Journal of Contemporary Management
Volume 15

The impact of implementing a vehicle tracking system in a ferrochrome smelter supply chain: a case study

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Abstract

In the current economic climate mining companies are under increased pressure to operate profitable. The management of the supply chain and the associated logistics activities, from the extraction of the ore, to the smelter and the final product to the customer, are important factors to the success of mining companies. Transport is a key element in this process and mining companies leverage the benefits of information systems in an effort to reduce transport costs and improve productivity.

The purpose of this research was to investigate the impact of the implementation of a vehicle tracking system on the operational efficiencies and performance of a fleet of earth moving equipment operating in a smelter operation at a mine. The research followed a case study approach based on the smelter operation of a ferrochrome mine in South Africa.

The results of the research indicate that the implementation of a vehicle tracking system in a fleet of earth moving equipment at a smelter resulted in increased levels of fleet performance leading to the reduction in the vehicle fleet size and its associated costs. In addition, service levels, measured according to pre-determined key performance indicators (KPIs) increased.

Key phrases

Fleet management; supply chain; transport management; vehicle utilisation and vehicle tracking system

1. INTRODUCTION

A supply chain is concerned with the support of the physical, information, financial and knowledge flows related to the movement of goods and services from the supplier to the end consumer (Kirovska, Josifovska & Kiselicki 2016:6). In this effort, transport and transport management play an important role to optimise the equilibrium between service, cost and quality.

Transport management relates to the planning, application and control of transport services in order to achieve organisational goals (Matotek & Regodić 2013:54) and includes fleet management that focuses on improving fleet efficiencies and reducing the overall cost (O'Brien & Marakas 2009:23).

The supply chain concept is applicable to the mining sector where it represents all of those integrated processes and operations that transform raw materials into the final product for delivery to the different customers (Slack, Brandon-Jones, Johnston & Betts 2015:4). A mining operation could be viewed as a series of complex processes i.e. raw material extraction, transport and transformation (Qaeze, Thierry & Guillaume 2015:1) and this complexity is increasing due to external and internal challenges (Agyei, Sarpong & Anin 2013:27).

The transformation process includes smelting during which the final product is extracted and then transported to the different customers to be used in different applications. Usually the geographic dispersion of the concentrate source(s) and the smelter(s) requires the transport of the concentrate from the source to the smelter furnace. Smelter production forecasts determine the concentrate volumes required to ensure optimal efficiencies i.e. the availability of the correct concentrate volume ensures that the powering down of the furnace or the build-up of stockpiles at the smelter is avoided (Georgalli & Anderson 2010:95).

The supply chain in a mining environment has a financial impact on all parties concerned and the implementation of a supply chain management philosophy to improve the supply chain is of key importance to any mining company. This is also applicable to the movement of concentrate at the smelter to ensure high levels of productivity and efficiencies. Transport is the link between the extraction and the transformation processes and transport management plays an important role in operating cost reduction and the maximisation of fleet utilisation (Matamoros & Dimitrakopoulos 2016:912 and Qaeze *et al*. 2015:2).

Matamaros and Dimitrakopoulos (2016:912) note that in certain mining operations transport may represent more than 50% of the total operating costs.

This research is based on the transport operation (inbound and outbound) at the smelter of an open cast chrome mine in South Africa that supplies ore to its smelter plant on a daily basis that produces ferrochrome. Ferrochrome is one of the major ingredients needed in the manufacturing process of stainless steel.

The transport of the bulk material at the smelter is performed by a diversified fleet of earth moving equipment (EME) and is outsourced to a third-party logistics company, known as an onsite bulk material handling (OSBMH) contractor. The fleet of vehicles consists of tipper trucks, articulated dump trucks, excavators, front end loaders, bulldozers, graders and water trucks. The OSBMH contractor is responsible to ensure that ore is adequately fed into the furnaces at the smelter; slag and metal are transported to different areas in the plant, and the loading of rail and road trucks with the final product. The operational performance of the smelter is highly dependent on the fleet performance and available capacity (Matamoros & Dimitrakopoulos 2016:911).

The main cost drivers for the EME fleet are machine hours and fleet utilisation. Inefficiencies in the EME fleet may lead to an increase in costs (increased fuel consumption, poor vehicle utilisation, an increase in the number of vehicles and associated operators) and lower productivity levels (Matamoros & Dimitrakopoulos 2016:912).

The ferrochrome smelter plant is a 24-hour operation, which implies that the EME fleet has to be operational and available for 21 hours out of 24, allowing three hours for shift changes. A major problem at the smelter is the proper management of the EME fleet to ensure high levels of fleet efficiencies and operational performance as per the smelter requirements (feed rate).

Fleet management allows companies that rely on transport to minimise the risks associated with vehicle investment, improve efficiency (reduce overall transport and staff costs) and improve productivity. Vehicle tracking forms part of fleet management and is defined as a vehicle-based system that incorporates data logging, satellite positioning and data communication to a back office application (Fagerberg 2016:1).

Although vehicle tracking has been successfully implemented in the road freight industry and other mine applications, it has not been used in an EME fleet at a ferrochrome smelter supply chain application.

This purpose of this research was to investigate the impact of the implementation of a vehicle tracking system in an EME fleet at a ferrochrome smelter plant and focused on two areas:

- fleet operational efficiencies
- general perceptions on fleet performance

In the following sections an overview of the relevant literature is provided, the research methodology is described, the results are presented and discussed and recommendations are made.

2. LITERATURE REVIEW

The supply chain relates to the movement of goods from raw materials stage through to the consumer and includes the information systems necessary to monitor all of these activities (Felea & Albastroi 2013:58; Sharma 2013:1). Supply chain management (SCM) is the process of planning, implementing and controlling the operations of the supply chain with the purpose to satisfy customer requirements as efficiently as possible (Kirovska *et al*. 2016:8). A well-functioning relationship between all the role players in the supply chain improve operational efficiency, increase profits and reduce costs (Tsai & Hung 2016:2757).

Logistics form an integral part of the supply chain (SC) and the primary goal for logistics is to safely get the right product to the right client at the right time in the most cost effective way (Daniela & Ovidiu 2014:34). This includes all the move and store activities from the point of raw material acquisition to the point of final consumption with its core elements being customer service, order processing, inventory management and transport. Daniela & Ovidiu (2014:36) state that transport is the key element in a logistics chain and the backbone of the entire supply chain.

Transport management is one of the most dominant logistics processes in business today and is one of the most important functions in a supply chain (Matotek & Regodić 2013:54). Transport management concentrates on assessments of the requirement for convenient transport, the requirements for a particular type of transport and transport service and maintaining the existing market for transport. Therefore transport management examines the present situation of the transport market and also the orientation of the next demand trends and opportunities to improve customer satisfaction requirements (Dicova & Ondrus 2010:75).

Fleet management, a function of transport management, allows a company relying on transport to minimise the risks associated with the vehicle investment, improve efficiencies and productivity and reduce overall transport costs (Saghaei 2016:1). Fleet management consists of vehicle tracking, maintenance management, driver management, tyre management, GEO-Zone management, incidents alerts, stolen vehicle alarms, route optimisation and fuel profiling (C Track 2017:Internet & Hu, Chiu, Hsu & Chang 2015:1). Fleet management allows for the monitoring of the key parameters required for a well-managed decision-making process (Saghaei 2016:1).

Information technologies, computers and communication systems can be used to solve transport problems (Hu *et al*. 2015:2). Effective fleet management depends on the availability of relevant information and this may be supplied by a fleet management system (Hu *et al*. 2015:2 & Saghaei 2016:2). When information systems are successfully managed it will lead to an increase in operational efficiency, productivity and customer service (O'Brien & Marakas 2009:23). A fleet management system is commonly utilised as an information technology control mechanism and represents an important contributor to operational efficiency, employee productivity and morale, and customer service and satisfaction (O'Brien & Marakas 2009:23). These systems have various short-term and long-term applications and companies have to evaluate the benefits that the technology (software and hardware) holds against the cost implication for that company (Saghaei 2016:4).

The most basic function of a fleet management system is vehicle tracking (Singh & Singh 2014:95) which improves productivity and efficiency levels (Partington 2016:28). Skydel (2015:44) and Saghaei (2016:2) state that technology like vehicle tracking, allows controllers to monitor vehicles and ensure fuel-efficient operations. Logistic companies in the road freight industry have for a long time recognised the value of successfully implementing fleet tracking in their vehicle fleets (Jamil, Soares & Pessoa 2017:166).

Vehicle tracking may be handled in two ways, actively of passively (Saghaei 2016:2). Active trackers relay vehicle information in real time, while passive trackers record the vehicle information on memory cards that may be downloaded at a later stage when the vehicle return to the base (Saghaei 2016:2).

Vehicle tracking software uses the global system for mobile communication (GSM) networks for communicating and optimising the use of general packet radio service (GPRS), GSM or long data facilities (NETSTARa 2017:Internet). The main benefits of vehicle tracking include real-time visibility, asset management, operational control and operator behaviour (C Track 2017:Internet, Hu *et al*. 2015:1; Istrefi & Cico 2013:264):

Mohammadi, Rai and Gupta (2015:240) state that it is important to improve the effectiveness and performance of capital intensive equipment like a vehicle fleet to achieve high levels of productivity. A similar sentiment is expressed by Okuda and Aiba (2016:1455) stating that operational efficiency is important to the success of a company and the determinants of efficiency need to be highlighted and managed. Various metrics have been used to evaluate the performance of a vehicle fleet, but availability and utilisation are key performance indicators for decision-making in a mine operation (Mohammadi *et al*. 2015:240).

Fleet utilisation relates to the productive use of available hours and can be calculated as follows (Mohammadi *et al*. 2015:242):

$$Utilisation = \frac{Actual\ hours\ worked}{Available\ hours}$$

Transport plays a key role in the mineral value chain and as such contributes to a mine's profits (Qaeze *et al*. 2015:8). In an effort to increase profits mining companies endeavour to minimise transport costs while ensuring that the production targets for the various ore processing streams (including the smelter) are met (Georgalli & Anderson 2010:91 and Matamoros & Dimitrakopoulos 2016:911). If the short term production targets are met it ensures that the strategic targets of the mine are met (Matamoros & Dimitrakopoulos 2016:912). However, to ensure that these short term production targets are met, the feed targets (volume requirements) of the various ore processing streams need to be satisfied which requires the management of mining equipment, including a vehicle fleet (Matamoros & Dimitrakopoulos 2016:912). Therefore, the management and dispatching of the mining fleet is of utmost importance to ensure minimum mining cost (through reduced transport cost), subject to the production targets i.e. meeting specific feed targets (Matamoros & Dimitrakopoulos 2016:912).

The main aim with transport management in a mine environment is the improvement of productivity and the reduction of operating costs (Matamoros & Dimitrakopoulos 2016:911). Transport productivity is negatively affected by broken down vehicles, security and safety issues and will result in a decrease in transport capacity, which has a negative impact on the ore processing process (Georgalli & Anderson 2010:95).

Matamoros & Dimitrakopoulos (2016:911) state that fleet management in the mineral value chain has an impact on equipment availability (capacity) and utilisation and therefore on the production performance at the mine, including the smelter.

The vehicle tracking system implemented in the EME fleet at the smelter operation under investigation is a combination of an active and passive device, delivering the date, time, position, heading and speed of a vehicle on a continuous basis. The system combines high definition tracking, an impact sensor, on-board computer information and fuel tank profiling (NETSTARb 2017:Internet). The system is set up to highlight items constituting a breach of normal operating procedures. The on-board memory card has sufficient memory to store 32 000 records and it records all information delivered by the global positioning system (GPS) at user-defined intervals (defaults every 15 seconds). It creates a record every time any user-defined operating parameter is exceeded. The standard memory records at 15-second intervals and will store approximately 130 hours of motion time (NETSTARb 2017:Internet).

The tracking system implemented in the EME fleet provides the following benefits (C Track 2017:Internet, Hu *et al.* 2015:1 and Istrefi & Cico 2013:264):

- **Real-time visibility**

EMEs are monitored constantly and trip replays highlight the historical route an EME has travelled. Comparing the route travelled with the actual/planned route indicates wastage of fuel and time if the EME deviated from the planned route.

- **Asset management**

The system provides the ability to manage EME maintenance and servicing scheduling and fuel monitoring. The system optimises transport costs via vehicle tracking and routing.

- **Operational control**

Odometers and hour meters accurately record distance travelled and operating hours for billing purposes and maintenance records. GEO fencing allows for real-time operational control.

- **Operator behaviour**

Driver behaviour is monitored through features such as speed and engine revolution measurement. This allows for improved driver behaviour, reduced fuel usage and lower maintenance cost and improved fuel consumption. This platform helps with driver retention as it provides driver feedback, thus allowing for training to change driving behaviour.

Smelter productivity is usually measured in tons/hour and is constrained by the capacity of the smelter (Fore & Msipha 2010:215). Managing the smelter performance enables the company to achieve high levels of productivity, but this depends on the ore feed rate. The smelter furnace is expected to operate on a 24 hour basis (Fore & Msipha 2010:208). Therefore, the EME fleet responsible for the ore feed at the smelter is required to operate on the same basis. A measure related to operational efficiency is the ideal cycle time and is measured in hours/ton (Siregar, Muchtar, Rahmat, Andayani, Nasution & Sari 2018:2). Focusing on fleet availability, fleet utilisation and the ideal cycle time allow the mine to minimise total mining cost subject to performance targets i.e. obtaining favourable economies of production (Matamoros & Dimitrakopoulos 2016:912).

3. RESEARCH METHODOLOGY

A case study approach was used to assess the impact of the implementation of a vehicle tracking system at the smelter operation of a ferrochrome producer in South Africa. Starman (2013:31) defines a case study as a comprehensive description of an individual case and its analysis, i.e. the characterisation of the case and the events, as well as a description of the discovery process of these features that is the process of research itself. This approach is used to study a case within a bounded context and uses multiple sources of information such as questionnaires, interviews and observations (Mohajan 2018:33). The research was similar to a longitudinal study since it reflected pre- and post-implementation scenarios. The pre-implementation period ranged from 1 August 2015 to 28 January 2016 and the post-implementation period ranged from 1 March 2016 to 31 August 2016.

In order to address the research objectives two sources of information were used i.e. observations from the EME fleet management system and satisfaction ratings of the operational performance of the EME by the smelter personnel.

The data obtained from the fleet management system related to the operational efficiency of the EME fleet and included the following:

- utilisation of EME hours;
- number of EMEs (fleet size);
- EME fuel consumption; and
- number of EME operators (drivers).

This data and smelter production data also allowed for the calculation of the EME fleet operating efficiency relating to the smelter production requirements. This was important since the contractor's agreement with the mine was based on a predetermined key performance indicator (KPI) equivalent to the production output of 10 000 tons of ferrochrome per month utilising not more than 2 600 EME hours i.e. 0.26 hours/ton (ideal cycle time). This data was collected on a weekly basis over the analysis period.

In addition to the metrics used to determine the impact of the implementation of the vehicle tracking system in the EME fleet at the smelter, satisfaction ratings of the fleet performance were obtained. These ratings reflected the perceptions of the smelter personnel at the different departments (raw materials, furnace and final product) of various service related matters contained in the service agreement including:

- machine availability;
- material movement;
- stock pile maintenance;
- housekeeping;
- slag removal; and
- final product movement.

The relevant personnel were required to rate the performance of the EME fleet on each of the services in terms of the following question:

Did the OSBMH contractor fully meet all the requirements set out in the area of responsibility?

The ratings were based on a 5-point Likert scale i.e. 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree and 5 = strongly agree. These ratings were completed on a weekly basis by the line managers of the different departments in association with the site supervisor at the ferrochrome smelter plant.

Data quality issues can be addressed by dealing with properties of validity and reliability (Field 2013:12). Validity is the extent to which a concept is accurately measured in a quantitative study (measures what it sets out to measure) and reliability refers to the accuracy of an instrument across different situations (Field 2013:12). The systems generated data could be viewed as valid and reliable since the actual measurements related to the research objectives and were used in the analysis and this was consistent for both scenarios i.e. before and after the implementation of the vehicle tracking system. The process to obtain the fleet performance ratings was the same for both scenarios and the ratings were obtained from the same respondents for both scenarios and could therefore be viewed as reliable and valid.

The data was tabulated and analysed utilising Microsoft Excel in order to generate the graphical illustrations. The impact of the implementation of the vehicle tracking system was assessed through hypothesis testing with the null hypothesis stating that the implementation had no impact on the EME fleet operational performance. This was achieved by the equality of the means test (t-test) (Field 2013:364). The statistical tests were performed on IBM SPSS Statistics version 24.

4. DISCUSSION OF THE RESULTS

4.1 Operational results

A comparison of operational measures such as available hours, tonnage handled, size of the vehicle fleet and vehicle utilisation before and after the implementation of the vehicle tracking system provides an indication of the impact of the tracking system on the EME fleet operation. In certain cases the weekly data was aggregated to monthly data for graphical illustration purposes. However, the weekly data was used for the tests of equal means before and after implementation of the vehicle tracking system.

Over the analysis period the monthly tonnages produced by the ferrochrome smelter plant remained relatively constant as illustrated in Figure 1 below. The ferrochrome smelter capacity was 48 000 tons of ferrochrome per month.

Figure 1: Monthly tonnage produced by smelter

Source: Calculated from company data

Figure 1 indicates that subsequent to a reduction in the monthly production over the first few months of the analysis period, an increase in production was recorded over the latter part of the analysis period after which production stabilised over the last two months of the analysis period.

Table 1 below shows the results of the equality of the means test (weekly tonnage) for the periods before and after the implementation of the vehicle tracking system. Note that the variances of the two groups (before and after) are assumed to be equal. (The Levene statistic does not reject the null hypothesis that the group variances are equal (Field 2013:193)).

TABLE 1: Equality of means test: weekly tonnage

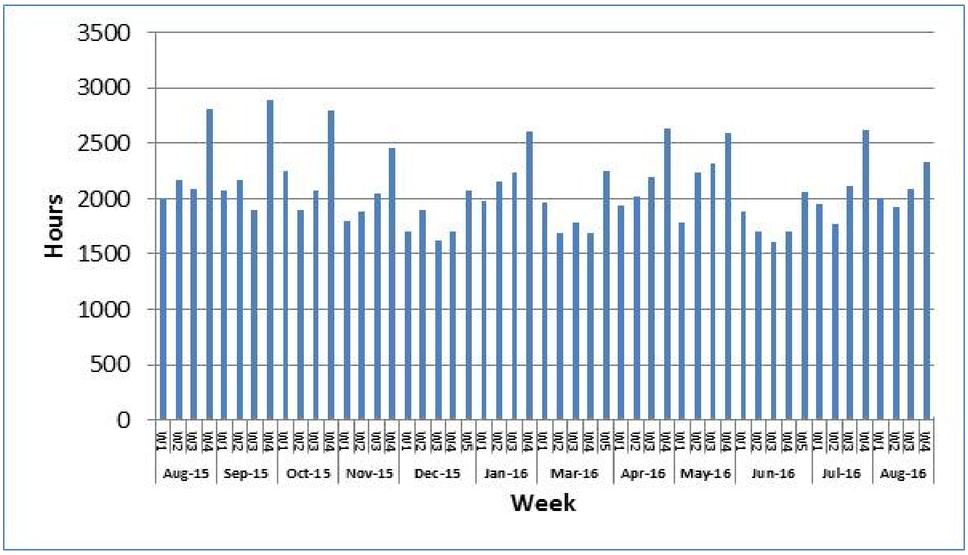
Mean (before)	Mean (after)	t	Degrees of freedom	Significance (two-tailed)
8075.96	8313.68	-0.684	48	0.497

Source: Calculated from company data

The test results indicate that there was no significant difference in the means of the weekly tonnage produced before and after the implementation of the vehicle tracking system.

The weekly hours worked (operating hours) by the EME fleet recorded a downward trend over the analysis period and is shown in Figure 2 below.

Figure 2: Weekly EME fleet operating hours



Source: Calculated from company data

The results of the equality of the means test (weekly operating hours) for the periods before and after the implementation of the vehicle tracking system are shown in Table 2. Note that the variances of the two groups (before and after) are assumed to be equal, based on the Levene test for equal group variances (Field 2013:193).

TABLE 2: Equality of means test: weekly operating hours

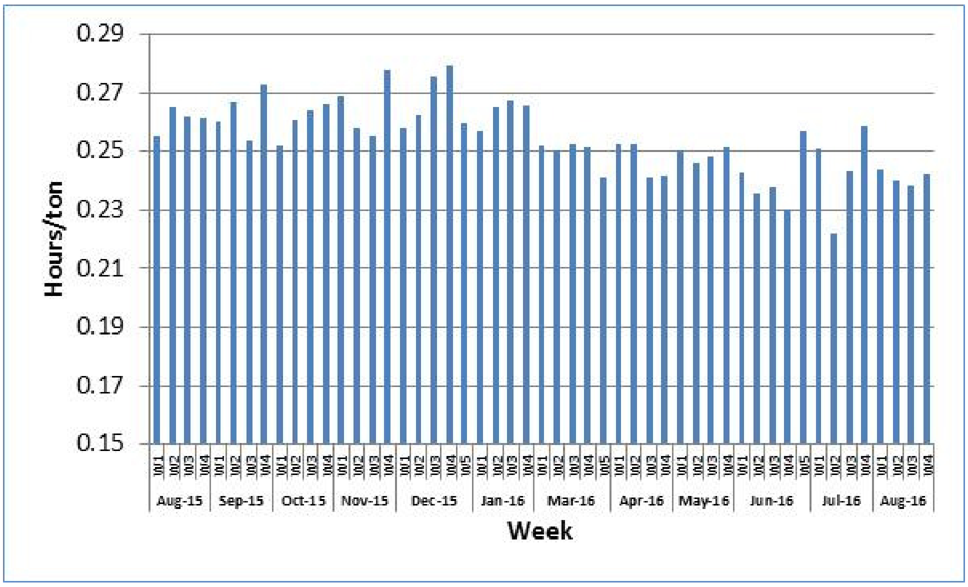
Mean (before)	Mean (after)	t	Degrees of freedom	Significance (two-tailed)
2129.16	2036.34	1.011	48	0.317

Source: Calculated from company data

The test indicates that there was no significant difference in the average weekly hours worked. However, the operating hours after implementation of the tracking systems was achieved with a reduced fleet size (see Figure 4).

The operating hours of the EME fleet in relation to the tonnages produced by the ferrochrome smelter plant was used as an indicator for operational efficiency. Figure 3 below shows the weekly operating hours per ton of ferrochrome produced for the EME fleet over the research period.

Figure 3: Weekly fleet operating hours/ton ferrochrome produced by smelter



Source: Calculated from company data

Figure 3 indicates that subsequent to the implementation of the vehicle tracking system the hours/ton ratio improved (decreased) indicating higher levels of EME fleet operational efficiency. The decrease in the hours/ton ratio should be interpreted in conjunction with the constant production levels (tonnage) over the analysis period. When the mine production (tonnages produced) and furnace feed rates are relatively low, the hours which the EME fleet utilise to conduct internal movement at the smelter plant should be low and vice versa.

Table 3 below shows the results of the equality of the means test (operating efficiency) for the periods before and after the implementation of the vehicle tracking system. Note that the variances of the two groups (before and after) are assumed to be equal, based on the Levene statistic (Field 2013:193).

TABLE 3: Equality of means test: weekly operating efficiency (hours/ton)

Mean (Before)	Mean (after)	t	Degrees of freedom	Significance (two-tailed)
0.2637	0.2449	8.498	48	0.00

Source: Calculated from company data

The equal means test results indicate that there was a significant difference between the mean operating efficiencies (hours/ton) of the two groups (before and after). The weekly mean reduced from 0.2637 hours/ton to 0.2449 hours/ton, indicating an increase in the fleet operating efficiency.

Another aspect that was considered was the EME fleet size. There were 42 EME vehicles on site during the period of 1 August 2015 to 31 February 2016. In March 2016 the number of EME vehicles was reduced by two vehicles, in May 2016 the EME fleet was reduced by another vehicle, while in July 2016 the EME fleet was further reduced by an additional two vehicles. The fleet reduction over the analysis period is illustrated in Figure 4.

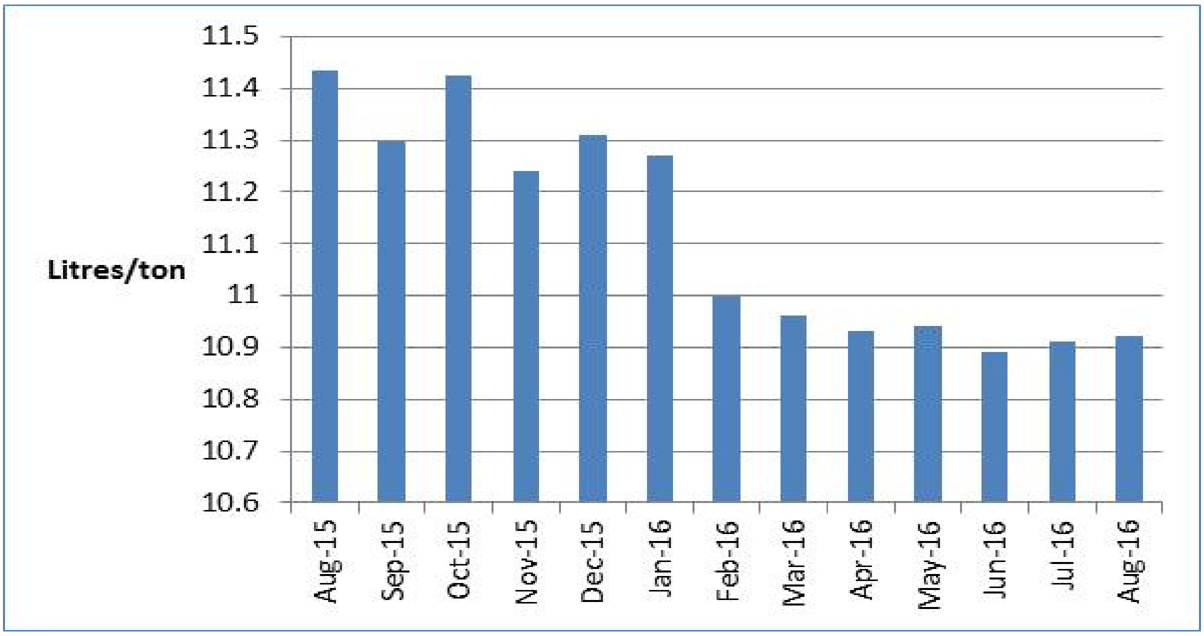
FIGURE 4: Size of the EME fleet

Source: Calculated from company data

The size of the EME fleet at the ferrochrome smelter plant was reduced from 42 vehicles at the start of the analysis period to 37 at the end of the analysis period, largely due to the increased operational efficiencies achieved in the reduction of the hours per ton during this period. Associated with the decrease in the number of EMEs, the number of operators was also decreased. The number of EME operators consists of four operators per EME as per a designated rotational four-shift cycle, with an additional three operators per shift to mitigate training days, annual leave and absenteeism.

In addition, the reduction in fleet size resulted in a decrease in the amount of fuel used and given that the tonnage produced remained relatively stable, implies a decrease in the fuel consumption (litres/ton). Figure 5 below shows the monthly fuel consumption (litres/ton) for the EME fleet.

Figure 5: Monthly EME fleet fuel consumption



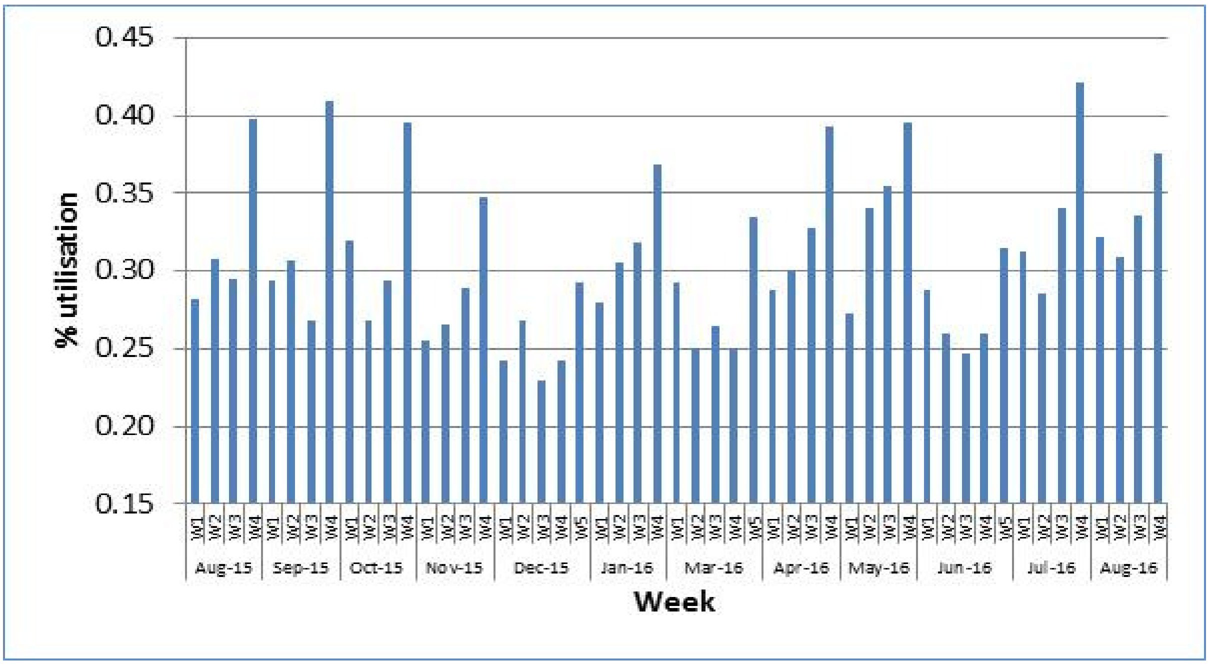
Source: Calculated from company data

The weekly EME fleet utilisation percentage is presented in Figure 6. The EME fleet utilisation is calculated as follows:

$$Utilisation\ \% = \frac{Actual\ hours\ worked}{Available\ hours}$$

The available hours were calculated on a basis of 24-hour availability for each day per week for each vehicle.

Figure 6: Weekly EME fleet utilisation



Source: Calculated from company data

The figure indicates a marginal increase in the monthly utilisation over the analysis period.

Table 4 below shows the results of the equality of the means test (fleet utilisation) for the periods before and after the implementation of the vehicle tracking system. Note that the variances of the two groups (before and after) are assumed to be equal (Levene statistic (Field 2013:193)).

Table 4: Equality of means test: weekly fleet utilisation (operating hours/available hours)

Mean (Before)	Mean (After)	t	Degrees of freedom	Significance (two-tailed)
0.3018	0.3139	-0.877	48	0.385

Source: Calculated from company data

Based on the test results in can be concluded that there was no significant differences in terms of the weekly fleet utilisation between the two groups subsequent to the implementation of the vehicle tracking system. However, the weekly mean operating hours remained the same (see Table 2) and this was achieved with a reduced vehicle fleet (see Figure 4).

The marginal reduction in the average weekly operating hours and the marginal increase in the average weekly fleet utilisation, in association with a marginal increase in the average weekly tonnage produced implied a significant decrease in the weekly fleet operating ratio i.e. an increase in operational efficiencies.

As a result of the increased operational efficiencies the fleet size was reduced which implied various cost benefits to the OSBMH contractor at the ferrochrome smelter. These cost elements related to fuel and the vehicle operators. In addition, a reduction in key performance indicator (KPI) penalties was recorded. (These penalties related to the operating efficiency (hours/ton)). The total monthly savings outweighed the initial implementation cost of the vehicle tracking system. A summary of the operating parameter means for the periods before and after implementation of the vehicle tracking system is shown in Table 5 below.

Table 5: Operating parameter comparison (before and after)

Operating parameter	Before implementation	After implementation
Utilisation (weekly)	30.18%	31.39%
Operating hours (weekly)	2129.19 hours	2036.34 hours
Tonnage (weekly)	8076 tons	8314 tons

Fleet size (monthly)	42 vehicle	39 vehicles
Operator count (monthly)	180 operators	169 operators
Hours/ton (weekly)	0.2637	0.2449

Source: Calculated from company data

4.2 Performance rating results

Managers at the raw materials, furnace and final product departments were required to rate the performance of the contractor (relating to various aspects of the operation) on a weekly basis and Table 6 below shows the frequency distribution (percentages) of the rating results for the different departments before and after the implementation of the vehicle tracking system.

Table 6: Rating frequency distribution (before and after)

Department	Rating	Frequency (%) Before implementation	Frequency (%) After implementation
Raw materials	1	0.0	0.0
	2	2.4	0.8
	3	24.0	10.8
	4	68.0	56.9
	5	5.6	31.5
Furnace	1	0.0	0.0
	2	1.1	0.0
	3	45.1	11.5
	4	49.1	81.9
	5	4.6	6.6
Final product	1	0.0	0.0
	2	0.6	1.6
	3	45.1	31.9
	4	51.4	54.4
	5	2.9	12.1

Source: Calculated from respondent data

Improvements in the ratings of the EME fleet performance levels at each of the departments were recorded over the analysis period. In order to test the significance of the improvement in the performance level ratings the t-test on the mean ratings was applied (Wadgave and Khairnar 2016).

The mean service level ratings for each department before and after the implementation of the vehicle tracking system are shown in Table 7 below.

Table 7: Mean service level rating (before and after)

Department	Before implementation	After implementation
Raw materials	3.77	4.20
Furnace	3.57	3.95
Final product	3.57	3.78

Source: Calculated from survey data

The results of the t-test on the equality of the means of the two samples (before and after the implementation of the vehicle tracking system) indicate that unequal means were recorded for all the departments. Since the mean performance ratings after implementation were higher compared to the means before implementation, it implies that significant increases in the performance level ratings were recorded subsequent to the implementation of the vehicle tracking system in the EME fleet.

5. CONCLUSION

The supply chain and effective supply chain management is important to a mine and consists of many "links" related to the different processes at a mine. This is also relevant to a smelter operation at a mine and the transport of material plays a vital role in this process to ensure minimum costs and optimal production levels at the smelter.

This research focused on the impact of implementing a vehicle tracking system on the operational performance of an EME fleet at the smelter operation of a specific ferrochrome mine in South Africa. The transport of the ore to the smelter furnace and the transport of slag and metal, as well as the ferrochrome ingots (final product) to the loading area is performed by the EME fleet, managed by a third party. The objective of the implementation of the vehicle tracking system was to improve fleet operational efficiencies in terms of vehicle availability, vehicle utilisation and fuel consumption resulting in reduced costs and increased performance levels.

Weekly fleet operational data obtained for two periods, before and after the implementation of the vehicle tracking system was used to assess the impact of the tracking system on the efficiency of the vehicle fleet. In addition, the relevant smelter personnel were surveyed on a weekly basis to assess the level of performance provided by the EME fleet.

During the analysis period, before and after implementation, the average monthly tonnages produced by the smelter increased slightly. However, during the same period the fleet size was reduced by 5 vehicles and the average weekly operating hours reduced slightly which resulted in a significant decrease in the important operating efficiency KPI (hours/ton). This KPI is also used by the mine to address contractual requirements.

The reduction of the fleet size implied that fleet related costs such as maintenance, tyres, fuel and personnel was also reduced.

Managers (mine employees) at the furnaces, final product and raw materials departments rated the performance levels provided by the EME fleet on a weekly basis and significant improvements in the average weekly performance ratings were recorded over the analysis period.

The implementation of a vehicle tracking system in an EME fleet at the smelter operation of a ferrochrome mine in South Africa resulted in increases in operational efficiencies, as well as performance level improvements. The improvements in the EME fleet operations (increased service levels and reduced costs) outweighed the system implementation and maintenance costs. It is evident from this research that the implementation of a vehicle tracking system in a fleet of earth moving equipment at a smelter plant resulted in reduced costs while maintaining the required service levels.

6. RECOMMENDATIONS

Although the research results were specific to the case study company the benefits of implementing a vehicle tracking system are applicable to any EME operation. However, the benefits depend on the pre-implementation operational efficiencies of the EME fleet.

The success of the vehicle tracking system depends on its users (managers and drivers). A company implementing a vehicle tracking system may either perform the management of the control centre internally or this function may be outsourced to the supplier. If the company decides to manage the control centre internally the users need be trained properly and ideally training should take place on a regular basis.

Additional fleet aspects, which were beyond the scope of this research, such as the service life of vehicles, maintenance and safety should also be considered as part of the decision to implement a vehicle tracking system. The recording of real-time data results in historical data that could be analysed to assist management increasing the operational efficiencies of the vehicle fleet relating to these aspects. Other benefits of implementing a vehicle tracking system that should also be considered are the availability of information to assist management with budgets and the replacement decision.

7. LIMITATIONS

A common critique of case study research is the issue of generalisability. This research focused on the transport operations (EME fleet) at a smelter plant of a ferrochrome mine in South Africa with specific financial and service objectives (KPIs). In addition, the EME fleet operation at the smelter is managed by a third-party with specific financial objectives. Another mining company may have different strategic objectives related to their smelter operation which could potentially impact on their decision to implement of a vehicle tracking system in the vehicle fleet at the smelter operation.

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