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## **The Futran Mass Transit System**

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### **Summary**

The Futran System is a suspended fixed guideway electric vehicle system that was developed in South Africa to enable safe, low cost, automated, environmentally safe haulage and transportation for people and goods. The system was tested and improved on a 1km test track and the first commercial sites are now being deployed. Light versions of the system are used for mass transit people pods, medium weight systems for bulk commodities haulage in the mining environment and heavy haul versions for 40 foot containers.

*Keywords: Autonomous, Automated, city traffic, smart grid, solar energy*

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### **1 Urgent need for new transportation solutions**

According to the United Nations [1] Africa is experiencing both the highest rate of population growth in the world as well as the highest rate of urbanization. As a result, the current urban population of approximately 450 million people is due to grow by an estimated 800 million more people by 2050. The current overpopulated and under serviced cities will therefore have to grow to 3 times their current size in the next 32 years. China currently has an urban population of approximately 800 million people, so in effect we will have to build the equivalent of every single Chinese city in Africa in the next 32 years.

Colonialism, poverty, skills shortages and lack of proper spatial planning meant that transport networks in African cities typically developed more in an ad hoc manner than along planned and controlled corridors that allows for future growth. Lack of maintenance and available funding has further led much of the existing road infrastructure to be in a very bad state, especially in the rainy season. As a result, gridlock and traffic congestion is already becoming the norm in most cities in Africa. Effective public transportation is rarely available and where it is, it is typically owned and operated by the private sector much more than the state and local authorities. The poor state of the roads and the prevalence of gridlock further makes such public transportation very inefficient and costly, further hampering the much needed economic revival required to cater for the massive growth that is now coming.

According to Middleton [3] Informal transport, mostly in the form of minibus taxis, dominates the public transportation sector. “This massive industry, which accounts for 72% of Johannesburg’s daily trips and 90% of Nairobi’s public transport, is unregulated across Africa”. He adds that, although these informal transport systems provide an important service given the lack of formal public transport systems, it is troubled by “unpredictable fares, schedules and routes; poor maintenance; lack of licensing (drivers and vehicles); recklessness; and safety concerns ranging from harassment to armed violence”. He also adds that drivers are incentivised to maximise revenue via full loads and quick turnaround times while they often disrespect passengers’ needs, safety and time.

Outside the cities, the focus is now on repairing and developing railway networks to open up the continent, especially for trading raw materials. War, lack of maintenance, maladministration and poor intra-regional cooperation between authorities have further led to the closing down of various rail networks that were once running over large parts of Africa. In a desperate bid to create reasonable transit corridors, especially the Chinese are now spending a vast amount of money on creating or repairing rail networks. According to Norton Rose Fulbright [2] the current value of rail projects across Africa is estimated at US\$495 billion. According to the authors “This represents a significant investment in a continent where less than 15 per cent of all freight is carried by rail. Notwithstanding the gloomy growth outlook, the maintenance and development of transport infrastructure along the entire supply chain of the continent is seen as a pre-requisite to growth in Africa. This is particularly relevant where commodity rich African countries are landlocked, transport costs are considerably higher than in other regions and the transport network is either non-existent, antiquated or in a state of disrepair”.

Given the tremendous need for public transportation in Africa and the impending high growth rate that these cities will now experience, it is clear that new privately funded and operated cost effective solutions that can run at a profit, such as the minibus taxi, will be needed to help Africa meet its needs. Also, the major focus and expense currently being incurred on deploying rail infrastructure shows just how big the need for rural infrastructure to move people and goods is.

The Furan System was developed to address these needs and is seen as a viable, green, African solution to African problems.

## 2 The Futran System

The Futran system is a Fractional Rapid Transit (FRT) system, designed to transport a range of pod types to take loads as light as a few hundred kilograms and as heavy as 40 tons using the same track type and the same motorised unit design. The flexibility and scalability of the system is unique and enables the system to be applied to a range of needs under a variety of conditions.

Fractional Rapid Transit (FRT) is a term created by Andries Louw, the inventor of the system, to describe the nature of the automated transport and haulage concept, as enabled by the Futran System. FRT is an overarching term that includes Personal Rapid Transit (PRT, as used in automated pod based public transportation), Group Rapid Transit (GRT), and Containerised Rapid Transit (CRT). According to Wikipedia [4], “Personal rapid transit (PRT) is a public transport mode featuring small automated vehicles operating on a network of specially built guideways. PRT is a type of automated guideway transit (AGT), a class of system which also includes larger vehicles all the way to small subway systems”

FRT, the wider term that is used to describe the Futran System, is enabled by breaking a bulk into small fractions, each small enough to be transported economically by themselves, and then moving these fractions in automated, driverless pods along a grid network from any point to any other point without having to stop in between. Such a bulk can be masses of people, goods, ore, minerals and even fluids.

Not only is the Futran system the lowest cost FRT system of this size ever designed, it is also the most scalable, flexible and versatile. It was designed in Africa for African conditions and as a result it can be manufactured, constructed, operated and maintained in Africa by local fabricators and entrepreneurs. It is also the only one of its kind (suspended) that has been built and demonstrated on a fully functional track, anywhere in the world.

The Futran system consists of:

- an elevated track network with switches that have no moving parts, from which moving stock is suspended,
- automated, motorised bogies that can individually select which route it is to take when going through a switch
- non-motorised slave bogies,

- skips, containers or pods attached to the bogies,
- loading and offloading systems (including stations in the case of people pods)
- on-site maintenance facilities
- a traffic management system
- a job card system where each automated moving unit (called a Nutran) can manage its own route without having to be in constant contact with the centralised traffic management system

Electrical motors are used to propel the motorised units and power can be drawn from the track using a feeder system such as a pantograph, or energy can be stored on board in a battery and carried along with the unit. The motorised units therefore can have all the elements of a self-driving Electric Vehicle (EV), including:

- An electric motor with a motor controller
- A control system, such as a VSD, to take and send commands to the system
- A battery for energy storage
- A monitoring and control system to ensure that it does not crash into a unit in front of it
- The ability to take evasive action, should the unit in front of it not follow the rules of the track for whatever reason
- Communication with a central co-ordinating traffic management control system

In essence these motorised units, called Nutrans, are nothing other than self-driving EVs that are restricted to run on a fixed track at fixed speeds. Virtually all of the technology developed for Electric Vehicles can therefore be used on these units.

Because the Nutrans use electric motors that propel the units along at speeds typically not exceeding 50km/h, and hard and robust wheels made from or nylon compound running on a steel track, both rolling resistance and wind resistance are minimal, making it extremely efficient to run and maintain the units. The electric motor and low energy consumption combination of course makes the system an ideal candidate for using renewable energy such as solar power.

In order to be truly effective in transforming the economies of countries in Africa, thousands of kilometres of Futran track need to be deployed across the continent in the next 20 to 30 years. It is therefore imperative to lower the cost of the track infrastructure as much as possible. A great deal of the development effort went into achieving this goal.

The steel track is suspended in the air using a superstructure made of steel and concrete. Because it is elevated in the air, the track is a moving structure and therefore it is not advisable to use bolts and welds on the track or the superstructure since bolts can come loose over time and welding creates weak spots. To solve this problem, a new structural element, the Solomons Knott Cross Beam, was developed and is being used for this purpose.

The Solomons Knot Cross Beam consists of four interlocking panels cut from sheet metal, together forming a column or beam with a solid steel skin and spaced interlocks in the inside. By now pouring concrete into the column, the interlocking elements are solidified in place while the steel adheres to the steel structure by binding to the steel flanges on the inside of the column, close to the centroid where the forces of movement are the least. Sheet metal of any thickness and grade can therefore be used to create columns and beams of any desired strength, simply by changing the cutting patterns of the laser cutting machine. Welding and screws can now be avoided.

By using the Solomons Knot Cross beam in the track design, a light weight, super strong, modular, elevated track system was created that is cost effective and super strong. By pouring the concrete into the columns the steel is spoilt at a standalone material, making it far less likely to be stolen, while the noise dampening effect is important, especially in urban environments.



Figure 1: The Solomons Knott Cross beam consists of four interlocked panels

The modular Futran track can now be deployed on almost any road and railway reserve, over obstacles and sensitive areas such as wetlands and rivers, high enough to enable animal and people migrations yet small enough not to be visually disturbing.

### 3 Futran Podcars

Because the Futran System superstructure has such a small footprint on the ground, the superstructure can easily be erected on the sidewalks of roads and the track can be elevated in the air, above the existing road network. By doing this, the system can be deployed using existing right-of-way corridors without demolishing any houses or buildings and without appropriating new land for the route, while the road system can still be used as before.

Futran Podcars are 6 to 12 seater units that can be used for private use (rent out the whole pod for yourself) or for shared use (lowest cost per trip). In the case of private use, the unit will be available on demand and take the occupant(s) directly to their end destination without stopping in between. In the case of shared use, on the other hand, the user may have to wait a while for the pod to arrive, and then be asked to climb over into another pod along the way, more than once in certain cases. However, the benefits of cost saving and time savings are so significant that most cost conscious consumers in Africa will prefer the low cost, shared service.

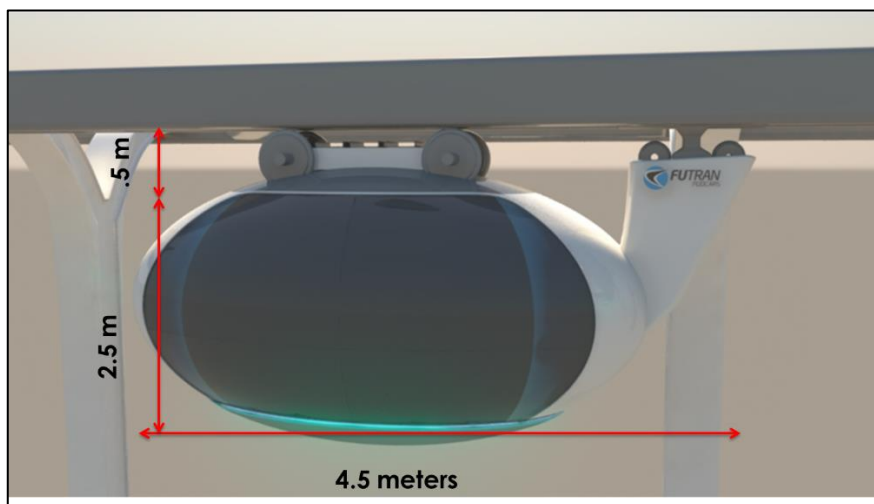


Figure 2: Typical Futran Podcar dimensions

Stations are designed to have 1 to 8 doors catering for a single pod in front of each door. Each station has a running lane in front of it where pods run at speeds of approximately 40km/h to 50 km/h past it, as well as an empty pod feeding lane running from the parking lot between it and the previous station from where the empty pods run into the parking bay. Lane switching exists before and after the offline stations for pods to enter and leave the station.

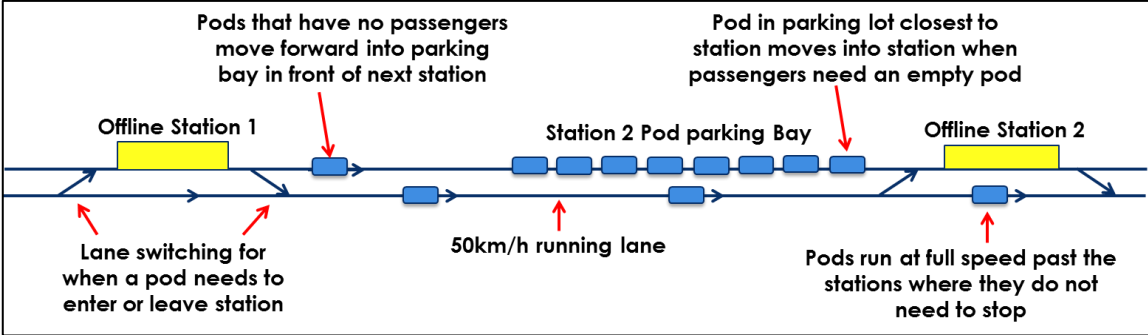


Figure 3: Station and parking bay design

These 1 to 8 door stations can be positioned as single stations or double stations (one on each side with the running track splitting the two) and the double stations can serve one direction (both the same direction) or both directions (one for each direction). Clearly, the track and its support structure increases in size whenever you have more than one station and therefore more than two tracks at the same location.

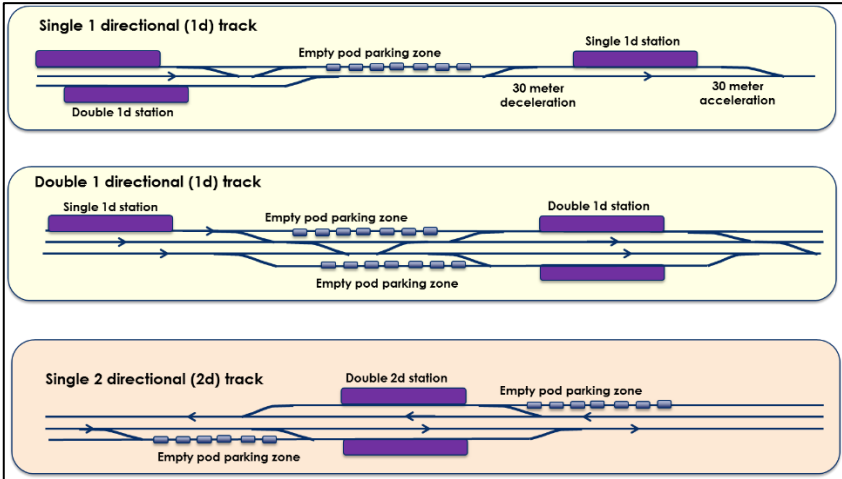


Figure 4: Various station configurations are possible

A great number of these small stations are now positioned all along the track to ensure an on-demand service close to any destination in the city. As can be seen in Fig 5, a number of blocks of approximately 7km x 7km are created where pods run at 50kms/h. These 7x7 blocks can then in turn again be connected via higher speed tracks that do not have stations along the route.

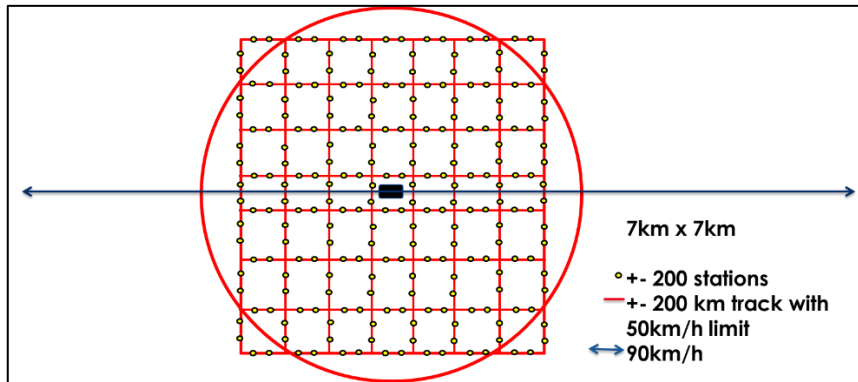


Figure 4: A great deal of small stations are positioned everywhere along the track network

Typically, 5 door stations are used along the grid although higher throughput stations can selectively be deployed. As can be seen from Table 1, each of the 5 door stations can handle approximately 1 000 people per hour climbing on and another 1000 people per hour climbing off. High throughput stations, on the other hand, can handle as many as 4 000 people when an average of 6 people per pod is used as the measure and more if more than 6 people per pod is used as the average.

Table 1: Each of the stations has significant throughput capacity

Station throughput given different variables					
Scenario	1	2	3	4	5
	Startup	Low	Medium	Expected	Optimistic
People per pod	4	4.5	5	5.5	6
Loading time (incl open / close)	24	22	20	18	16
Changeover time (all doors)	90	75	70	65	60
Maximum efficiency	70%	75%	80%	85%	90%
Loading cycles per hour	32	37	40	43	47
<b>People per hour</b>					
<b>5 door station</b>	<b>442</b>	<b>626</b>	<b>800</b>	<b>1 014</b>	<b>1 279</b>
<b>8 door station</b>	<b>707</b>	<b>1 002</b>	<b>1 280</b>	<b>1 622</b>	<b>2 046</b>
<b>10 door bi-dir station</b>	<b>884</b>	<b>1 253</b>	<b>1 600</b>	<b>2 028</b>	<b>2 558</b>
<b>16 door bi-dir station</b>	<b>1 415</b>	<b>2 004</b>	<b>2 560</b>	<b>3 244</b>	<b>4 093</b>

As can be seen in Table 2, it is possible to run 20 000 people or more per line per hour on a single line when the units are configured to run in the mini-train format and an average of 6 people per pod is used. These numbers increase impressively when the average number of people per pod increases closer to the 12 maximum passengers per pod.

Table 2: A single track can handle in excess of 20 000 people per hour

Track throughput given different variables					
Scenario	1	2	3	5 POD TRAINS	8 POD TRAINS
	Startup	Low	Medium	Expected	Optimistics
Speed (km/h)	40	45	50	50	50
Headway (Secs)	2.5	2	1.75	1.5	1.5
Average People per pod	4	4.5	5	6	6
Maximum efficiency	70%	75%	80%	80%	85%
Meters per second	11.1	12.5	13.9	13.9	13.9
Headway	27.8	25.0	24.3	20.8	20.8
Pods per hour	1440	1800	2057	3600	4100
<b>People per hour</b>					
<b>Single track throughput</b>	<b>4 032</b>	<b>6 075</b>	<b>8 229</b>	<b>17 280</b>	<b>20 910</b>
<b>Double track throughput</b>	<b>8 064</b>	<b>12 150</b>	<b>16 457</b>	<b>34 560</b>	<b>41 820</b>

In public transportation system, three things determine the throughput capacity of a track. These are:

- 1) Speed (the faster the units run, the quicker they circulate and the more people they can carry)
- 2) Average people per unit (the more people per unit, the higher the throughput)
- 3) Following distance (the shorter the following distance, the more units can be fitted onto the track per kilometre)

In the case of the fixed track, automated Futran podcars, speed and following distance is used to measure the time between two podcars, as opposed to the distance between them. This measurement is referred to as headway, which translates into the minimum time you allow between two units. Because the distance increases as the speed increases and you still require the same time to elapse between two units passing the same point, the throughput stays the same when you increase speed without reducing headway.

Table 4: Headway, measured in seconds, determines track capacity

Speed (m/s)	Headway (seconds)	Distance between units	Throughput per minute
4	2	8	30
5	2	10	30
6	2	12	30
7	2	14	30
8	2	16	30

Traditionally, regulators wanted the headway between units to be determined by measuring the distance it would take for a unit to make a full stop from full speed without compromising the safety of the passengers. At 50km/h, for instance, this distance is approximately 35 meters and it will take 2.5 seconds, so conservative proponents of the art will round it off to 3 seconds over 42 meters (sufficient reaction time and passenger comfort) and progressive proponents to 2 seconds over 28 meters (slightly faster braking and therefore seatbelts would be required, as well as instantaneous reaction times).

These calculations are all based on the assumption that it is possible for a unit to go from full speed (50km/h) to a complete standstill, requiring the unit following it to use the full headway distance to come to a standstill at that same point. Clearly, this is only possible if a tree or large object, much heavier than the pod itself, obstructs the guideway, which can only happen with an open guideway system and not with an elevated closed guideway system where nothing can fall onto the track itself. With an elevated, closed track system, such as the Futran System, the assumption can be made that a unit can only come to an instantaneous standstill if the track itself is physically broken, something that must be picked up by the central control system as and when it happens so that it can stop or re-route all traffic moving in that direction. Any other sudden stops will be the result of either emergency braking (initiated by the system or in cases where power or communication is lost) or internal mechanical failure, such as when a bearing seizes, a wheel comes off or an axle breaks. In all such cases the momentum of the unit will still propel it forward over a certain distance and the unit will not come to a complete stop immediately.

By taking the distance over which the pod is likely to come to a stop into account, and employing automated response systems that reacts the moment it detects that a pod in front of it is not maintaining its speed, headway can safely be reduced to 1.5 seconds or less, thereby doubling throughput.

To further increase throughput, units can be run in virtual mini-trains of five to eight units, five to ten meters apart from each other. The drive and bogie system running inside the enclosed guideway is longer than the pods and have shock absorbers in the front and back. This enables the units to absorb the shocks from touching each other or colliding in the bogie system inside the enclosed guideway, thereby protecting the pods which are now unlikely to collide into each other, as long as the drive and bogie system stays intact.

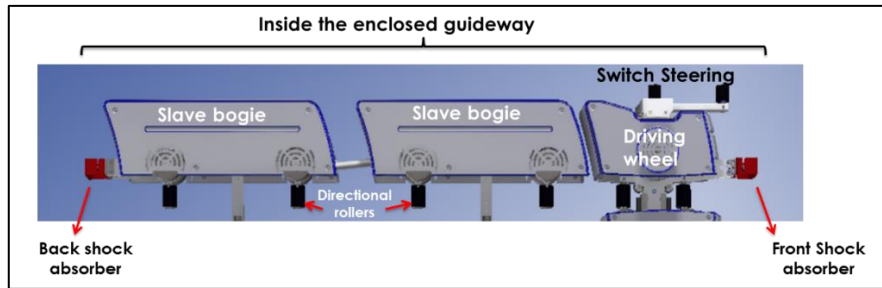


Figure 5: The shock absorbers of the Nutran system

Should the front unit of a mini-train have to make a sudden stop, each unit in the mini-train, which are digitally connected to each other, will stop at the same time, thereby maintaining their following distances.

Should a unit anywhere along the mini-train have a sudden and unexpected breakdown, the unit behind it has the five meters extra space to stop before it “collides” into the unit in front of it that is still busy decelerating, and each unit after that then also has the additional 10 meters to stop. By utilising this mechanism, the pods progressively absorb the energy as they connect to become a single unit and each one experiences less and less of the sudden deceleration.

Podcar mini-trains of 5 units each that run 5 meters apart and each have an overall drive and bogie system length of 5.5 meters will have an overall length of 52 meters that will be used to absorb sudden bursts of deceleration, while virtual mini-trains of 8 pods each will have an overall distance of 84 meters to achieve the same.

Using the Solomons Knott Cross beam to lower the cost of manufacturing the tracks and solar panels to power the system, the combination of operating cost and capital cost results in very competitive rates for the users, especially where sufficient numbers of users are available, as in most African cities.

When each pod runs 350 billable kilometres per day with an average of 6 people on board and the operators levy a 25% profit margin into the running of the system and as many as 40 pods are available per km of track, travel rates of below 5 US cents per km will be charged certain times of the day.

Table 5: Even while running at a profit, public transport costing is extremely low

Time slot	Trip Distance in kms			
	5	10	20	30
5h00 to 6h00	\$ 0.40	\$ 0.60	\$ 1.00	\$ 1.40
6h00 to 6h30	\$ 0.55	\$ 0.80	\$ 1.30	\$ 1.80
6h30 to 7h00	\$ 0.70	\$ 1.00	\$ 1.60	\$ 2.20
7h00 to 9h00	\$ 0.85	\$ 1.20	\$ 1.90	\$ 2.60
9h00 to 9h30	\$ 0.70	\$ 1.00	\$ 1.60	\$ 2.20
9h30 to 15h00	\$ 0.35	\$ 0.50	\$ 0.80	\$ 1.10
15h00 to 16h00	\$ 0.50	\$ 0.70	\$ 1.10	\$ 1.50
16h00 to 18h00	\$ 0.80	\$ 1.10	\$ 1.70	\$ 2.30
18h00 to 18h30	\$ 0.65	\$ 0.90	\$ 1.40	\$ 1.90
18h30 to 21h00	\$ 0.45	\$ 0.65	\$ 1.05	\$ 1.45
21h00 to 5h00	\$ 0.25	\$ 0.40	\$ 0.70	\$ 1.00
<b>Trip time (Minimum)</b>	6	12	24	36
<b>Trip time (Maximum)</b>	16	22	34	46

## 4 Futran Mine haulage systems

By increasing the carrying capacity of the track to handle 15 to 20 ton units, the system is ideally positioned to be used as a haulage system in mines across Africa.

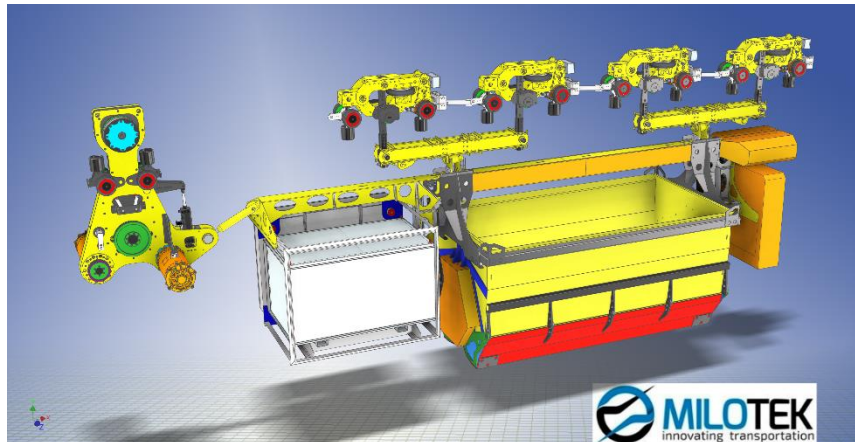


Figure 6: Bottom discharge Futran mining skips

As a mine haulage system, the Futran system has a great number of advantages for mines in Africa. Apart from its cost effectiveness, it has much lower impact on the environment, it can use solar power, even in the remotest parts of Africa where diesel and grid power is often difficult to get hold of, animals can still migrate below the system, dust and noise levels are much lower than with trucks, obstacles such as rivers and mountains can easily be traversed, multiple goods can be transported on the same system, and capacity can easily be increased or decreased, depending on demand.

The mining version of the Futran system has undergone 2 years of testing and improvement at a 1km test site in South Africa, and is now ready for commercial deployment. The first clients are going live early in 2018.



Figure 7: The 1km mining system test site in South Africa

Because the systems are self-propelled, use solar power and battery storage, and can run 24 hours per day without stopping, these mining system tracks can also be deployed over very long distances, making it a viable environmentally friendly and cost effective alternative to railway lines in future.

## 5 Futran Container Haulage systems

By increasing the carrying capacity of the track even further, the Futran container haulage system is enabled where 40 foot containers weighing as much as 35 tons can be moved around along the elevated track. This is an important addition to the overall solution, especially as a mechanism to increase the handling and throughput capacity of ports in Africa. Unlike normal container port automation, the Futran System adds overhead movement to the automation process, thereby enabling vastly improved productivity without increasing the size of container terminals. When inland dry ports are made available, even as far as 100kms away from the port, the Futran Container Handling solution will manage the extended port as if it is one virtual port, using the seaside terminal just for loading and offloading while using the inland terminal for storage and intermodal transfer.

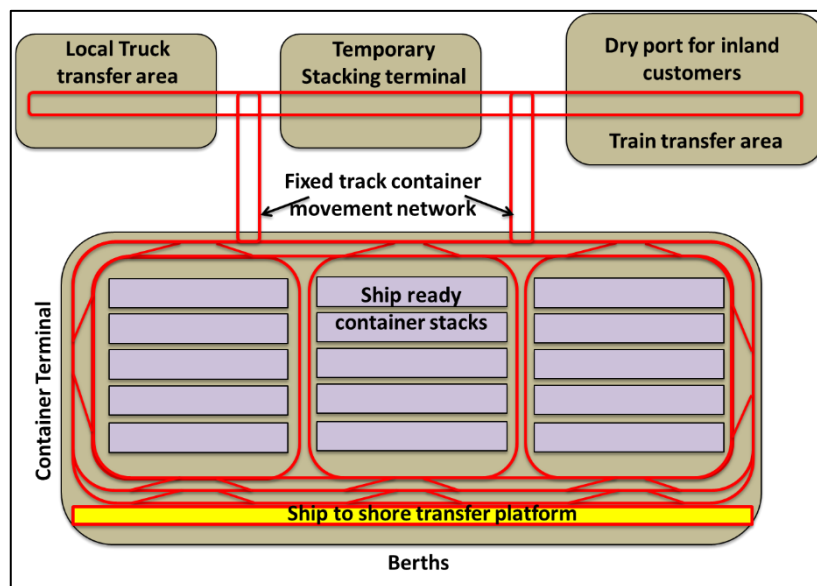


Figure 8: By moving containers over road and railway lines, a new virtually integrated port can be created

As can be seen from Fig 9, ground based transportation does not interfere with the Futran System, enabling the operators to increase the available work space for the port operators.

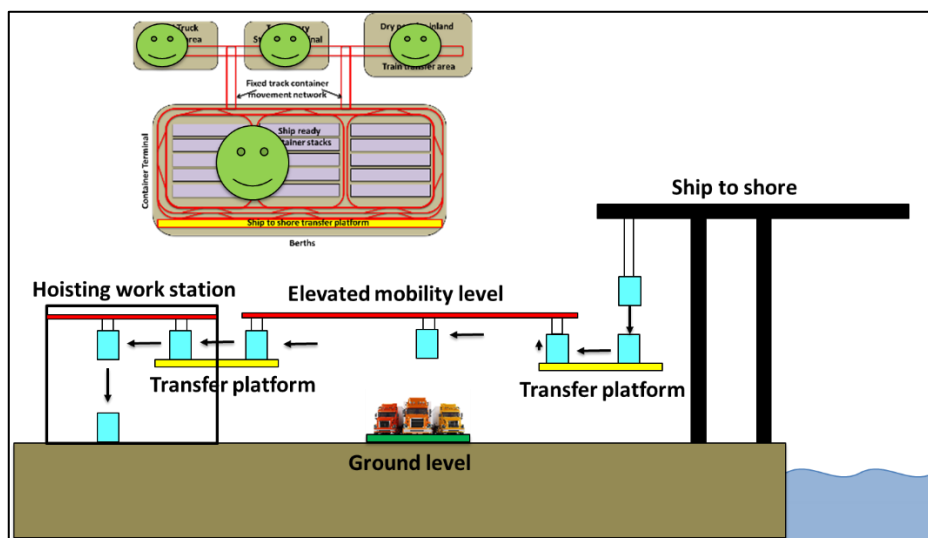


Figure 9: Ground level obstacles are negated by moving containers on the elevated level

## 6 . Conclusion

The self-driving EV market is a necessary and logical evolution of the automobile and need to be adopted on a global scale. However, where road and support infrastructure is weak or does not exist, as in most parts of Africa, we need to create an even further evolution of the EV vehicles. It is to address this market, especially in Africa, that the Futran System was created. By creating a low cost track infrastructure that can be deployed along existing right-of-way corridors along which automated fixed guideway EV vehicles run, we can transform the African continent and the destiny of its peoples.

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## Author



Andries Louw, M.Com (RAU). Andries is the inventor of the Futran system and founder of the businesses tasked with taking them to market. With 20 years executive experience in large IT and business consulting firms, Andries is applying the lessons learned in a fast changing environment to the more conservative fields of engineering and transportation. Currently, Andries is Head of Innovation for Milotek, CEO of Futran Podcars and Business Development Director for Cross Beam Fabricators, three core Futran businesses. .