The optimization of optical fibre installation methods in South Africa

by

Pierre Jacques Vorster

25327918

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Executive summary

Optical fibre is an old technology that has found numerous new applications as the telecommunications industry has flourished. The South African optical fibre market has exploded and the race is on to install fully functional optical fibre networks. Numerous companies have joined the race and because of the nature of the market, the main aim for these companies is rollout. There are different methods of installing optical fibre networks and it would seem that the process with the biggest capacity would be in-road mechanical trenching. In saying that, there have been some unforeseen difficulties in streamlining this process because of the differences in road conditions as supposed to European countries. The construction of optical fibre networks also consists of a number of phases and the South African network is still in the preliminary phases. The first target for these companies is the corporate industry and it is estimated that optical fibre networks will only reach households within the next ten years. The aim is obviously to install these networks as soon as possible. Reason being, the faster a company enters the market the faster a company can start generating revenue. Through basic alterations to the existing installation process output can be vastly improved.

The acceleration of the rollout will increase company profits as well as delivering a service that will greatly benefit the general public a well as increasing the well-being of South Africa.

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1. Introduction

1.1 Background

Optical fibre is an old technology that has found numerous new applications as the telecommunications industry has grown. Through the whole of Europe as well as the United Kingdom optical fibre networks have been installed because of its immense bandwidth capacity as well as the high speed of data transfer. Installing optical fibre networks is a slow labour intensive process, and with the optical fibre market exploding in South Africa, the race is on for fully operational networks. There are various ways of installing optical fibre, as shown in Figures 1 to 8 below.

Fig. 1 - Directional drilling

Fig. 2 - Direct burial

Fig. 3 - Inside sewer

Fig. 4 – Mole Ploughing

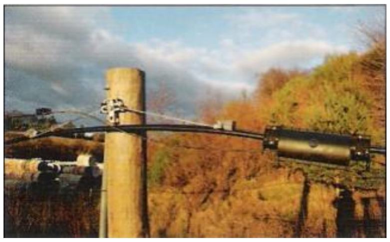

Fig. 5 – Aerial

Fig. 6 - Trenching

Fig. 7 – Semi aerial

Fig. 8 – Slot cutting

Each process has its advantages as well as disadvantages; however the main aim in the installation process is output. The nature of the market requires that as much infrastructure is installed as quickly as possible. Therefore, in-road mechanical trenching/slot cutting has the largest capacity per machine per day. Many methods are labour intensive and the production rates are dependent on human factors.

Optical fibre networks installation methods have been developed in Europe. It would therefore be the logical step to copy their processes directly to local optical fibre networks. However there are a number of obstacles that are faced in South Africa. Records of engineering services under the road surface and on the sidewalks are often not available or not properly logged. The cutting of services under the road surface can cause significant delays and costs. Keeping this in mind, the optimization of this process will still yield an installation capacity which far exceeds the capability of manual labour.

Optical fibre networks consist of three components:

1. Installation of the "backbone" network.
2. Installation of the access network.
3. Connecting the end users to the network.

The in-road mechanical trenching is only used for the first two components.

1.2 The problem

The equipment that is utilised for in-road trenching typically has a substantial capacity. However the process does not only consist of cutting or drilling. There are many obstacles such as water pipes, gas pipes, electrical wiring etc. that have to be manually removed before the excavation can be undertaken and ducts can be laid.

This whole process has to be optimised in order to utilise the maximum capacity of the trenching equipment. The rollout is not only measured by the trenching speed but the reinstatement process must also be taken into account. Currently the system in South Africa is greatly underachieving as supposed to the possible capacity proven in Europe.

1.3 The focus

Optimization of the trenching processes in the South African environment is the focus of this report as well as identifying the differences between South African and European roads. There will certainly be similarities between the problems in both cases and much can be learnt from European practices. A major difference between South African and European cities is the population densities – the European cities are much more densely populated than local cities.

1.4 Project aim

The aim of the project is to investigate optimization of the installation processes as well as allocating the needed resources in order to facilitate the elimination of bottlenecks. Furthermore the aim is to improve overall logistics.

1.5 Project Scope

An in-depth literature review was conducted to establish the similarities and differences between South African and European systems and the focus was to establish whether some of the European systems can be applied locally. Some time studies were also undertaken on the various elements of the process.

The process can be broken down into the following elements:

a) Surveying (detection of pipes and cables under the road surface).

b) Mechanical trenching, obstacle clearance, duct laying, backfill (replacement of the excavated soil) and reinstatement of the road surface.

These elements can further be subdivided into smaller elements and a time study was conducted on all these elements. The composition of the soil under the road surface may vary; therefore this factor was also taken into account. After all the standard times have been determined, the capacities of all the different elements within the process were identified and compared. The need for additional resources that should be allocated in order to eliminate the bottlenecks was identified. As the number of obstacles on sections will not be constant, a model had to be constructed depicting the required resources that should be allocated in order to keep the process streamlined. A significant number of variables had to be taken into account and an effort was therefore made to standardise the process as far as possible.

1.6 Deliverables

The deliverables for the project are the following:

- Standard times for the elements within the process.
- A detailed summary of the bottlenecks within the processes.
- Recommendations on alterations/modifications to the process.
- Full resource allocation recommendations in order to keep the process streamlined.
- An implementation plan for the new process. (New traffic teams etc.)
- A presentation in order to notify the operations side as to what the new process entails.
- Implementation of the new process as well.

1.7 Project Plan

There exist a number of tasks that were vital to the completion of this project. The activities are as follows:

1. Develop project proposal
2. Study methods utilised in other countries
3. Identify potential problems from previous cases
4. Conduct time studies
5. Make recommendations on how to improve process through a report
6. Implementation of recommendations
7. Study access networks methods from previous cases
8. Design new process alternatives for access network
9. Formulate implementation plan
10. Prepare presentation
11. Implement new process

2. Literature review

2.1 Introduction

The main purpose of a literature review is information gathering. It is important to be up to date on the current available literature on a certain topic. A literature study broadens thinking on certain topics and can give valuable insight into existing methods and alternative solutions. It is important to be aware of all the possible available in order to select the solution most suited to a particular problem.

Shepard (2001) indicated that optical fibre is the next big technological “thing”. Optical fibre networks have taken the market by storm and because of its bandwidth and speed capabilities it is unparalleled in the marketplace.

However optical fibre networks do not only consist of optical fibre cables. An optical fibre network comprises of many different components including switches, multiplexers, routers etc. With the huge capabilities that optical fibre possesses, it was paramount that the accompanying components follow the technological trend.

There have been great advances in optical component technology and manufacturers have scrambled to stay in touch with the technological curve. An optical fibre network is, in principal, the same as the old telephone networks that were installed. When the telephone networks were installed it could not be conceived that the end user would need more bandwidth than what could be provided by the telephone cables.

However nobody could have predicted the massive shift in paradigm the industry would experience. According to the network consulting firm Ryan Hankin Kent Inc., Communications traffic between 1998 and 2002 grew by more than 1700 percent. These figures will have multiplied enormously at this point in time and it is growing exponentially. The reason for this growth can be attributed to the growth of broadband systems and applications. People are downloading more and more because they can. Consumers are downloading movies, music, e-books etc. This whole process will escalate as time passes, exerting more pressure on the existing system. The existing technologies can handle this change only up to a certain point before it is no longer sufficient, resulting into the shift to optical fibre networks.

Service providers are scrambling to be part of this technological shift. Companies in South Africa like Telkom, Neotel, MTN, Cell C, and Vodacom have all entered the optical fibre race. The race is on to install optical fibre networks as quickly as possible in order to secure potential clients before other service providers can compete. The first target group for the service providers is the corporate sector. According to Johan van der Lith from Dark Fibre Africa Ltd., it is unlikely that optical fibre will reach the household users within the next ten years.

The main aim is to connect the world through optical fibre. Currently there are optical fibre cables being laid between continents. The local network is only a small piece in a global puzzle. The world-wide optical fibre network consists of five network regions:

- Metropolitan enterprise: The metropolitan enterprise segment covers the needs of the corporate environment, Office parks, CBDs etc.
- Metropolitan access: The metropolitan access covers the needs of the household users.
- Metropolitan backbone: The backbone is responsible for transferring high volumes of traffic between users within the metropolitan area.
- Long-haul: Long-haul is the part of the network that is used to connect cities, countries and continents.
- Submarine long-haul: This part of the network is used to connect mostly continents. It has the most challenges, because as the name suggests, it is done under water. The maintenance in these harsh environments play a huge role and it is difficult to send maintenance personnel down into these environments. (Shepard 2001:12)

2.2 Installation methods

There are a number of different methods of installing the cables in metropolitan networks, each having their advantages and disadvantages. Certain methods can only be used for certain metropolitan applications. The methods are as follows (Emtelle 2009: 8):

- Direct burial

  This is the most common method adapted in South Africa. Telkom SA as well as Neotel and various other sub-contractors have adopted this method. The networks cannot be exclusively constructed by means of direct burial because of bridge crossings and various obstacles along the way. However vast majority of the work can be carried out by the method. In order to bury the duct a trench has to be dug.

The process is undertaken manually by workers with shovels and picks and is incredibly labour intensive. The trenches that are dug are much wider than needed for the ducting. The shovels that are used have a certain width and therefore the trenches cannot be narrowed. Furthermore all the material that is excavated is stored on the side of the trenches resulting in a messy ordeal.

There are some advantages though: Because labourers are used with minimal machinery, there is no costly maintenance on machines and no capital needed to buy heavy machinery. Plus the chances of cutting services under the surface are significantly reduced. The main drawback of this method is the speed. Many labourers are required to maintain the speed that machines are capable of. Many labourers mean a lot of supervision and all the problems that accompany it. Most companies also do not have the significant capital needed for purchasing expensive machinery. In saying this, this method still remains the most popular method in South Africa.

- <u>Directional drilling</u>

  Direction drilling is a very expensive method. Some sub-contractors will charge up to R1000 per meter for directional drilling. This is a last resort for most companies. It is mostly used for passing under train tracks and for drilling under storm water pipes. This method is adopted by all companies but it is sub-contracted as many companies do not have expensive directional drills.

- <u>Inside sewer</u>

  The method of installing the optical cables within the sewer is one that is not adopted in the South African market. A number of problems can arise from this method. Firstly the cables are under tension. This can put strain on the cables over a long period. Secondly, the maintenance work that has to be done on the cables is made difficult because of the size of the pipes. There is also the possibility that the cables can be damaged by vermin living in the sewer pipes.

- Mole ploughing

  This method is used for the long-haul projects between cities that were mentioned earlier. This method cannot be used within the metropolitan area. The application on long-haul projects is not the focus of this project and this method is therefore not further discussed in this report.

- Aerial

  When Telkom SA first started with the idea of installing optical fibre cables they were keen on hanging fibre on poles. The reason being that they already had all the poles in place for their telephone networks (Joubert 1991). As time passed they realised that because the cables were under tension and were exposed to the elements it would create maintenance problems. Fibre relies on internal reflection and can therefore be damaged by consistent wind storms over many years. Telkom decided that they could significantly prolong the fibre cables lifetime if they decided to bury it. The aerial route is accepted more for the "last mile fibre" that is connected to the end users.

- Trenching

  Trenching requires relatively big machines that are quite expensive. The trenching machines are not designed to operate within the metropolitan areas. They are large and difficult to manoeuvre. Furthermore they cause significant disturbances because the material that is excavated will be left next to the trench much in the same way as excavating by pick and shovel. Trenching machines are operated mostly next to highways where sufficient space is available for the operations.

- Mechanical in-road trenching

  Mechanical in-road trenching was developed in France. Equipment was developed that are capable of cutting a 110mm wide trench in the road. The ground that is excavated is then vacuumed by a machine mounted on the back of the excavator. This results in a perfectly square trench and no dirt on the sides or within the trench.

  The main advantage of this method is its speed and clean operation. It can excavate up to 1.5 km per day according to the manufacturers (Marais International) of the machines.

The drawback of machines is obviously its price. In a highly competitive market, however, speed is the main advantage. An example of the equipment is shown in Figure 9 below (Cleanfast). More details of the method are provided in the next section.

Fig 9. - Mechanical in-road trenching (Cleanfast)

There are a number of other methods that have to be implemented in areas where the above mentioned methods cannot be utilized. For example, sleeves are attached to bridge crossings in order to provide the cables within the sleeves. These methods all have their different uses and applications. They also have their advantages and disadvantages.

2.3 Mechanical in-road trenching

The firm Muvoni Weltex has imported six machines for mechanical in-road trenching. These machines are called Cleanfasts. The equipment can be used for the installation of the backbone and access components of the optic fibre network.

Because of the high cost of the equipment, it is important that the process has to be optimised in order to justify the huge capital investment. There are many factors that influence the performance of the equipment and the process is quite complex. . The process comprises the following activities:

- For in-road mechanical trenching to be carried out in metropolitan areas a permit has to be obtained from the local municipality. These permits are called way-leaves. These permits stipulate that a mechanical trench may be cut in the road 300mm from the curb stone. Obtaining this documentation has proven to be a difficult task. When way-leaves are being obtained too slowly, this can result in machines being idle. However way-leaves are being released at a pace that insures the machines will always be utilized.

- After the way-leaves are obtained, a surveying team detects pipes and obstacles underneath the road surface and mark the positions of these services on the road surface with paint. Obstacles include water pipes, gas pipes, electrical wiring etc. The trench line is also marked on the side of the road. Roads have to be surveyed and marked before they can be excavated.
- Once the road has been marked, trenching can commence. The trenching process can be sub-divided into three operations. The equipment is first moved in to start excavating the narrow trench. As the equipment reaches the obstacles that have been marked by die surveying team, the trenching blade is lifted and moved over the obstacle. Trenching at the obstacles is undertaken manually. The next step is to insert the ducting sleeves into the trench. Four ducts are inserted into the trench insuring that there is sufficient capacity for a number of fibre cables. Lastly a mixture of sand, soil and cement is put into the trench in order to secure and protect the ducting. The mixture is then allowed to settle for seven days and is tested for strength.
- After the backfill mixture has hardened and has passed the quality test the reinstatement team can move in. The way-leave stipulates that the road surface has to be restored to its previous state after the duct installation has been completed. The last step is to reinstate the bitumen on the road surface. A milling machine is sent over the top part of the trench. This ensures that when the bitumen has hardened it does not subside beneath the road surface. The material excavated after the milling is then cleared with mechanical brooms and by hand. Lastly the bitumen is distributed into the trench by a paving machine or by hand and then compacted by rollers.
- The fibre is then “blown” into the duct with a compressor. This process is limited to a distance of between 500-800 meters depending on the number of bends in the duct. Manholes are installed every 500 meters from which the fibre can be inserted.
- The duct is pressure tested and a mandrel is sent through in order to detect any possible defects.

- After the respective municipalities have inspected the trench lines and manholes the way-leave is signed off.

Most of the operations that are undertaken before actual excavation starts should not affect the capability of the process of lying duct. This report will focus on the process of excavating the trenches, clearing the obstacles, laying the duct and reinstating the soil mixture back into the trenches.

Time studies were conducted on the individual elements that the process is comprised off. However there are many factors that can influence the standard times of these elements:

- Hardness of the ground to be excavated.
- Number of obstacles that has to be cleared before the duct can be lain.
- How far the site is from the yard. Concrete mixers only have a capacity to fill 150 meters of trench per truck per trip. The turnaround times off these trucks will greatly influence the capability of the process.
- How long it takes for teams to arrive at their designated sites. The way-leaves only permit certain times that excavation is permitted.
- The duct lying as well as backfill processes must wait for obstacles to be cleared. This can greatly affect the performance of the system.

All these factors have to be taken into account when establishing the appropriate methods that should be considered to optimise the process. One option would be to establish how these factors were overcome in the countries where the methods had previously been used.

There are many factors that are different in South Africa as opposed to countries where the method had previously been deployed. Many of the older roads in South Africa were constructed by means of the macadam process whereby rocks were taken from the mines and used to construct road layers (Hilton Vorster). These rocks complicate the trenching operation because they are mauled to the surface and break away some of the road pavement. This widens the trench resulting in an increase of backfill needed.

Another issue is that surveying teams cannot always detect all the obstacles beneath the road surface. This results in water pipes being damaged with resultant loss in production performance.

The services in other countries are better documented, so they can be marked from plans. This results in higher levels of performance as supposed to South Africa. This was identified to be the most problematic of all the factors influencing throughput.

2.4 Possible optimisation tools

There are a number of different strategies that can be applied to this problem. There are many ways of analysing and approaching this problem and a number of different techniques were considered:

1. Time study
2. Line balancing
3. Simulation
4. Algorithms
5. Theory of constraints
6. Linear programming

These different methods are discussed briefly below.

Time study: Time standards have to be established in order to calculate different activity capabilities. There are three elements that can assist in the calculation of standard times: Estimations, historical data, and work measurement activities (Niebel & Freivlds 2003:373). These standard times are needed in order to implement many of the techniques needed to solve the optimization problem. The times can be measured by stopwatch and converted to standard times.

Line Balancing: The excavation process can be classified as an assembly line in order to apply line balancing principles. The process of line balancing can be described as a tool to improve process throughput while reducing the manpower required and lowering of the costs. By establishing the capacities of the different elements within the process through time studies the "assembly line" can be balanced and the output of the process can be improved. The line balancing model consists of a network diagram stating the predecessors as well as the successors for the various activities as well as the standard times for these activities.

Simulation: Simulation refers to huge variety of applications used to mimic a process in order to determine the bottlenecks and queues within a system (Kelton, Swets & Sadowski 2010:1). Standard times are needed in order to simulate a process and these standard times are fed into the appropriate software. Arena provides software facilitating the simulation process and it provides for a huge number of variables to be inserted into the model. Simulation is used to conduct numerical experiments in order to better understand a system and its restrictions. Simulation is a strong tool because of the level of complexity it can facilitate. Many other methods require a higher level of simplification in order to build a model. These simplifications can sometimes put the validity of the model under suspicion. In the last decade the popularity of simulation has risen greatly because of the advances in simulation software. The simulation software is very versatile and powerful. Surveys conducted at various academic institutions have revealed that out of all industrial engineers that have graduated, simulation is the tool that is used the second most in practice (Kelton, Swets & Sadowski 2010:5). There are also some drawbacks: The inputs that are required by the simulation models can be random, resulting in random outputs. The uncertainties of certain outputs can, however, be quantified and reduced. Simulation can be used to predict the future and can aid in the elimination of possible future problems. Simulation is often used if uncertainties concerning a system are present. Through the gathering of data the uncertainties concerning the process are minimised and it is therefore not necessary to simulate the process in order to determine how the process behaves.

Algorithms: An algorithm can be viewed as a formula or procedure that solves a recurring problem. Algorithms are complex and most simulation software contains predetermined algorithms.

Theory of constraints: The theory of constraints is a method that is widely considered to be a method that can greatly improve the throughput and productivity of a company. This method helps companies to locate the critical points that have to be improved in order to optimise the process. If certain activities are identified as crucial points and improved, the other activities will become weaker and there for become the weak links in the chain. A chain is only as strong as its weakest link and the theory of constraints is based on this rule. Goldratt (1990:15) indicates that before we can deal with the improvement of any section of a system, we must first define the system's global goal; and the measurements that will enable us to judge the impact of any subsystems and any local decision, on this global goal. The theory of constraints is comprised of five steps as developed by Goldratt:

1. Identify the system constraints
2. Exploit these constraints
3. Eliminate everything else to the decision made in step 2
4. Elevate the constraints
5. Restart the process by going back to step 1.

This method ensures the continuous improvement of a process.

Linear programming: George B. Dantzig developed the Simplex method in 1947. The method is used for the solving of a huge class of optimization problems called Linear Programming problems (Winston & Venkataramanan 2003: 49). Linear programming is concerned with the allocation of limited resources to known activities in order to obtain the global goal. Programming was synonymous with the word "planning" in the 1940's and is now part of the field of operations research. Linear programming models consist of an objective function. This function is used to formulate the goal of the model, whether it is to maximise profit or to minimise cost. There are a number of different functions that can be formulated. This objective function is followed by a set of constraints and conditions. Software can be used for the solving of these linear models and programs like LINGO simplify the solutions to these problems. Linear programming can be used for a wide variety of applications from bakeries, shipping etc. When working with a large number of variables and constraints, this method can become very complicated and difficult to formulate.

2.5 Literature review conclusion

The time study method was selected for the purposes of this project to establish the capacities of the different elements within the process. The manufacturer of the equipment claims a capacity that far exceeds the actual performance figures obtained locally. As discussed previously there are many factors limiting the process in South Africa that was not encountered in other countries. Therefore time studies were conducted and performance ratings assigned in order to establish the standard times suited for the South African market.

Because the equipment is used at different sites the whole process will be viewed as a mobile assembly line. Line balancing principles can therefore also be applied to the process. The maximum capacities of the elements within the process can be determined and compared in order to identify the bottlenecks in the process.

3. Data collection and analysis.

By determining the capacities of the different elements in the process, the capacities can be compared in order to identify the possible bottlenecks. The resource utilization can be determined for the existing method as well as the proposed method.

3.1 Current capabilities

3.1.1 In-road trenching equipment

The capacities of the in-road trenching machines depend largely on the composition of the soil under the road surface. Every Cleanfast machine records the production hours on its wheel, therefore an average hourly utilization can be determined.

The way-leaves stipulate that trenching may be undertaken from 09:00to 15:30. The operators have an half an hour lunch so the effective work hours amounts to 6 hours per trenching machine.

Information was obtained for a total of six trenching machines for the period 12 February 2009 to 17 September 2010. The following table provides information on the utilisation of the Cleanfast trenching machines:

Cleanfast utilization							
Cleanfast	Date	Months	Working Days	Wheel hours	Relevant hours	Hours/Day	Average hours/ machine/day
1	12 - 02 - 2009			281			
	17 - 09 - 2010	18	360	867	586	1.63	
2	12 - 02 - 2009			401			
	17 - 09 - 2010	18	360	992	591	1.64	
3	12 - 02 - 2009			177			
	17 - 09 - 2010	18	360	808	631	1.75	
4	12 - 02 - 2009			145			
	17 - 09 - 2010	18	360	658	513	1.43	
5	12 - 02 - 2009			0			
	17 - 09 - 2010	18	360	422	422	1.17	
6	12 - 02 - 2009			50			
	17 - 09 - 2010	18	360	568	518	1.44	
							1.51

Table 1 – Cleanfast Utilization

The average production metres per month for six operating machines were obtained as follows:

2009: 17 300 m per month

2010: 21 587 m per month

The assumption is made that the production teams have 20 working days per month. The average production metres for the full period were determined as follows for the six machines:

19 445 m per month

972 m per working day

Per machine, the production metres are as follows:

3241 m per machine per month

162 m per machine per day

The equipment on average worked for 1.51 cutting hours per machine per day. This means that the equipment operates at a speed of 162/1.51 = 107.28 m per hour per machine.

Given a maximum of 6 working hours per day, a maximum of 6 x 108.28 = 643.7 metres of cutting can be undertaken per day per machine. The resource utilization percentage is therefore:

1.51 cutting hours/machine/day ÷ 6 possible working hours = 25.16 %

3.1.2 Batching Plant & Concrete Mixing Trucks

Muvoni Weltex Network Technologies is currently operating one batching plant. Six concrete mixer trucks are used to transport the loads from the batching plant to the various sites.

Through time studies it was determined that the batching plant takes 30 minutes for each batch to be loaded; that is the time from when one truck stops in front of the batching plant until the next truck stops to be loaded. The batching plant currently has a 10 000 litre tank from which it fills the trucks. The water flows into the tank at a lower rate than it is pumped into the trucks; therefore the first six batches are done at optimal pace where after the rate slows. It would thus be beneficial to install a second water tank on the existing batching plant.

Every load that is transported by the concrete trucks can fill approximately 150 metres of trench, depending on the width and depth of the trench. However, the trucks are not cleaned every day which reduces the quantity of material that can be transported per truck load. Some companies specialize in industrial cleaning products that can be used to clean the inside of the concrete mixers on a regular basis. A specially formulated acid is poured into the mixer while it is turning. It is left inside for 30 min and then the contents in the drum can be washed away with water. It would be beneficial for Muvoni Weltex Network Technologies to invest in such a product in order to maximise the loads they are delivering to site.

Previously, it was indicated that the six trenching machines produced an average of 972 m trench per day. Given that a truck can fill about 150 metres of trench, it was determined that the following number of loads is required per day:

972.175 meters filled per day ÷ 150 meter loads = 6.48 loads per day

The operations team never works on more than two separate sites at once so these loads are typically distributed to two different sites. The travel times to site greatly influence the amount of loads that can be delivered to site. A basic model was constructed to evaluate the number of possible batches that can be delivered to two different sites given that there is only one batching plant.

The model is based on the assumption that no additional overtime should be required and that the trucks will only depart and arrive at the batching plant during the normal working hours of 07:00 to 16:00. The trucks may only arrive and depart from the site between the hours of 09:00 to 15:30. Travelling times to site of 20 minutes, 40 minutes, 60 minutes and 80 minutes were used in the model.

a) 20 minute travel time to one site or two sites with 20 minutes travel time

The schedule for backfill loads, schedule for the batching plant as well as the arrival schedule on site follows:

Backfill Driver Instructions

Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	20 min	08:40	09:00	09:30	09:50	
2	Truck 2	1	Location 2	20 min	09:10	09:30	10:00	10:20	
3	Truck 3	1	Location 1	20 min	09:40	10:00	10:30	10:50	
4	Truck 4	1	Location 2	20 min	10:10	10:30	11:00	11:20	
5	Truck 5	1	Location 1	20 min	10:40	11:00	11:30	11:50	
6	Truck 6	1	Location 2	20 min	11:10	11:30	12:00	12:20	
7	Truck 1	1	Location 1	20 min	11:40	12:00	12:30	12:50	
8	Truck 2	1	Location 2	20 min	12:40	13:00	13:30	13:50	
9	Truck 3	1	Location 1	20 min	13:10	13:30	14:00	14:20	
10	Truck 4	1	Location 2	20 min	13:40	14:00	14:30	14:50	
11	Truck 5	1	Location 1	20 min	14:10	14:30	15:00	15:20	
12	Truck 6	1	Location 2	20 min	14:40	15:00	15:30	15:50	

Table 2 – Backfill Driver Instruction 20 minute travel time

From this table it can be seen that the last truck will arrive back in the yard before 16:00 and that no overtime is required.

Batching Plant 1 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6	Truck 7	Truck 8	Truck 9
08:10 - 08:40	1								
08:40 - 09:10		2							
09:10 - 09:40			3						
09:40 - 10:10				4					
10:10 - 10:40					5				
10:40 - 11:10						6			
11:10 - 11:40	7								
11:40 - 12:10 LUNCH									
12:10 - 12:40		8							
12:40 - 13:10			9						
13:10 - 13:40				10					
13:40 - 14:10					11				
14:10 - 14:40						12			

Figure 10 – Batching Plant Schedule 20 minute travel time

The batching plant schedule shows that if the batching plant is running at full capacity, with a travel time of 20 min to site, it can produce a maximum of 12 batches:

12 Batches × 150 m/batch = 1800m per day that can be backfilled

Site 1		Site 2	
Batch No.	Time	Batch No.	Time
1	09:00 - 09:30		30 min idle
	30 min idle	2	09:30 - 10:00
3	10:00 - 10:30		30 min idle
	30 min idle	4	10:30 - 11:00
5	11:00 - 11:30		30 min idle
	30 min idle	6	11:30 - 12:00
7	12:00 - 12:30		LUNCH 12:00 - 13:00
	Lunch 12:30 -13:00	8..	13:00 - 13:30
	30 min idle		30 min idle
9	13:30 - 14:00	10	14:00 - 14:30
	30 min idle		30 min idle
11	14:30 - 15:00	12	15:00 - 15:30

Figure 11 – Resource Utilization on both sites 20 min travel time

The site arrival schedule shows that there are a lot of idle time for workers on site there is only one batching plant and two different sites.

b) 40 minute travel time to one site or two sites with 40 minutes travel time

Backfill Driver Instructions

Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	40 min	08:20	09:00	09:30	10:10	
2	Truck 2	1	Location 2	40 min	08:50	09:30	10:00	10:40	
3	Truck 3	1	Location 1	40 min	09:20	10:00	10:30	11:10	
4	Truck 4	1	Location 2	40 min	09:50	10:30	11:00	11:40	
5	Truck 5	1	Location 1	40 min	10:20	11:00	11:30	12:10	
6	Truck 6	1	Location 2	40 min	10:50	11:30	12:00	12:40	
7	Truck 1	1	Location 1	40 min	11:20	12:00	12:30	13:10	
8	Truck 2	1	Location 2	40 min	12:20	13:00	13:30	13:40	
9	Truck 3	1	Location 1	40 min	12:50	13:30	14:00	14:40	
10	Truck 4	1	Location 2	40 min	13:20	14:00	14:30	15:10	
11	Truck 5	1	Location 1	40 min	13:50	14:30	15:00	15:40	

Table 3 – Backfill Driver Instruction 40 minute travel time

A 40 minute travel time only reduces the maximum amount of loads to 11 loads:

11 loads × 15 m/load = 1650m per day can be backfilled

Batching Plant 1 Schedule									
Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6	Truck 7	Truck 8	Truck 9
07:50 - 08:20	1								
08:20 - 08:50		2							
08:50 - 09:20			3						
09:20 - 09:50				4					
09:50 - 10:20					5				
10:20 - 10:50						6			
10:50 - 11:20	7								
11:20 - 11:50 LUNCH									
11:50 - 12:20		8							
12:20 - 12:50			9						
12:50 - 13:20				10					
13:20 - 13:50					11				

Figure 12 – Batching Plant Schedule 40 minute travel time

It can once again be seen that the batching plant is running at full capacity.

Site 1	
Batch No.	Time
1	09:00 - 09:30
	30 min idle
3	10:00 - 10:30
	30 min idle
5	11:00 - 11:30
	30 min idle
7	12:00 - 12:30
	Lunch 12:30 -13:00
	30 min idle
9	13:30 - 14:00
	30 min idle
11	14:30 - 15:00

Site 2	
Batch No.	Time
	30 min idle
2	09:30 - 10:00
	30 min idle
4	10:30 - 11:00
	30 min idle
6	11:30 - 12:00
	LUNCH 12:00 - 13:00
8..	13:00 - 13:30
	30 min idle
10	14:00 - 14:30
	30 min idle

Figure 13 – Resource Utilization on both sites 40 min travel time

The idle time of the workers on site remain the same.

c) 60 minute travel time to one site or two sites with 60 minutes travel time

Backfill Driver Instructions

Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	60 min	08:00	09:00	09:30	10:30	
2	Truck 2	1	Location 2	60 min	08:30	09:30	10:00	11:00	
3	Truck 3	1	Location 1	60 min	09:00	10:00	10:30	11:30	
4	Truck 4	1	Location 2	60 min	09:30	10:30	11:00	12:00	
5	Truck 5	1	Location 1	60 min	10:00	11:00	11:30	12:30	
6	Truck 6	1	Location 2	60 min	10:30	11:30	12:00	13:00	
7	Truck 1	1	Location 1	60 min	11:00	12:00	12:30	13:30	
8	Truck 2	1	Location 2	60 min	12:00	13:00	13:30	14:30	
9	Truck 3	1	Location 1	60 min	12:30	13:30	14:00	15:00	
10	Truck 4	1	Location 2	60 min	13:00	14:00	14:30	15:30	
11	Truck 5	1	Location 1	60 min	13:30	14:30	15:00	16:00	

Table 4 – Backfill Driver Instruction 60 minute travel time

Batching Plant 1 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6	Truck 7	Truck 8	Truck 9
07:30 - 08:00	1								
08:00 - 08:30		2							
08:30 - 09:00			3						
09:00 - 09:30				4					
09:30 - 10:00					5				
10:00 - 10:30						6			
10:30 - 11:00	7								
11:00 - 11:30 LUNCH									
11:30 - 12:00		8							
12:00 - 12:30			9						
12:30 - 13:00				10					
13:00 - 13:30					11				

Figure 14 – Batching Plant Schedule 60 minute travel time

Site 1			Site 2	
Batch No.	Time		Batch No.	Time
1	09:00 - 09:30			30 min idle
	30 min idle		2	09:30 - 10:00
3	10:00 - 10:30			30 min idle
	30 min idle		4	10:30 - 11:00
5	11:00 - 11:30			30 min idle
	30 min idle		6	11:30 - 12:00
7	12:00 - 12:30			LUNCH 12:00 - 13:00
	Lunch 12:30 -13:00		8..	13:00 - 13:30
	30 min idle			30 min idle
9	13:30 - 14:00		10	14:00 - 14:30
	30 min idle			30 min idle
11	14:30 - 15:00			

Figure 15 – Resource Utilization on both sites 60 min travel time

The analysis for the 40 minute travel time as well as the 60 min travel time yields the same maximum number of batches as well as the same idle times of workers on site.

d) 80 minute travel time to one site or two sites with 80 minutes travel time

Backfill Driver Instructions									
Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	80 min	07:40	09:00	09:30	10:50	
2	Truck 2	1	Location 2	80 min	08:10	09:30	10:00	11:20	
3	Truck 3	1	Location 1	80 min	08:40	10:00	10:30	11:50	
4	Truck 4	1	Location 2	80 min	09:10	10:30	11:00	12:20	
5	Truck 5	1	Location 1	80 min	09:40	11:00	11:30	12:50	
6	Truck 6	1	Location 2	80 min	10:10	11:30	12:00	13:20	
7	Truck 1	1	Location 1	80 min	10:40	12:00	12:30	13:50	
8	Truck 2	1	Location 2	80 min	11:40	13:00	13:30	14:50	
9	Truck 3	1	Location 1	80 min	12:10	13:30	14:00	15:20	
10	Truck 4	1	Location 2	80 min	12:40	14:00	14:30	15:50	

Table 5 – Backfill Driver Instruction 80 minute travel time

Batching Plant 1 Schedule									
Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6	Truck 7	Truck 8	Truck 9
07:10 - 07:40	1								
07:40 - 08:10		2							
08:10 - 08:40			3						
08:40 - 09:10				4					
09:10 - 09:40					5				
09:40 - 10:10						6			
10:10 - 10:40	7								
10:40 - 11:10 LUNCH									
11:10 - 11:40		8							
11:40 - 12:10			9						
12:10 - 12:40				10					

Figure 16 – Batching Plant Schedule 80 minute travel time

Site 1			Site 2	
Batch No.	Time		Batch No.	Time
1	09:00 - 09:30			30 min idle
	30 min idle		2	09:30 - 10:00
3	10:00 - 10:30			30 min idle
	30 min idle		4	10:30 - 11:00
5	11:00 - 11:30			30 min idle
	30 min idle		6	11:30 - 12:00
7	12:00 - 12:30			LUNCH 12:00 - 13:00
	Lunch 12:30 -13:00		8..	13:00 - 13:30
	30 min idle			30 min idle
9	13:30 - 14:00		10	14:00 - 14:30
	30 min idle			30 min idle

Figure 17 – Resource Utilization on both sites 80 min travel time

The 80 minute travel time yields one less batch than the 40 minute and 60 minute travel times. The number of batches yielded with the different travel times is summarized in the following table:

Batch Summary	
Travel time	No. Of batches
20 minutes	12
40 mintues	11
60 minutes	11
80 minutes	10
Average	11

Table 6 – Batch Summary

The process is currently yielding an average of 6.48 batches per day therefore the resource utilization factor reads as follows:

6.48 batches per day ÷ 11 batches per day = 58.9 % utilization factor

3.1.3 Duct Trucks

There are four duct trucks available for production. The duct arrives in the yard on reels and these reels hold 1000m of ducting on each reel. Each truck can carry one reel of duct. The total ducting capacity is therefore 4000m per day and the resource utilization factor is as follows:

972.175 production m/day ÷ 4000m capacity = 24.3 % utilization factor

3.2 Current process

From the current capabilities it can be determined that the current process is operating below optimum performance. The resources are available but are not being properly utilised. The following flowchart shows the current process:

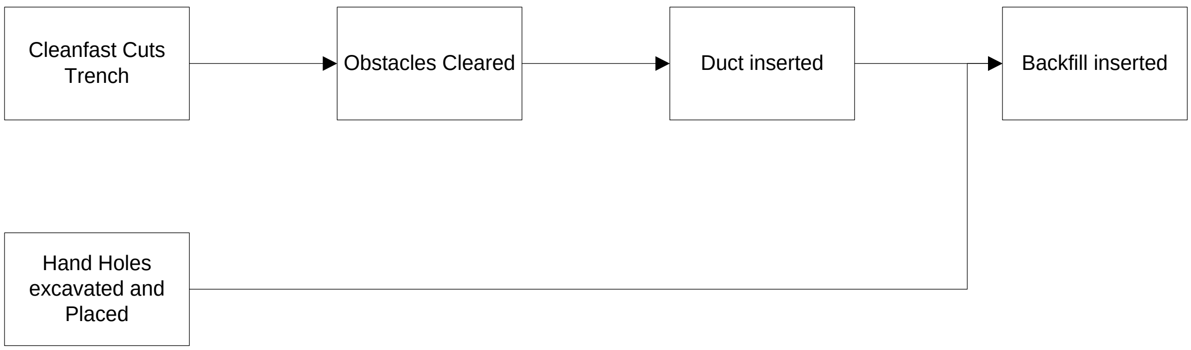

Figure 18 – Flowchart of Current Process

The resource utilization is influenced by the following factors:

- There is a maximum amount of open trench that can be left overnight. Therefore the Cleanfast machines can only cut what they can close and a maximum of 500 meters can be left open. The Cleanfast trenching equipment should be the limiting factor in this process. The costs of these machines are high and the equipment should be operating at maximum capacity. Currently the site supervisors are stopping the equipment when the rest of the resources in the process are falling behind.
- The obstacles that have to be cleared manually is the main reason why the resource utilization factors are so low The number of backfill loads determines the meters that can be cut by the Cleanfast. The backfill capacity should always exceed the Cleanfasts cutting capacity.
- The maximum amount of backfill loads can never be inserted into the ground because the obstacles have to be cleared first before the ducting can be laid. This is the main reason

why the resource utilization factors are so low. Some areas like Pretoria CBD contain many obstacles, resulting in the batching plant being idle for long periods of time.

- Water pipes are sometimes damaged by the Cleanfasts. Depending on the gradient of the road, the water then runs into the trench. If the backfill mixture is too close to the water pipes that are damaged the backfilled can be damaged. The backfill supervisor does not want to order backfill loads before he is not certain that there are not any more pipes that can be damaged.

- Planning is not done in advance resulting in long meetings being held in the mornings. The teams should arrive on site before 09:00 in order to maximise the permitted working time.

- The hand holes are not excavated and placed in advance. A hole is excavated under the curb stone in order to insert the duct from the trench into the hand hole. Because these holes are not excavated before the ducting team arrives an excess of duct is pulled from the reels and left on the sidewalk. Once the holes are finished the duct can then be inserted under the curb stone. However the backfill cannot be inserted up until the sidewalk because the ducting has to be bent in order to insert it into the holes under the curb stones. This results in 5 meter pieces of trench that can only be completed once the duct has been inserted under the curb stone.

A summary of the current process capabilities and the resource utilization factors follows:

Resource Utilization Current Process			
Resource	Capability (m)	Current performance (m)	Utilization factor
Cleanfast	3862.2	972.175	0.25
Backfill	1650	972.175	0.59
Ducting	4000	972.175	0.24

Table 7 – Resource utilization current process

3.3 Second batching plant

Muvoni Weltex is in the process of installing a second batching plant. This will increase the trench that can be filled, thereby increasing overall production. However, the current batching plant is not even running at full capacity and the process will therefore have to be changed in order to justify the additional batching plant.

The capabilities with the additional batching plant included was analysed and the maximum number off batches that can be dispatched to site determined. Once again the 20 minute, 40 minute, 60 minute and 80 minute travel times were used and all the combination between these four times were also analysed to determine the idle times on site as well as on the batching plant.

By determining the maximum batches that the batching plants can deliver the supervisors will know how much they can allow the Cleanfast trenching equipment can cut. This will be directly proportional to the travel distance from site. Muvoni Weltex has the option of hiring additional concrete mixers and the optimal time to hire additional mixers will also be analysed:

a) 20 minute travel time to one site or two sites with 20 minutes travel time to each:

Backfill Driver Instructions Proposed

Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	20 min	08:40	09:00	09:30	09:50	
2	Truck 2	2	Location 2	20 min	08:40	09:00	09:30	09:50	
3	Truck 3	1	Location 1	20 min	09:10	09:30	10:00	10:20	
4	Truck 4	2	Location 2	20 min	09:10	09:30	10:00	10:20	
5	Truck 5	1	Location 1	20 min	09:40	10:00	10:30	10:50	
6	Truck 6	2	Location 2	20 min	09:40	10:00	10:30	10:50	
7	Truck 1	1	Location 1	20 min	10:20	10:40	11:10	11:30	
8	Truck 2	2	Location 2	20 min	10:20	10:40	11:10	11:30	
9	Truck 3	1	Location 1	20 min	10:50	11:10	11:40	12:00	
10	Truck 4	2	Location 2	20 min	10:50	11:10	11:40	12:00	
11	Truck 5	1	Location 1	20 min	11:20	11:40	12:10	12:30	
12	Truck 6	2	Location 2	20 min	11:20	11:40	12:10	12:30	
13	Truck 1	1	Location 1	20 min	12:00	12:20	13:20	13:40	
14	Truck 2	2	Location 2	20 min	12:00	12:20	13:20	13:40	
15	Truck 3	1	Location 1	20 min	13:00	13:20	13:50	14:10	
16	Truck 4	2	Location 2	20 min	13:00	13:20	13:50	14:10	
17	Truck 5	1	Location 1	20 min	13:30	13:50	14:20	14:40	
18	Truck 6	2	Location 2	20 min	13:30	13:50	14:20	14:40	
19	Truck 1	1	Location 1	20 min	14:10	14:30	15:00	15:20	
20	Truck 2	2	Location 2	20 min	14:10	14:30	15:00	15:20	
21	Truck 3	1	Location 1	20 min	14:40	15:00	15:30	15:50	
22	Truck 4	2	Location 2	20 min	14:40	15:00	15:30	15:50	

Table 8 – Backfill Driver Instruction 20 minute – 20 minute travel time

It can be seen from the table that it is possible to dispatch 22 bathes in ideal conditions.

22 batches × 150 m/batch = 3300 m of backfilled trench

Therefore the Cleanfasts can cut anything up to 3300 m per day if there are two sites with 20 minutes travel time each or one site with 20 minutes travel time.

Batching Plant 1 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
08:10 - 08:40	1					
08:40 - 09:10			3			
09:10 - 09:40					5	
09:50 - 10:20 10 min idle	7					
10:20 - 10:50			9			
10:50 - 11:20					11	
11:30 - 12:00 10 min idle	13					
12:00 - 12:30 LUNCH						
12:30 - 13:00			15			
13:00 - 13:30					17	
13:40 - 14:10 10 min idle	19					
14:10 - 14:40			21			

Batching Plant 2 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
08:10 - 08:40		2				
08:40 - 09:10				4		
09:10 - 09:40						6
09:50 - 10:20 10 min idle		8				
10:20 - 10:50				10		
10:50 - 11:20						12
11:30 - 12:00 10 min idle		14				
12:00 - 12:30 LUNCH						
12:30 - 13:00				16		
13:00 - 13:30						18
13:40 - 14:10 10 min idle		20				
14:10 - 14:40				22		

Figure 19 – Batching Plant Schedules 20 minute – 20 minute travel times

There are periods were the batching plant is idle for ten minutes but this idle time does not allow for an additional truck to be hired. The additional truck would take half an hour to be loaded resulting in idle time for the existing trucks. An half an hour lunch is permitted in the middle of the day as agreed by management and workers.

Site 1			Site 2	
Batch No.	**Time**		**Batch No.**	**Time**
1	09:00 - 09:30		2	09:00 - 09:30
3	09:30 - 10:00		4	09:30 - 10:00
5	10:00 - 10:30		6	10:00 - 10:30
	10 min idle			10 min idle
7	10:40 - 11:10		8	10:40 - 11:10
9	11:10 - 11:40		10	11:10 - 11:40
11	11:40 - 12:10		1 2	11:40 - 12:10
	10 min idle			10 min idle
13	12:20 - 12:50		14	12:20 - 12:50
	Lunch 12:50 -13:20			Lunch 12:50 -13:20
15	13:20 - 13:50		16	13:20 - 13:50
17	13:50 - 14:20		18	13:50 - 14:20
	10 min idle			10 min idle
19	14:30 - 15:00		20	14:30 - 15:00
21	15:00 - 15:30		22	15:00 - 15:30

Figure 20 – Resource utilization on site 20 min – 20 min travel times

The backfill workers on site also have idle times of ten minutes and the optimal time to allow the workers a half an hour lunch is determined on both sites.

b) 20 minutes travel time to Site 1 and 40 minutes travel time to Site 2:

Backfill Driver Instructions

Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	20 min	08:40	09:00	09:30	09:50	
2	Truck 2	2	Location 2	40 min	08:20	09:00	09:30	10:10	
3	Truck 3	1	Location 1	20min	09:10	09:30	10:00	10:20	
4	Truck 4	2	Location 2	40 min	08:50	09:30	10:00	10:40	
5	Truck 5	1	Location 1	20 min	09:40	10:00	10:30	10:50	
6	Truck 6	2	Location 2	40 min	09:20	10:00	10:30	11:10	
7	Truck 1	1	Location 1	20 min	10:20	10:40	11:10	11:30	
8	Truck 2	2	Location 2	40 min	10:40	11:20	11:50	12:30	
9	Truck 3	1	Location 1	20 min	10:50	11:10	11:40	12:00	
10	Truck 4	2	Location 2	40 min	11:10	11:50	12:20	13:30	
11	Truck 5	1	Location 1	20min	11:20	11:40	12:10	12:30	
12	Truck 6	2	Location 2	40min	11:40	12:20	12:50	13:30	
13	Truck 1	1	Location 1	20 min	12:00	12:20	12:50	13:10	
14	Truck 3	2	Location 2	40min	12:30	13:10	13:50	14:30	
15	Truck 2	1	Location 1	20 min	13:00	13:20	13:50	14:10	
16	Truck 5	2	Location 2	40min	13:10	13:50	14:20	15:00	
17	Truck 1	1	Location 1	20 min	13:40	14:00	14:30	14:50	
18	Truck 4	2	Location 2	40min	14:00	14:40	15:10	15:50	
19	Truck 6	1	Location 1	20 min	14:10	14:30	15:00	15:20	
20	Truck 2	2	Location 1	20 min	14:40	15:00	15:30	15:50	

Table 9 – Backfill Driver Instruction 20 minute – 40 minute travel time

It can be seen from the above figure that it would be possible to dispatch 20 loads to two different sites with 20 minutes and 40 minutes travel time respectively:

20 loads × 150 m/load = 3000 m of backfilled trench per day

On the first day of trenching these figures would not be achievable as the Cleanfasts would first have to open trench to be backfilled. However on the second day of trenching trench would have been left open the previous day.

Batching Plant 1 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
08:10 - 08:40	1					
08:40 - 09:10			3			
09:10 - 09:40					5	
09:50 - 10:20 10 min idle	7					
10:20 - 10:50			9			
10:50 - 11:20					11	
11:30 - 12:00 10 min idle	13					
12:30 - 13:00 30 min idle		15				
13:10 - 13:40 10 min idle	17					
13:40 - 14:10						19

Batching Plant 2 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:50 - 08:20		2				
08:20 - 08:50				4		
08:50 - 09:20						6
10:10 - 10:40 50 min idle		8				
10:40 - 11:10				10		
11:10 - 11:40						12
12:00 - 12:30 20 min idle			14			
12:40 - 13:10 10 min idle					16	
13:30 - 14:00 20 min idle				18		
14:10 - 14:40 10 min idle		20				

Figure 21 – Batching Plant Schedules 20 minute – 40 minute travel times

It can be seen from the batching plant schedule that the idle times on batching plant 1 is minimal but an additional truck could decrease the utilization of batching plant 2. An additional truck would decrease the batching times between batches 8 and 10 to 20 minutes.

Site 1		Site 2	
Batch No.	**Time**	**Batch No.**	**Time**
1	09:00 - 09:30	2	09:00 - 09:30
3	09:30 - 10:00	4	09:30 - 10:00
5	10:00 - 10:30	6	10:00 - 10:30
	10 min idle		50 min idle
7	10:40 - 11:10	8	11:20 - 11:50
9	11:10 - 11:40	10	11:50 - 12:20
11	11:40 - 12:10	1 2	12:20 - 12:50
13	12:20 - 12:50		Lunch 12:50 -13:20
	Lunch 12:50 -13:20	14	13:20 - 13:50
15	13:20 - 13:50	16	13:50 - 14:20
	10 min idle		20 min idle
17	14:00 - 14:30	18	14:40 - 15:10
19	14:30 - 15:00		
20	15:00 - 15:30		

Figure 22 – Resource utilization on site 20 min – 40 min travel times

The optimal times to allow lunch breaks on site can be established. It would be preferable to allow lunch and tea breaks for workers in idle times in order to maximise productive time on site.

c) 20 minutes travel time to Site 1 and 60 minutes travel time to Site 2:

Backfill Driver Instructions

Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	20 min	08:40	09:00	09:30	09:50	
2	Truck 2	2	Location 2	60 min	08:00	09:00	09:30	10:30	
3	Truck 3	1	Location 1	20min	09:10	09:30	10:00	10:20	
4	Truck 4	2	Location 2	60 min	08:30	09:30	10:00	11:00	
5	Truck 5	1	Location 1	20 min	09:40	10:00	10:30	10:50	
6	Truck 6	2	Location 2	60 min	09:00	10:00	10:30	11:30	
7	Truck 1	2	Location 2	60 min	10:20	11:20	11:50	12:50	
8	Truck 3	1	Location 1	20 min	10:50	11:10	11:40	12:00	
9	Truck 2	2	Location 2	60 min	11:00	12:00	12:30	13:30	
10	Truck 5	1	Location 1	20 min	11:20	11:40	12:10	12:30	
11	Truck 4	2	Location 2	60 min	11:30	12:30	13:00	14:00	
12	Truck 6	1	Location 1	20 min	12:00	12:20	12:50	13:10	
13	Truck 3	2	Location 2	60 min	12:30	13:30	14:00	15:00	
14	Truck 5	1	Location 1	20 min	13:00	13:20	13:50	14:10	
15	Truck 1	2	Location 2	60 min	13:20	14:20	14:50	15:50	
16	Truck 6	1	Location 1	20 min	13:40	14:00	14:30	14:50	
17	Truck 2	2	Location 1	20 min	14:10	14:30	15:00	15:20	
18	Truck 4	1	Location 1	20 min	14:40	15:00	15:30	15:50	

Table 10 – Backfill Driver Instruction 20 minute – 60 minute travel time

18 batches can be produced with site 1 at a 20 minute travel time and site 2 at a 60 minute travel time. From these tables it can be seen how the different travel times affect the concrete mixer trucks' ability to deliver batches to site.

18 batches × 150 m/batch = 2700 m/day

Batching Plant 1 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
08:10 - 08:40	1					
08:40 - 09:10			3			
09:10 - 09:40					5	
10:20 - 10:50 40 min idle			8			
10:50 - 11:20					10	
11:30 -12:00 10 min idle						12
12:30 - 13:00 30 min idle					14	
13:10 -13:40 10 min idle						16
14:10 - 14:40 30 min idle				18		

Batching Plant 2 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:30 - 08:00		2				
08:00 - 08:30				4		
08:30 - 09:00						6
09:50 - 10:20 50 min idle	7					
10:30 - 11:00 10 min idle		9				
11:00 11:30				11		
12:00 - 12:30 30 min idle			13			
12:50 - 13:20 20 min idle	15					
13:40 - 14:10 20 min idle		17				

Figure 23 – Batching Plant Schedules 20 minute – 60 minute travel times

Two extra trucks would be beneficial as they would decrease the idle times on the batching plants after the first six loads to 10 minutes and 20 minutes respectively. The addition of two extra trucks would deliver two extra loads to site, giving an additional capacity of 300 m.

20 loads × 150 m/load = 3000m/day

Site 1			Site 2	
Batch No.	Time		Batch No.	Time
1	09:00 - 09:30		2	09:00 - 09:30
3	09:30 - 10:00		4	09:30 - 10:00
5	10:00 - 10:30		6	10:00 - 10:30
	40 min idle			50 min idle
8	11:10 - 11:40		7	11:20 - 11:50
10	11:40 - 12:10			10 min idle
	10 min idle		9..	12:00 - 12:30
12	12:20 -12:50		11	12:30 - 13:00
	Lunch 12:50 - 13:20			Lunch 13:00 - 13:30
14	13:20 - 13:50		13	13:30 - 14:00
	10 min idle			20 min idle
16	14:00 - 14:30		15	14:20 - 14:50
17	14:30 - 15:00			
18	15:00 - 15:30			

Figure 24 – Resource utilization on site 20 min – 60 min travel times

The 2 additional loads would decrease the idle time on site after the first six loads to 10 minutes and 20 minutes respectively.

d) 20 minutes travel time to Site 1 and 80 minutes travel time to Site 2:

Backfill Driver Instructions Proposed									
Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	20 min	08:40	09:00	09:30	09:50	
2	Truck 2	2	Location 2	80 min	07:40	09:00	09:30	10:50	
3	Truck 3	1	Location 1	20min	09:10	09:30	10:00	10:20	
4	Truck 4	2	Location 2	80 min	08:10	09:30	10:00	11:20	
5	Truck 5	1	Location 1	20 min	09:40	10:00	10:30	10:50	
6	Truck 6	2	Location 2	80 min	08:40	10:00	10:30	11:50	
7	Truck 1	2	Location 2	80 min	10:20	11:40	12:10	13:30	
8	Truck 3	1	Location 1	20 min	10:50	11:10	11:40	12:00	
9	Truck 2	2	Location 1	20 min	11:20	11:40	12:10	12:30	
10	Truck 5	1	Location 2	80 min	11:20	12:40	13:10	14:30	
11	Truck 4	1	Location 2	80 min	11:50	13:10	13:40	15:00	
12	Truck 6	2	Location 1	20 min	12:20	12:40	13:10	13:30	
13	Truck 3	1	Location 2	80 min	12:30	13:50	14:10	15:30	
14	Truck 2	2	Location 1	20 min	13:00	13:20	13:50	14:10	
15	Truck 1	1	Location 1	20 min	14:00	14:20	14:50	15:10	
16	Truck 6	2	Location 1	20 min	14:30	14:50	15:20	15:40	

Table 11 – Backfill Driver Instruction 20 minute – 80 minute travel time

The batching plant can produce 16 batches for two sites with 20 minutes and 80 minutes respectively:

16 batches × 150 m/load = 2400 m/day

This is way under the Cleanfasts' capacities; therefore additional trucks would be beneficial.

Batching Plant 1 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
08:10 - 08:40	1					
08:40 - 09:10			3			
09:10 - 09:40					5	
10:20 - 10:50 40 min idle			8			
10:50 - 11:20					10	
11:20 - 11:50				11		
12:00 - 12:30 10 min idle			13			
13:30 - 14:00 60 min idle	15					

Batching Plant 2 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:10 - 07:40		2				
07:40 - 08:10				4		
08:10 - 08:40						6
09:40 - 10:10 60 min idle	7					
10:50 - 11:20 40 min idle		9				
11:50 - 12:00 30min idle						12
12:30 - 13:00 30min idle		14				
14:00 - 14:30 60 min idle						16

Figure 25 – Batching Plant Schedules 20 minute – 80 minute travel times

With the addition of three extra trucks the idle times on site as well as the idle time of the batching plant can be reduced. This would yield four extra loads to site:

19 loads × 150m/load = 2850 meters of backfilled trench per day

Site 1			Site 2	
Batch No.	Time		Batch No.	Time
1	09:00 - 09:30		2	09:00 - 09:30
3	09:30 - 10:00		4	09:30 - 10:00
5	10:00 - 10:30		6	10:00 - 10:30
	40 min idle			70 min idle
8	11:10 - 11:40		7	11:40 - 12:10
9	11:40 - 12:10			Lunch 12:10 - 12:40
	Lunch 12:10 - 12:40		1 0	12:40 - 13:10
12	12:40 - 13:10		11	13:10 - 13:40
	10 min idle			10 min idle
14	13:20 - 13:50		13	13:50 - 14:20
	30 min idle			
15	14:20 - 14:50			
16	14:50 - 15: 20			

Figure 26 – Resource utilization on site 20 min – 80 min travel times

The idle times on site will be reduced by 60 minutes on each site respectively by the addition of two trucks.

e) 40 minute travel time to one site or two sites with 40 minutes travel time to each:

Backfill Driver Instructions									
Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	40 min	08:20	09:00	09:30	10:10	
2	Truck 2	2	Location 2	40 min	08:20	09:00	09:30	10:10	
3	Truck 3	1	Location 1	40 min	08:50	09:30	10:00	10:40	
4	Truck 4	2	Location 2	40 min	08:50	09:30	10:00	10:40	
5	Truck 5	1	Location 1	40 min	09:20	10:00	10:30	11:10	
6	Truck 6	2	Location 2	40 min	09:20	10:00	10:30	11:10	
7	Truck 1	1	Location 1	40 min	10:40	11:20	11:50	12:30	
8	Truck 2	2	Location 2	40 min	10:40	11:20	11:50	12:30	
9	Truck 3	1	Location 1	40 min	11:10	11:50	12:20	13:00	
10	Truck 4	2	Location 2	40 min	11:10	11:50	12:20	13:00	
11	Truck 5	1	Location 1	40 min	11:40	12:20	12:50	13:30	
12	Truck 6	2	Location 2	40 min	11:40	12:20	12:50	13:30	
13	Truck 1	1	Location 1	40 min	13:00	13:40	14:10	14:50	
14	Truck 2	2	Location 2	40 min	13:00	13:40	14:10	14:50	
15	Truck 3	1	Location 1	40 min	13:30	14:10	14:40	15:20	
16	Truck 4	2	Location 2	40 min	13:30	14:10	14:40	15:20	
17	Truck 5	1	Location 1	40 min	14:00	14:40	15:10	15:50	
18	Truck 6	2	Location 2	40 min	14:00	14:40	15:10	15:50	
19									

Table 12 – Backfill Driver Instruction 40 minute – 40 minute travel time

18 batches can be dispatched to the two different sites:

18 batches × 150 m/batch = 2700 m/day

Batching Plant 1 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:50 - 08:20	1					
08:20 - 08:50			3			
08:50 - 09:20					5	
10:10 - 10:40 50min idle	7					
10:40 - 11:10			9			
11:10 - 11:40					11	
12:30 - 13:00 50min idle	13					
13:00 - 13:30			15			
13:30 - 14:00					17	

Batching Plant 2 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:50 - 08:20		2				
08:20 - 08:50				4		
08:50 - 09:20						6
10:10 - 10:40 50min idle		8				
10:40 - 11:10				10		
11:10 - 11:40						12
12:30 - 13:00 50min idle		14				
13:00 - 13:30				16		
13:30 - 14:00						18

Figure 27 – Batching Plant Schedules 40 minute – 40 minute travel times

Site 1

Batch No.	Time
1	09:00 - 09:30
3	09:30 - 10:00
5	10:00 - 10:30
	50min idle
7	11:20 - 11:50
9	11:50 - 12:20
11	12:20 - 12:50
	50min idle
13	13:40 - 14:10
15	14:10 - 14:40
17	14:40 - 15:10

Site 2

Batch No.	Time
2	09:00 - 09:30
4	09:30 - 10:00
6	10:00 - 10:30
	50min idle
8	11:20 - 11:50
10	11:50 - 12:20
12	12:20 - 12:50
	50min idle
14	13:40 - 14:10
16	14:10 - 14:40
18	14:40 - 15:10

Figure 28 – Resource utilization on site 40 min – 40 min travel times

Two additional trucks would be beneficial as it would yield an extra four loads to the sites. It would reduce the 50 minute idle times on the batching plants as well as on both sites to 20 minutes. Once again it would be beneficial to allow the workers tea and lunch breaks in the idle time.

22 batches × 150 m/load = 3300 m/day

f) 40 minutes travel time to Site 1 and 60 minutes travel time to Site 2:

Backfill Driver Instructions Proposed

Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	40 min	08:20	09:00	09:30	10:10	
2	Truck 2	2	Location 2	60 min	08:00	09:00	09:30	10:30	
3	Truck 3	1	Location 1	40 min	08:50	09:30	10:00	10:40	
4	Truck 4	2	Location 2	60 min	08:30	09:30	10:00	11:00	
5	Truck 5	1	Location 1	40 min	09:20	10:00	10:30	11:10	
6	Truck 6	2	Location 2	60 min	09:00	10:00	10:30	11:30	
7	Truck 1	2	Location 2	60 min	10:40	11:40	12:10	13:10	
8	Truck 2	1	Location 1	40 min	11:00	11:40	12:10	12:50	
9	Truck 3	2	Location 2	60 min	11:10	12:10	12:40	13:40	
10	Truck 4	1	Location 1	40 min	11:30	12:10	12:40	13:20	
11	Truck 5	2	Location 2	60 min	11:40	12:40	13:10	14:10	
12	Truck 6	1	Location 1	40 min	12:00	12:40	13:10	13:50	
13	Truck 2	2	Location 2	60 min	13:20	14:20	14:50	15:50	
14	Truck 1	1	Location 1	40 min	13:40	14:20	14:50	15:30	
15	Truck 4	2	Location 1	40 min	14:10	14:50	15:20	16:00	
16									

Table 13 – Backfill Driver Instruction 40 minute – 60 minute travel time

15 batches can be dispatched to both sites:

15 batches × 150 m/batch = 2250m/day

Batching Plant 1 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:50 - 08:20	1					
08:20 - 08:50			3			
08:50 - 09:20					5	
10:30 - 11:00 70 min idle		8				
11:00 - 11:30				10		
11:30 - 12:00						12
13:10 - 13:40 70 min idle	14					

Batching Plant 2 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:30 - 08:00		2				
08:00 - 08:30				4		
08:30 - 09:00						6
10:10 - 10:40 70 min idle	7					
10:40 - 11:10			9			
11:10 - 11:40					11	
12:50 - 13:20 70 min idle		13				
13:40 - 15:10 20 min idle				15		

Figure 29 – Batching Plant Schedules 40 minute – 60 minute travel times

Site 1		Site 2	
Batch No.	**Time**	**Batch No.**	**Time**
1	09:00 - 09:30	2	09:00 - 09:30
3	09:30 - 10:00	4	09:30 - 10:00
5	10:00 - 10:30	6	10:00 - 10:30
	70 min idle		70 min idle
8	11:40 - 12:10	7	11:40 - 12:10
10	12:10 - 12:40	9	12:10 - 12:40
12	12:40 - 13:10	11	12:40 - 13:10
	70 min idle		70 min idle
14	14:20 - 14:50	13	14:20 - 14:50
15	14:50 - 15:20		

Figure 30 – Resource utilization on site 40 min – 60 min travel times

Four additional trucks would be beneficial as it would yield six additional loads and the one 70 min idle period on both sites and both batching plants will be reduced to 10 min. The other idle period will be reduced to 40 min. The six extra loads will change the daily capacity to:

21 batches × 150 m/load = 3150 m/day

8) 40 minutes travel time to Site 1 and 80 minutes travel time to Site 2:

Backfill Driver Instructions

Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	40 min	08:20	09:00	09:30	10:10	
2	Truck 2	2	Location 2	80 min	07:40	09:00	09:30	10:50	
3	Truck 3	1	Location 1	40 min	08:50	09:30	10:00	10:40	
4	Truck 4	2	Location 2	80 min	08:10	09:30	10:00	11:20	
5	Truck 5	1	Location 1	40 min	09:20	10:00	10:30	11:10	
6	Truck 6	2	Location 2	80 min	08:40	10:00	10:30	11:50	
7	Truck 1	2	Location 2	80 min	10:40	12:00	12:30	13:50	
8	Truck 3	1	Location 1	40 min	11:10	11:50	12:20	13:00	
9	Truck 2	2	Location 2	80 min	11:20	12:40	13:10	14:30	
10	Truck 5	1	Location 1	40 min	11:40	12:20	12:50	13:30	
11	Truck 4	2	Location 2	80 min	11:50	13:10	13:40	15:00	
12	Truck 6	1	Location 1	40 min	12:20	13:00	13:30	14:10	
13	Truck 3	2	Location 1	40 min	13:30	14:10	14:40	15:20	
14	Truck 5	1	Location 1	40 min	14:00	14:40	15:10	15:50	

Table 14 – Backfill Driver Instruction 40 minute – 80 minute travel time

14 batches can be dispatched to the different sites:

14 batches × 150 m/batch = 2100 m/day

Batching Plant 1 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:50 - 08:20	1					
08:20 - 08:50			3			
08:50 - 09:20					5	
10:40 - 11:10 80 min idle			8			
11:10 - 11:40					10	
11:50 - 12:20 10 min idle						12
13:30 - 14:00 70 min idle					14	

Batching Plant 2 Schedule

Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:10 - 07:40		2				
07:40 - 08:10				4		
08:10 - 08:40						6
10:10 - 10:40 90 min idle	7					
10:40 - 11:10		9				
11:20 - 11:50 10 min idle				11		
13:00 - 13:30 70 min idle			13			

Figure 31 – Batching Plant Schedules 40 minute – 80 minute travel times

Site 1

Batch No.	Time
1	09:00 - 09:30
3	09:30 - 10:00
5	10:00 - 10:30
	80 min idle
8	11:50 - 12:20
10	12:20 - 12:50
	10 min idle
12	13:00 - 13:30
	40 min idle
13	14:10 - 14:40
14	14:40 - 15:10

Site 2

Batch No.	Time
2	09:00 - 09:30
4	09:30 - 10:00
6	10:00 - 10:30
	90 min idle
7	12:00 - 12:30
	10 min idle
9..	12:40 - 13:10
11	13:10 - 13:40

Figure 32 – Resource utilization on site 40 min – 80 min travel times

Five additional trucks would be beneficial and would yield 6 extra loads while reducing the idle times on site as well as the idle times on the batching plants by a total of 180 minutes. The additional loads will increase the capacity to:

20 batches × 150 m/batch = 3000 m/day

h) 60 minutes travel time to Site 1 and 60 minutes travel time to Site 2:

Backfill Driver Instructions									
Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	60 min	08:00	09:00	09:30	10:30	
2	Truck 2	2	Location 2	60 min	08:00	09:00	09:30	10:30	
3	Truck 3	1	Location 1	60 min	08:30	09:30	10:00	11:00	
4	Truck 4	2	Location 2	60 min	08:30	09:30	10:00	11:00	
5	Truck 5	1	Location 1	60 min	09:00	10:00	10:30	11:30	
6	Truck 6	2	Location 2	60 min	09:00	10:00	10:30	11:30	
7	Truck 1	1	Location 1	60 min	11:00	12:00	12:30	13:30	
8	Truck 2	2	Location 2	60 min	11:00	12:00	12:30	13:30	
9	Truck 3	1	Location 1	60 min	11:30	12:30	13:00	14:00	
10	Truck 4	2	Location 2	60 min	11:30	12:30	13:00	14:00	
11	Truck 5	1	Location 1	60 min	12:00	13:00	13:30	14:30	
12	Truck 6	2	Location 2	60 min	12:00	13:00	13:30	14:30	
13									

Table 15 – Backfill Driver Instruction 60 minute – 60 minute travel time

12 batches can be dispatched to the different sites:

12 batches × 150 m/batch = 1800 m/day

Batching Plant 1 Schedule						
Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:30 - 08:00	1					
08:00 - 08:30			3			
08:30 - 09:00					5	
10:30 - 11:00 90min idle	7					
11:00 - 11:30			9			
11:30 - 12:00					11	

Batching Plant 2 Schedule						
Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:30 - 08:00		2				
08:00 - 08:30				4		
08:30 - 09:00						6
10:30 - 11:00 90min idle		8				
11:00 - 11:30				10		
11:30 - 12:00						12

Figure 33 – Batching Plant Schedules 60 minute – 60 minute travel times

Site 1			Site 2	
Batch No.	Time		Batch No.	Time
1	09:00 - 09:30		2	09:00 - 09:30
3	09:30 - 10:00		4	09:30 - 10:00
5	10:00 - 10:30		6	10:00 - 10:30
	90 min idle			90 min idle
8	12:00 - 12:30		7	12:00 - 12:30
10	12:30 - 13:00		9	12:30 - 13:00
12	13:00 - 13:30		1 1	13:00 - 13:30

Figure 34 – Resource utilization on site 60 min – 60 min travel times

Four additional trucks would yield 8 extra batches to site while reducing the idle times on both site and both batching plants to 30 minutes respectively. This addition will increase the daily backfill capacity to:

20 batches × 150 m/batch = 3000 m/day

i) 60 minutes travel time to Site 1 and 80 minutes travel time to Site 2:

Backfill Driver Instructions									
Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	60 min	08:00	09:00	09:30	10:30	
2	Truck 2	2	Location 2	80 min	07:40	09:00	09:30	10:50	
3	Truck 3	1	Location 1	60 min	08:30	09:30	10:00	11:00	
4	Truck 4	2	Location 2	80 min	08:10	09:30	10:00	11:20	
5	Truck 5	1	Location 1	60 min	09:00	10:00	10:30	11:30	
6	Truck 6	2	Location 2	80 min	08:40	10:00	10:30	11:50	
7	Truck 1	2	Location 2	80 min	11:00	12:20	12:50	14:10	
8	Truck 2	1	Location 1	60 min	11:20	12:20	12:50	13:50	
9	Truck 3	2	Location 2	80 min	11:30	12:50	13:20	14:40	
10	Truck 4	1	Location 1	60 min	11:50	12:50	13:20	14:20	
11	Truck 5	2	Location 2	80 min	12:00	13:20	13:50	15:10	
12	Truck 6	1	Location 1	60 min	12:20	13:20	13:50	14:50	

Table 16 – Backfill Driver Instruction 60 minute – 80 minute travel time

12 batches can be dispatched to the different sites:

12 batches × 150 m/batch = 1800 m/day

Batching Plant 1 Schedule						
Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:30 - 08:00	1					
08:00 - 08:30			3			
08:30 - 09:00					5	
10:50 - 11:20 110 min idle		8				
11:20 - 11:50				10		
11:50 - 12:20						12

Batching Plant 2 Schedule						
Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:10 - 07:40		2				
07:40 - 08:10				4		
08:10 - 08:40						6
10:30 - 11:00 110 min idle	7					
11:00 - 11:30			9			
11:30 - 12:00					11	

Figure 35 – Batching Plant Schedules 60 minute – 80 minute travel times

Site 1	
Batch No.	Time
1	09:00 - 09:30
3	09:30 - 10:00
5	10:00 - 10:30
	110 min idle
8	12:20 - 12:50
10	12:50 - 13:20
12	13:20 - 13:50

Site 2	
Batch No.	Time
2	09:00 - 09:30
4	09:30 - 10:00
6	10:00 - 10:30
	110 min idle
7	12:20 - 12:50
9	12:50 - 13:20
11	13:20 - 13:50

Figure 36 – Resource utilization on site 60 min – 80 min travel times

Six additional trucks would be beneficial, yielding 9 additional batches that can be dispatched to site while reducing the idle times on site to 20 minutes. The additional batches would increase the daily capacity to:

21 batches × 150 m/batch = 3150 m/day

j) 80 minutes travel time to Site 1 and 80 minutes travel time to Site 2:

Backfill Driver Instructions									
Batch No.	Driver	Batching Plant	Location	Travel Time	Time Out (Yard)	Arrival Time (Site)	Depart Time (Site)	Time in	Report to
1	Truck 1	1	Location 1	80 min	07:40	09:00	09:30	10:50	
2	Truck 2	2	Location 2	80 min	07:40	09:00	09:30	10:50	
3	Truck 3	1	Location 1	80 min	08:10	09:30	10:00	11:20	
4	Truck 4	2	Location 2	80 min	08:10	09:30	10:00	11:20	
5	Truck 5	1	Location 1	80 min	08:40	10:00	10:30	11:50	
6	Truck 6	2	Location 2	80 min	08:40	10:00	10:30	11:50	
7	Truck 1	1	Location 1	80 min	11:20	12:40	13:10	14:30	
8	Truck 2	2	Location 2	80 min	11:20	12:40	13:10	14:30	
9	Truck 3	1	Location 1	80 min	12:20	13:40	14:10	15:30	
10	Truck 4	2	Location 2	80 min	12:20	13:40	14:10	15:30	
11	Truck 5	1	Location 1	80 min	12:50	14:10	14:40	16:00	
12	Truck 6	2	Location 2	80 min	12:50	14:10	14:40	16:00	
13									

Table 17– Backfill Driver Instruction 80 minute – 80 minute travel time

12 batches can be dispatched to the different sites:

12 batches × 150 m/batch = 1800 m/day

Batching Plant 1 Schedule						
Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:10 - 07:40	1					
07:40 - 08:10			3			
08:10 - 08:40					5	
10:50 - 11:20 130 min idle	7					
11:50 - 12:20 30 min idle			9			
12:20 - 12:50					11	

Batching Plant 2 Schedule						
Time:	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6
07:10 - 07:40		2				
07:40 - 08:10				4		
08:10 - 08:40						6
10:50 - 11:20 130 min idle		8				
11:50 - 12:20 30 min idle				10		
12:20 - 12:50						12

Figure 37 – Batching Plant Schedules 80 minute – 80 minute travel times

Site 1			Site 2	
Batch No.	Time		Batch No.	Time
1	09:00 - 09:30		2	09:00 - 09:30
3	09:30 - 10:00		4	09:30 - 10:00
5	10:00 - 10:30		6	10:00 - 10:30
	130 min idle			130 min idle
8	12:40 - 13:10		7	12:40 - 13:10
10	13:10 - 13:40		9	13:10 - 13:40
12	13:40 - 14:10		1 1	13:40 - 14:10

Figure 38 – Resource utilization on site 80 min – 80 min travel times

Eight additional trucks would be beneficial and would yield eight extra batches to site with every truck delivering just one batch to site. The additional batches would increase the daily backfill capacity to:

20 batches × 150 m/batch = 3000 m/day

By determining the maximum amount of backfill batches that can be delivered to the different sites, the Cleanfasts have an indication of the maximum meters they can excavate. The end goal is to have the Cleanfast running at full capacity. The following table illustrates the backfill analysis summary:

Backfill Analysis Summary						
Travel Time (minutes)	Current Capacity (batches)	Meters	Additional Trucks	Extra Batches	Additional Meters	Total Meters
20 min-20 min	22	3300	0	0	0	3300
20 min-40 min	20	3000	1	1	150	3150
20 min-60 min	18	2700	2	2	300	3000
20 min-80 min	16	2400	3	3	450	2850
40 min-40 min	18	2700	2	4	600	3300
40 min-60 min	15	2250	4	6	900	3150
40 min-80 min	14	2100	5	6	900	3000
60 min-60 min	12	1800	4	8	1200	3000
60 min-80 min	12	1800	6	9	1350	3150
80 min-80 min	12	1800	8	8	1200	3000
Average	15.9	2385	3.5	4.7	705	3090

Table 18 – Backfill Analysis Summary

The backfill analysis summary can aid the operations team in maximizing the production meters by providing them with a clear indication of what the capability of the batching plants and backfill trucks are as well as providing a framework if additional trucks have to be hired.

4. Proposed new process

4.1 Introduction

By rearranging the current process and making a few additions the resources can be utilised more optimally as well as eliminating bottlenecks. A flowchart illustrates the proposed process:

Figure 39 – Flowchart new process

4.2 Proposed changes

The following changes are proposed:

- The manual excavation of the hand holes should be undertaken before the trenching team arrives on site. This will ensure that the backfill trucks do not have to fill pieces of open trench at a later stage. If the excavation can be undertaken in advance, it would be beneficial to reinstate the area around the hand hole before the trenching team arrives.

- Obstacles should be cleared in advance by equipment called a City Trencher. Another option would be to clear the obstacle with the Cleanfast machines but this would reduce the production of the equipment. The company has currently got the City Trencher available and it is not being utilized.

  The clearance of obstacles is the major bottleneck in the process and by clearing the obstacles in advance the batching plant can be fully utilised. By utilising the batching plant and concrete mixer trucks the Cleanfast utilization will improve and eventually the Cleanfasts will be fully utilized.

  If the obstacles are cleared in advance the excavations around the obstacles will have to be closed because of health and safety issues. By sealing the excavations, rainwater will be prevented from enlarging the excavations. The area around the obstacles will be filled with river sand so the Cleanfast can vacuum the sand around the obstacle when the trenching group arrives. It often occurs that locations are indicated on the road surface by the surveying team but when the ground is cleared there are no obstacles present. These locations will be indicated on the road surface and the Cleanfast can then simply cut through these unnecessarily marked locations. This will also improve the Cleanfasts' production meters. The obstacle excavations will have to be sealed in order to prevent rainwater from eroding the temporary sand backfill and enlarging the excavations; bitumen will be applied as a temporary seal. Obstacles are often marked and cleared by the obstacle teams and then still damaged when the last soil is cleared around it by hand. Workers damage the water pipes by accidently hitting them with picks and shovels. These damaged pipes are often water pipes and this can result in water flowing down into the trench. By clearing the obstacles in advance these problems would not affect the operations but would rather be dealt with in advance.

- When the operations team receive a works order the number of obstacles that were marked is not taken into account. The scheduling is done according to trenching meters required, however the number of obstacles that were marked greatly influences the production rates. The obstacle teams are dispatched to site without knowing how many obstacles have to be cleared. Some days there are no obstacles present but the obstacle clearance teams are still dispatched. By clearing the obstacles in advance the obstacle teams will be fully utilised and applied where they are needed. An example would help to demonstrate the situation:

One operations team is scheduled to cut 980 m in Johannesburg CBD. Every operations team contains one obstacle clearance team. This job is scheduled for a single team to complete in one day. It is scheduled according to the meters that have to be cut. Because this job is scheduled in Johannesburg CBD there are a lot of services present. The 980 m piece contains 75 obstacles that have been marked by the surveying team. Data was gathered and it was established that one obstacle team can clear approximately 25 obstacles per day. Therefore it would take three days just to clear the obstacles. The trenching takes one day and the obstacle clearance takes three days. While the obstacles are being cleared the ducting team as well as the backfill teams are idle. No backfill batches can be dispatched to the site before the obstacles are cleared. The second team has a 2 km job that contains no obstacles. The obstacle team is therefore idle for two days while the first team takes three days to clear their obstacles.

Through identifying and clearing obstacles before trenching operations start and allocating the resources accordingly the whole process will flow better and production rates will increase significantly.

- Undetected water pipes can result in time being lost. If water pipes that weren't marked are damaged the water can flow back into the trench. This is another reason why the backfill supervisors do not order the maximum amount of batches per day. The supervisors often wait for a large piece of open trench before they order backfill loads. This leads to a portion of the day being lost as well as leaving a large amount of trench open overnight which is not favourable. A number of ideas were generated to try and prevent the water from flowing into the trench. The best solution would be to insert an inflatable bag into the trench as soon as the water pipe has been cut. The bag will then be inflated by air supplied from the Cleanfast. Water pumps will be used to divert the water. This will stop the water from flowing into the trench until the water leak can be repaired. This will allow the trench to be filled by backfill while the problem is isolated.

The changes in the process will enable the concrete mixer trucks as well as batching plants to be optimally utilised and will increase the utilization of the trenching equipment.

A summary of the proposed process capabilities and the resource utilization factors follows; this summary excludes the hiring of additional trucks:

Resource Utilization Proposed Process			
Resource	Capability (m)	Potential performance (m)	Utilization factor
Cleanfast	3862.2	2385	0.62
Backfill	2385	2385	1.00
Ducting	4000	2385	0.60

Table 19 – Resource utilization proposed process with no additional concrete mixers

The resource utilization with the proposed process change is vastly increased but the end goal of utilizing the Cleanfasts at 100% is still not realized. The hiring of additional concrete mixers as they are needed influence the resource utilization in the following way:

Resource Utilization Proposed Process			
Resource	Capability (m)	Potential performance (m)	Utilization factor
Cleanfast	3862.2	3090	0.80
Backfill	3090	3090	1.00
Ducting	4000	3090	0.77

Table 20 – Resource utilization proposed process with additional concrete mixers

With the two batching plants operating at full capacity and the additional trucks being hired in the Cleanfasts are still only running at 80 % capacity. Once the current resources are utilised at full capacity the option can be explored of adding an additional batching plant and hiring more concrete mixing trucks.

4.3 Advantages of proposed process change

The following are the advantages of the proposed change to the process:

- No additional resources are required.
- Problems are dealt with in advance. Problems do not effect the trenching operations anymore.
- Idle time on resources is decreased considerably.
- Vast improvement in production figures.
- Better cash flow through the company because of an increase in monthly income.
- Time spent on individual sites reduced therefore fewer disturbances in traffic.

4.4 Disadvantages of proposed process change

The disadvantage of the proposed change is as follows:

- Small additional cost incurred when clearing the obstacles in advance. Bitumen is needed to seal the holes

.

4.5 Financial analysis

Additional costs versus potential increase in potential revenue:

Additional costs:

Additional batching plant = R 500 000 (Once-off cost)

Additional bitumen per month = R 15 000

Increase in Potential Revenue:

Current production: 19 445 m/month × R415 /m = R 8 069 675

Potential production without the hiring of additional mixing trucks:

47 700 m/month × R 415/m = R 19 795 500

Total additional costs = R 515 000

Increase in potential revenue = R 11 725 825

Hiring additional trucks cost about R3400 per day. For every load a tuck delivers to site, an additional 150 meters can be filled. 150 meters extra per load times R415/meter = R 62 250 extra revenue generated per extra load delivered. Therefore it is beneficial to hire additional trucks.

5. Conclusion

Muvoni Weltex Network Technologies is currently achieving sub-par production figures. There is a lack of proper planning in advance and numerous problems in the operations process are not being addressed.

Through the analysis of the different elements it can be concluded that the resources are being poorly utilised and that there is significant room for improvement. By changing the sequence within the trenching process and the addition of a second batching plant the production rates can be vastly improved. The implementation of this new approach will improve the process output as well as improving resource utilisation.

By simply adjusting the resources and allocating the resources where they are needed the output of the process can be vastly increased. The proposed system will have to be enforced and constantly updated and controlled in order for this project to be a success. By determining the resource capacities the planning and scheduling will be done more accurately and the limiting resource, the Cleanfast trenching equipment, can be optimally utilised.

The advantages of this proposed process change far exceed the disadvantages. Muvoni Weltex Network Technologies will benefit greatly from this new approach and the overall productivity will increase.

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