PAPER 2

Rapid response engineering:

An overview of technological developments and its implication in the municipal infrastructure space

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ABSTRACT

South African parastatals and local authorities are faced with a massive challenge: ageing infrastructure, complex protocols, political pressure, community needs; all potent ingredients for the perfect storm! On the other side of the execution crevasse is the private sector, cautious to risk their money, their time and their expertise. Consultants are often faced with projects from government clients which have run out of time, money and sometimes political will. It may lead to frustration, scepticism, doubt, and eventually the damning decision that it may be better to just walk away. But what impression would that make on our public servants, our colleagues, the very people we serve?

In our experience, the stumbling block often happens between idea and execution, or budget vs expenditure. We are often asked to help in seemingly impossible time-lines, with seemingly impossible budgets, on seemingly impossible problems which urgently begs for solutions.

Our company have embarked on a journey to find new ways of exploring, digesting, advising and executing in the municipal infrastructure space: Our presentation will explore, amongst others, the possibilities of drone-based surveying, the wins, the risks, the requirements, the limitations. We will look at rapid 3d modelling – or rather, as we refer to it – shaping of structures, geometries and sites.

With a multitude of 3d models to our disposal, and with the use of 360 cameras, we have ventured into the world of VR and, as a continuation, the merging of the "possible" with the "real", termed "augmented reality" and "mixed reality".

We have realised that these technologies are providing new tools to take on new challenges. Amid limited time and budget, we can say with greater confidence "yes – pick me!", we are up for the challenge! There is no future if we turn our backs to the seemingly impossible. But when we discover extra-ordinary ways of dealing with ordinary problems, we may find ourselves venturing into unchartered possibilities."

INTRODUCTION

Our young democracy is faced with many challenges. Amongst one of the most pertinent is infrastructure delivery. Our municipalities and local authorities are tasked with a massive responsibility to channel public funds into projects which should, ultimately, uplift the community and make possible the dream of "a better life for all".

This is not only a noble cause, it is a constitutional mandate. When our efforts to achieve our project goals fail, we not only fail ourselves and our colleagues and clients, but we also fail in a far bigger stage.

It is therefore of utmost importance to become burdened with why we fail when we do. What are the challenges, what are the possibilities, and how can we mobilize these possibilities to succeed? Our paper will highlight some annoying stumbling blocks, discuss some exciting new possibilities, and pose some uncomfortable challenges to our reader.

INDUSTRY CHALLENGES

Design Processes

Currently consultant's service offering to government institutions is based on the progression of professional services as set out in the government gazette for engineering professional services. This process is typically divided in stages, from inception to design, then procurement and finally construction.

The general expectation from most consultants is that this process should run linear. That is, an inception stage should define the scope, the preliminary design should reflect the clients scope perception in more real terms and lay it down or accomplish agreement around a concept and its cost implications. The detail design stage assumes a well rooted concept which will lead to a product on paper which can be priced. On selection of a contractor, the detail design is then executed, managed, documented and closed-out by the professional team on behalf of the client.

Although this is the ideal staged approach, the reality very seldom reflects this progression to the frustration of both the client and the service provider.

It begs the question whether this one-dimensional approach has not perhaps reached its expiry date? Iteration, logical decision gates, multi-dimensional exploration, and convergent/divergent processes have become widely excepted in private industry and are often key to beating the competitor. None of these non-linear strategies are accommodated in the current staged project approach followed in the civil engineering space.

Should we not consider this inherent failure in attempting to stay in this box as an indication to the fact the problems we face in infrastructure development are far too complex for the box we are trying to squeeze it in?

Scope Creep

The most damning and obvious symptom of the shortfall of the linear staged design approach is what we affectionately refer to as scope creep. This holds true from the client perspective as well as the service provider.

As consultants, we are often faced with the reality of a client needs being ambiguous. From the client's point of view, the consultants are often perceived to dig out costs and risks which seems to only line their pocket and undermine the ultimate goal.

This common narrative illustrates the disconnect in our industry between service offerings, expectations, political and socio-economic agendas and good engineering.

Consultants are bound by an ethos which demands from them to be responsible towards the public well-being. This is often confused with

an uncompromising demand on quality, safety factors, sometimes even over-design, and certainly a dislike in "cheap" construction.

The other side of the same story begs the development of infrastructure to serve communities, be implemented effectively and efficiently with, as is common in developing countries, seriously constrained budgets.

The tug-of-war, so to speak, between these ideas, is often what leads to scope creep. If the tugging causes the middle-ground to shift continuously more rapidly, a project will most certainly lead to no-where. However, if, by some manner of diplomacy and mutual understanding, the middle-ground converges, a project may be birthed into reality.

This is one example where iteration is key. Although it is not accounted for in the staged development approach, it happens in any case. Unfortunately, it happens at the expense of a lot of frustration, energy, time and cost. When it fails, it ultimately fails at the expense of society.

Communication

Another key factor to a public infrastructure project's success is communication. Traditionally we are tasked with producing reports and drawings to communicate or staged output from consultant to client. We are stuck in the ideas of a system which functions on the premise that consulting engineers report to municipal engineers, and engineers understand one another, right?

Today we are faced with a vastly different reality: In the consulting space, the face at the meeting with the client can take on a wide range of substance. We want to advance our younger generation, we want to promote multi-disciplinary exposure, we have a shortage of registered professionals. The same holds true on the client side.

Long gone are the days of large staffed municipal engineering offices. Our public servants have to be multi-skilled, politically savvy, fight corruption, balance mandates with expenditure targets, manage expectations and budgets.

Our assumption that our reports and drawings will be adequate and comprehensive communication vessels is, to say the least, wishful thinking.

The currency of time

Our industry is locked down in a debate surrounding professional fees, tenders and discounts. There are those who call for a return to the days of published professional fees in the one camp, and on the other extreme are the free-market, procurement activists driving our industry rates lower and lower.

It is interesting to note, however, that the discussions are mostly around fiat money. However, the currency of time is often forgotten.

Time is not only of the essence in calculating monitory fees, it is also a commodity that is in constant fluidity once a project gets going. More often than not, our projects are ultimately bound by deadlines: Contracts running out, financial year end, expenditure targets, etc. The above-mentioned challenges transpire, but the timeline often does not adapt accordingly. And as much as the project-timeline may not move forward, everyday ticks along.

We have learnt in our industry that time is almost always against us. We try to catch up by working longer hours, burning away weekends, sacrificing time with loved ones, or simply failing in making the deadlines. Whether it is the family life, or the project goals, or our health, something inevitably fails.

Again, the currency and cost of time points us to the fact that our current approach to project execution is vastly lacking.

Authentication

In a world plagued by the evil of corruption, the security of authentication becomes more and more crucial. In our quest to root out corruption, we demand, and we are tasked with, putting pen to paper. Our comfort in a signature is perhaps naively misplaced. We assume a set of wet-signed paper printed construction drawings is proof of well executed deliverables.

Unfortunately, this demand for authentication is costly. It consumes tons of paper, volumes of space, hours of time and, in the bigger scheme of things, probably adds little value.

In the past decade, the world has been presented with a revolutionary new way of ensuring authentication. During the 90's and early 2000's we were forced to come to grips with a new era of information as the digital age dawned. However, our brand spanking new global internet had one major flaw. How could we know if anything was authentic?

The older generation was quick to point out this short-coming, and a general consensus on the return to paper information as a means of originality was widely adopted.

However, the advancement of digital signatures and block-chain technology has brought authentication to the digital age. We can now deal with a digital transfer of value, not only of data. If we can harness these technologies responsibly, it can not only save us time and money, but it can add a level of reliability and preservation of authentic information over a long period of time, far superior to the paper-based systems we currently rely on.

Vuca World

Vuca stands for: Volatile, Uncertain, Complex and Ambiguous.

Volatile

Volatility refers to the rate at which things continuously change. In many cases we observe innovative and new ways of engineering challenges as well as the changing demands with reference to urbanization. This implies that technologies and methods we use today may provide solutions but will quickly become obsolete. Cases like this can be seen where we saw the Blackberry company experience an exponential growth with its smartphone. Even touch touchscreen smartphones found it difficult to compete, until the launch of the iPhone. The rapid success of the Blackberry smartphones was short-lived, and iPhone collapsed the sales of Blackberries which consequently collapsed within two years.

Uncertain

Not one day is ever the same or ever will be, what is the 'in thing' now can be outdated tomorrow, this is the age that we are living in. Today we may have budget to undertake large scale projects and then tomorrow funds need to be allocated. Conversely, we may have already embarked on a project and clients increase the scope of work which may require additional resources to deliver. Factor such as these forces consulting engineers to become more flexible and adaptable to such changes. To ensure that we can continue to deliver great value to our clients, we streamline the design to construction processes.

Complex

Interrelation has uncannily made things more complex. It is quite rare a problem can be solved as simply at face value. The ability for one challenge to affect an action and gain an immediate reaction has been replaced by forces and events being interconnected. The compounded effect of various challenges means we need to be equipped to provide

solutions which address not only the easily identifiable issues, but also a variety of reasonable possibilities. An easy example is how we combine data collected with a drone, a 360-degree camera, and photogrammetry software to create models providing data to electrical, mechanical and civil engineers in the built environment. Clearly, it is a labyrinth of possibilities that are highly complex.

Ambiguous

Due to information overload and technology evolving at a supersonic speed, ambiguity is not a stranger. Information has now become less reliable and contradictory. By unifying our BIM workflows, we ensure that the data used is reliable and applicable in multiple disciplines. Using various tools such as Google Earth Pro, Mappable and data verification through our own rapid collection, we are ensuring that our data provides well informed engineering solutions.

TECHNOLOGY

Softer Software

The 90's and early 2000's was characterized by a rapid expansion in micro computing power. It paved the way for advanced software development and enabled the evolution of "Computer Aided Drafting" or CAD, and "Building Information Modelling" or BIM. These buzz-words became the driver to move the industry from paper to digital, but it happened slowly and was costly.

Although the production of deliverables and reports eventually moved to the PC, the software was still geared to ultimately produce the paper versions of the pre-digital era. Even today, the assumption that early conceptualizing on paper is unbeatable by digital systems is the order of the day, and the final product returns the output to paper again.

That premise is slowly eroding. A good typist can outperform a hand writer quite easily, no one would dispute that. Our word processors today can auto-correct, spell check, format etc. We all use it and has become quite comfortable and dependent on it.

Like-wise, 3d conceptualizing is following suite. The release of Sketch-up in the late 2000's changed our thinking on the complexities of 3d modelling. Suddenly every-one could model anything. The sketch-up 3d warehouse database remains one of the largest databases of 3d modelled objects in the world.

Sketch-up re-introduced simplicity and accessibility. It paved the way to the idea that conceptualization in virtual 3d space is possible. Half a decade later the underlying theme has shifted to simplicity and speed rather than complexity. (Donley, 2011)

Software companies, such as Belgium based BricSYS, is challenging the status quo and promoting a new approach to 3d conceptualization. The aim is speed, accuracy, ease of creation, shaping instead of building. Although the front-end interface seems to have become simpler, it is backed by a new evolution in software code by means of artificial intelligence and machine learning. (Newton, 2018)

The next progression in software technology will be to make it easier, faster, more accessible to more people, more inclusive and more diverse. 3d Modelling will no longer be a novelty but will be as quick and easy as typing a paper on a PC-based word processor.

Restrictive Hardware

In the last decade, we have seen a large-scale evolution of tech tools to aid the commercial project design, review and construction. Some of these technologies include the use of unmanned aerial vehicles (drones) to gather data paired with a drastic advancement in optical equipment.

Drones are commonly known for their use in military surveillance for decades and today similar examples are applicable in industry for security systems, inspections and aerial surveillance. Our particular interest has been in the ability to gather multi spectral survey data on a land, public infrastructure and services. Applications include visual inspection to assess conditions, provide 3d models for detailed visualization of a site, getting data from inaccessible areas and work without any downtime. The data collected is easily adapted into various data workflows that is currently in use by consulting engineers, clients as well contractors.

Technological advances in drones mean they are able to embed data such as ground elevations, geolocation, thermal and infrared data along with high resolution photographs. Systems on the drones include reliable craft stabilization controls and navigation as camera stabilizations to maintain consistent reliable data. In addition to this, the data collection can be mapped out prior to the flight ensuring consistent repeatable and autonomous flights. All combined, this eliminates the risk of human error, where human inputs are only used to interrupt the flight should safety conditions change.

Today, drones are regulated as aircraft by the South African Civil Aviation Authority. As detailed as the regulation is, it has come under much scrutiny as the technology advances much faster than the legislation can keep up with. The current challenge in the process of getting drones in the sky is not only a lengthy process but is quite expensive whereas the actual drone flights are more efficient and offer increased productivity. Although we have found ways to overcome this hurdle, our registered drones and pilots are more focused on continuously evolving the use of the drone technology in various project applications. (NIAS, 2018)

Photogrammetry

The first stereoscope was used in 1838 by Sir Charles Wheatstone. Stereoscopes are used to view two overlapping photos to create the perception of depth. Photogrammetry is the digitization and recording of measurements based on the same principle.

Although the mathematics and logic behind the algorithms of digital photogrammetry are highly complex, the outcome is easiest explained by the analogy to the stereoscope. However, the significance of being able to record the stereo-effect outcome in a digital form is far-reaching!

When we combine this new digital ability with the perceived ease of access to get very small camera's in seemingly un-usual places, it opens an array of new possibilities.

We have found that our drone flights can provide us with a low-altitude, well overlapped, array of aerial photographs which can be post-processed with photogrammetry. The result is a terrain point-cloud, or high-density digital elevation mesh.

But photogrammetry is not only usefull as a post-processing tool for drones. It can just as effectively be applied to objects or spaces.

When an array of photos is taken around an object or in a space, and the camera position and angle can be calculated, the same mathematical process can be used to build a point-cloud of the object or space. When the images are back-draped over a triangulated surface resulting from the point-cloud, a virtual depth calibrated model emerges, of which the post-processing use is limitless.

This may seem quite complicated to grasp, but the result of this technique has already become public domain. Google Earth and Google street view have become well known tools in many engineering offices, yet many users don't understand or appreciate the process of how easily such data is obtained, processed and publicized to the public.

Going Paperless

For generations, paper has been the comfort of professionals. Favoured for accessibility and allowing engineers to make quick references to drawings, paper is continuing to be the go-to for jotting down notes. In current times where the environmental conditions are constantly changing, the reliance on paper has increasingly become a major burden. Very often there are a multitude of engineers who review designs and details of drawings. Between the engineering consultant and the client, these drawing are printed out on a large scale. The review process then becomes tedious with back and forth reprints of design changes and adaptation. It is easy to identify many possible technological solutions which are readily available, the challenge is rather different: culture.

We have all the technology required to go paperless and reduce feedback times, while enhancing productivity with design review, modifications and adaptations. Yesterday we used fax mail and today we can sign pdf files without a single piece of paper being printed. Clients (engineers at the municipalities) need not sit behind a desk and review drawing after drawing on paper. Consulting engineers need not print out multiple copies of A0 drawings to be sent to the various reviewers, who will then come back with a multitude of changes.

What is key will be to encourage the use of various technological tools that aid the visualization of designs beyond them being printed on paper. There are many ways to do this, of which the most obvious is to project 3d data on a 2d viewing window. We have all been accustomed to this technique by the arrival of television, which evolved into the computer screen and can even be projected on a large flat surface such as a cinema.

In 1895 the showcase of "The Arrival of the Train" caused the audience to react to the screening. We are at such a point again in history. We are at the dawn of new visualization capability which may require a bigger paradigm shift than what we are comfortable with.

Spatial Immersion

Virtual reality and augmented reality are developing tools to visualize objects and spaces on a 3-dimensional platform.

Taking into consideration the cost of modifications both in the design phase as well as variations in construction on site, it becomes obvious that a solution is essential to ensure all parties involved have cohesive context. That is, the consulting engineer, the client as well as the contractor on site are able to visually feel and experience the resulting project.

By using virtual reality, we are immersing the client into the design options. The client is then able to walk through the design and interact with it as if they are physically in the space. This means design review becomes simplified, and way more efficient. The net effect is that a contractor will also be immersed into the detailed design and may contribute to variations prior to construction. Additionally, with an overlay of the design, the contractor and client can monitor progress of the build whilst comparing the current progress versus the design.

FIGURE 1 Reality, 2018

Further to this, we can collaborate with engineers who may be able to provide expert advice regardless of where they are. Through-out the constructions phase, additional real-time data is collected to build 360-degree imagery which is used to monitor progress as well as variations. The net result is that all parties involved receive continuous detailed reports in a visually immersive representation and can very quickly make well informed responses to the changes.

Such a collaboration environment saves time, communicates much clearer and levels expectations.

ADOPTION

The "So-What" question

So, what is the use of all these new technologies in the context of the industry challenges and what to do with it?

In some cases, the potential gains are obvious, where-as in some other cases one needs to be explored in more detail. But even when the advantages of taking a different approach to a project execution is clear, it may still be very hard to convince people to try it, not least adopt it.

In our quest to seek practical implementation in the technologies we encounter, we have stumbled upon another hurdle. The comfort zone, the fear of change, the paradigm cage; people generally stick to what they are comfortable with, and what they know. It is therefore not strange that a lot of our excitement on new possibilities is met with – "so what".

Just do It

Despite overcoming the hurdle of the unfamiliar, the industry at large remains reluctant to explore new possibilities. So, what is the best cure for this stagnant disease?

We have found that one of the most convincing ways of introducing a new idea is to simply – "just do it" – all of course with-in safety and reason. In hind-sight we can quite confidently say that the Wright brothers would have left us still travelling for weeks on end on ocean liners if they did not have the courage to "just do it"!

In his book, "Start with Why: How Great Leaders Inspire Everyone to Take Action", Simon Sinek argues the case of why certain leaders, or companies, are more successful than others. He ties it down to buying into ideas, not just products or services. Ideas can inspire people to go beyond the status quo paradigm. It can move us to action and, in doing so, inspire others.

Sinek points out how adoption of ideas progress, starting with the minority of people being inventors, then convincing early adopters, and eventually reaching a critical mass where an invention or idea spills over to become the new norm. (Sinek, 2009)

This course of action is exactly what we are hoping will inspire our industry, and to drive the point home, we have injected our technological purpose into real projects:

Case 1: Hostels Refurbishment

Among other external factors which caused some delays on the delivery of this, a major risk to the success was time. The contract with the

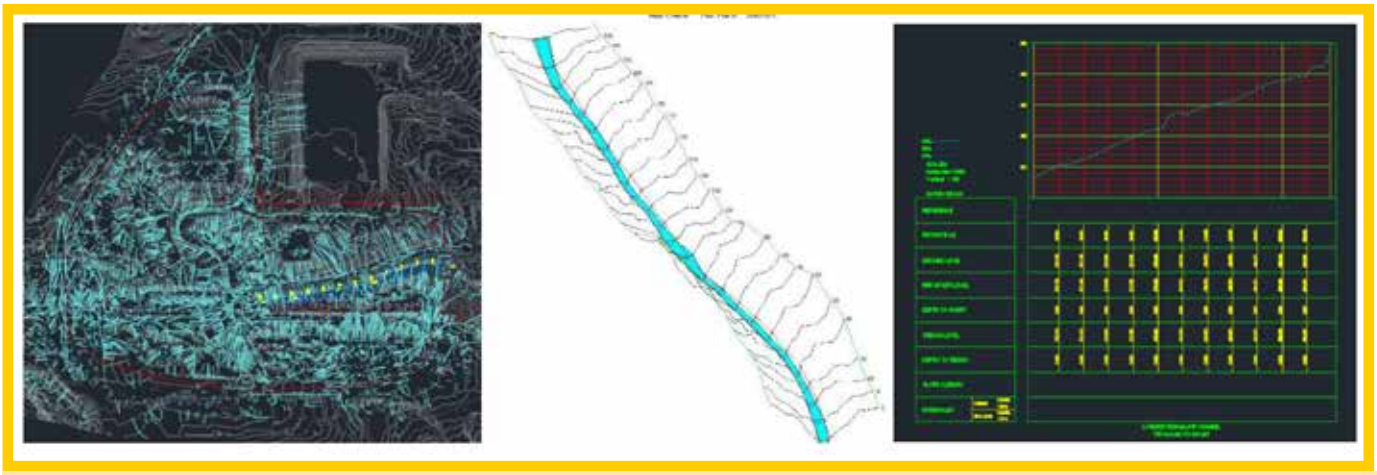

FIGURE 2: Stormwater run-off analysis

municipality was nearing a close in the space of three weeks and we faced the urgent need to deliver the best value to the client.

A surveyor needed to be procured to assess the landscape, engineers needed to go to the site and assess structural conditions and design of a solution to be presented to the client. Employing traditional methods meant this task would be impossible as the procurement of a surveyor alone takes several weeks, not taking into account the processing of the data. In addition to this, the site of 31 hectares would run a bill in the hundred-thousand-rand mark.

We arranged for a drone to be flown over the site. The administration and risks involved were address and permissions acquired. Planning included preprogramming the flight plan and safety risk mitigation. On the day of the flight, weather was checked, and we were fortunate to have ideal conditions for the autonomous flight. The drone pilot along with an assistant were guided to a vantage point whereby they would easily monitor the flight of the drone. The actual flight was 10 min to cover the 31 hectares. This also did allow us to conduct a secondary flight at a perpendicular flight path to the first flight.

Data was collected in the form of georeferenced photos. As the drone system is equipped with GPS connectivity and accompanied by a calibrated Inertial Measurement Unit (IMU), the photographs taken have a reference point which allows us to build a map. This map is composited through photogrammetry algorithms in software which produces various data sets.

The wealth of data allowed us various perspectives. Thanks to the level of detail and accuracy of the drone system we could derive minute changes in the topography. We could easily identify various services including powerlines, stormwater drains and maintenance holes via the high-resolution photographs.

Data that has been stitched together 3d models combined with video footage of the site produced an invaluable understanding of not only the problems on the site but possible causes.

We found the deterioration of main supporting elements poses a risk to the over-all structural integrity of the buildings, which poses a risk to the occupants and, in turn, the client. The deteriorated state of the apartment block buildings is caused by excessive and long-term exposure to moisture. The reinforced concrete subjected to a continuous cycle of wetting and drying are prone to corrosion.

The main sources of moisture exposure on the buildings are from the roof (due to water-proofing damage) and from the ground level. The latter is by far the more serious situation as is evident from the damage observed. Not only does this corrosion pose a threat to the supporting integrity of the entire structure, but it should be further noted that the lower storey members are under the highest stress as they carry the full weight of the stories above them.

It seems like a lot of water damage occurs at the lower levels of the buildings because of insufficient or dilapidated storm-water channeling systems.

Further to this, we are able to process the data for other applications without the need to go back to the site for an additional survey. All this data was produced with a half day of flight and ground inspection, a few hours of processing the data and most of the time spent on analysing the data producing various report.

The big win was that we were able to cover a large area within a single day and process the data the following day. We were able to reach areas which would have been high risk for persons. Within the two week period, we were able to provide advice to our client to the same value, if not more, than what would have taken a month or two.

Case 2: Branch Refurbishment

At the start of 2018 our company joined a contractor-architect joint venture to refurbish branches for a national bank. We were tasked with the mechanical ventilation and fresh air designs, electrical reticulation design and structural engineering. Since our team formed part of the contracted party in this case, we had to adapt in working parallel with our contractor partner to achieve our common goals, whereas we are more used to checking up on the contractor on behalf of the client.

Our project posed logistical challenges. Branch refurbishments had to be executed in less than two months. Our client often notified our team of new branch requirements with little design time to spare, and the locations were scattered all over the country.

As we had to deal with multiple branch projects at a given time at different locations, the engineering team ran into travelling logistics problems. During construction, we had to monitor installations against the designs, but it was often not feasible to be at more than one place at a time. To add to our woes, we also had to deal with the time consumption and travelling cost of visiting remote branch locations where access was not always easy.

Luckily, our younger generation engineers had the skill to marry challenge to tech, and we started to experiment. The idea was to purchase a 360 camera, send it off to site and let it be our eyes. They wanted to bring the site to their desktops.

FIGURE 3: Snippet of 360 degree photo

Our engineers set out to mark spots out in the branch where the site-foreman would take 360 panoramic still images with the camera mounted on a hard hat. The photos were then sent back to the office, where our clever engineers placed the photo's in a 3d model of the branch to create the correct relative location. With a bit of orientation correction, the team managed to create a virtual tour, or walkthrough, of the branch. The quality of the panoramic photos was good enough to comment on duct and reticulation installations without needing to physically visit site. In fact, the quality was so good that our electrical engineer could distinguish a single switch light box from a dual switch one.

Although our team opted to visit the branches in any case, they were able to cut down on weekly site visits and saved a massive amount of time and travelling cost in the process. The camera investment paid its dividends in the first two months of use!

Despite proving a concept in practice, the experiment lead to more unforeseen insights. Our team quickly realized that they were able to compare photo records with one another on a weekly basis. This facilitated communication to the site team further, as the contractor and sub-contractors could be shown in the immersed panoramic space what was missing. The next logical step was to use this method of viewing to show the client what progress has been made. The inspection tool quickly earned a heap of bragging rights!

CONCLUSION

Our developing nation is faced with a mountain of challenges in the municipal infrastructure space. It is not difficult to complain about it, list the problems or even point fingers. As service providers and public servants, we need to strive to progress from our current teenage tendencies and tackle our problems and challenges in a mature and collaborative attitude.

As we reach adulthood so to speak, we should identify and dissect these challenges in an objective and analytical way before we start to debate solutions.

Our bag of solutions to any well-defined challenge is only as deep as our awareness of the possibilities. There can be no suggestion to try a new path if that path cannot be conceived. No-one would have considered power flight as a means of mass transportation if the world had not learnt of the possibility of powered flight.

The next step seems to be as simple as trying. When we pick from our bag of possibilities, we must be brave enough to take the first steps. We may not hit the mark first time, we may fail, we may waste a bit of time or a bit of money, but we will never know if we don't try.

RECOMMENDATIONS

Our paper seeks to inspire our colleagues, both in public service and in the private sector, to be bold. We recommend a dose of optimistic critical thinking, both aimed at ourselves and to that with which we interact daily.

We wish to inspire an inquisitive appetite for the new and the inventive. By following the inspirational inventors of our age, we become inspired ourselves, and our bag of knowledge on what is happening in the world becomes deeper and richer.

We wish to challenge you to continue the search for ways and means to ensure a better life for all. What better platform can we ask for than to serve our communities through our local authorities, whether as consultant or public servants? And what better application of new, exciting and inspirational technologies than to uplift and serve our communities by succeeding!

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