The most suitable methods for distributing RTK/DGPS data
- The most suitable communication for distributing RTK/DGPS data
- The cost of establishing the stations and/or network
- The cost of running the stations and/or network
- The running costs for RTK and GIS rovers
- Computing the baselines between stations to check the positions of the antennas
- The budget that is available today
- The budget that will be available in future
- Charging for services and data
- Who is effectively the owner
- Who from the organisation will be effectively in charge of supervising the system
- What is planned for promoting the services
- What is the vision over the next 5 years
- Does a business plan and a financial plan available

5. CHARGING FOR PRODUCTS SUCH AS RINEX AND RTK/DGNSS DATA.

Reference stations and networks require significant investments.
Running costs, particularly for networks, have to be considered.

Some organizations establish standalone reference stations or networks purely for their own use. Other organizations provide products and services for the GPS user community: they allow access to RINEX files and possibly raw data files on an FTP server, they distribute

RTK and DGPS data, and they may even provide transformation parameters in order that RTK and GIS rovers can easily transform WGS84 values into the local coordinate system.

If users of GNSS rover receivers are able to obtain the required data easily and reliably from permanent reference stations, they derive benefits from the services and do not need to invest in additional receivers for use as temporary field references.

Many organizations that operate reference stations and networks are interested in recovering at least part of their investment and covering their running costs. They would like to charge for the data and the services that they provide.

With the advent of new satellite constellations (COMPASS/BEIDOU, GALILEO) provisional budget must be consider to upgrade the installation on both hardware and software knowing that replacing the most sensitive element – the GNSS antenna – will force for having a new set of very precise coordinates.

6. ECONOMICAL JUSTIFICATION FOR A GNSS POSITIONING INFRASTRUCTURE

It is well recognized today that a reference network comprised of permanent GNSS stations provides the fundamental infrastructure required to meet the needs of professional GPS users in many areas of surveying and mapping. Examples of applications are found in survey control work, densification of existing geodetic networks, acquisition of data for GIS applications, cadastral operations, determination of fiducial points for photogrammetric work, monitoring of engineering works, mapping of utility corridors, assets, etc. In fact, the number of applications benefiting from the establishment of permanent networks seems to be growing daily.

The widespread use of RTK GNSS and DGNSS techniques has encouraged decision-makers to look for ways to replace traditional geodetic networks with networks of permanent GPS reference stations. For example, a tighter control of the networks can be achieved from the data supplied by permanent reference stations both in post-processing and in real-time. With streaming data, the influence of those spatial and temporal errors affecting GPS measurements can be estimated in real-time. This in turn means the quality of the transmitted corrections is improved and the range of RTK GNSS increased.

7. CAN THE COSTS ASSOCIATED WITH PERMANENT GNSS NETWORK BE RECOVERED?

The majorities of permanent GPS networks have been, and will continue to be for some time to come, initiatives primarily from government agencies.

These government entities have been able to justify the costs of implementing GPS networks by citing the approach of "preventable costs"; similar to the strategy used to finance the establishment of classical geodetic networks decades earlier. The return on the original investment is not measured in nominal terms of hard revenue but in keeping the costs borne by the industry lower than the alternative. This approach also encourages network standardization and avoids the appearance of a patchwork of private, customized networks for project-specific purposes.

The net result of these free, but limited, services has been to give the user the impression that the distribution of differential GPS corrections should remain free of charge, and that the cost of establishing and maintaining the networks, and providing services should be assumed by the network operators.

This statement is supported by the marked decrease in the number of paying users for the GNSS correction services provided by companies a few years ago. They have since struggled to remain competitive in the face of the U.S. presidential decision to turn off Selective Availability on the GNSS signal.

Even today, agencies are facing an uphill battle in trying to convince potential users to subscribe to their GNSS corrections services. The primary reason is the disproportionate cost for the offered services with regard to the limited number of customers.

It may be useful to compare our present situation with that of cellular phone service providers several years ago. There is no denying that these companies are now seeing healthy profits from the various levels of wireless service they offer today. However, when the products were first introduced to the public, the companies gambled on the presupposed reliability and variety of services to lure the customers, and offset an often complex and costly infrastructure.

Evidence that their investments paid off can be found in the steady increase in the number of users over the years and the attraction for new service offerings being rolled out on a regular basis. These services are indeed new applications that users have been willing to pay for.

8. NEED FOR NEW INFORMATION BROADCAST SERVICE BASED ON GNSS NETWORK

This is not wishful thinking resulting from our infatuation with communication technologies, but truly an achievable goal. Decision-makers wish to control the quality of services based on the type of products their networks provide.

They are also committed to providing GNSS network solutions in the appropriate reference system. Coordinate transformations should not been seen purely as side products: the very purpose of permanent GPS networks is to offer a complete integrated datum-consistent solution. To those who argue that the transformation algorithms could be integrated into the rover units, and that a certain level of control can be achieved by forcing the user to calibrate his system on existing control points; we answer that in doing so, we have eschewed our responsibility for providing a complete solution.

We must add also that the software applications used to manage permanent GPS networks could, and even should, incorporate functions to monitor usage and/or charge users for services.

Provider companies have already begun to integrate user monitoring applications into their software products by including the display of user positions, recording the number of requests for specific services, and generating statistical information that form the basis for charging users.

This type of functionality is now considered essential by the GNSS Network operators giving them the ability to exercise control over their networks in order to enhance the value of their services.

The subject of increased data integrity is then creating considerable interest among GPS network operators. What if they could provide a service that bypassed the problems that users routinely encounter in processing their own data?

A reliable network service providing high-quality and high-fidelity solutions would no doubt generate significant revenue.

9. **TO SUCCEED OR TO FAIL WITH A GNSS NETWORK PROJECT**

All the previous considerations should however not hide the scope of this paper concerning the way to succeed or to fail a GNSS Network RTK project.

There is a clear indicator to measure the success or the failure of a GNSS Network project and that is the number of users actually connected to the services. Being setup as a free of charge or pay service, the number of users must generally be greater than 10 by GNSS Reference Station. For a GNSS Network of let's say 25 GNSS Reference Stations, the operator should question himself is the number of users is less than 250 while networks of 100 stations actually are not far to support 2500 users.

And with new interest of the non surveying communities such farmers and contractors it's clear that that rule of thumb must be adapted and reviewed.

If we often prefer to listen about the success, it's also in our human nature to learn by our mistakes and failures and the case of a GNSS Network does not differ than any other project with some specifics that must be carefully considered.

The most important is to remind the sentence that "how a project starts, a project ends". If a GNSS Network starts without serious investigation on user's needs and expected services delivered in term of accuracy and availability, reliability and format, it will fail. If a GNSS Network starts without reviewing and consulting with all the potential users, it will fail. Marketing is certainly important and no one will be surprised to assist a failure when few people were aware about the proposed services.

What do you mean by infrastructure?

We often refer a GNSS Network RTK as a positioning infrastructure while in general the services delivered are mainly RINEX files, corrections streams and centralized post-processing facility. Except for that last case, a GNSS Network RTK is not delivering the user's position. In Japan and in Germany there are GNSS Network RTK operators that allow the use of a Client Server RTK service where the users are streaming their rover observations to a central site and from where they get their positions processed centrally in real time.

If we compare a GNSS Network RTK with a well known communication infrastructure such a high way we could say that the road and tool gates are what we have with the system. Services can complement such gas station and shopping centre, recreational area and at first for sure emergency services, police and rescue.

That doesn't mean that the high way owner will prevent any driver to eventually crash his car or to cause an accident. The drivers are fully responsible about the way they drive. Education and sanction for strange behaviour and high speed are often used to prevent accidents but again at the end the driver is alone.

In our case, the driver is the GNSS rover user and he should first know how to use his equipment at its best, understanding that a minimum number of satellites must be in view and that the configuration (GDOP) is a key success factor.

The highway authority is our GNSS Network RTK operator and is responsible for delivering on real time the best corrections, integrity and availability. Communication is the most sensitive factor for both player and we can in our example assimilate the communication with the weather conditions if the telecommunication partner is not under control or not integrated as partner. While weather (ionosphere) can certainly also be a disturbing factor especially when we reach a peak in the solar activity which is the case today.

Also it is becoming a good practice for a GNSS Network operator to deploy several permanent rover RTK in order to monitor exactly as the users the performances of the system otherwise discussions will flow in and out about who is right and wrong.

Normally any kind of vehicles are allowed on a high way and that must be the rule here as well. Often the GNSS Network RTK infrastructure supports any brand of GNSS RTK rover by distributing standard formats such RINEX, RTCM and NTRIP protocol. But that must be explained and there is a great benefit for the GNSS Network RTK owner to deliver extensive documentation for the potential new user.

Too many times we have questions about how the existing equipment is compatible or not…

Pre-analysis, investigation and market research

That is the starting point and methods exist to not only put in face what will be available in term of service and what kind of different classes of users will be served.

That is often an easy mistake to start from the today capacity of a GNSS Network RTK in term of functionalities to derive the expected target community. That will not make the infrastructure evaluating over the time.

The right way is to question all the organisations and individual about their need in term of positioning. Accuracy, reliability, availability, cost, charging mechanism, rover equipment needed with the associated communication device and the transmission services are several of the questions that helps to drive the preliminaries.

Then a map can be drawn and at the start the future owner will have an idea about the number of potential users and what the functionalities he has to consider satisfying the needs.

Unfortunately we know cases where that analysis has not carried out properly and when the project is released there is a big disappointment when the potential users seem not interested by the services and are still considering setup their own local GNSS Reference Station.

It may be helpful to ask the support from consultants or from other organisations that did such projects successfully. The role of a consultant is critical for building a complex infrastructure so why not to consider?

Normally at that stage a business plan, a financial plan and the business model(s) must be drafted and regularly reviewed.

The network operator is not necessarily the owner

Organisations traditionally in charge of geodetic operations are often responsible for studying and deploying GNSS Networks to turn their geodetic passive network into an active one. Most of the time and by nature (governmental agencies) those organisations are not business or profit oriented and should consider in the operations a tier operator who will be responsible for making the services profitable.

We have seen cases where even the system provider or telecommunication partner has been charged for the operations and for charging the services or simply to deliver the subscriptions.

The idea to place the infrastructure for concession should be considered when the owner doesn't have experience and capacity for charging and managing the revenue of the services.

It's all about marketing

Questions rose also about how to target more users. We know projects where after several years of operation, responsible asks us how to bring more users connecting to the system. There are professional organisations that should be informed and most probably have some interest that their members are part of the user community.

We never waste our time to educate people and to teach them what exactly the system will deliver in term of benefit and also what the system will never be able at that present time to deliver.

In some place there is an annual meeting with all the users to review the services and to derive where improvements are requested and what kind of new services will be appreciated to leverage the number of users.

When users are happy with the services it's also good marketing to let them share their experiences with new coming members.

The most common reasons to fail

If we cannot list in that paper all the reasons such project will with a great probability encounter some failures there are however several points that are very sensitive

- Communications is one of the major reasons. The users complain that they cannot get the corrections all the time leading them to discouragement and lost in efficiency on the field. If not addressed properly on timely manner, such users will consider to setup back their own local GNSS Reference Station. But communication problem can also be on the infrastructure side where regularly several GNSS Reference Stations are not streaming their raw data.
- Improper coordinates is another reason to fail. Not only must the coordinates of all the GNSS Reference Stations be accurately determined in the same reference frame that the satellites precise orbits are but the transformation from that reference frame to the local grid coordinate system must be accurately addressed as well. We do know GNSS Network RTK where there is no user just because the coordinates that they can derive don't match with the geodetic control points.
- Who is operator? If the organisation in charge of delivering the associated services of a GNSS Network RTK infrastructure doesn't have 24/7 a call centre with an expert reaction to address the user's issues or to repair the system in case of down operations, the project will fail. Often there is not enough man power allocated to the project and if there is only one champion he will quickly burn out especially with success and more and more users. The people who are installing and serving the system must have a deep knowledge on the GNSS technology, communication, IT infrastructure, on site intervention etc. Last no least, we have also seen unfortunately organisation where the initiator left by leaving no one capable to take over. In that case all the investment is fading away.
- Charging too much or just for free. Organisations that has no confidence in the deliveries or organisations who most of the time don't want to take responsibility, will offer the service for free with the net result that if something is going wrong, after all no one is paying for the service when it works. On the other side, charging too much will prevent people to consider the costs if they exceed what they can manage themselves by using a local GNSS Reference Station setup.

The reasons to succeed

The good news is that there are also reasons to succeed and we would like to summarise what we have identified as key factors for successful projects.

The main reason to succeed is to have a deep understanding about the need to have such infrastructure and associated services.

Often no people are questioning about the importance to have a proper geodetic frame especially when GIS is part of the main activity of the organisation. Coordinates are just vital to carry the information. But traditionally the geodetic points were delivering for a small amount of money hidden by the public investment to maintain the geodetic network.

When the users are adopting massively GNSS RTK technique to provide positioning, the need is there because potential users are already looking for lowering costs, improving the quality and efficiency.

In general the reasons to succeed are found in a careful deployment of the GNSS Network RTK and the associated services. The so called “hotspot” strategy is paying off most of the time. Looking to serve first the community of users who are interested by the services will lead the organisation to phase its services.

The second reason to succeed is to plan for the success with business plan, financial plan, various business models and long term vision. Having an infrastructure where every user is “connected” must leverage the interest to provide much more services. After all, the communication is established and it would be a shame to leave it without taking the opportunity to use the “carrier” to provide much more than just the corrections.

The third reason is to correctly lead the project (previous proper planning will prevent piss poor performances) and to have competent people and common goals. Again there is nothing new as any project success is based on those remarks. But we are often surprised to see that such common senses are not necessarily present everywhere.

Finally the success of such project is reflecting how performing an organisation is managing successfully other projects.

There is no question about the need for such infrastructure today and in the future as every place with an intense economical activity that needs positioning, a GNSS Network RTK will be just what is needed. Every city, airport, harbour, region, country will face that needs anyway. Our civilisation is digital and we are looking for being ubiquitous in our social transaction.

The responsible for setting up and maintaining GNSS Network RTK infrastructures will have to follow up also the technology and have a critical review. Today the academics are bringing PPP (Precise Point Positioning) as a panacea to suggest that such infrastructure may become obsolete.

Also with the advent of new satellite constellations it has been quoted that the distance between the GNSS Reference Stations will become greater than the recommended 80-100 km in medium latitude areas while actually no one can still get access to those future signals. However 20 years ago, no one would have even imagined running GPS in real time mode over long distance. Communications were radio based and even Internet was not considered as a data streaming media.

At the end of the day, that is the user’s new applications and challenges that will decide the operators to implement more sophistication, while on the other side staying close to the research world is definitively the place to anticipate the future.

10. CONCLUSIONS

After having been technology driven from the last decade to convince large organisations to consider the deployment of GNSS Network and with the soon coming new GNSS constellations such COMPASS/BEIDOU and GALILEO, questions are raised about how finally justify the costs of such positioning infrastructure and eventually to make them profitable.

The crucial question is however how to make such project successful?

There is no doubt that in that paper the authors are just questioning the matter and they will continue to elaborate on that topic based on their quite unique and extensive experience in other publications.

Projects are the fact and based on people and organisation and we may not wonder that rules exist to make them successful or failure. Common sense are often neglected when people are blind by technology and forget finally that a solution is an answer to a problem or a need that must be clearly expressed and declined in term of expecting functionalities.

The good news is that any of such projects can be re-analysed and re-engineered to turn eventually any issue or failure into success.

The authors will warmly welcome any remark, experience; question and request related to that sensitive topic and would be pleased to contribute to any project confronted with questions raised in their paper.

BIOGRAPHICAL NOTES

Joël van Cranenbroeck is currently Business Technology Manager at Leica Geosystems AG, Heerbrugg, Switzerland. He led the development of hardware and software solutions for GNSS Network-RTK since 2001 and made significant contributions in geodetic monitoring development and applications such as the method for aligning high rise structures (such as the Burj Dubai). Joel is Chair of Working Group 6.2 in FIG Commission 6, awarded in 2009 the title of Honored Lecturer of the Siberian State Academy of Geodesy in Novosibirsk, and senior scientist consultant for two universities in Belgium. He designed numerous projects for structural monitoring applications such as bridges, dams, tunnels, etc. He worked at the Belgian Cadastre organization, at the Geodetic Department of the Belgian National Geographical Institute and in Star Informatic – GIS software based Belgian company – before he joined Van Hopplynus, the Leica Geosystems exclusive representative in Belgium in 1993 as product specialist in GPS, GIS, Engineering and Industrial applications.

Vincent Lui is Sales Manager and Technical Specialist at Leica Geosystems Hong Kong office, in charge of GNSS products, GNSS network system and engineering solution including structural deformation monitoring for Hong Kong, Macau, Taiwan and Mongolia. Vincent is currently developing a GNSS network infrastructure and a number of positioning services and systems in Hong Kong that serve for many applications including deformation monitoring in the area of subsidence, landslide, bridge, water dam and high-rise building. He has over 17 years of experience in the field of GNSS, navigation, reference station infrastructure and tunnel & subsidence monitoring in Hong Kong and China.

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