A LITERATURE OVERVIEW OF CENTRAL TYRE INFLATION SYSTEMS

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LITERATURE REVIEW

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ABSTRACT

The South African Sugar cane industry has identified central tyre inflation (CTI) as a technology that could improve vehicle performance and reduce costs. This specific need is due to the fact that transport comprises up to 20 % of a cane grower's production costs because of poor vehicle utilization. Consequently it is important that transport costs should be reduced in order for the sugarcane industry to maintain profitability.

Central tyre inflation technology offers benefits such as improved mobility and savings in road maintenance costs, but more importantly can also reduce the two largest operational expenses on a transport vehicle namely fuel and tyres .

In this literature review the basic workings of a CTI system is explained, the various areas in which CTI systems offer benefits are examined and the cost benefit of implementing a CTI system is analyzed.

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1. INTRODUCTION

The South African Sugar cane industry has identified central tyre inflation (CTI) as a technology that could improve vehicle performance and reduce costs. This specific need is due to the fact that transport comprises up to 20 % of a cane grower's production costs because of poor vehicle utilization. Consequently it is important that transport costs should be reduced in order for the sugarcane industry to maintain profitability (Bezuidenhout, 2006).

Central tyre inflation technology offers benefits such as improved mobility and savings in road maintenance costs, but more importantly can also reduce the two largest operational expenses on a transport vehicle namely fuel and tyres (Oberholzer, 2003).

The objective of this literature review is to (1) gain an understanding of the basic workings of a CTI system, to (2) analyze the various areas in which CTI offers benefits, and (3) to do a cost benefit analysis on a CTI system.

1.1 Definition

Central Tyre Inflation (CTI) is a mechanical component system installed on a vehicle that enables the vehicle operator to adjust the inflation pressure of each individual tyre while the vehicle is in motion in accordance with changing vehicle speed, road and load conditions (Stuart et al., 1987).

CTI systems have three general goals:

- **Detect** when the air pressure in a particular tyre has dropped. i.e. constantly monitor the air pressure in each tyre,
- **Notify** the driver if there is a problem with the pressure of a particular tyre, and
- **Inflate or deflate** the tyre to the required level, there has to be an air supply as well as a check valve that opens only when needed.

1.2 History

During World War II the mobility requirements in the former Soviet Union and Warsaw pact countries were extremely demanding due to poor road and highway quality. Consequently, a considerable effort was made by these countries to develop systems to improve mobility, including primary suspensions and central tyre inflation systems (Kaczmarek, 1984).

Kaczmarek (1984) stated that "One of the most effective and well proven systems that have been adapted to wheeled tactical vehicles to improve the overall vehicle mobility is CTI." However, after World War II no serious consideration of the benefits of CTI occurred until the early 1980's, where after most of the military tactical vehicles produced in the United States were equipped with CTI (Adams, 2002).

Today the largest application of CTI is in the forestry industry. Since 1983 the United States Forest Service has been testing the feasibility of Central Tyre Inflation technologies (Altunel and de Hoop, 1998). Brown and Sessions (1999) summarized several of the United States Forest Services sponsored research programs to evaluate the impact of CTI in commercial logging operations on Forest Service lands. The rough nature of logging roads forces vehicles to slow down in order to limit the vehicle vibrations which negatively impact the vehicle as well as the health of the operators. The results of their research showed that, with CTI the overall vehicle's speed could be increased as a result of the tyres being optimally suited to the road surface conditions.

While forestry is considered the dominant user of CTI, it is used extensively in other industries namely; military tactical wheeled vehicles, commercial concrete mixer trucks, articulated dump trucks and assorted agricultural vehicles. However, the benefits derived from CTI are common to all industries, these benefits being potential cost savings in road construction and maintenance, lower vehicle maintenance costs, increased vehicle mobility and traction, extended hauling seasons where applicable and improved health and safety for drivers (Greenfield, 1993).

2. BASIC OPERATION OF A CENTRAL TYRE INFLATION SYSTEM

A CTI system permits a vehicle operator to optimize tyre and vehicle performance by varying inflation pressures in response to changing operating conditions (load, road and vehicle speed) while the vehicle is moving (Foltz and Elliot, 1996).

The idea behind the CTI system is to provide control over the air pressure in each tyre as a way to improve the performance of the vehicle as changes in operating conditions occur. Changes in operating conditions such as a truck being fully loaded to being empty, a change in road surface which necessitates a reduction/increase in vehicle speed or a change in the terrain in which one is operating which affects the traction of the vehicle.

Tyre deflection is the key to understanding the use of CTI technology. Tyre deflection is defined as the change in tyre section height from the freestanding height to the loaded height. The percentage deflection is the ratio of that change to the freestanding section height. At the lowered inflation pressures (increased tyre deflection), the tyre's imprint or contact area is greatly increased and the load is applied over a substantially larger area (Sturos *et al*., 1995).

Figure 1 illustrates how an increase in tyre deflection results in a larger footprint. A larger tyre footprint can have the following advantages in appropriate circumstances:

- Reduced stress applied to road surfaces,
- Improved traction,
- Reduced tyre bouncing (or "hop"), and
- Improved operator comfort.

Decreasing tyre deflection (reducing the tyre footprint) will result in a smaller contact area which is also beneficial under the correct situation. A smaller contact area reduces the resistance that a tyre has when it rolls. The extra rolling resistance that the underinflated tyre has causes the vehicle's engine to work harder which results in increased fuel consumption (Anon, 2006).

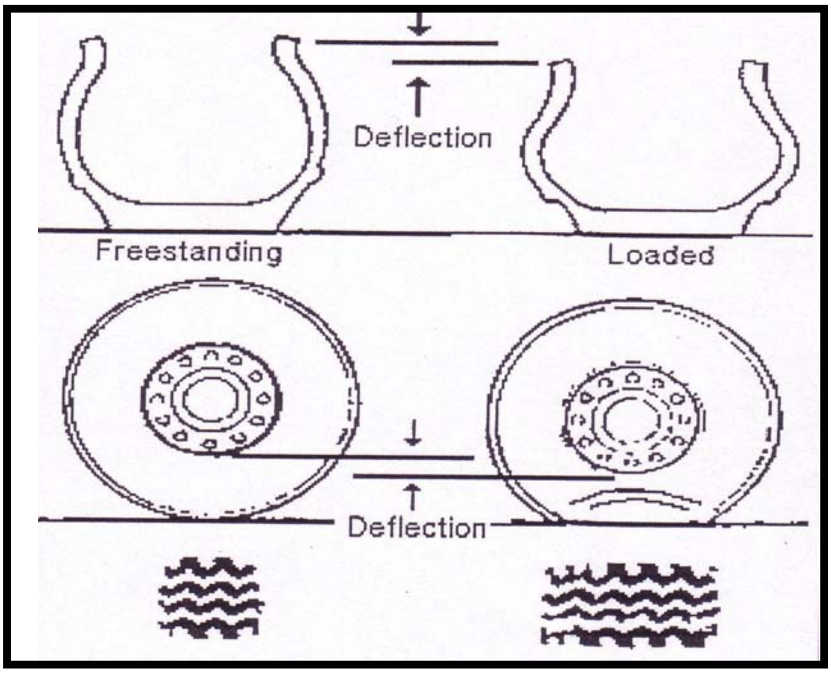


Figure 1. Increased tyre deflections result in larger footprints (Anon, 2006).

When tyres are underinflated the tread wears more quickly. Underinflated tyres also overheat more quickly than properly inflated tyres, which cause tyre damage. Because tyres are flexible, they flatten at the bottom when they roll (see figure 1). This contact patch rebounds to its original shape once it is no longer in contact with the ground. This rebound creates a wave of motion along with some friction. When there is less air in the tyre, that wave is larger and the friction is greater and the friction creates heat. If enough heat is generated, the rubber that holds the tyre's cords together begins to melt and the tyre eventually fails.

While all CTI systems vary in design, they all share some common elements. These elements being:

- All CTI systems use some type of **valve** to isolate individual tyres to prevent air from flowing out of all the tyres when one tyre is being checked or inflated/deflated.

- The system has to have a method for sensing the tyre pressures. In most cases a **central sensor** relays information to an electronic control unit and then to the driver is used.
- All CTI systems have to have an **air source.** In most cases the existing onboard source for braking or pneumatic systems is used. When using an existing air source it is important that its original function is not jeopardized.
- There has to be a way to **get the air from the source to the tyres,** this is usually through the axle. CTI systems either use a sealed-hub axle with a hose from the hub to the tyre valve or else they run tubes through the axle with the axle acting as a conduit.
- Finally, there has to be a **pressure relief valve** to vent air from the tyre without risking damage to the hub or rear-axle seals.

Figure 2 shows the overall components of a CTI system.

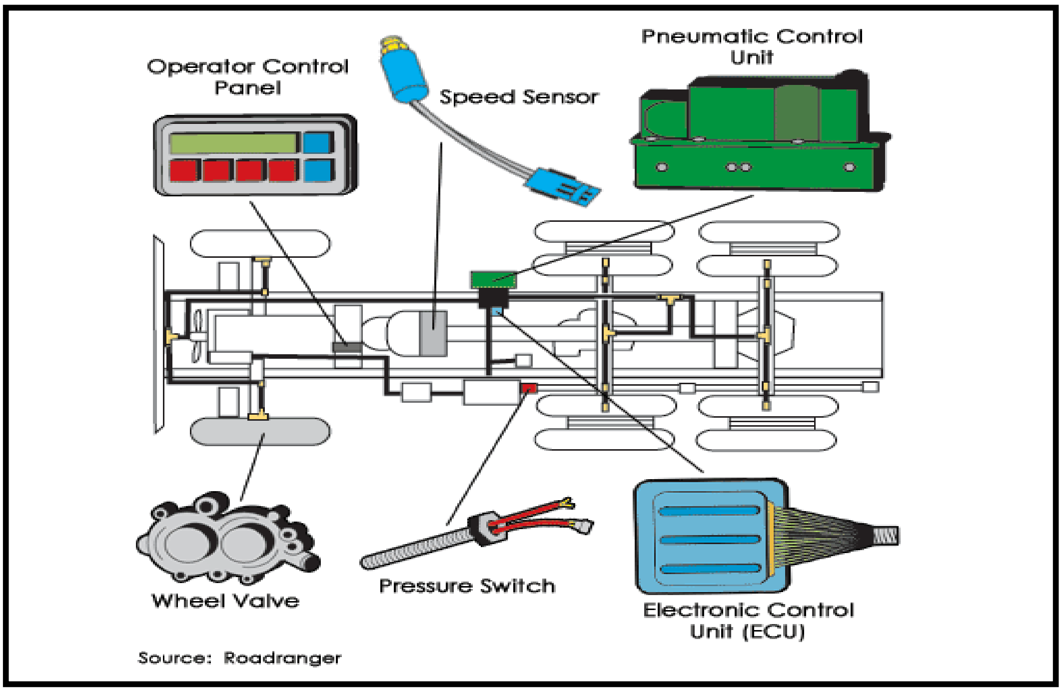


Figure 2. Components of a CTI system (Roadranger Vehicle Components, 2006).

More detail of each major component will be examined in the following sections.

2.1 Air source

Central tyre inflation systems installed on military and commercial vehicles typically use the existing onboard air systems used to actuate the brakes of the vehicle. The capacity of the air system was usually increased due to the increased volume of air required by the CTI over and above what is required for the brake system (Adams, 2002). Modern day systems still make use of the installed air system for actuating the brakes.

Air is supplied from the existing air pressure tank on the truck trailer and/or trailer. An in-line first stage filter and pressure protector valve is mounted onto the tank. Air pressure is then routed via airlines to the pneumatic and electronic control unit. From the control unit airlines run to each axle of the truck and trailer. How the airlines connect to each wheel differs between drive, steering and trailer axles. In the case of a trailer axle the airlines would enter the axles at each end of the axle beam and in the case of a truck axle the airlines could be externally mounted such as in the case of the trailer or the airlines could be routed internally through the axle with the axle acting as a conduit (Anon, 2006). Figure 3 is an illustration of a CTI air supply.

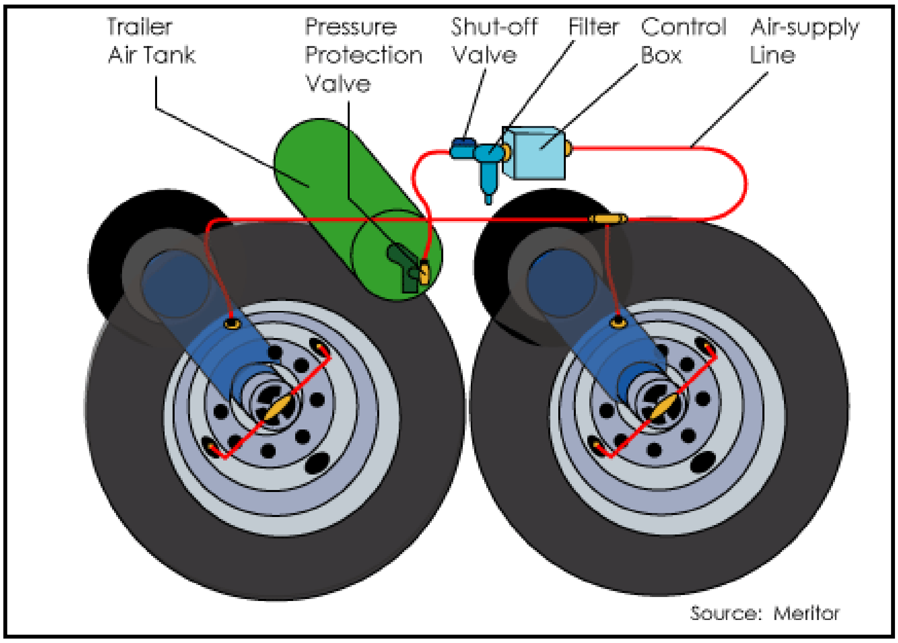


Figure 3. CTI air supply (Arvinmeritor Automotive Supplies, 2006).

2.2 Rotary joint

The most critical component of the system is the rotary joint that enables the air to travel from the fixed components of the vehicle to the rotating vehicle tyres. The rotary coupling is attached to the wheel hub at the end of each axle and is connected to the air system. The airlines connecting the rotary coupling are usually very strong stainless steel hoses due to the fact that they are exposed and vulnerable to being damaged. The rotary joint is comprised of air and oil seals and bearings and connects the air hose from the non-rotating axle to the rotating hubcap. Its air seals prevent leakage, and the oil seal prevents contamination. The rotary hub also has a vent to release air pressure in the hubcap (Anon, 2006). Figure 4 is an illustration of the pathway that the air travels for inflation or deflation once it gets to the wheel and also shows the rotary joint. This example is of a CTI system where the air passes through the axle hub.

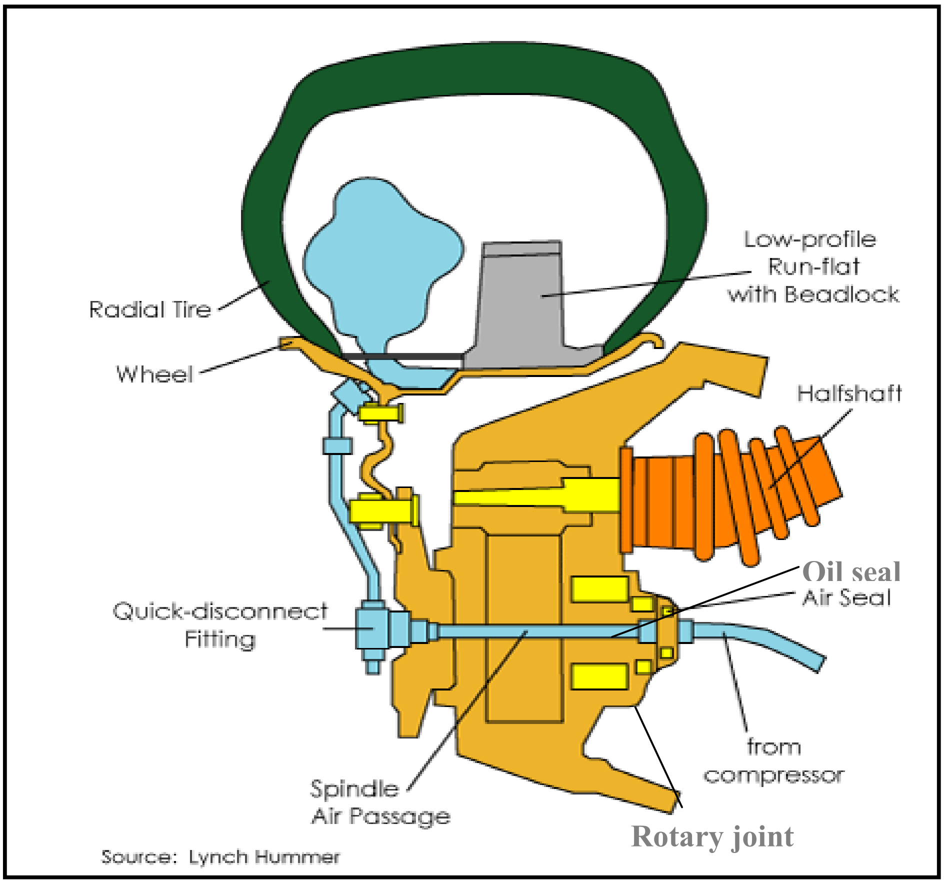


Figure 4. CTI system, at the wheel (Lynch Hummer, 2006).

In the illustration above, the air tubing runs from the vehicle's air compressor through the wheel hub and then to the tyre valve. The "quick disconnect fitting" allows the tyre to be separated from the CTI system for removal or servicing. The quick disconnect fitting is also beneficial in that if a large object snares the air supply hose this joint will automatically disconnect the hose from the wheel valve to prevent damage. Stop-valves in the air hose and wheel valve will automatically prevent further air loss. The system will immediately warn the driver of the disconnection whereafter the air hose can be reconnected to the wheel valve.

2.3 Control System

Modern day CTI systems have an electronic control unit (ECU). The ECU processes driver commands and monitors all signals throughout the system. The ECU sends commands to the pneumatic control unit, which directly controls the wheel valves and air system. The pneumatic control unit also contains a sensor that that transmits tyre pressure readings to the ECU. The ECU is mounted in the vehicle cab allowing the driver to select tyre pressures suitable for the load and speed of the vehicle, the tyre pressures are also digitally displayed on the control system. Tyre pressures selected for different road sections can be stored within the ECU (Anon, 2006). Figure 5 shows the control panel of the Redline Eltek CTI system, as the operator would see it when mounted on the dash of the truck.

Selected Setting	Push Button Switch	Description
Highway Loaded	4	Select this switch when travelling above 70 kph with a load on vehicle (Paved highway or high speed secondary road).
Highway Unloaded	3	Select this switch when travelling above 70 kph with no load on vehicle (Paved highway or high speed secondary road).
Off-Highway Loaded	2	Select this switch when travelling below 70 kph with a load on vehicle (Low quality road or slow speed secondary road).
Off-Highway Unloaded	1	Select this switch when travelling below 70 kph with no load on vehicle (Low quality road or slow speed secondary road).

Figure 5. An example of a Redline Eltek CTI control panel (Anon, 2006).

While the example above is an example of an advanced ECU system there are base ECU models that will basically maintain a driver selected tyre pressure throughout the system. The driver is able to select the correct tyre pressure via simple controls mounted either in the cab or on the vehicle somewhere. Protection valves prevent accidental under or over inflation. All CTI systems will also warn the driver if a significant demand for air pressure is made on the system as in the case of a puncture.

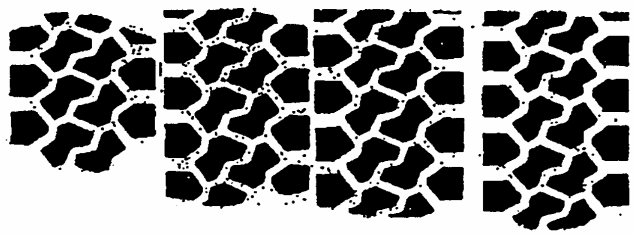
Safety features are commonly incorporated into the ECU of CTI systems. Safety systems such as ‘over speed warning’, ‘low air brake supply pressure’ and ‘extreme/sudden loss of tyre pressure’ are common to most CTI systems. If the vehicle’s speed exceeds the set point for the current inflation pressure/operation mode, an ‘over speed’ warning will alert the vehicle operator of the condition. In the case where the CTI system and the air brakes share a common air supply, the supply of air to the brakes will always have priority over the CTI system. When there is not enough compressed air to supply the brakes with the required amount of air and the CTI system then the driver will be alerted to ‘low air brake supply pressure’ and the CTI system will not operate until such time as there is an adequate amount of air. Similarly if there is an unexplained drop in tyre pressure in anyone of the monitored tyres, the ECU will alert the driver to the situation. The zone in which the pressure drop occurred is usually indicated on the digital display unit.

3. BENEFITS OF USING A CENTRAL TYRE INFLATION SYSTEM

It is largely recognized that the installation of a CTI system results in increased traction, improved vehicle mobility and utilization, higher off-highway travel speeds, improved driver comfort, reduced road surface damage, reduced fuel consumption and extended tyre life (USDA,1993). The following sections will highlight several of these advantages.

3.1 Improved Traction

Vehicle mobility increases with the use of CTI. This is due to the fact that CTI enables tyre pressure to be lowered which results in a larger contact area between the tyre and the ground. Consequently, contact pressure on the ground decreases which improves vehicle traction (Bradley, 1996). Figure 6 illustrates the increase in the length of tyre tread footprint in relation to the drop in tyre inflation pressure.



Tire Pressure	620 kPa	414 kPa	310 kPa	207 kPa
Print Length	25.8 cm	32.0 cm	33.8 cm	36.3 cm
Deflection	8.5%	15%	23%	30%

Figure 6. Tyre footprint and deflection with changes in tyre pressure (Bradley, 1996).

Excessive tyre deflection and distortion in the sidewall area will lead to uneven tread wear, radial cracks, cord fatigue and excessive heat generation. Under inflation can also cause an excessive bead rocking in the tyre flange area which will results in further loss of air pressure as the seal between the rim and the bead is affected. It is therefore important to know what the manufacturers rated tyre deflection for a particular tyre traveling at particular speed is.

Sturos, Brumm and Lehto (1995) from the North Central Forest Experiment Station in Houghton USA conducted a research/ demonstration field test to evaluate the effects of lowered tyre pressure on traction. Two structured tests were conducted whereby drawbar pull and rolling resistance were measured on snow and ice using hard and soft tyres. With an unloaded truck, drawbar pull increased by 31 % on freshly packed snow and by 37 % on icy roads, using lower tyre inflation pressures (see Table 1). With the truck loaded, traction increased by 6 % on icy roads with soft tyres, but there was no difference on freshly packed snow (Sturos *et al.*, 1995). Tests were also conducted on loose sand roadways. The average load that was measured in the rolling resistance tests on loose sand roadway was reduced by 45 % when lowered tyre inflation pressures were used (Sturos *et al.*, 1995). The conclusion that resulted from the test was that the use of the CTI system significantly increased traction on snow and ice.

Table 1. Results of drawbar pull tests (Sturos *et al.,* 1995)

Average drawbar pull (kg)				
Tyre Pressure	**Truck Empty**		**Truck Loaded**	
	Freshly Packed Snow	Icy Road	Freshly Packed Snow	Icy Road
Soft Tyres (345 kPa)	4349.3	2137.8	7264	2917.8
Hard Tyres (689 kPa)	3314.2	1558.5	7300.3	2752.1
Percent increase	31.2	37.2	-	6.0

Powel and Brunette (1991) from the USDA Forest in Idaho, USA, showed that the use of CTI-equipped trucks can increase the number of operating days due to enhanced vehicle traction and flotation. When wet road conditions reduced traction to the point where operations where unable to continue, the use of CTI systems enabled operations to continue due to the increase in traction that is achievable when using CTI.

Tests were conducted by Bradley (1993) to evaluate the tractive benefits of a CTI system. The tractive benefits achievable by reducing the inflation pressure of the drive tyres were quantified through a truck pull test, which found tractive gains up to 39 % on loose gravel. The maximum grade climbable by the loaded test truck fitted with CTI was estimated to increase by 8 % on gravel surfaces (Bradley, 1993). In another test conducted by Bradley (1991), it was reported that lowering tyre pressure from 620 kPa to 205 kPa increased tractive effort by 42 % on a flat gravel surface.

3.2 Improved Driver Comfort and Cargo Safety

By reducing tyre inflation pressure a softer ride can be achieved which improves the comfort of the driver and consequently results in less driver fatigue. The softer ride will also reduce the shock loading that is transmitted to the vehicle, which is potentially damaging to cargo (Rummer *et al*., 1990).

Adams (2002) conducted tests to evaluate the effect of using CTI on the ride quality of a vehicle. He showed that an average ride quality improvement of 99 % was achieved for CTI pressures compared to correct inflation pressures. At a lower speed, the CTI pressure showed an average ride quality improvement of 177 % compared to correctly inflated tyres. Ride quality is quantified by the vibrations the driver experiences through the seat of the vehicle. Sensors were placed on the seat of the vehicle and the vibration levels of the seat are recorded (Adams *et. al*., 2002). It must be noted though that correct tyre pressures are specified by the tyre manufactures in order to prevent damage to the tyres, therefore by lowering the pressure below the correct pressure the ride quality could be significantly improved but at the same time could be detrimental to the health of the tyre.

Similarly to Adams, Altunel (1998) analyzed data collected by the US Army Corps of Engineers and the Waterways Experiment Station to evaluate the effect of lowering tyre pressures on a log truck driver's seat using CTI technology. Their analysis concluded that lowering the tyre pressure to match the road surface appear to decrease vibration levels in the driver's seat from 10 to 25 %. Almost all drivers involved in the CTI tests commented on the improvement in vehicle ride which resulted in them feeling less fatigued after a day of driving (Brown and Sessions, 1999).

A trial of CTI in was initiated by Bradley (1991) to evaluate the impact of CTI on driver comfort. The truck drivers involved in the trial reported reduced vibration and shock loading with reduced inflation of the drive tyres. The driver's opinion was substantiated by comparing the maintenance records of the test vehicle to those of a control fleet of similar trucks. Monthly repair time was reduced by 26 %, largely because of fewer vibrations which caused cracks and loosened bolts, and less cab component damage (Bradley, 1993).

Anon (2006) performed tests for the United States Forest Service that clearly demonstrates the points above. Two closely matched trucks were operated over identical test courses for an extended period, one with conventional tyre pressures and the other at reduced tyre pressures (the truck was equipped with CTI). Vibration levels were measured and the truck with high inflation pressure recorded six times more vertical energy than the truck with lowered inflation pressure. The high pressure truck exhibited four times the part failures and eight times greater cost of repairs than the truck with lowered tyre pressures. Although the test conditions were extreme and one could not expect the same magnitude of cost reduction in commercial applications, it is clear that the use of lowered tyre pressure, under the right conditions, can reduce maintenance costs and significantly improve the comfort of the driver.

3.3 Reduced Road Maintenance, Construction Costs and Sediment Production

Morkel (1994) stated that a correctly designed road and constructed forest road has a theoretically pre-determined serviceable life. Whether or not the road lasts as long as it was designed for is largely determined by the maintenance it receives. In addition, the life of a road can be shortened or increased depending on whether or not the vehicles that travel that road are road-friendly (Stuart *et al*., 1987).

Vehicles with low tyre inflation cause less road damage than comparably loaded vehicles with higher tyre inflation pressure, and roads on which vehicles with low tyre pressures are operated, require less surface material because the ground contact pressure imparted through the longer tyre footprint is lower (Foltz and Elliot, 1996). Figure 7 is an illustration of this point.

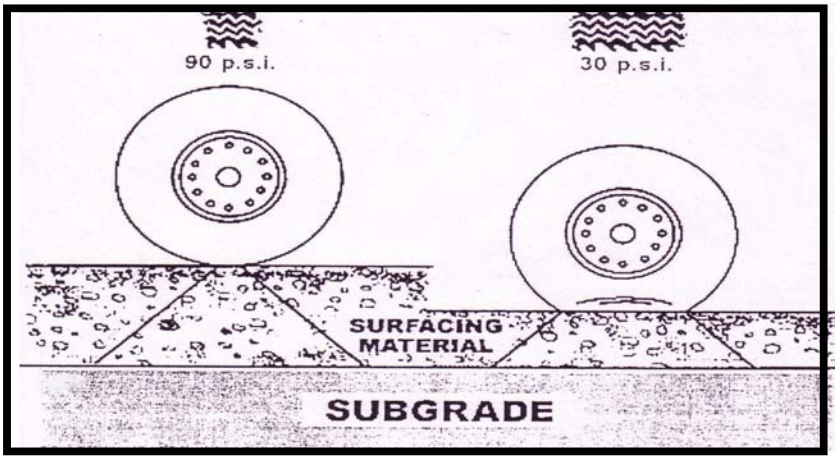


Figure 7. Lower inflation pressures translating into thinner layer of surface material required (Anon, 2006).

Tests were conducted by Sturos, Brumm and Lehto (1995) to determine the cost saving in dirt road construction due to the use of CTI systems. The tests showed that when CTI is used, less gravel surfacing is needed to stabilize sand roads and consequently a 62 % reduction in road construction costs was realized in their study (Sturos *et al*., 1995).

Foltz and Elliot (1996) conducted a study where they measured and modelled the impact of tyre pressures on road erosion specifically using CTI technology to reduce the tyre pressure on unpaved roads. The tyre inflation pressures were held constant at 1260 kPa and 980 kPa for two road sections respectively. The tyre inflation pressure on a third road section was varied between 420 kPa and 980 kPa to match the load and speed of the vehicles. The amount of sediment produced on the different sections over which the vehicles with different inflation pressures were driven was recorded over a three year period. The results are shown in Table 2 (Foltz and Elliot, 1996).

Table 2. Percentage of reduced sediment production achieved by reducing tyre inflation pressure (compared to 1260 kPa).

Year	**Number of trucks that passed over each section**	**Constant reduced pressure- 980 kPa**	**Varied pressure 420 to 980 kPa**
1992	501	28%	54%
1993	601	44%	84%
1994	1117	……	63%

3.4 Increased Fuel Efficiency

Ljubics's (1985) studies indicate that there is an optimum tyre pressure for a particular road surface in order to maximize fuel efficiency. However, unlike an asphalt road where fuel consumption steadily declines with an increase in tyre pressure, fuel consumption on a gravel road declines to a point and thereafter increases to almost mirror the decline. This phenomenon is illustrated in Figure 8. Ljubic's studies indicate that the optimum tyre inflation pressure is lower and more specific for a gravel road and that selecting an inappropriate pressure will effect fuel consumption, and consequently the running cost of the vehicle (Ljubic, 1985).

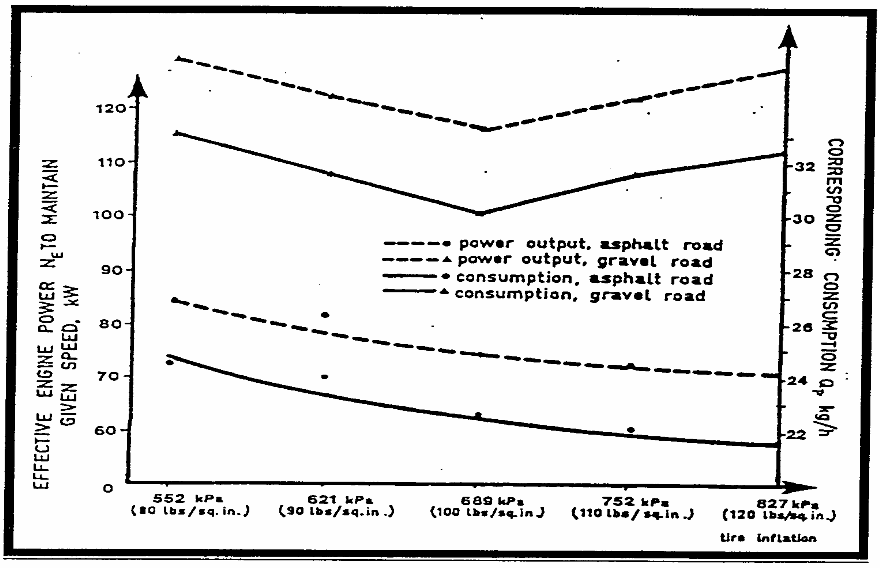


Figure 5. The effect of tyre inflation pressure on fuel consumption for a gravel and asphalt road (Ljubic, 1985).

3.5 Extended Tyre Life and Decrease in Tyre Costs

Central tyre inflation technology increases tyre life by precisely setting and maintaining the tyre pressures recommended by the tyre manufactures for all phases of a haul route. Operating tyres at low inflation pressures reduces wheel slip and creates a more flexible tyre carcass. This permits a tyre to mould itself over or around sharp roadway rocks, thus resisting being punctured or torn. The results are reductions in tread wear, in sidewalls cuts and tread faces, and in depth and frequency of stone penetrations (Bradley, 1993). However, operating tyres with lowered inflation pressure at the incorrect speed can cause the tyre to heat up, and if enough heat is generated the tyre will fail. It is therefore imperative that tyres be operated at the correct pressure, speed and load combination. In Figure 7 the faded areas indicate areas of excessive tread wear.

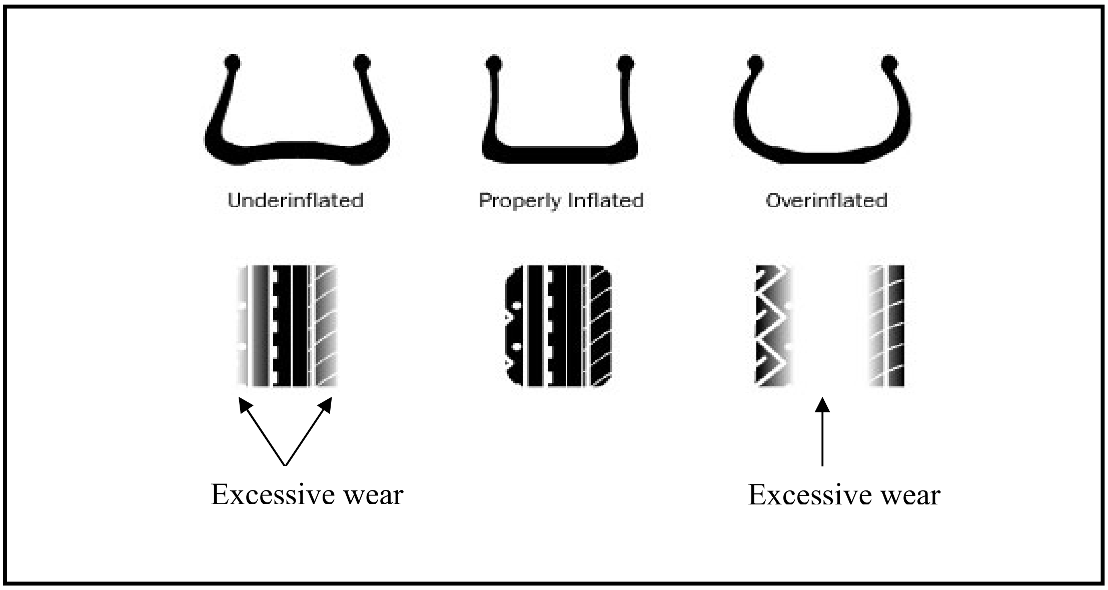


Figure 9. Illustration of excessive tyre wear when tyres are operated at incorrect pressures.

Bradley (1997) conducted a study of the effects of implementing CTI technology on tyre life. His study showed that with the implementation of CTI, a 90 % increase in the life of new drive tyres is possible and a 26 % increase in life of retreaded tyres. The number of tyres that were damaged after the implementation of the CTI system was reduced by 28 %. Table 3 shows the complete results of his study.

Table 3. Tyre use and repair summary (Bradley, 1997)

Description	Control Truck	CTI Truck	CTI vs. Control (% Difference)
Number of tyres used	74.8	54	-27.8
Number of new tyres	16.3	14	-14.1
Number of retread tyres	58.5	40	-31.6
Tyres used per year	40.8	29.5	-27.7
Life of new drive tyres (km)	60 000	114 000	90.3
Wear rate of new drive tyres (km/mm)	3288	6258	90.3
Life of retread drive tyres (km)	49 545	62 240	25.6
Wear rate of retread tyres (km/mm)	3 285.3	4 127	25.6
Number of flat repairs	8.8	6	-31.8
Number of flat tyres replaced	27.5	20	-27.3
Number of flat tyres punctured or damaged	19.8	14.2	-28.3
Drive tyre retread rejection rate (%)	30	0	-100

An example of the potential cost saving that can be realized when utilizing a CTI system correctly is discussed in the next chapter.

4. COST BENEFIT ANALYSIS

A cost benefit analysis will be demonstrated using a real life example. The data used in this example is based on the Hellberg Transport Management software called HTM TransSolve 7. This software is used extensively in the transport industry to calculate among other things the operating cost of a specific vehicle. Other data used in this example was supplied by Kilopascal Systems which is a company that specializes in CTI systems.

There are three segments of the total transport cost that are positively affected by the implementation of CTI, these components being tyre life, fuel consumption and maintenance costs. In this example the cost saving that can be achieved in each of these segments will be shown and the total cost of a CTI system will be compared to overall saving. However, the cost of increased management due to the CTI management is not known and should be considered.

<u>Specifications of vehicle used in cost analysis example</u>
Truck Type: Mercedes Benz actors 2648LS
Contract period: 5 years
Average kilometres truck will travel per annum: 150 000
Total kilometres over contract period: 750 000

<u>Costs and savings</u>

Tyre Life

If a CTI system is installed onto a unit (unit = Truck and trailer combination) the expected minimum increase in tread life is 33 %. This percentage is the minimum increase in tread life that can be expected in the tyre tread life of a normal tyre if the correct tyre pressure is used for all road/load/speed conditions. The study conducted by Bradley (1997) showed that by implementing CTI technology the life of new drive tyres was increased by 90 %. Consequently, using an increase of only 33 % in this calculation can be viewed as conservative. Table 4 and Table 5 show the cost of tyres over the five year contract period with CTI and without CTI respectively.

Table 4. Tyre cost without CTI.

Vehicle tyre details and costs without CTI				
	Axle Group 1	**Axle Group 2**	**Axle Group 3**	**Axle Group 4**
Number of tyres	2	8	8	8
Cost per tyre	4200	3760	3760	3760
Cost for total axle group	8400	30080	30080	30080
Kms per tyre life	80000	100000	100000	100000
Number of tyre sets per 5 years	9	8	8	8
Cost over 5 years	75600	240640	240640	240640
Total cost for all axle groups	R 797 520			
Percentage unplanned failures (5%)	R 39 876			
Total cost	**R 837 396**			

Table 5. Tyre cost with CTI.

Vehicle tyre details and costs with CTI (33% increase in tread life)				
	Axle Group 1	**Axle Group 2**	**Axle Group 3**	**Axle Group 4**
Number of tyres	2	8	8	8
Cost per tyre	4200	3760	3760	3760
Total cost	8400	30080	30080	30080
Kms per tyre life	106400	133000	133000	133000
Number of tyres per 5 years	7	6	6	6
Cost over 5 years	58800	169624	169624	169624
Total cost for all axle groups	R 567 672			
Percentage unplanned failures (5%)	R 28 384			
Total cost	**R 596 056**			

The total saving that can be achieved over a five year contract period through the implementation of CTI technology for the truck specified in this example is R 241 340.

Fuel Consumption

The expected increase in fuel economy due to the use of a CTI system is 5 %. This is the percentage by which the correct tyre pressure will positively affect fuel consumption. On paved roads, as tyre pressure increases tyre rolling resistance will decrease. This decreased drag requires less power to maintain a given speed. The decrease in required power decreases fuel consumption. This occurrence is illustrated in chapter 3 Figure 8.

Table 6. Fuel and lubricant costs with and without CTI

Fuel and lubricant costs without CTI	
Fuel consumption (km/l)	1.8
Fuel price (R/l)	6.4
Litres per year	83333
Cost per year	533333
Litres per 5 years	416667
Cost per 5 years	2666667
Top up oil and grease as percentage of fuel cost (%)	0.5
Cost per 5 years	13333.33
Total Cost	**2680000**

Fuel and lubricant costs with CTI (5% increase in fuel economy)	
Fuel consumption (km/l)	1.89
Fuel price (R/l)	6.4
Litres per year	79365
Cost per year	507937
Litres per 5 years	396825
Cost per 5 years	2539683
Top up oil and grease as percentage of fuel cost (%)	0.5
Cost per 5 years	12698.41
Total Cost	**2552381**

The saving that can be achieved through reducing fuel consumption due to the implementation of CTI technology during the five year contract period is R127 619.

Maintenance

A 10 % reduction in maintenance cost can be expected due to the implementation of CTI. Lowering the tyre pressure to match the road surface decreases vibration levels of the truck up to 25 %. A trial of CTI conducted by Bradley (1993) showed that monthly repair time of trucks was reduced by 26 % after the implementation of the CTI system. A 10 % reduction in maintenance cost is conservative for this calculation.

Table 7. Maintenance costs with and without CTI

Maintenance costs without CTI	
Vehicle (R/km)	0.5
Trailer (R/km)	0.1
Cost per year	90000
Cost over 5 years	**450000**

Maintenance costs with CTI	
Vehicle (R/km)	0.45
Trailer (R/km)	0.09
Cost per year	81000
Cost over 5 years	**405000**

Saving in maintenance costs over the five year contract period will be R 45 000.

The combined saving due to increased tyre life, reduced fuel consumption and reduced maintenance cost over a five year period will be approximately R 414 000. The capital cost of a complete CTI system from Kilopascal Systems is R 100 000. As mentioned before the cost of managing the system and possibly the cost involved in training drivers to use the system is not accounted for. However, from the example above it can be seen that the implementation of a CTI system is definitely economically viable.

5. CONCLUSION

Central tyre inflation systems have many advantageous benefits in the transportation industry. These benefits include, improved vehicle mobility due to the increase in traction when tyre pressures are lowered, improved ride quality and cargo safety due to the reduction in vehicle vibrations when the correct tyre pressure is used for a particular road condition, reduced road maintenance because sediment production is limited and lowered road construction costs, increased fuel efficiency and a considerable increase in the tyre life of vehicles. All these benefits contribute to a considerable cost saving in the overall operation of a transportation vehicle.

Consequently, it appears that central tyre inflation is a worth while investment. However, the successful implementation of central tyre inflation in South Africa has not been extensively examined and the suitability of central tyre inflation to South African roads and operating conditions needs to be examined.

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A FEASIBILITY SURVEY TO ASSES THE MANAGEMENT AND PERFORMANCE OF VEHICLES USING CENTRE TYRE INFLATION AND AUTOMATIC WEIGHING SYSTEMS IN THE SUGAR CANE INDUSTRY

T Pletts

PROJECT PROPOSAL

Submitted in partial fulfillment of the
requirements for the degree of MScEng

School of Bioresources Engineering and Environmental Hydrology
University of KwaZulu-Natal
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TABLE OF CONTENTS

1. INTRODUCTION

This project proposal introduces and provides a brief background to the two technologies being studied, namely Central Tyre Inflation (CTI) and Automatic Onboard Weighing (AOW). The envisaged value of implementing these technologies to transport vehicles in the Sugar Industry is projected. The overall project hypothesis is stated and project objectives are listed. The scope of the project is suggested and project deliverables and a time schedule for these deliverables is included.

1.1 Background

CTI

Central Tyre Inflation is a system whereby tyre pressures of a vehicle/trailer can be automatically adjusted (i.e. inflated or deflated) from within the vehicle during operation and in the case of a trailer the tyre pressure is adjusted from within the vehicle that is attached to the trailer. CTI has been in use from as early as World War II when CTI became standard equipment in most wheeled military vehicles and more recently CTI has been used to a large extent in the forestry transportation industry. Central tyre inflation enables a vehicle operator to adjust a vehicle’s tyre pressure to best suit the road or surface conditions on which the vehicle is operating. Research has shown that this has benefits on ride quality, traction of the vehicle, tyre life and reduced road surface damage (Adams, 2002).

AOW

Automatic onboard weighing systems being considered in this project are comprised of load cells that are attached to a vehicle, which in turn relay the mass placed on each axle to a system that calculates the total payload being placed on a vehicle. The total payload is then displayed on a digital screen located within the vehicles cab and also allows the payload to be recorded through either storing it electronically or a print out.

AOW is used widely throughout the transportation industry, especially in the forestry industry (Ranta and Rinne, 2004). AOW allows maximum payloads to be achieved and enables overloading of trucks to be minimized (Cole, 2005 and Cole, 2006).

1.2 Envisaged value

In the South African sugarcane industry, the transportation of sugarcane to sugar mills constitutes up to 30% of a grower's production costs. The cost of vehicles and vehicle maintenance is high and therefore the use of vehicles should be optimized. CTI systems have been used successfully in other transportation industries (i.e. road freight) to operationally adjust tyre inflation pressures according to the vehicles load, the terrain and road surface conditions. The benefits being (1) longer tyre life, (2) reduced fuel consumption, (3) reduced soil compaction, (4) reduced road maintenance, (5) improved ride comfort and (6) reduce vehicle maintenance. Likewise AOW systems have been adopted by industries such as timber to assist transporters to (7) optimizes their payloads. The use of CTI and AOW systems in the sugarcane industry has been limited and it is envisaged that the adoption of these technologies could benefit the sugarcane transportation in the same areas that other industries have benefited (Bezuidenhout, 2006).

2. HYPOTHESIS

The hypothesis of this project is that the economic value and performance of a sugarcane vehicle will be enhanced if CTI and/or AOW systems are correctly used and managed.

2.1 Scope

What is IN scope:
Comprehensive literature review, a detailed survey of systems already in operation, statistical analyses of survey data, economic estimates of the benefits / losses associated with these systems, information synthesis and practical recommendations with respect to implementation, operation and management.

What is OUT of scope:
Physically installing and assessing these systems in the sugar industry. Providing improved system designs.

2.2 Objectives

1. To conduct a comprehensive literature survey on the use of CTI and AW systems in agriculture.
   Measure: Literature Review
2. To identify other users of these systems and survey their functionality.
   Measure: Progress report
3. To estimate the economic feasibility of these systems within the sugarcane transport scenario.
   Measure: Progress report and economic model
4. To identify the reasons why these technologies to date have not been implemented in the sugarcane industry.
   Measure: MSc Dissertation chapter

5. To provide detailed recommendations with regard to the use and adaptiveness of these systems in sugarcane.
   Measure: MSc Dissertation chapter

3. METHODOLOGY

The following sections propose the methodology that will be implemented in order to meet the project objectives.

3.1 Literature review

Conduct a comprehensive literature review on CTI and AOW systems with key focuses being on understanding how the systems work, where the systems have been successfully implemented, what attributed to the successful implementation and where possible limitations to the systems have been identified.

3.2 Information collection

Other transportation industries using CTI and AOW to be identified and approached. Questionnaires and survey templates will be compiled for collection of data from the approached industries.

3.3 Analysis

An economic model will be developed to synthesize the surveyed data and to extrapolate results into a sugarcane vehicle scenario. All this information will be used to generate suitable recommendations towards installing and using these systems on sugarcane vehicles in the sugar industry.

4. TIME AND WORK SCHEDULE

The Gantt chart below contains time periods allocated to the various stages of the project. Time periods may be slightly longer or shorter depending on the outcomes of each task.

4.1 Gantt chart

	TIME PERIOD															
	2006									2007						
	Jan	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	April	June	July	Aug
MILESTONE																
Literature Review	■	■	■	■	■											
Identify industries	■	■														
Questionnaire and template compilation					■											
Industry Survey						■	■	■	■							
Develop economic model									■	■						
Data analysis											■					
Write up												■	■	■	■	
Steering committee meeting 1			■													
Steering committee meeting 2											■					
Steering committee meeting 3														■		

5. BUDGET AND RESOURCES NEEDED

5.1 Budget

DESCRIPTION	2006	2007	Total
Student subsistence	48 000.00	48 000.00	96 000.00
Academic fees	11 810.00	11 810.00	24620.00
Operating Expenses	5 000.00		5 000.00
Transportation and communication	1 500.00		1 500.00
Administration and Secretarial	1 000.00		1 000.00
Enhancement (extra course work)	3 000.00		3 000.00
			131 120.00

5.2 Resources needed

A desktop computer with internet and library access is required. The computer will be used for communication, research, data processing and document writing. The literature review will require a large amount of internet searching.

Telephone access will be needed.

A vehicle will be required. A large amount of traveling will be required to operation sites and to various participants that are involved in this projects particular area of investigation.

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